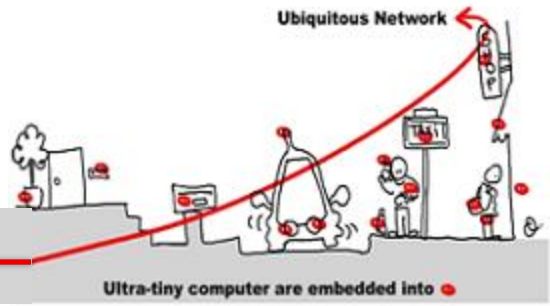
Middleware for Ubiquituous Computing



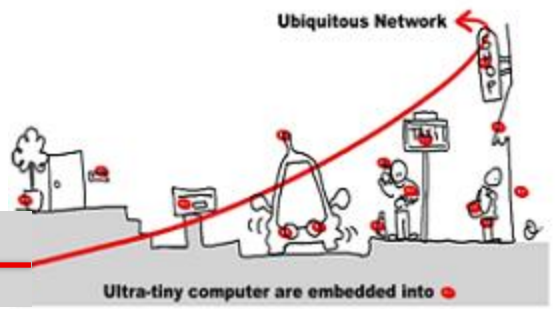
- Middleware … from distributed systems to network of things
- UbiComp Middleware :

  http://www.tigli.fr/doku.php?id=cours:muc_2013_2014

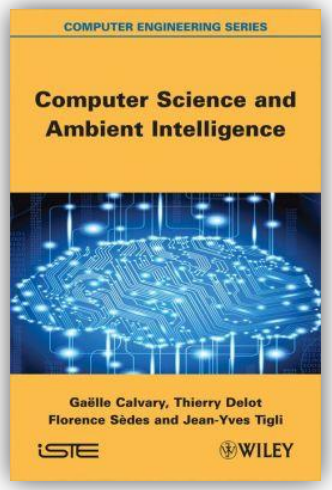
Main Instructor : Ass. Prof. Jean-Yves Tigli
http://www.tigli.fr
at Polytech of Nice - Sophia Antipolis University

Email : tigli@polytech.unice.fr

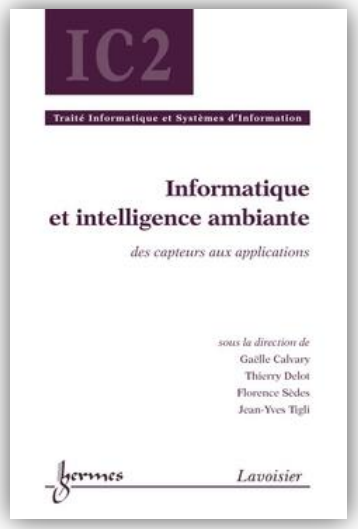
New challenges in ubiquitous computing

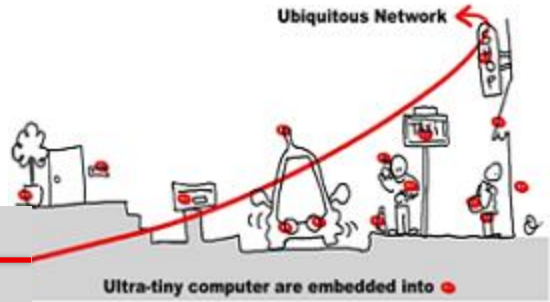


[2013] Gaëlle Calvary, Thierry Delot, Florence Sèdes, **Jean-Yves Tigli**, editors. "Computer Science and Ambient Intelligence" 335 pages, ISTE Ltd and Wiley & Sons Inc, March 2013, ISBN 978-1-84821-437-8



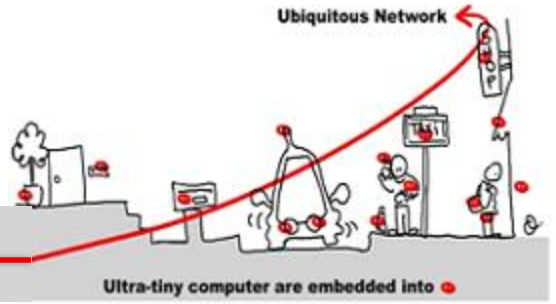
[2012] Gaëlle Calvary, Thierry Delot, Florence Sèdes, **Jean-Yves Tigli**. "Informatique et Intelligence Ambiante : des Capteurs aux Applications (Traité Informatique et Systèmes d'Information, IC2)" Hermes Science, July 2012, ISBN 2-7462-2981-1





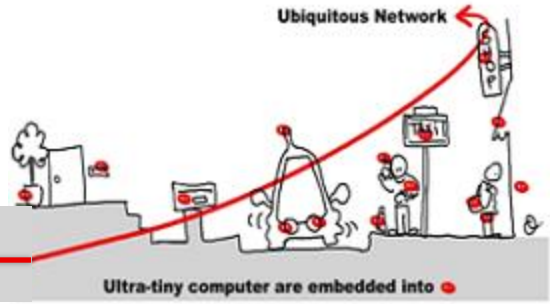
INTRODUCTION TO UBICOMP REQUIREMENTS

UbiComp Software for What ?



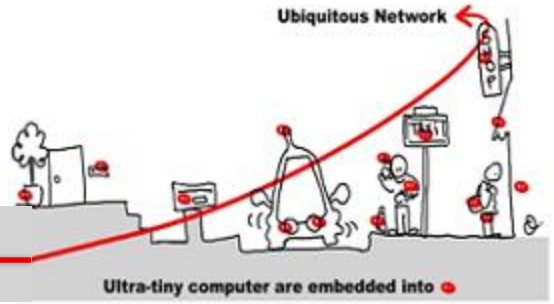
- Video Introduction … the main purpose and societal interest
  - http://www.dailymotion.com/video/xqj9f1_ambient-comp-end-user-gb-hd_tech

Ubiquituous Computing : UbiComp



Capteur biologique Multi fonction
Miroir Interactif
Vitrage Multi fonction
Capteur biologique
Web cam
Capteurs de présence
Robot aide ménagère
Réfrigérateur Intelligent
Isolant thermique modulable
Régulateur de température
Panneau Solaire
Stockage d'énergie
Détecteur d'humidité de pelouse
Arroseur automatique

What are the main challenges ?



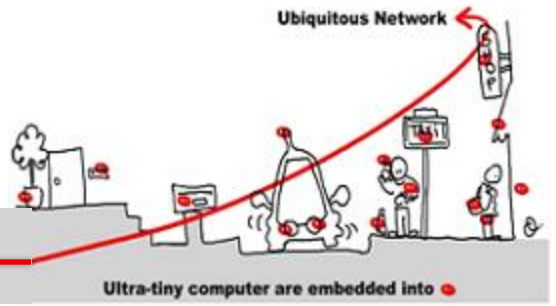
- Service Continuity or how to program a continuous application,
  - In spite of physical environment changing
  - In spite of software platform or software infrastructure changing

  Without exactly knowing what these features will be at runtime

  …

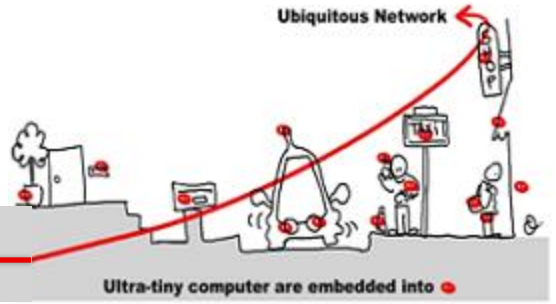
1. Ubiquituous Application are situated in a real and physical changing world
2. Expert users (new programmers)
   - Can design the software application at design time
   - Can adapt the software application at runtime
   - But the application must be autonomous to react to the environment changing

Expert Users and Multi-Domain adaptation



- Ubiquitous Middleware must continuously adapt at runtime, application requirements to changing computing environment (due to mobility) in multiple domains :
  - HMI,
  - Power,
  - Network bandwidth,
  - Devices availability, …

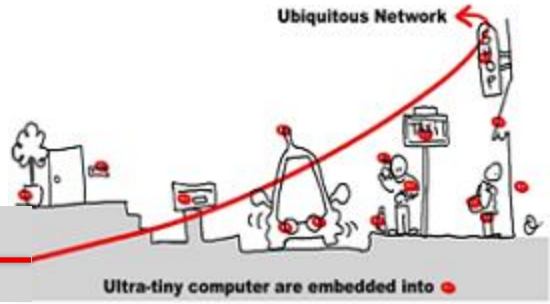
Autonomy and Reactive adaptation



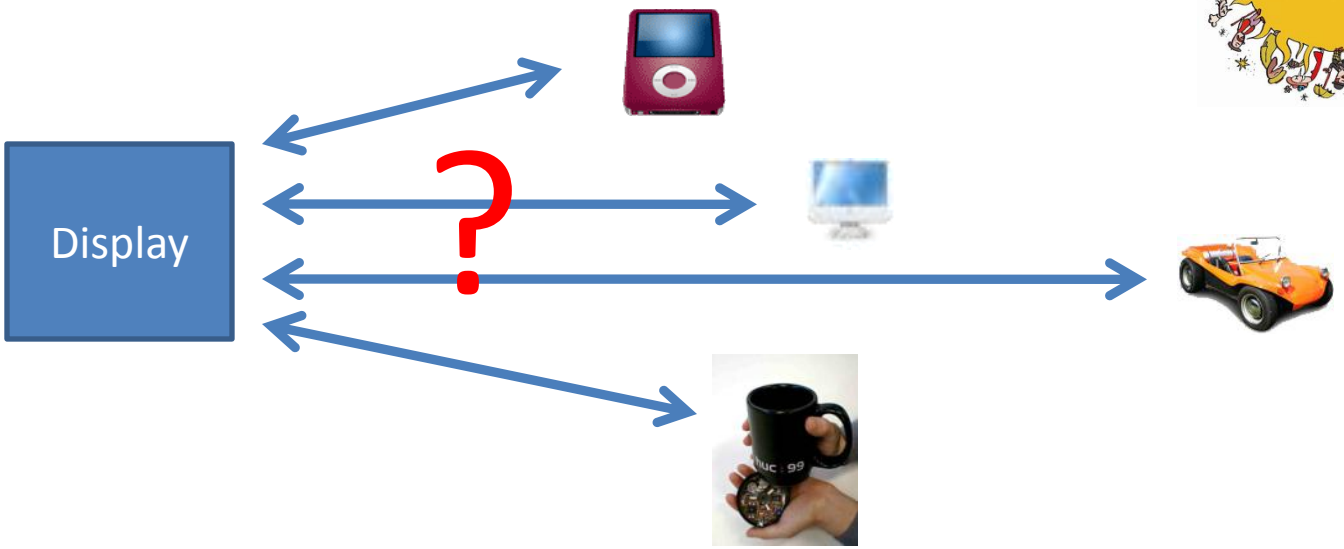
- Reactive adaptation is defined as the ability for the Ubiquitous applications to perceive the environment and adapt to changes in that environment in a timely fashion.

- Ubiquitous Middleware must provide reactive adaptation mecanism to changing operational environment.

Interoperability and Semantic adaptation

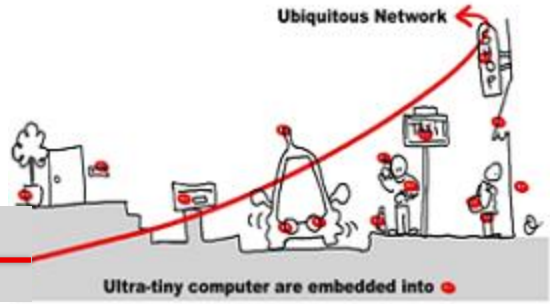


- Ubiquitous Middleware must match at run-time the current operational environment and application requirements.

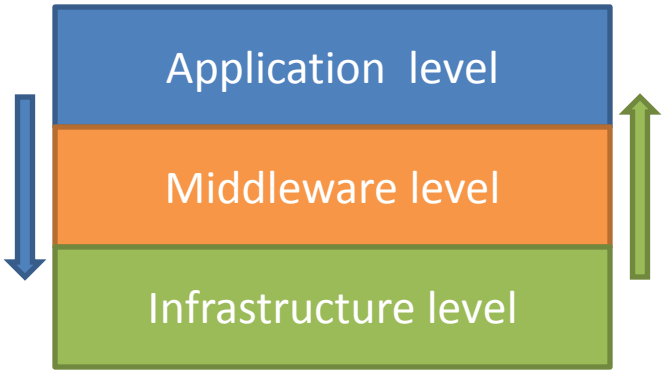


Can match with ?

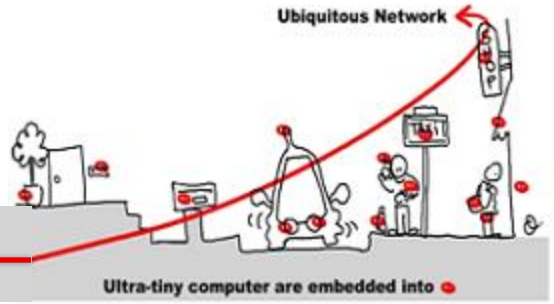
Context and Real world interaction



- Ubiquitous Computing applications are continuously interacting with a real world, partly unknown at design time and, always changing at runtime in uncountable manner
- We witness to a kind of inversion in the classical software methodology where the software applications levels are much more stable and stationary than the software infrastructure level.

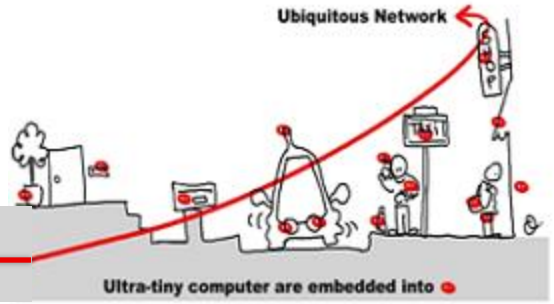


Then What are UbiComp Software difficulties ?



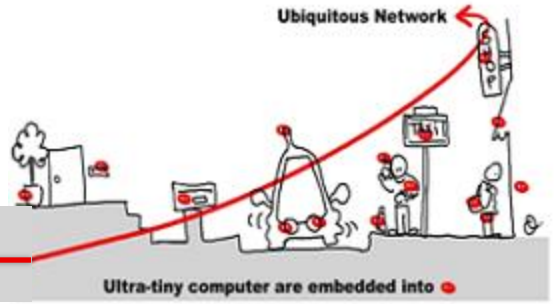
- Video Samples of Research Projects (see MUC Web Site) :
  - Continuum and the PhotoShuffler (IIHM Research Team at the Computer Sciences Laboratory of Grenoble)
  - Continuum and the Mobile Worker on the field
  - UbiFlood and Heterogeneous Devices on the field (STIC ASIA project with Nat. Univ. Of Singapore, AIT Thailand and India …)

- Let Try to find a solution in a Middleware to help Expert User to Design and Maintain UbiComp Software applcation

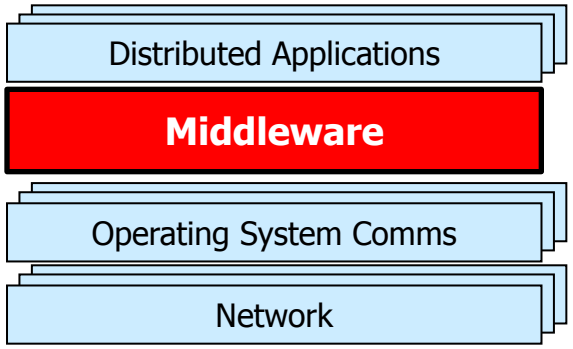


INTRODUCTION TO MIDDLEWARE

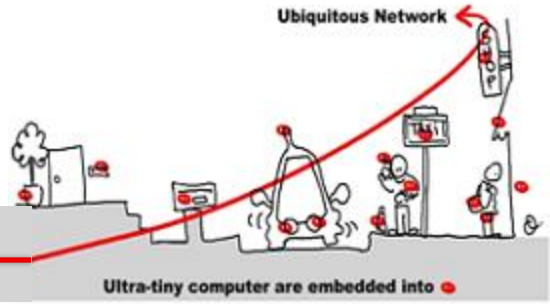
What is Middleware ?



- What is Middleware?
  - Layer between OS and distributed applications
  - Provides common programming abstraction and infrastructure for distributed applications
  - Hiding distribution, i.e. the fact that an application is usually made up of many interconnected parts running in distributed locations.
  - Hiding the heterogeneity of the various hardware components, operating systems and communication protocols that are used by the different parts of an application.
  - Supplying a set of common services to perform various general purpose functions, in order to avoid duplicating efforts and to facilitate collaboration between applications.



Generic definition



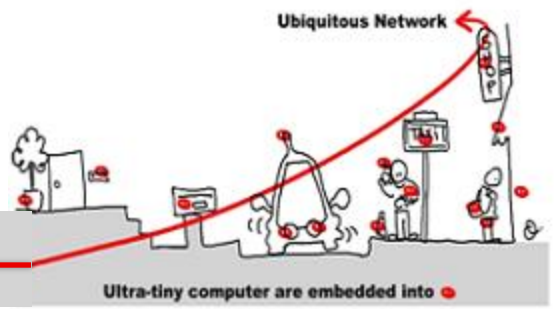
- *"The intersection of the stuff that network engineers don't want to do with the stuff that applications developers don't want to do."*

  [Kenneth J. Klingenstein ('99)]

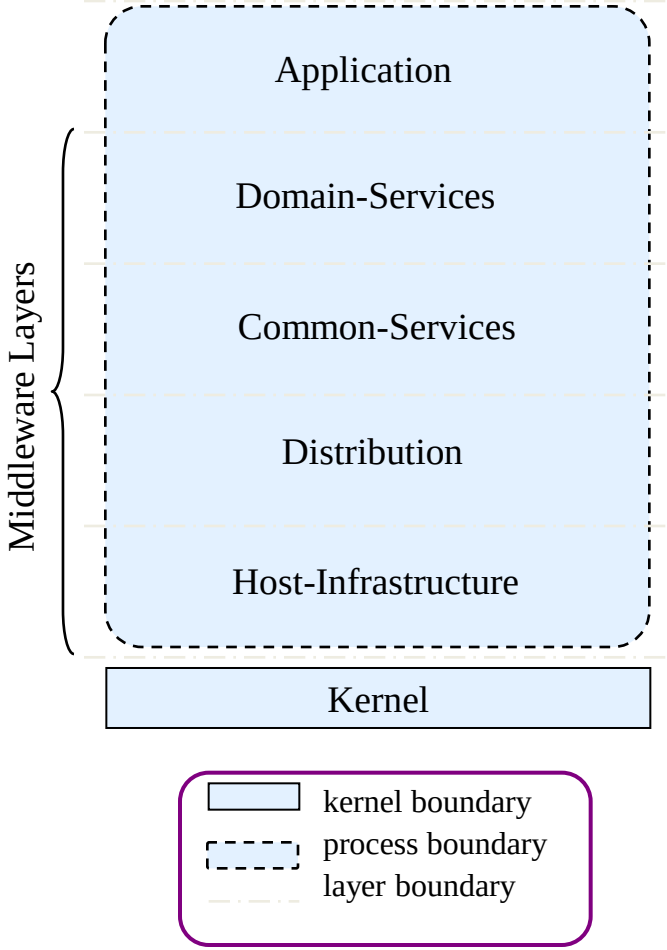
- But mainly to deal with distribution of software applications at the beginning

Middleware can be a Stack of Middlewares :

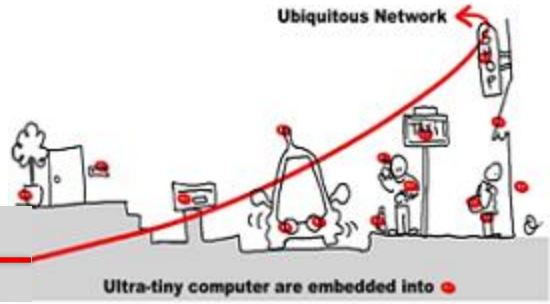
E. Schantz and D. C. Schmidt Taxonomy (2002)



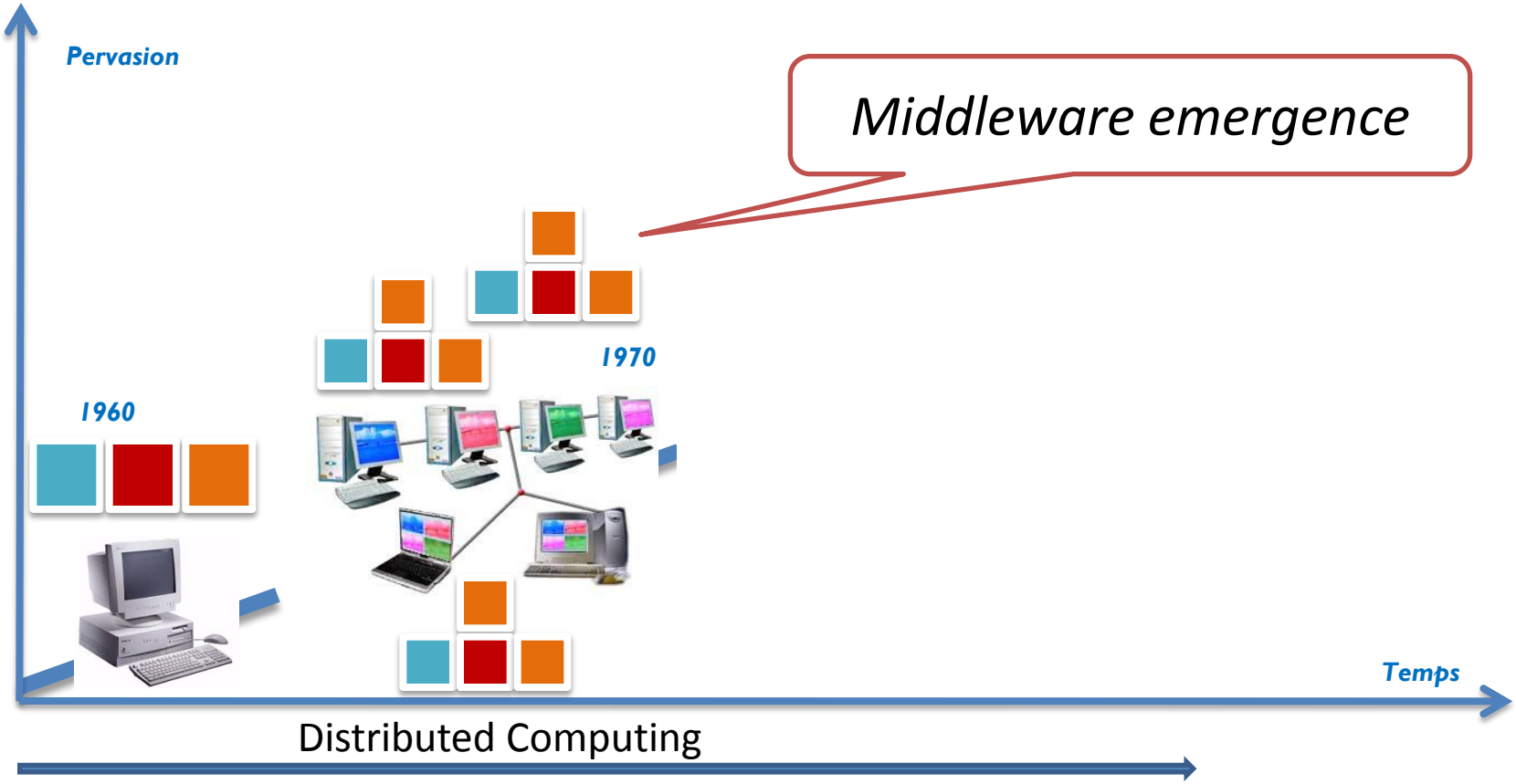
- Schantz and Schmidt decomposed middleware into four layers:
  - Domain-Services
    - Tailored to a specific class of distributed applications
  - Common-Services
    - Functionality such as fault tolerance, security, load balancing and transactions
  - Distribution
    - Programming-language abstraction
  - Host-Infrastructure
    - Platform-abstraction



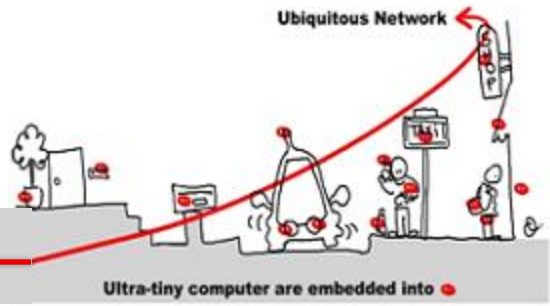
Distributing Computing



- From distributed systems …



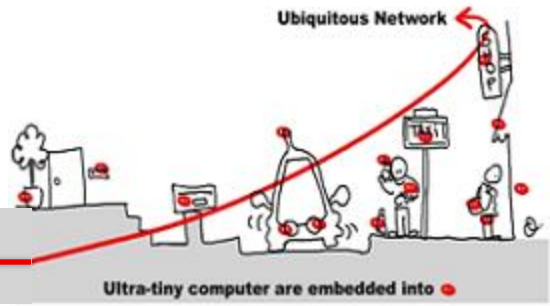
Middleware and software distribution



- The term middleware first appeared in the late 1980s to describe network connection management software
- It did not come into widespread use until the mid 1990s, when network technology had achieved sufficient penetration and visibility.

MAIN REFERENCE:
http://sardes.inrialpes.fr/~krakowia/MW-Book/Chapters/Preface/preface.html

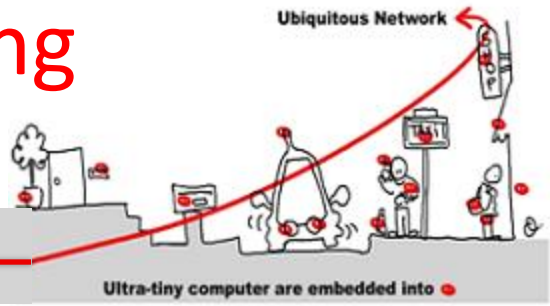
Middleware for Distribution features



- Middleware provides support for technical services (some of):
  - Naming, Location, Service discovery, Replication
  - Protocol handling, Communication faults, QoS
  - Synchronisation, Concurrency, Transactions, Storage
  - Access control, Authentication

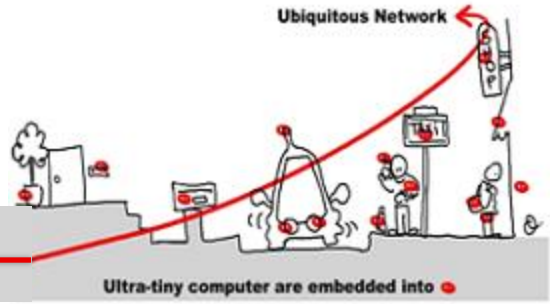
- Middleware dimensions:
  - Request/Reply vs. Asynchronous Messaging
  - Language-specific vs. Language-independent
  - Proprietary vs. Standards-based
  - Small-scale vs. Large-scale
  - Tightly-coupled vs. Loosely-coupled components

Four types of Middleware according communication paradigms

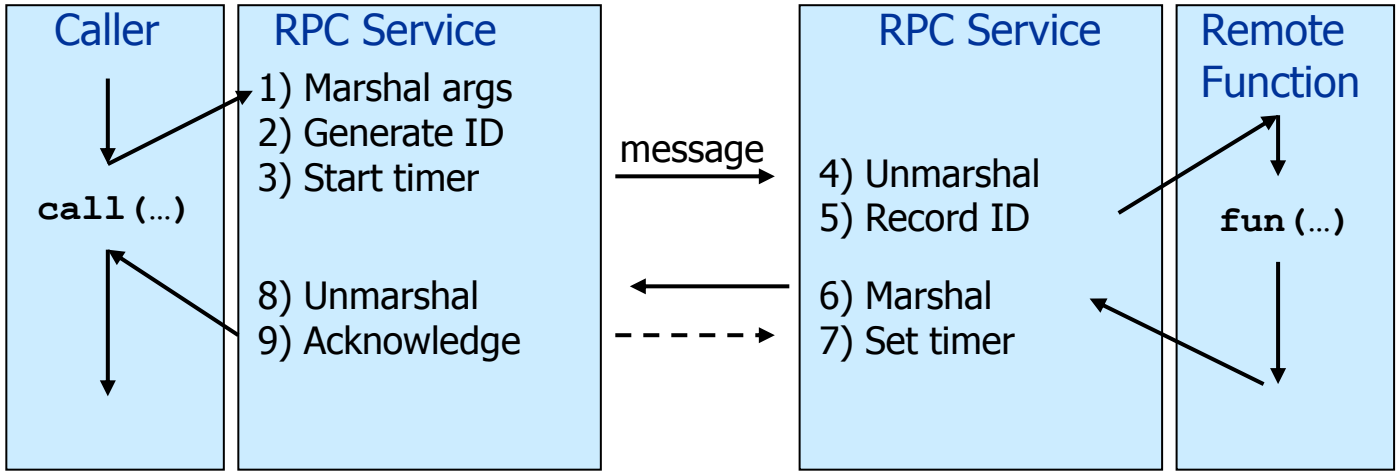


- Part I: Remote Procedure Call (RPC)
  - Historic interest
- Part II: Object-Oriented Middleware (OOM)
  - Ex. Java RMI
  - Ex. CORBA
- Part III: Message-Oriented Middleware (MOM)
  - Ex. Java Message Service
- Part IV: Event-Based Middleware
  - Cambridge Event Architecture
- They are prerequisites !
- **If you need practice, feel free to ask some tutorials and references**

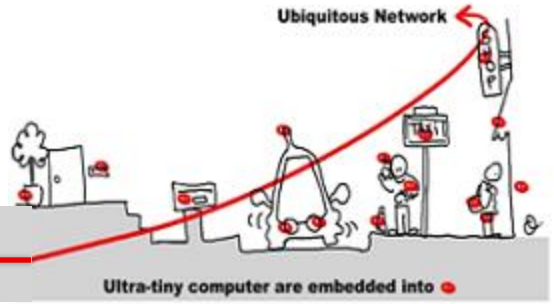
Part I: Remote Procedure Call (RPC)



- Masks remote function calls as being local
- Client/server model
- Request/reply paradigm usually implemented with message passing in RPC service
- Marshalling of function parameters and return value

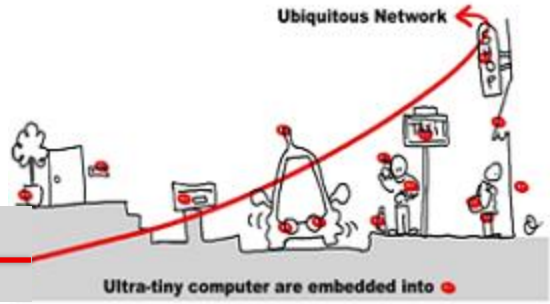


Properties of RPC

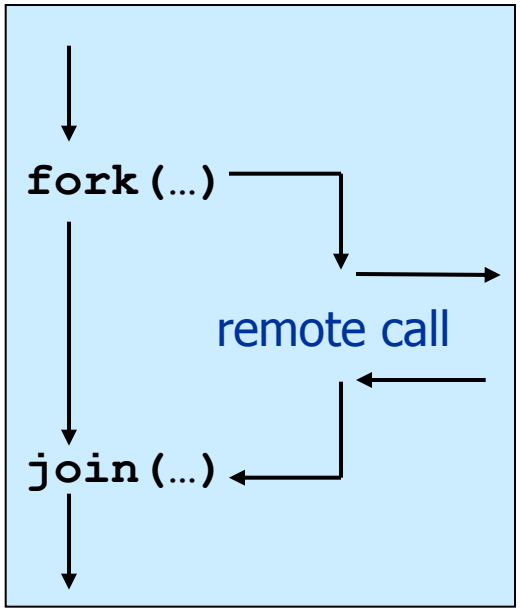


- Language-level pattern of function call
  - easy to understand for programmer
- Synchronous request/reply interaction
  - natural from a programming language point-of-view
  - matches replies to requests
  - built in synchronisation of requests and replies
- Distribution transparency (in the no-failure case)
  - hides the complexity of a distributed system

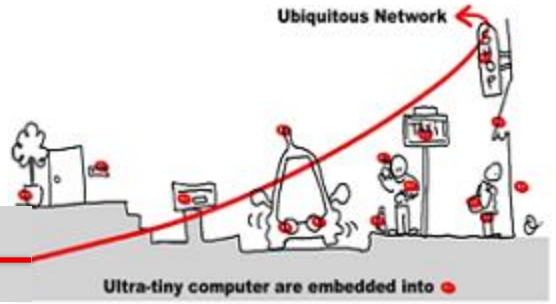
Disadvantages and limitations of RPC



- Synchronous request/reply interaction
  - tight coupling between client and server
  - client may block for a long time if server loaded
  - leads to multi-threaded programming at client
  - slow/failed clients may delay servers when replying
  - multi-threading essential at servers
- Distribution Transparency
  - Not possible to mask all problems
- RPC paradigm is not object-oriented
  - invoke functions on servers as opposed to methods on objects



Do you know ?

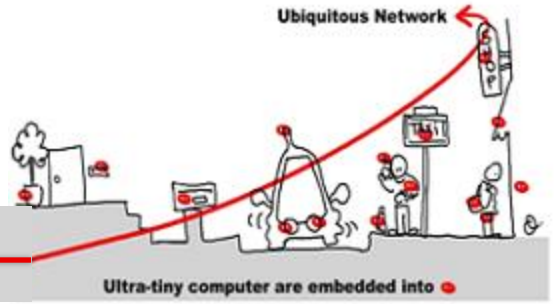


- Any example for RPC based Middleware ?

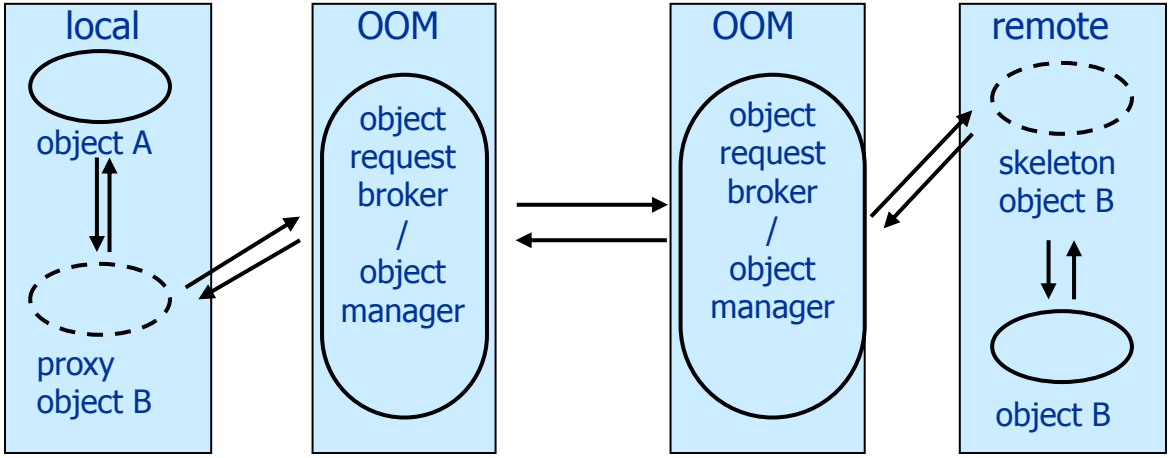
- in your background …

- Example :
  - See XML-RPC : http://www.tutorialspoint.com/xml-rpc/
  - One kind of Web Service Middleware Communication paradigm is RPC
    - See W3C consortium : http://www.w3schools.com/webservices/

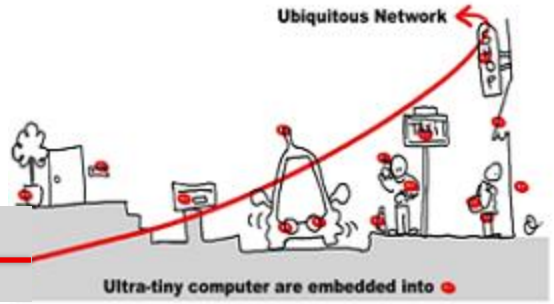
Part II: Object-Oriented Middleware (OOM)



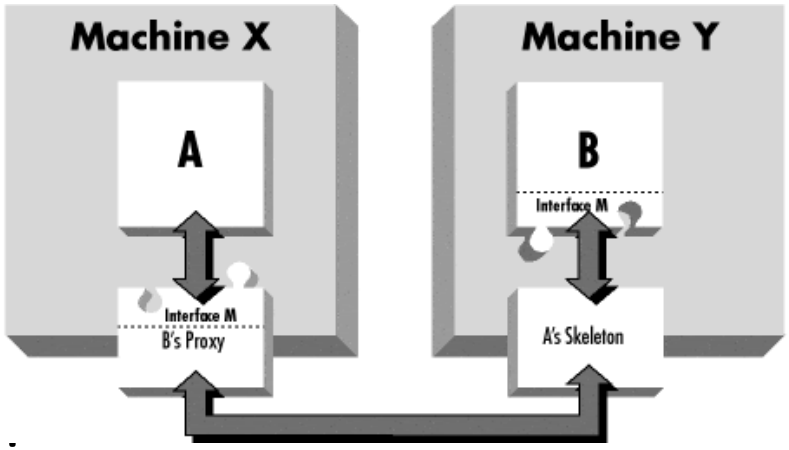
- Objects can be local or remote
- Object references can be local or remote
- Remote objects have visible remote interfaces
- Masks remote objects as being local using proxy objects
- Remote method invocation



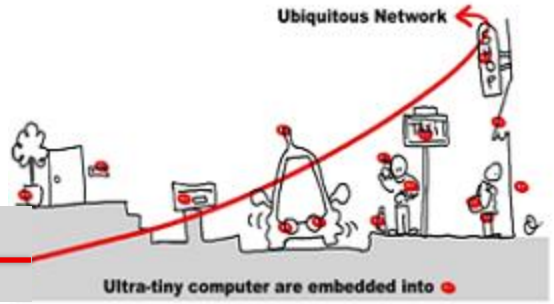
Properties of OOM



- Support for object-oriented programming model
  - objects, methods, interfaces, encapsulation, …
  - exceptions (were also in some RPC systems)
- Synchronous request/reply interaction
  - same as RPC
- Location Transparency
  - system (ORB) maps object references to locations

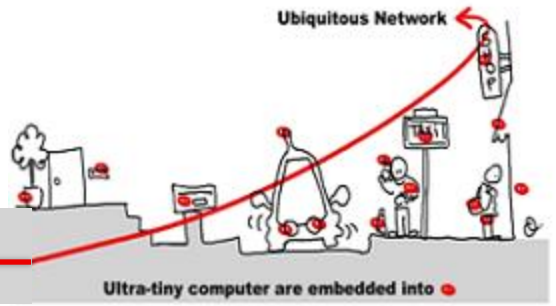


Do you know ?



- Any example for OOM ?
- in your background …
- Examples …

Java Remote Method Invocation (RMI)

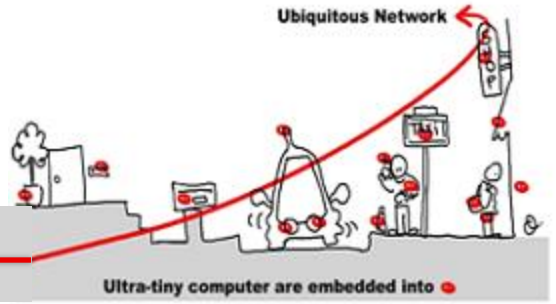


- Covered in Java programming
- Distributed objects in Java

```
public interface PrintService extends Remote {
  int print(Vector printJob) throws RemoteException;
}
```

  - RMI compiler creates proxies and skeletons
  - RMI registry used for interface lookup
  - Entire system written in Java (single-language system)

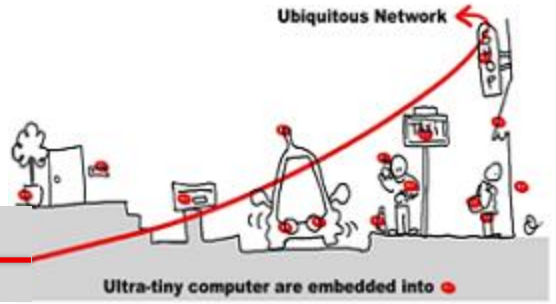
CORBA



- Common Object Request Broker Architecture
  - Open standard by the OMG (Version 3.0)
  - Language and platform independent

- **Object Request Broker** (ORB)
  - General Inter-ORB Protocol (GIOP) for communication
  - Interoperable Object References (IOR) contain object location
  - CORBA **Interface Definition Language** (IDL)
    - Stubs (proxies) and skeletons created by IDL compiler

CORBA IDL

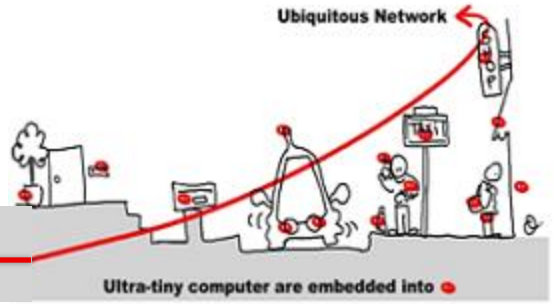


- Definition of language-independent remote interfaces
  - Language mappings to C++, Java, Smalltalk, …
  - Translation by IDL compiler
- Type system
  - basic types: long (32 bit), long long (64 bit), short, float, char, boolean, octet, any, …
  - constructed types: struct, union, sequence, array, enum
  - objects (common super type Object)

```
typedef sequence<string> Files;
interface PrintService : Server {
  void print(in Files printJob);
};
```

- Parameter passing
  - in, out, inout
  - basic & constructed types passed by value
  - objects passed by reference

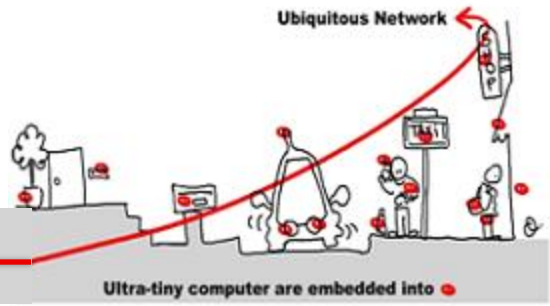
Advantages and Disadvantages of OOM



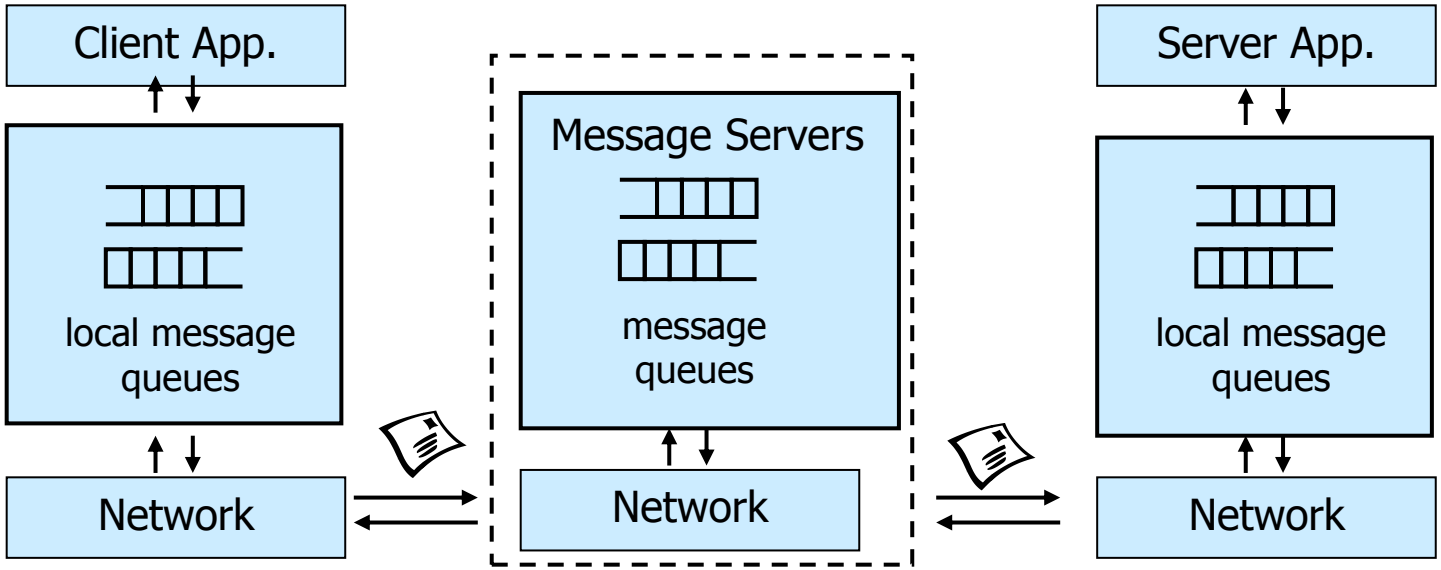
- Totally transparent distributed programming

- Synchronous request/reply interaction only
  - So CORBA oneway semantics added Asynchronous Method Invocation (AMI)
  - But implementations may not be loosely coupled
- Distributed garbage collection
  - Releasing memory for unused remote objects
- OOM rather static and heavy-weight
  - Unadapted for ubiquitous systems and embedded devices

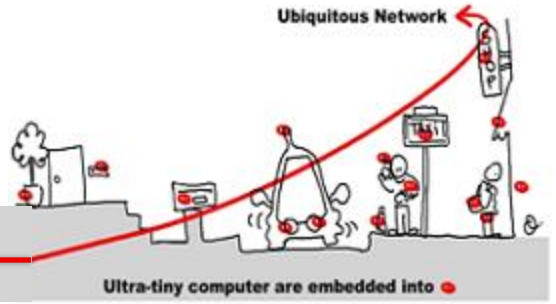
Part III: Message-Oriented Middleware (MOM)



- Communication using messages
- Messages stored in message queues
- message servers decouple client and server
- Various assumptions about message content

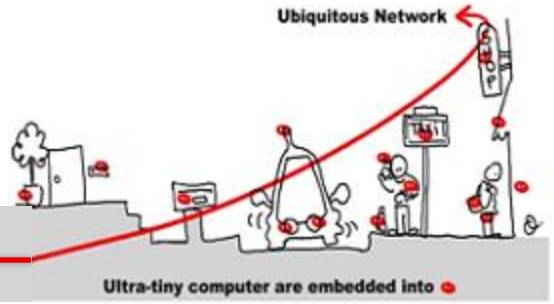


Properties of MOM



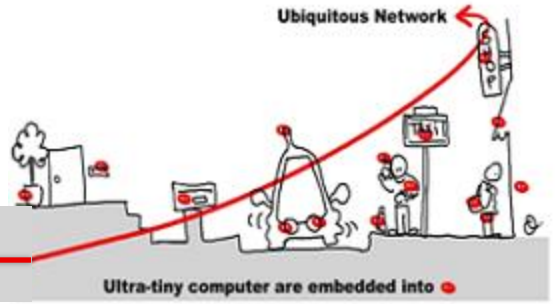
- Asynchronous interaction
  - Client and server are only loosely coupled
  - Messages are queued
  - Good for application integration
- Processing of messages by intermediate message server(s)
  - May do filtering, transforming, logging, …
  - Networks of message servers

Java Message Service (JMS)



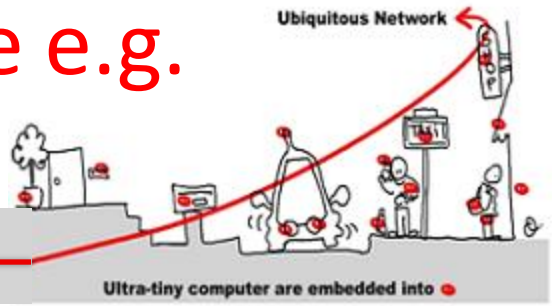
- API specification to access MOM implementations
- Two modes of operation *specified*:
  - Point-to-point
    - one-to-one communication using queues
  - Publish/Subscribe
    - cf. One pattern for Event-Based Middleware (ex . Java)
- JMS Server implements JMS API
- JMS Clients connect to JMS servers
- Java objects can be serialised to JMS messages

Disadvantages of MOM

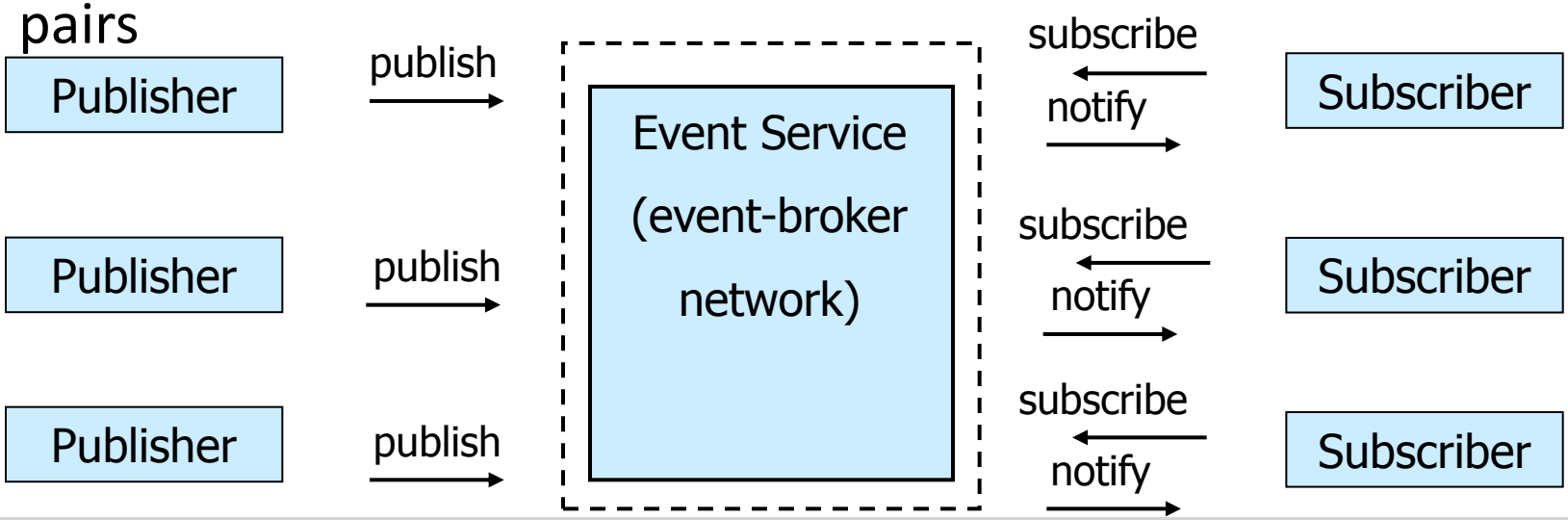


- Poor programming abstraction (but has evolved)
  - Rather low-level (cf. Packets)
  - Request/reply more difficult to achieve, but can be done
- Message formats originally unknown to middleware
  - No type checking (JMS addresses this – implementation?)
- Queue abstraction only gives one-to-one communication
  - Limits scalability (JMS pub/sub – heavy implementation of event based communications)

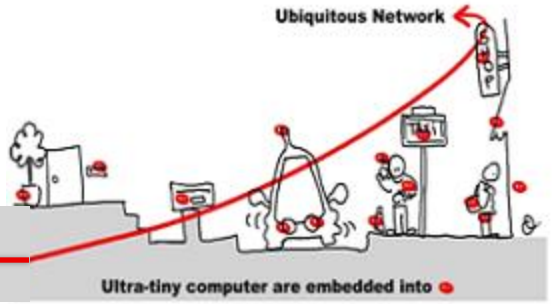
Part IV: Event-Based Middleware e.g. Publish/Subscribe Pattern



- Publishers (advertise and) publish events (messages)
- Subscribers express interest in events with subscriptions
- Event Service notifies interested subscribers of published events
- Events can have arbitrary content (typed) and name/value pairs

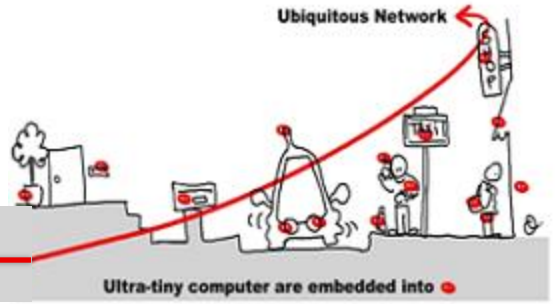


Properties of Publish/Subscribe



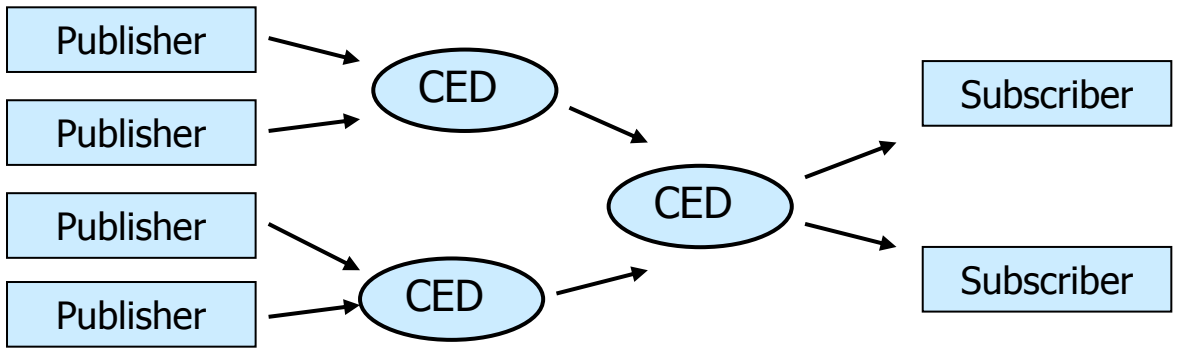
- Asynchronous communication
  - Publishers and subscribers are loosely coupled
- Many-to-many interaction between pubs. and subs.
  - Scalable scheme for large-scale systems
  - Publishers do not need to know subscribers, and vice-versa
  - Dynamic join and leave of pubs, subs
- (Topic and) Content-based pub/sub very expressive
  - Filtered information delivered only to interested parties

Composite Event Detection (CED)

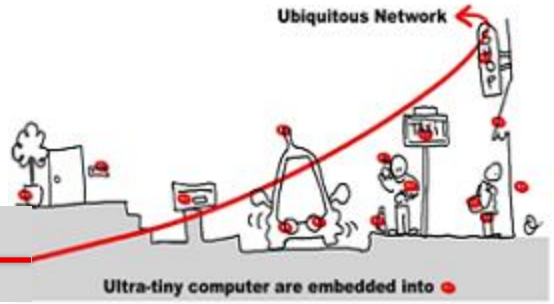


- Content-based pub/sub may not be expressive enough
  - Potentially thousands of event types (primitive events)
  - Subscribers interest: event patterns
- Composite Event Detectors (CED)
  - Subscribe to primitive events and publish composite events

- Alternative Implementation … (need multicast communications)



Summary

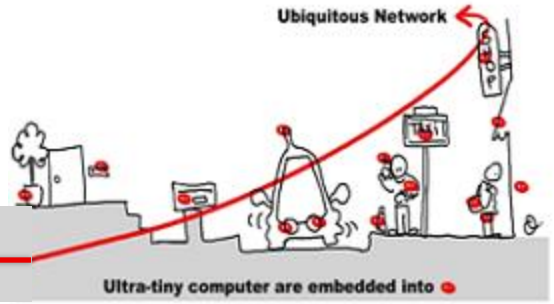


- Middleware is an important abstraction for building distributed systems

1. Remote Procedure Call
2. Object-Oriented Middleware
3. Message-Oriented Middleware
4. Event-Based Middleware

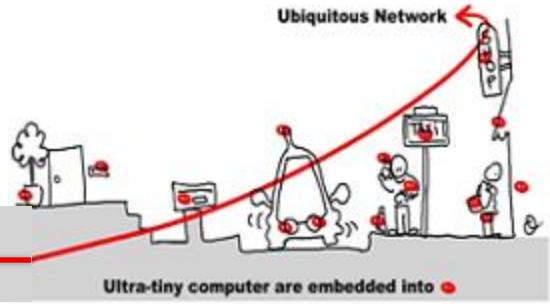
- Synchronous vs. asynchronous communication
- Scalability, many-to-many communication
- Language integration
- Ubiquitous systems, mobile systems

Classification: Where to use them ?



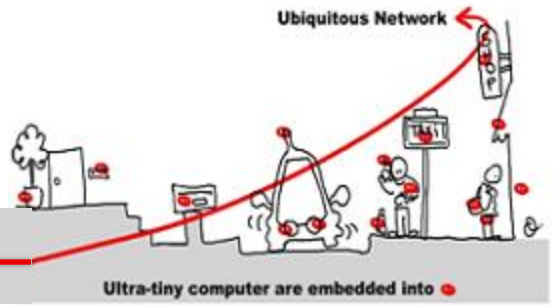
- *Middleware: Past and Present a Comparison*, [Hennadiy Pinus 2004]
- MOM can be used in the applications,where the network or all-components availability is not warranted
- RPCs could be used in small, simple applications with primarily point-to-point communication. "RPCs are not a good choice to use as the building blocks for enterprise-wide applications where high performance and high reliability are needed.“

Classification: Where to use them ?



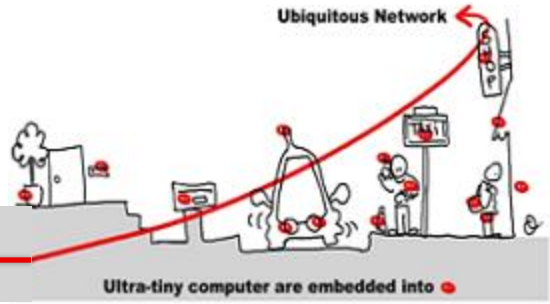
- *Middleware: Past and Present a Comparison*, [Hennadiy Pinus 2004]
- OOM "should be considered for applications where immediate scalability requirements are somewhat limited. These applications should be part of a long-term strategy towards object orientation.“
- Event-based “is a decoupled, many-to-many communication paradigm, well-adapted for building large-scale distributed systems” [Pietzuch 2002]

New Trends : SoM, Service oriented Middleware



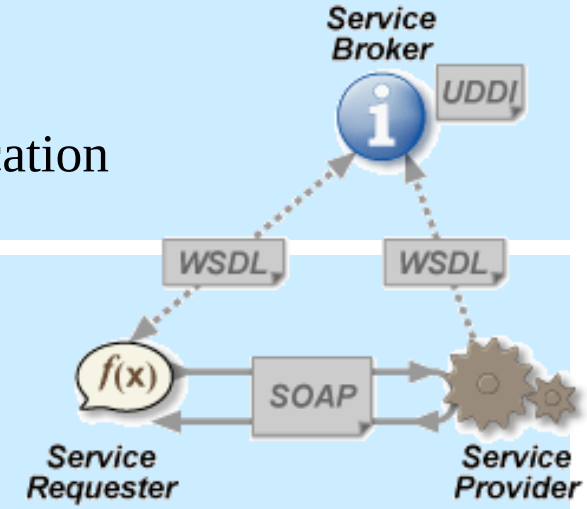
- The SOA style is structured around three key architectural components: (i) service provider, (ii) service consumer, and (iii) service registry.
- The SOA design is structured around four key functionalities : service description, discovery, access and composition in the Future Internet of services
- The Service-Oriented Middleware (SOM) is in charge of enabling the deployment of services and coordination among the four key conceptual elements and four key functionalities that characterize the SOA style and design.

Example : Web Services, SOAP based



Communication

- Message content expressed in **XML**
- **S**imple **O**bject **A**ccess **P**rotocol (**SOAP**)
  - Lightweight protocol for sync/async communication



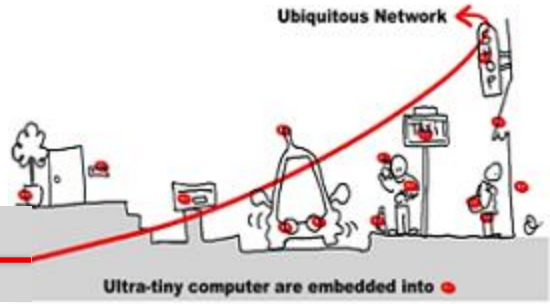
Service Description

- **W**eb **S**ervices **D**escription **L**anguage (**WSDL**)
  - Interface description for web services

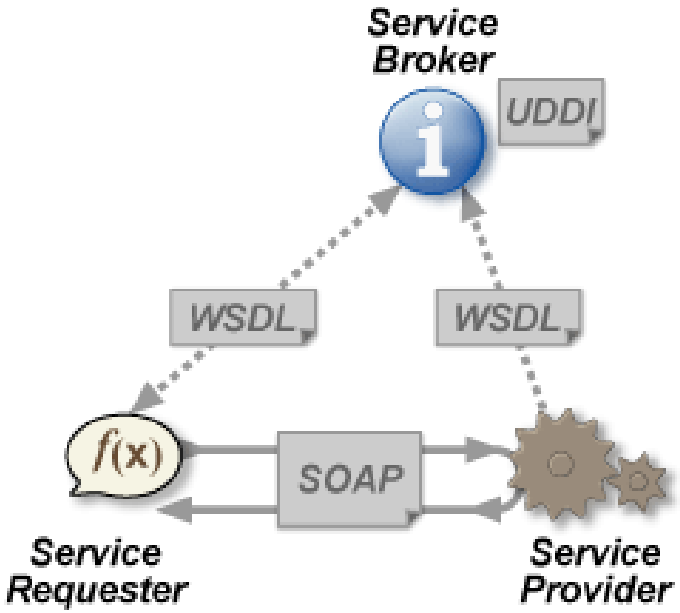
Service Discovery

- **U**niversal **D**escription **D**iscovery and **I**ntegration (**UDDI**)
  - Directory with web service description in WSDL

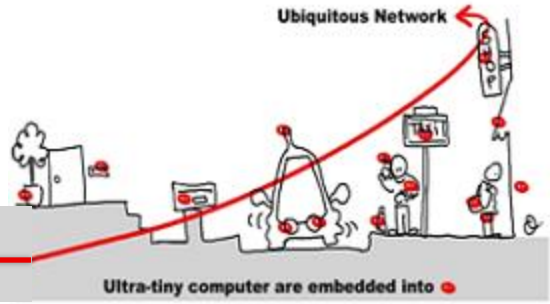
Example Communication : SOAP



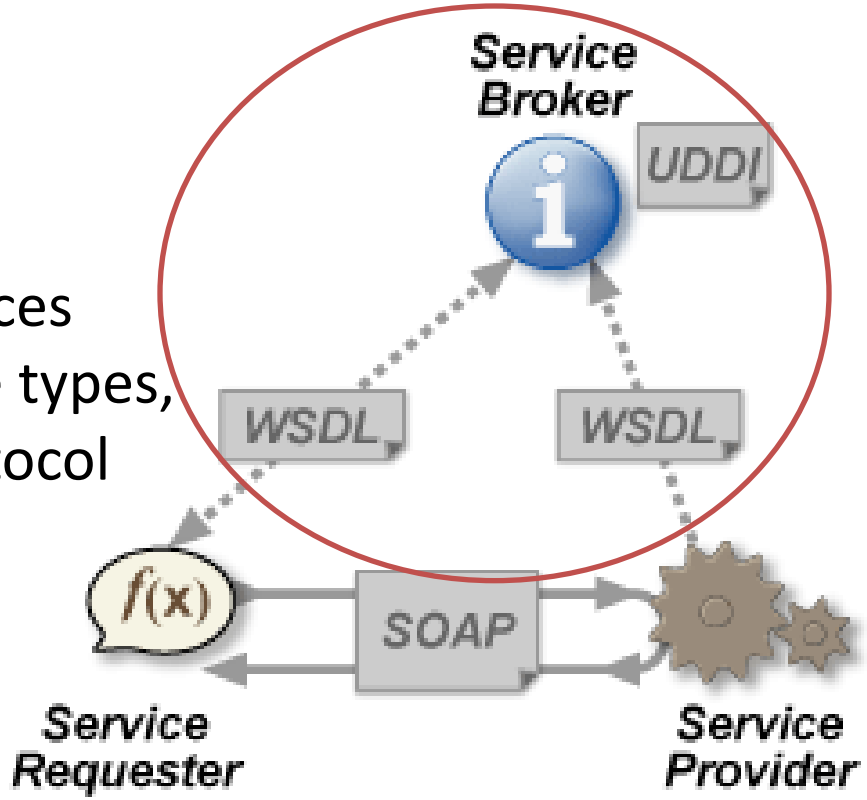
- XML-based protocol defining message format
- One-way asynchronous technology
  Can use a variety of message passing styles: RPC, publish/subscribe
- Primary underlying protocol is HTTP, but others can be used (SMTP)



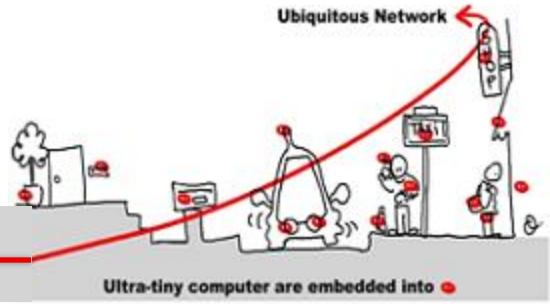
Example Service Description : WSDL



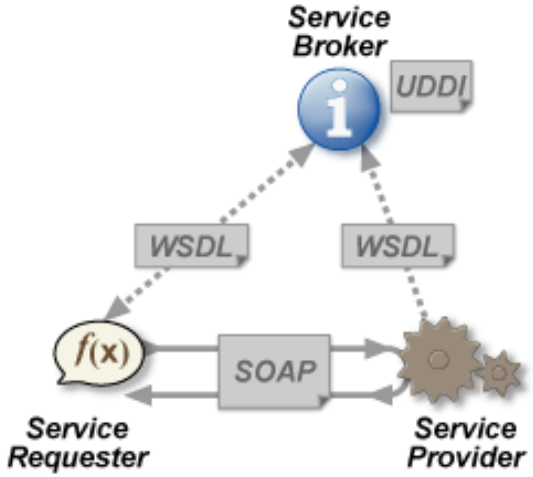
- XML-based language
- Service Discovery Protocol
- Defines/describes Web services interfaces, data and message types, interaction patterns and protocol mappings



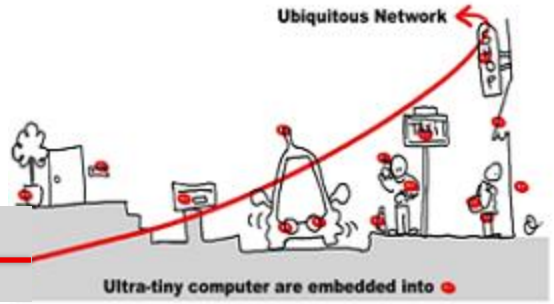
Example Discovery : UDDI



- Web Services Registry (of WSDL documents)
- Protocol for discovering and publishing Web Services
- UDDI registry is accessed by XML-based SOAP messages



Properties of Web Services

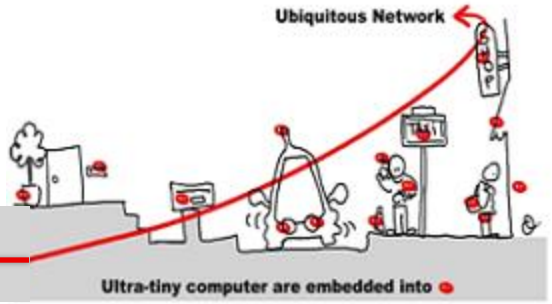


- Language-independent and open standard
- SOAP offers MOM-style communication:
  - Asynchronous messaging like MOM
  - Supports internet transports (http, smtp, ...)
  - Uses XML Schema for marshalling types to/from programming language types
- WSDL says how to use a web service

- UDDI helps to find the right web service
  - Exports SOAP API for access

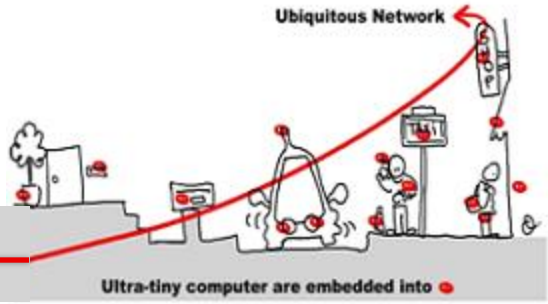
Search wsdl sample files and used it

Disadvantages of Web Services



- Low-level abstraction
  - leaves a lot to be implemented
- Interaction patterns have to be built
  - one-to-one and request-reply provided
  - one-to-many?
  - still synchronous service invocation, rather than notification
- No location transparency

Interroperability… and Research Challenges

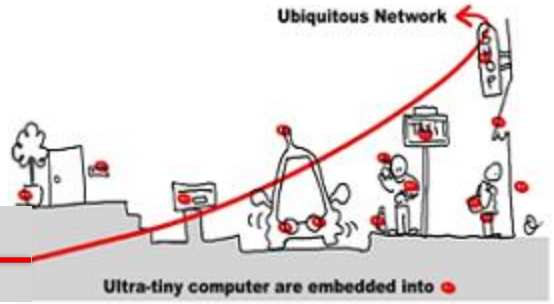


Interroperability between Technology :

- Thanks to a common software platform
- Thanks to a common network protocol
- Research Challenge : Adpative Middleware like Emergent Middleware

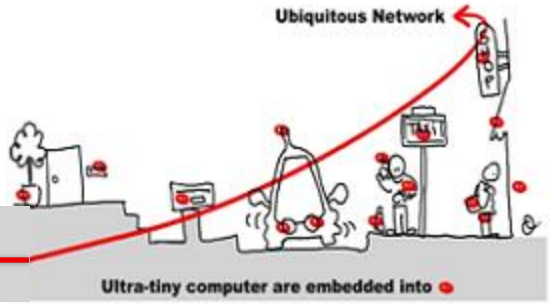
Emergent Middleware *by Paul Grace, Gordon S. Blair and Valerie Issarny , [5,6]*

What we lack, so far



- General interaction patterns
  - we have one-to-one and request-reply
  - one-to-many? many to many?
  - notification?
- Dynamic joining and leaving
- Location transparency (good or bad thing ?)
  - anonymity of communicating entities
- Support for Device
  - data values from sensors
  - lightweight software
- And other requirements for Ubiquitous Computing …

References



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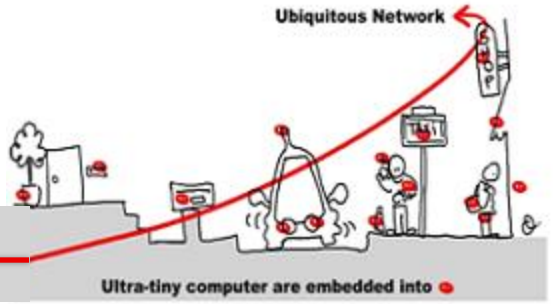

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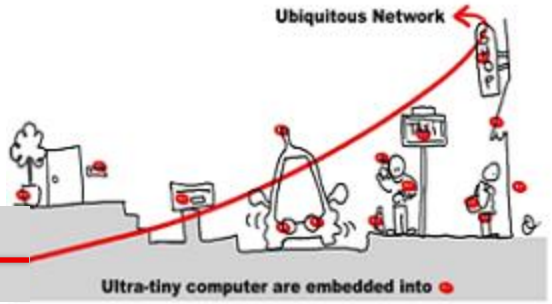

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