On the Design Framework of Context Aware Embedded System

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Request

- Position, View Point
- Software Engineering for Embedded System
- Requirement and Implementation

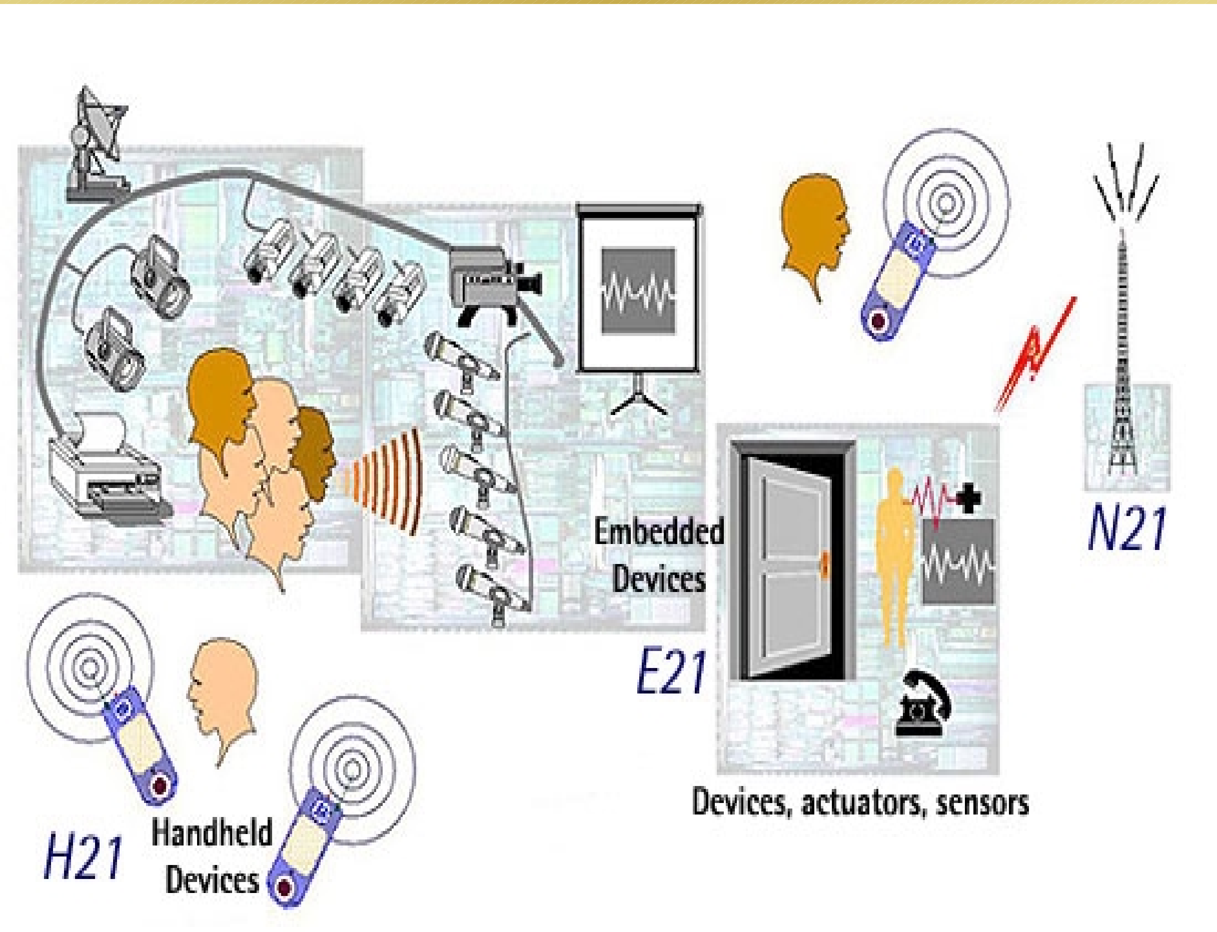
Outline

- From Single device to Coordinated Smart Space
- Context Awareness: A New Challenge
- Aspect Oriented Software Design
- Scarlet – The IIT Context Aware Infrastructure
- Conclusion and Open Questions

Embedded Systems: What is the new

- Devices become smaller and more powerful
- What is the new challenge?
- From “autonomous computing” to coordinated “human-center computing”

Coordinated Embedded System – Smart Space



- Modern Warships
- What is the relation with pervasive computing?

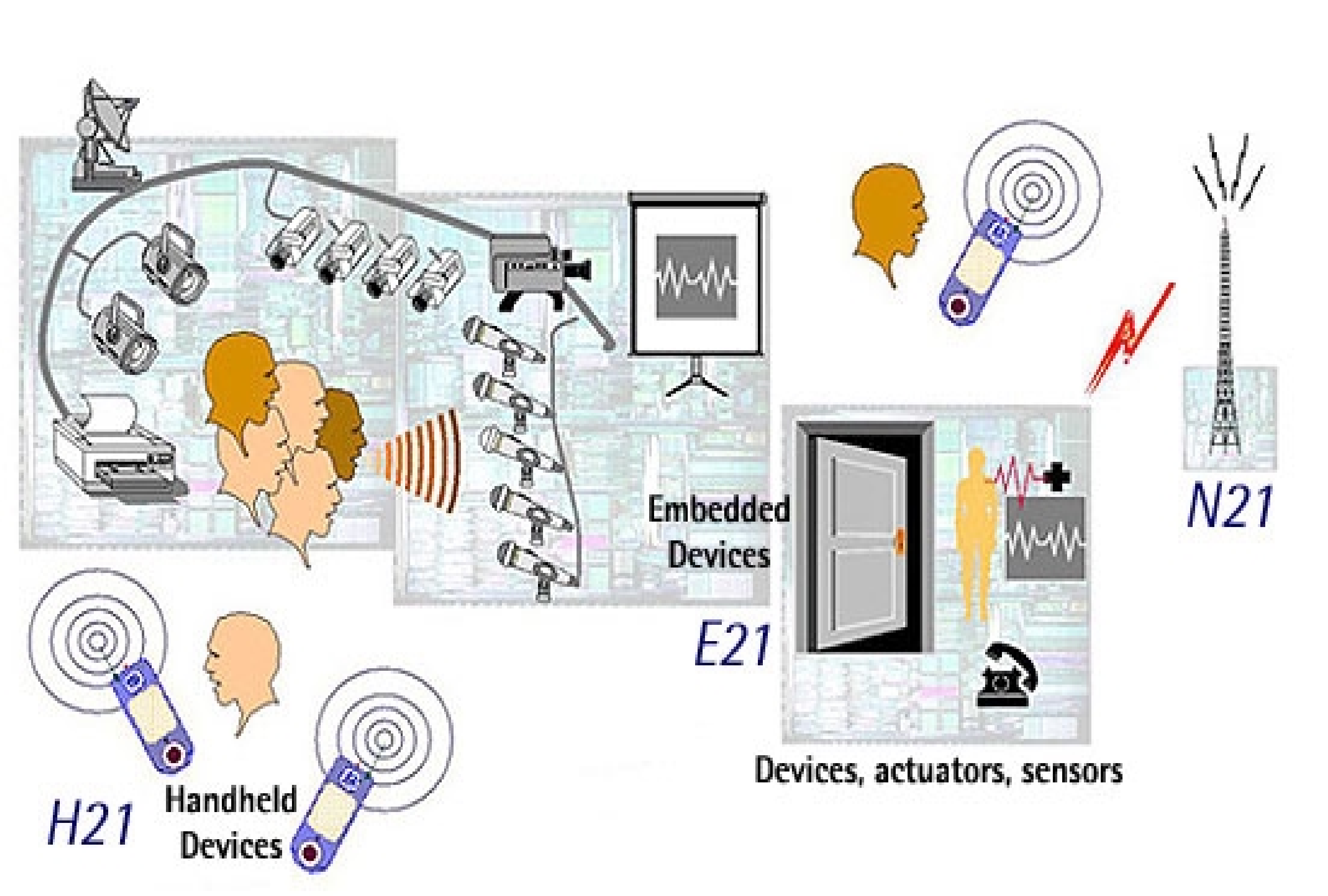
Pervasive Computing

- Computers have become an embed intrinsic part of a sophisticated, networked, pervasive and ubiquitous computing environments around humans.
- Pervasive Computing: create a ubiquitous environment that combines processors and sensors with network technologies (wireless and otherwise) and intelligent software to create an immerse environment to improve life.
- Is that ubiquitous environment a ubiquitous, coordinated embedded system?

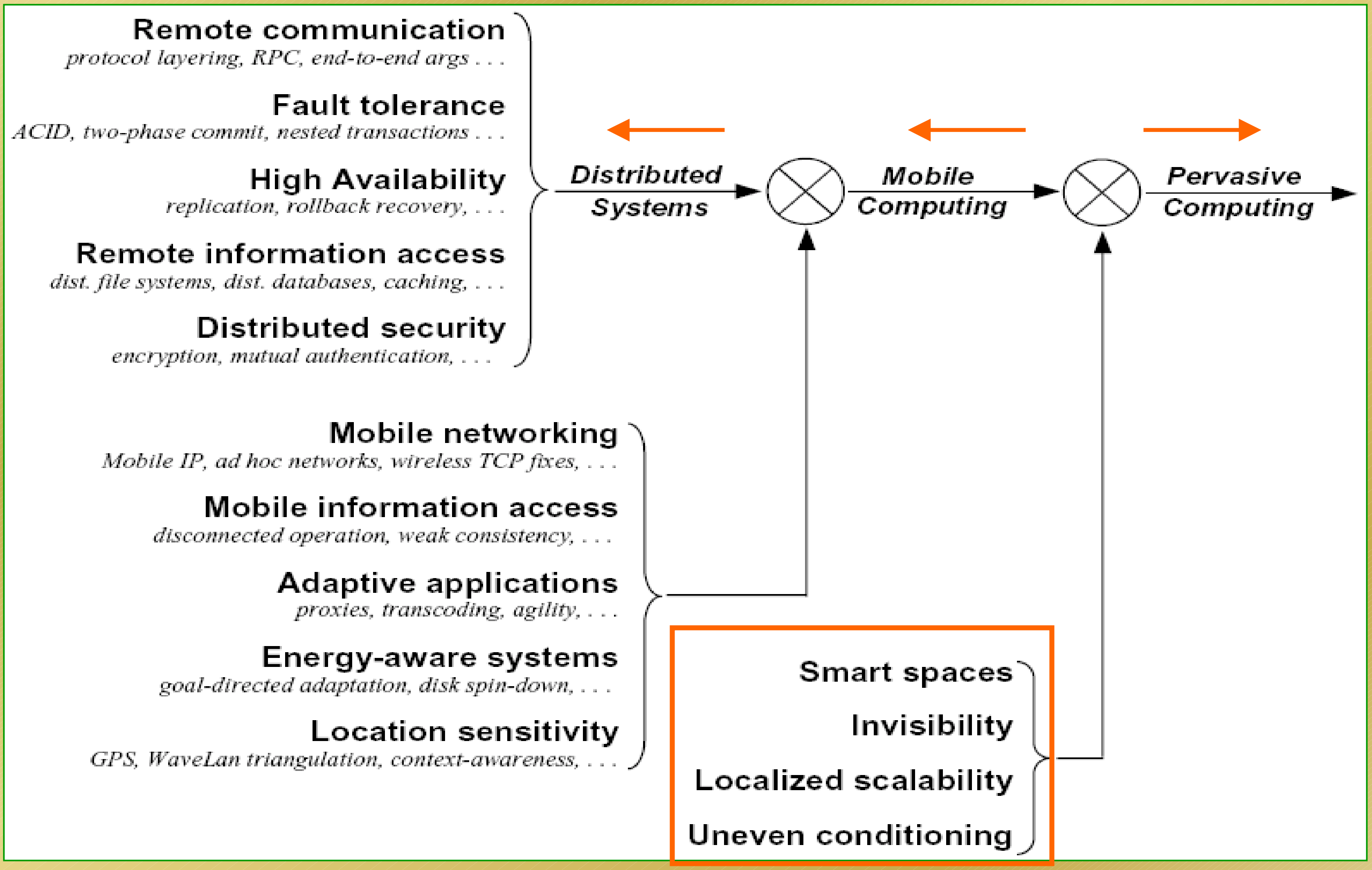
Pervasive Computing

continue

MIT's view of pervasive computing



Evolution of Pervasive Computing



Remote communication
protocol layering, RPC, end-to-end args . . .

Fault tolerance
ACID, two-phase commit, nested transactions . . .

High Availability
replication, rollback recovery, . . .

Remote information access
dist. file systems, dist. databases, caching, . . .

Distributed security
encryption, mutual authentication, . . .

Mobile networking
Mobile IP, ad hoc networks, wireless TCP fixes, . . .

Mobile information access
disconnected operation, weak consistency, . . .

Adaptive applications
proxies, transcoding, agility, . . .

Energy-aware systems
goal-directed adaptation, disk spin-down, . . .

Location sensitivity
GPS, WaveLan triangulation, context-awareness, . . .

Smart spaces

Invisibility

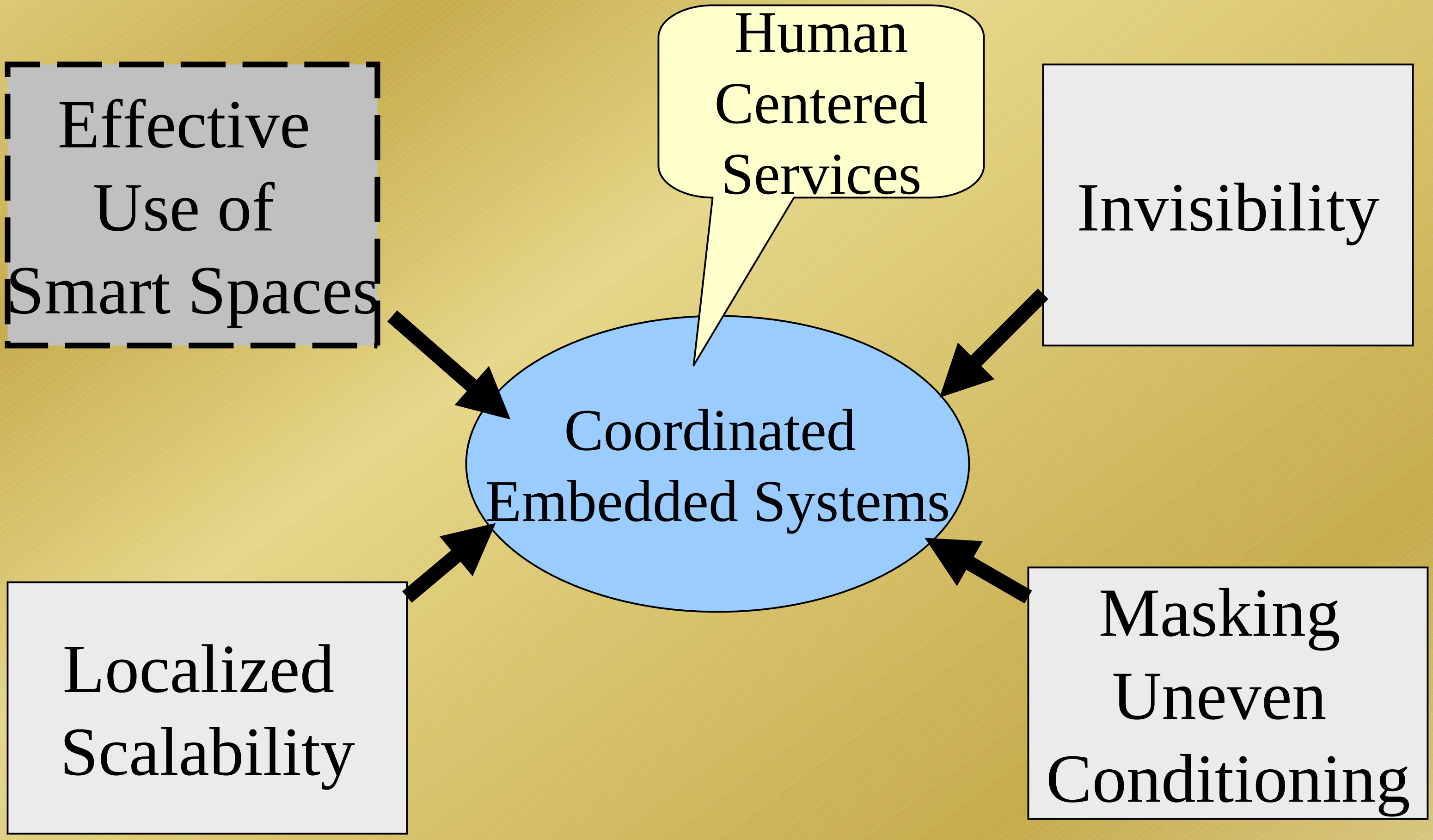
Localized scalability

Uneven conditioning

Distributed Systems → *Mobile Computing* → *Pervasive Computing*

By Satyanarayanan.

Context Awareness is a Challenge


Effective Use of Smart Spaces
Human Centered Services
Invisibility
Coordinated Embedded Systems
Localized Scalability
Masking Uneven Conditioning

SCS

Context Aware Embedded System

- Context
  - Useful information other than user input
- Context Awareness
  - Ability to *capture*, *understand* and *adap*t to surrounding context information
- Context aware embedded system
  - Capture context information via ‘embedded’ devices Takes action without explicit user input
  - Improves user experience by achieving collaboration and integration of embedded systems

Role of Context

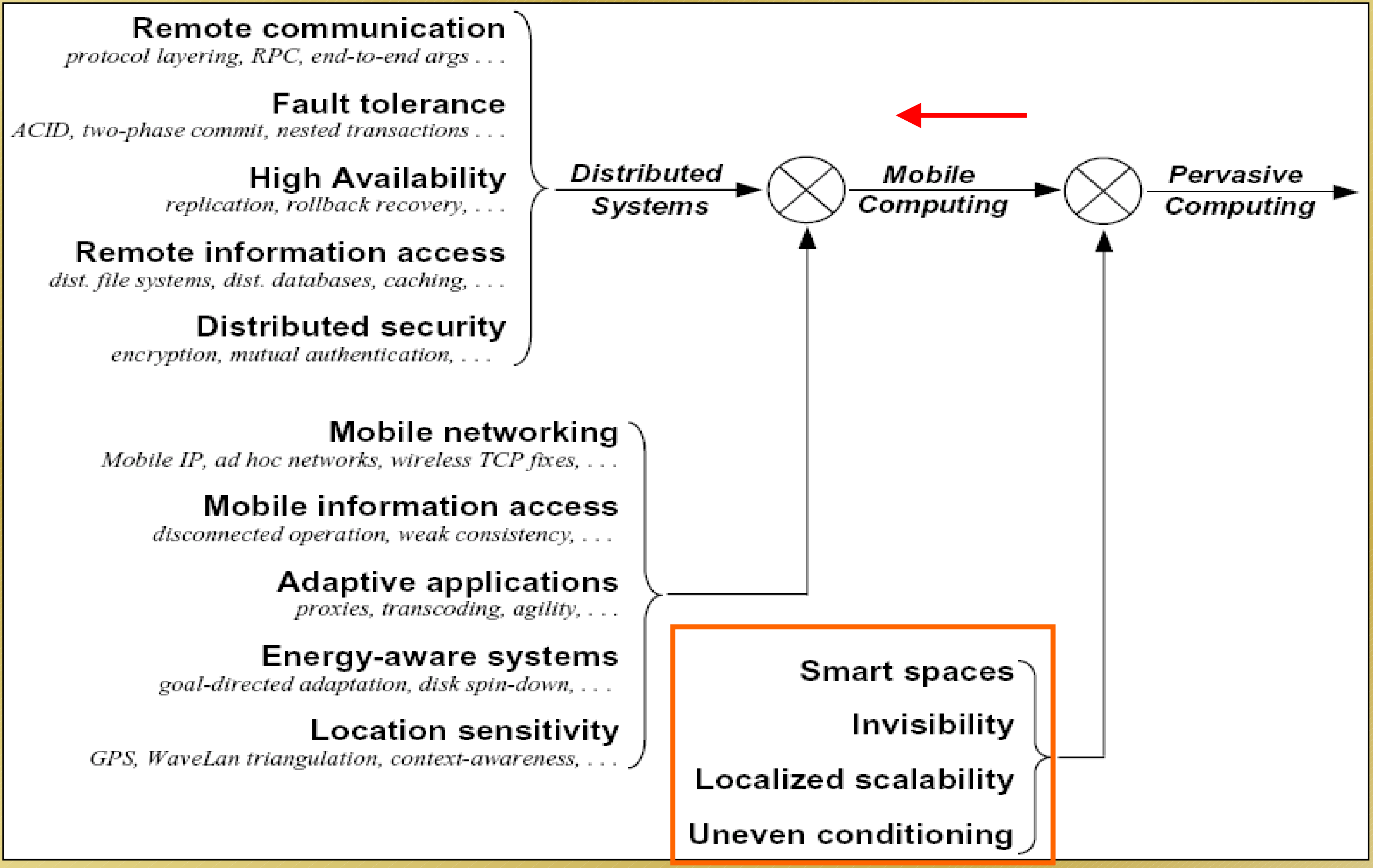
Traditional Class Environment

- Professor T informs students about the updated course website for lecture slides
- They need to bring the slides in the class for better understanding
- Some of the students either did not read the notification
- some of them forgot about it before the class

Smart Class Environment

- If
  - Professor T is moving towards the projector and
  - lights in the room are off
- Then the environment pervasively transfers the presentation slides from the professor's handheld device to students' handheld device
- The projector starts the presentation

Mobile Computing



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Smart spaces
Invisibility
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Uneven conditioning

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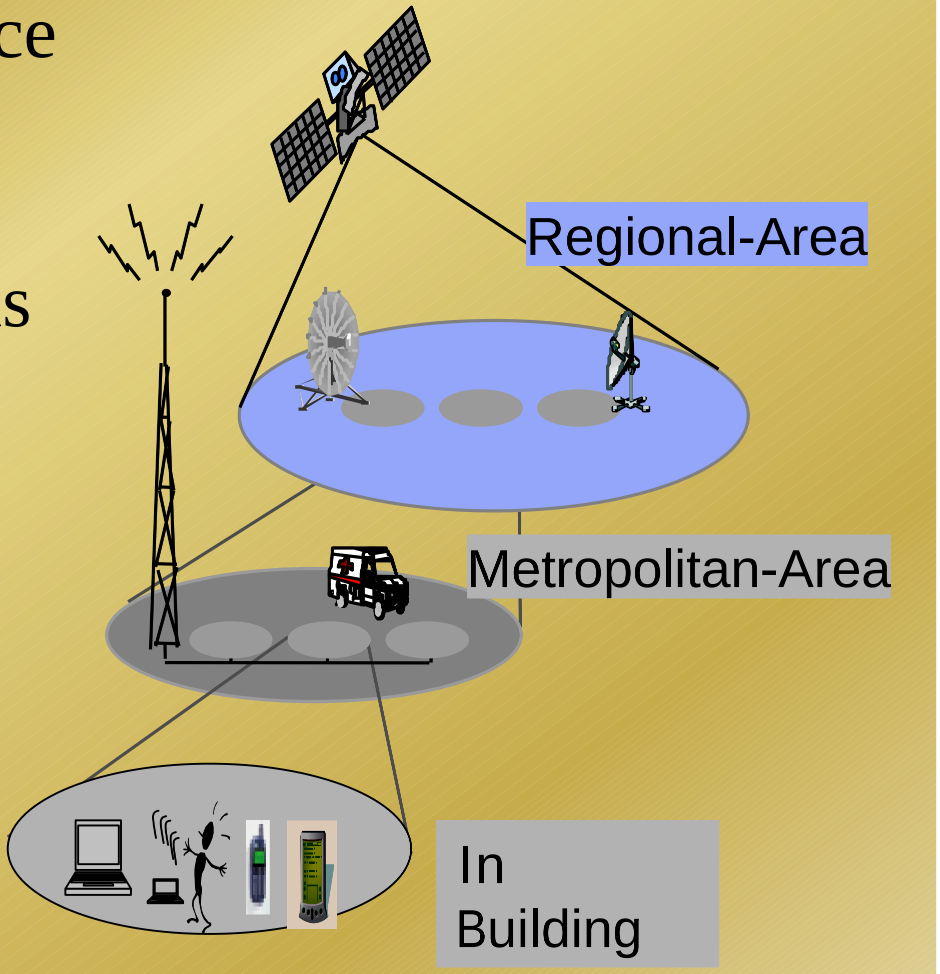
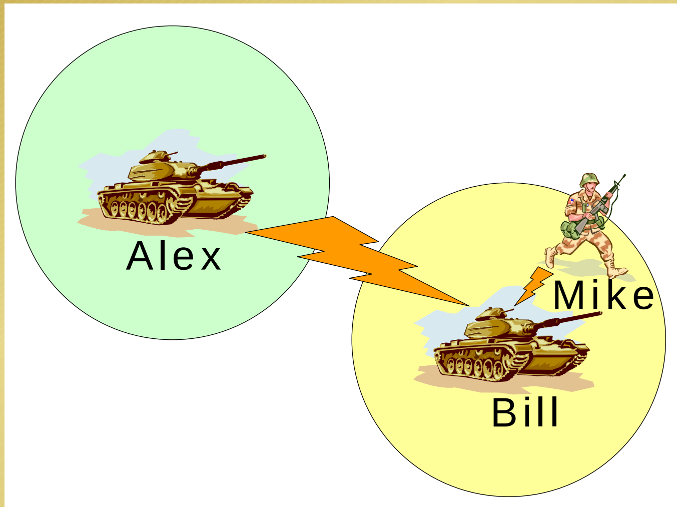
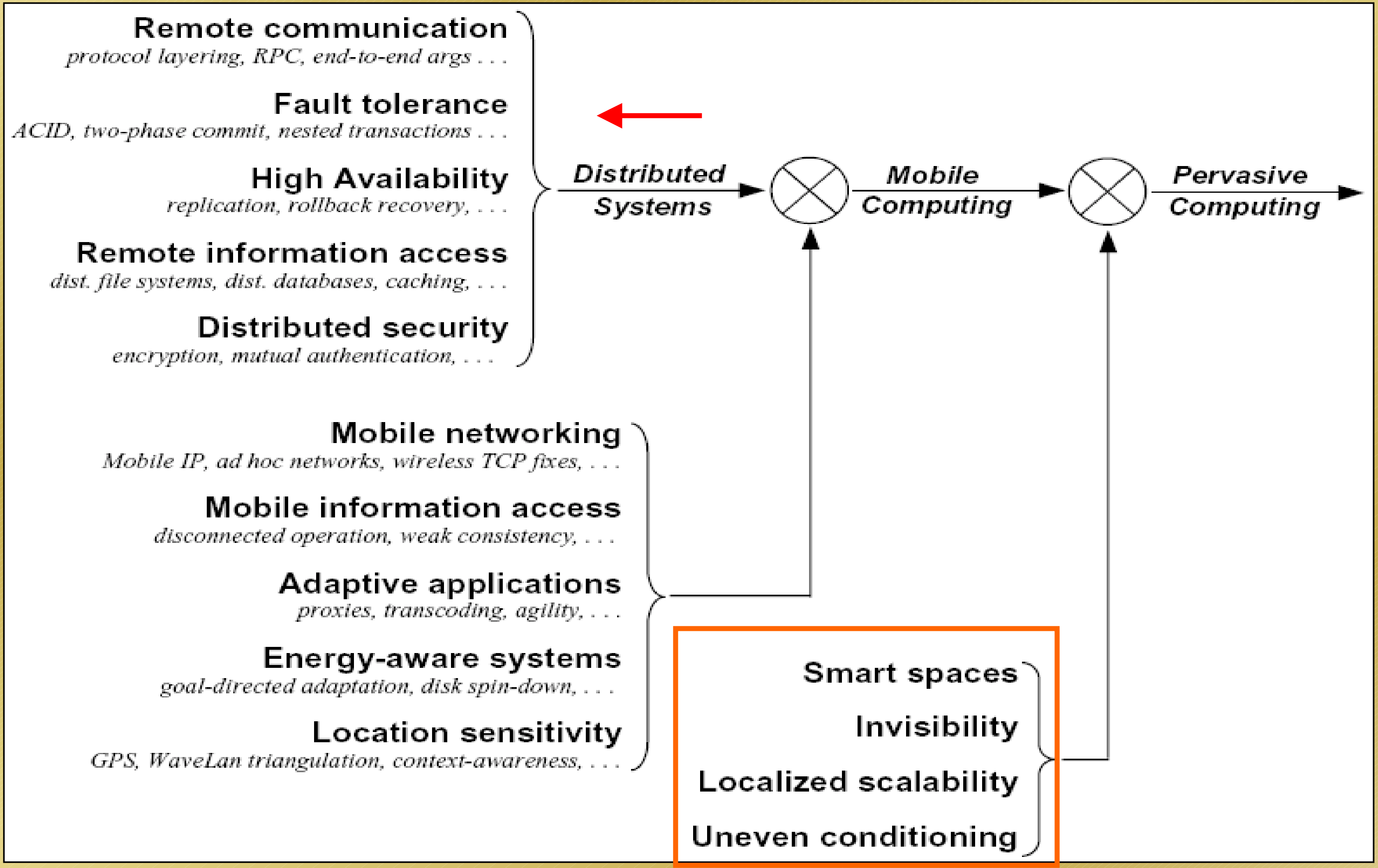
Continued Service is a Challenge

- Any time, any where service
- Device, network mobility
- Adaptation, context aware
- Application software versus infrastructure system





Distributed System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Grid Computing

- Global computing infrastructure
- Mimic electrical power grid
- Resources sharing
- Research Focus
  - Abstraction of Common Services into an Infrastructure
  - Supporting application development

Smart Cyberspace as a Challenge

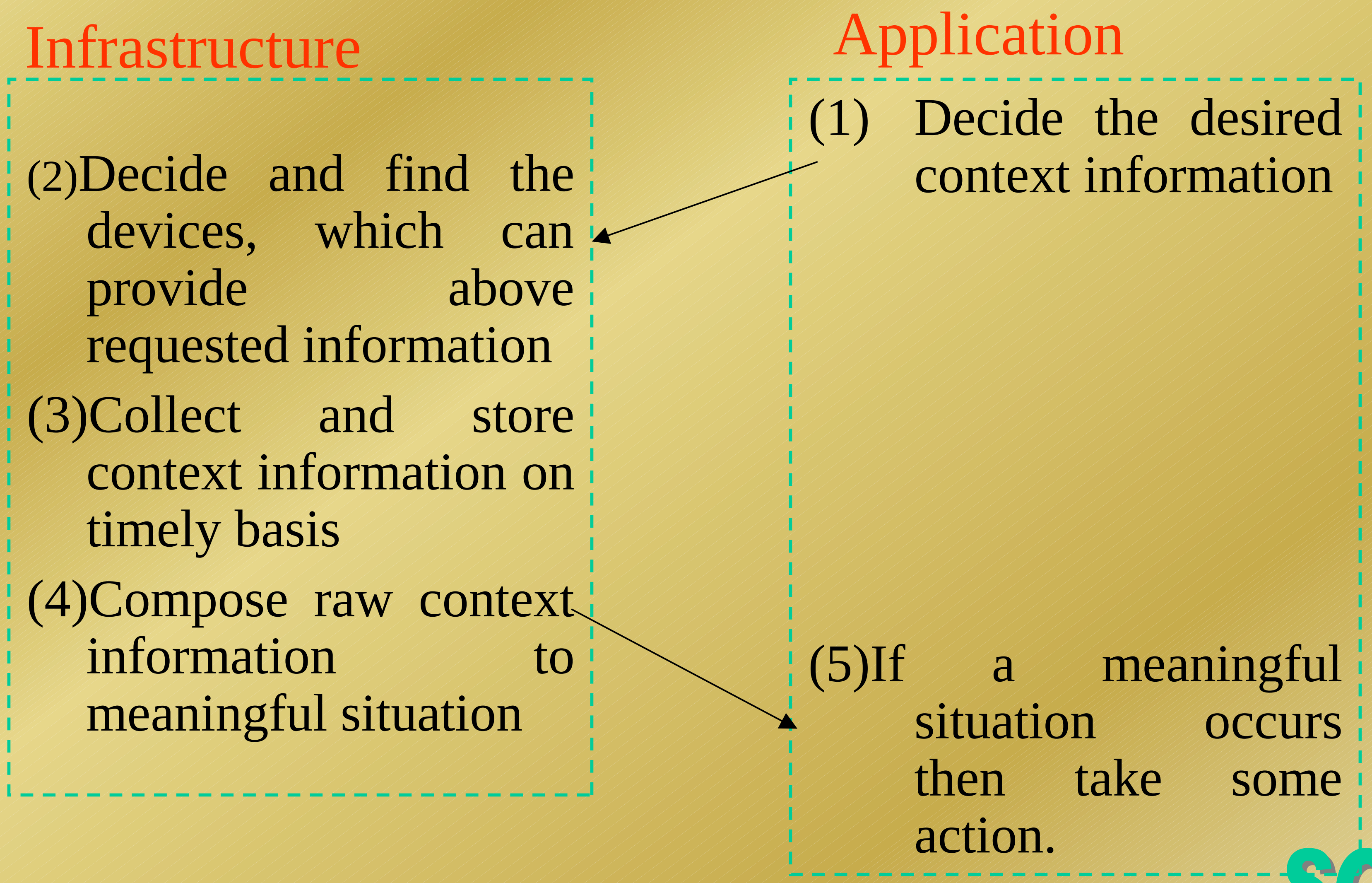
- Grid as the computing infrastructure
- Embedded systems form the end `smart space' for `human centered' service
- Embedded devices as the entry to the cyberspace
- Global smartness

SCS

Context Aware System Design

- Existing context aware systems
  - Tied to a specific platform
  - Requires too much knowledge to expand
  - Too difficult to expand
  - Not modular and lacked reuse of common functionality
- Seeking to develop a framework for something better
  - Infrastructure – common functionality
  - Applications – adaptation-specific functionality

Separation of Application and Infrastructure



Infrastructure

(2)Decide and find the devices, which can provide above requested information

(3)Collect and store context information on timely basis

(4)Compose raw context information to meaningful situation

Application

(1) Decide the desired context information

(5)If a meaningful situation occurs then take some action.

Software Engineering (finally!)

- Increasing complexities due to growth in technologies
- Integration and Extensibility are critical issues
- Current design approaches cannot decouple the complexities arising out of integration and evolution intent

Need Better Design Methodology !!!
Can Aspect Orientation Help?

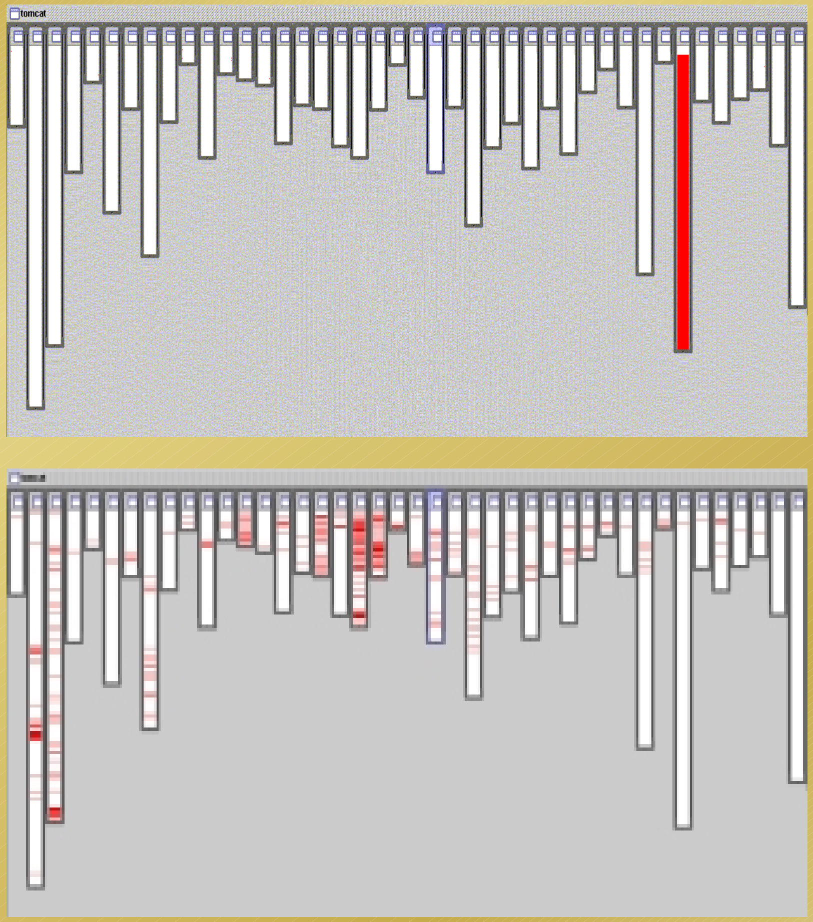
Aspect Oriented Software Development

- Relatively new design methodology based on the principle of 'Separation of Concerns'
- 'Concern'
  - Well defined entity in a software (e.g. Security, Synchronization, Logging, Functional properties, etc) l
- 'Crosscutting Concern'
  - A concern whose implementation crosscut the implementation of other concerns
  - Results in 'Tangled Code'
- 'Aspect'
  - A modularized realization of crosscutting concern

Example

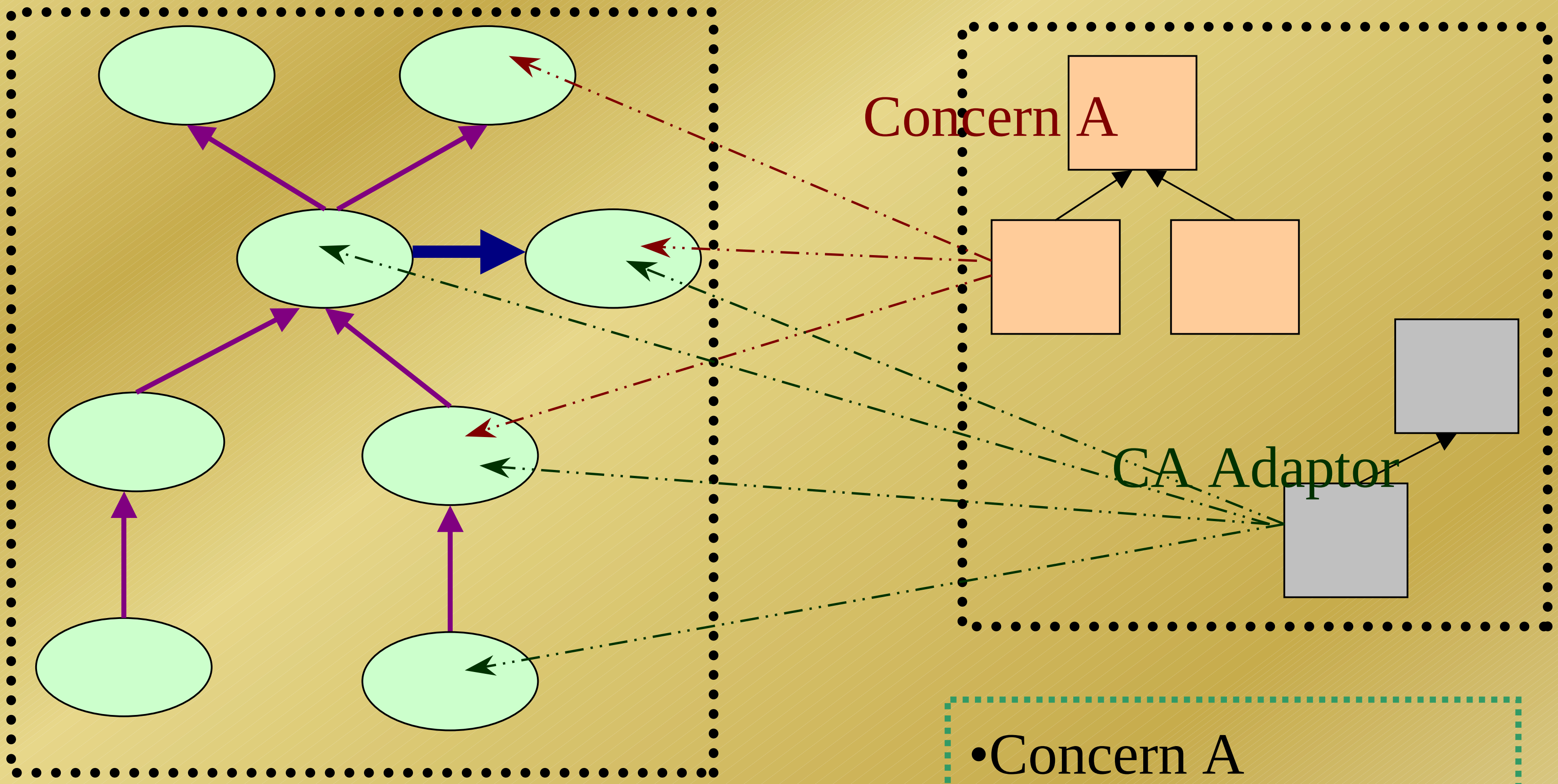
- Good Modularity
  - XML Parsing concern modularized in one component

- Bad Modularity
  - Code for Logging concern is scattered across multiple components



Figures from AspectJ tutorial – source code for org.apache.tomcat

Adaptation is a Concern of CA Applications



- Concern A
- Concern B: CA Adaptor

Context Aware Infrastructure Requirements

Functional Requirements

- Context collection
- Context Storage/Management
- Context Subscription/Delivery
- Context Analysis/Composition Ability

Non Functional Requirements

- Scalability
- Modularity
- Cross platform
- Security
- Extensibility
- Ability to Evolve
- Quality of Service
- Fault Tolerance
- Mobility
- User Friendly Interface

Context Aware System is a good candidate to apply Aspect Orientation!!!

Implementation

- Scarlet: A IIT context aware infrastructure prototype
- Follows design principles of Grid’s OGSA (Open Grid Service Architecture)
  - Grid computing has faced similar challenges
  - Caused much of the problems with the change from Globus 2.x to Globus 3 (OGSA)

Cross-Platform

- OS & language independent
- Specifying a comm. model, rather than object parameters
- SOAP over HTTP for most communication
- Context providers are described using WSDL documents

Modular

- Every part of Scarlet is a module
  - base, provider, consumer, registry, etc
- Allows easy replacement with customized components
- Only needed components are loaded

Extensible

- In the future we may need additional functionality
  - Context caching, preemptive fetching, etc
- Different size systems have different needs

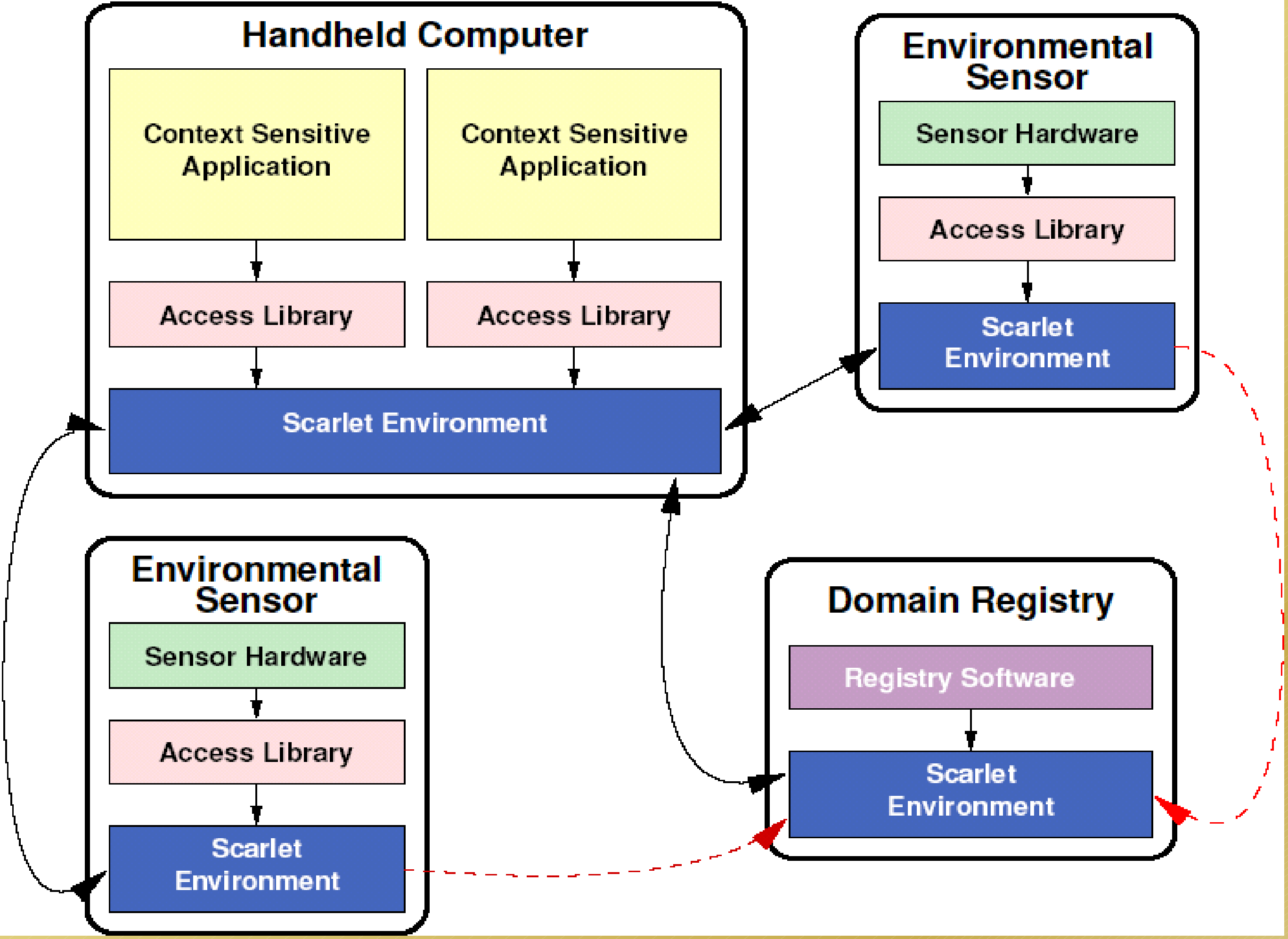
Scalable

- Supporting all devices from embedded sensors to super computers
- Acceptable to deliver limited functionality for some devices
  - A handheld doesn't need a domain registry

Some Implementation Details

- Uses following tools
  - Python 2.2
  - SOAPpy 0.10
  - PyXML 0.8.2
- Runs on variety of systems (not complete list)
  - Windows 98/2000/XP
  - Linux x86, MIPS, SPARC, and Arm (embedded)
  - OpenBSD x86 and SPARC
  - Solaris x86 and SPARC

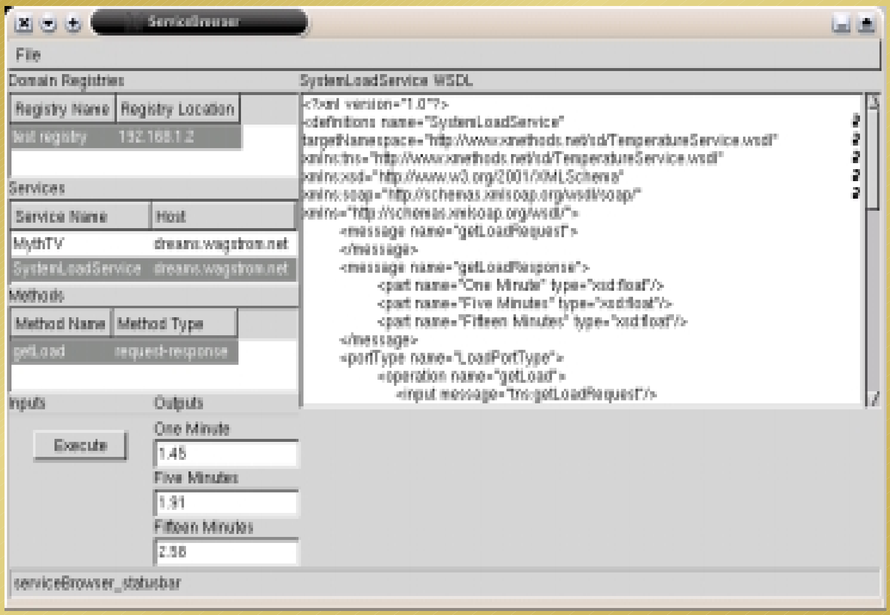
Scarlet Network



SCS

Sample Applications

- Service Browser
- Wireless Strength Monitor
- Television Assistant
- Tour Guide



Domain Registries

Registry Name	Registry Location
test registry	192.168.1.2

Services

Service Name	Host
MythTV	dreams.wagstrom.net
SystemLoadService	dreams.wagstrom.net

Methods

Method Name	Method Type
getLoad	request-response

Inputs

Outputs

One Minute: 1.45

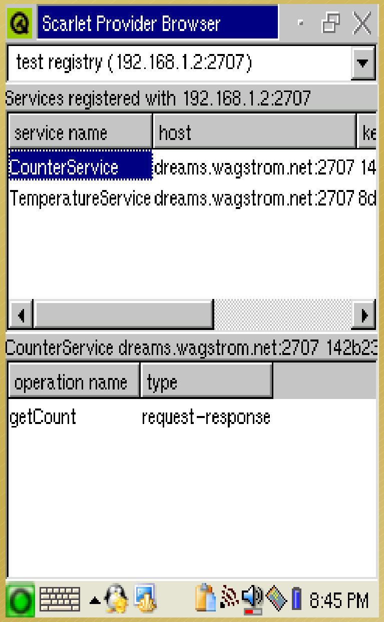
Five Minutes: 1.91

Fifteen Minutes: 2.58

SystemLoadService WSDL

```
<?xml version="1.0"?>
<definitions name="SystemLoadService"
targetNamespace="http://www.xmethods.net/sd/TemperatureService.wsdl"
xmlns:tns="http://www.xmethods.net/sd/TemperatureService.wsdl"
xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns:soap="http://schemas.xmlsoap.org/wsdl/soap/"
xmlns="http://schemas.xmlsoap.org/wsdl/">
        <message name="getLoadRequest">
        </message>
        <message name="getLoadResponse">
                <part name="One Minute" type="xsd:float"/>
                <part name="Five Minutes" type="xsd:float"/>
                <part name="Fifteen Minutes" type="xsd:float"/>
        </message>
        <portType name="LoadPortType">
                <operation name="getLoad">
                    <input message="tns:getLoadRequest"/>
```

serviceBrowser_statusbar



test registry (192.168.1.2:2707)

Services registered with 192.168.1.2:2707

service name	host	ke
CounterService	dreams.wagstrom.net:2707	14
TemperatureService	dreams.wagstrom.net:2707	8d

CounterService dreams.wagstrom.net:2707 142b23

operation name	type
getCount	request-response

Conclusion

- Position: Technical advance in embedded system lead to new challenges in software engineering/development
- Context aware, Continued Service, Global Smartness
- Aspect Orientated: a base of software design
- Scarlet: a context aware computing infrastructure
- Questions in Software Engineering
  - New language for context representation?
  - New modeling for context awareness?
  - Is the client/server model a good model for Grid computing?
  - Can peer-to-peer extended beyond file sharing?
  - …