Software Development for Mobile Computing

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Who am I?

- University of Rochester, NY, USA
  - Assistant Professor (on leave)
  - Department of Computer Science
- Politecnico di Milano, Italy
  - Visiting researcher
  - Dip. Elettronica e Informazione
- Research Interests
  - Middleware for Mobile Computing
  - Middleware for Sensor Networks
  - Algorithm development for mobile environments

Preliminaries

- Ask questions, feel free to interrupt me
- Introductions
  - Where you are from?
  - Why you are here at this school?
- These slides will be available *later*
- Acknowledgements
  - Gian Pietro Picco, Politecnico di Milano
  - Cecilia Mascolo, University College, London

Course Objectives

- Provide an understanding the challenging issues for software development in mobile environments
- Survey significant research efforts in enabling mobile software development, specifically middleware
- Understand one middleware (LIME) in depth, its features, programming environment, etc.
- If time, explore software development for sensor networks

Outline

- Introduction and Major Issues
- Commercial Mobile Middleware
- Next-Generation Mobile Middleware
- Case Study – LIME
- Middleware for Wireless Sensor Networks
- Open Issues and Future Directions

Distributed Systems

"One on which I cannot get any work done because some machine I have never heard of has crashed"

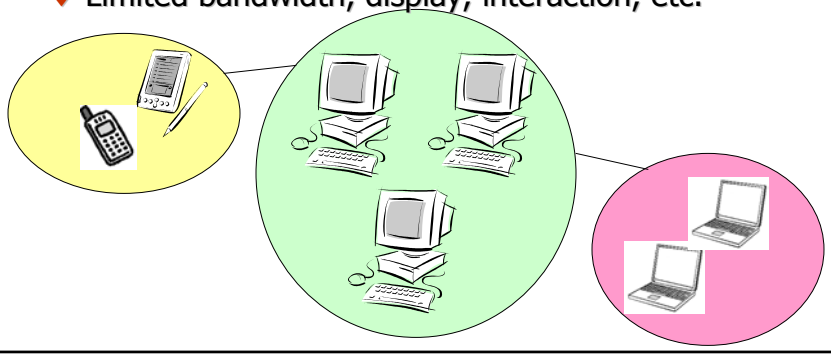
L. Lamport

Traditional Distributed Systems

- Fixed hosts, permanent connection, high bandwidth and stable links, static context
- Motivations for distribution:
  - Speed: parallelize computation
  - Scalability: accommodate more users
  - Economics: clusters cheaper than mainframes
  - Heterogeneity: different specialized components
  - Fault tolerance: improve management of hardware and software faults
  - Resource sharing: access control, authorization
  - Inherent distribution: e.g., games, mobility

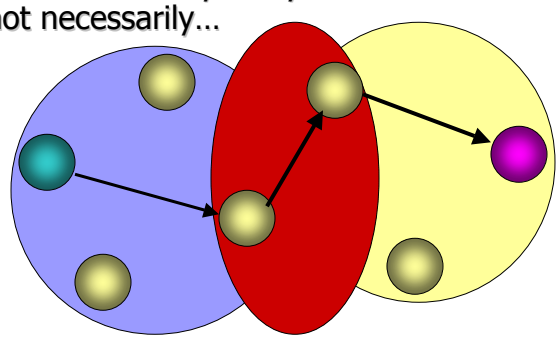
Nomadic Distributed Systems

- More mobile than traditional systems
- Core of fixed hosts
- Wireless base stations, e.g., bridges
- A set of mobile hosts roaming and accessing network from different locations
- Limited bandwidth, display, interaction, etc.



Mobile Ad-hoc Distributed Systems

- Pushing mobility to the extreme, remove infrastructure
- Mobile hosts, intermitted network, non stable links, dynamic environment
- Clusters formed dynamically
- Communication may be symmetric and transitive but not necessarily…



Mobile Networks: Nomadic and Ad-hoc

- Fault tolerance:
  - Disconnection is not a fault
  - Availability is key feature, disconnected operation
- Heterogeneity:
  - Connection, hosts, OS,…
- Scalability:
  - Bandwidth shared in a cell, channel allocation
- Resource sharing:
  - Transactions and security
- Adaptability:
  - Entering new domains is trivial

Middleware: Motivation

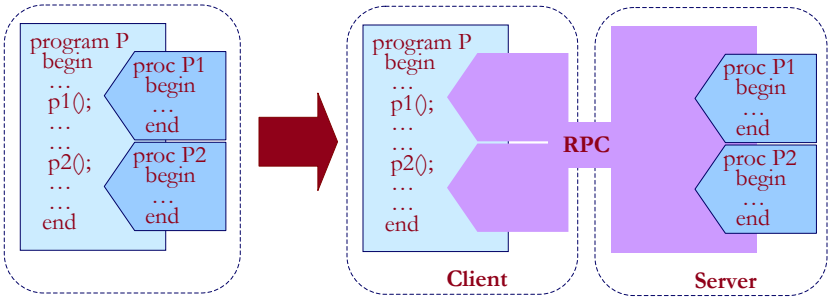
- Middleware sits between the operating system and the application
- Facilitate the development of distributed applications
- Provide developers with ***abstractions***, hiding details of distribution, enabling rapid, dependable development
- Typical features include communication primitives, replication, concurrency management, etc.

Middleware for Traditional Systems

- Fault-tolerance: disconnection is infrequent
  - Stable connectivity (synchronous communication)
  - Replication of data allows fault tolerance in terms of data
- Adaptability: adapt to change through interfaces and clear component integration functionalities
- Heterogeneity: different software and hardware is hidden behind communication primitives independent from them
- Scalability: replication of services and efficient discovery mechanisms
- Resource sharing: transactions and authentication techniques are used

Conventional Middleware

- Examples are:
  - Remote procedure call (RPC)
  - Message-oriented middleware (MOM)
  - Transactional middleware
  - Object-oriented middleware like CORBA and RMI



Why Middleware for Mobile?

- Mobile platform requirements are demanding
- Cannot assume stable connectivity
- Need support for handling a dynamically changing context
  - Cannot assume a high degree of coupling between the communicating parties
  - Cannot hide as much context information as before
- Want rapid, reliable application development

Middleware for Nomadic and Ad-hoc Systems (1/2)

- Fault-tolerance:
  - Disconnection is frequent: synchronous mechanisms do not fit, consider asynchronous mechanisms (e.g., tuple spaces, publish/subscribe)
  - Replication of data, also for off line operations
- Adaptability:
  - Context awareness allows reconfiguration and functionality changes.
  - Need some mechanism to react to changes
  - Need new primitives to expose context (e.g., detect neighbors, noise, etc.)

Middleware for Nomadic and Ad-hoc Systems (2/2)

- Heterogeneity:
  - More heterogeneous environment, however scarce resources
  - Run time reconfiguration is essential
- Scalability:
  - Decentralized discovery and quality of service configuration of the wireless link
- Resource sharing:
  - Transactions or weak consistency and server-side authentication techniques are used (on nomadic)

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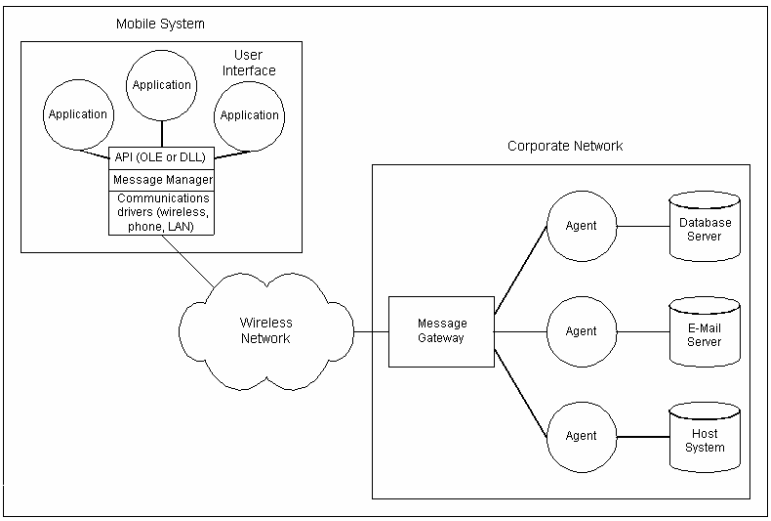
Commercial Mobile Middleware

- Beyond Windows "briefcase"
- Web search for "mobile middleware" reveals a wealth of information, research and commercial
- Straightforward, common solution is to exploit a proxy
- Specific systems to consider
  - WAP – Wireless Application Protocol
  - WML – Wireless Markup Language
  - JMS – Java Messaging Service

Common Solution: Proxies

- A mobile client relies on the presence of a proxy on the fixed network, buffering client requests and server replies
  - Allows the client to disconnect, e.g., to save battery power, and gather the results upon the next reconnection
  - Example: Oracle Mobile Agent, and many others
  - Disconnection is made explicit to the end user, and it is assumed that the user can do useful work while disconnected
- Often, a thin client is exploited, essentially providing a remote, mobile user interface
  - Little or no computation takes place at the client
  - Example: InfoPad project

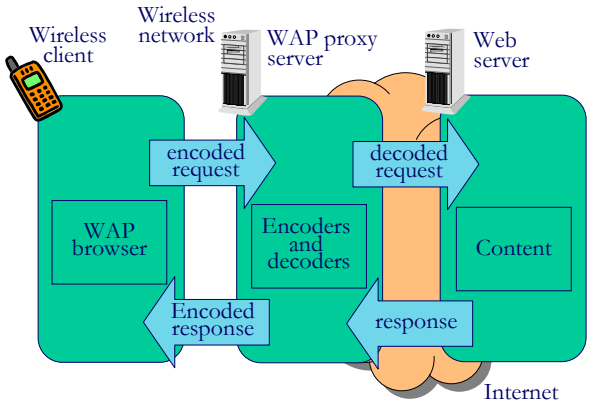
Oracle Mobile Agents



Wireless Application Protocol (WAP)

- WAP Forum: founded by Ericsson, Motorola, Nokia, and Phone.com in December 1997 and counting over 300 members
- Goal: provide wireless access to the Internet from small wireless devices
- Content: a suite of protocols and specifications, that optimize data transfer for wireless communication
  - e.g., transmitting a compressed binary encoding, or providing lightweight transactions and security
  - Works in combination with the major wireless technologies
- NTT DoCoMo's iMode is a competing technology, available only in Japan (where it has ~39 million users as of July 2003)
  - Packet oriented (always on), cHTML, charge by volume…

WAP Architecture



- The proxy server (or gateway) translates a request from the WAP stack into a request for the WWW stack and vice versa

Wireless Markup Language (WML)

- Evolved from XML, HTML, and Phone.com's proprietary language
- Tailored to the design of Web pages that must be rendered on very small screens, without keyboards
  - Permits the scaling from two-line screens to larger ones found on smart phones
  - Provides a "deck of card" metaphor, with a "card" being the unit of content transmission
- Web sites conceived for WAP users must be developed in WML, or translated by a server that converts HTML in WML (e.g., one running a Cocoon servlet)
- Extensible, i.e., developers can add new markup tags
- Lightweight scripting language, WMLScript, is also provided

WAP Stack

- WAP defines its own stack, optimized for wireless communication
  - Binary transmission is used instead of text (more compact)
- Other protocols of the stack support specific needs:
  - WTP (Wireless Transaction Protocol) provides specialized support for transactions (e.g., in e-commerce)
  - WSP (Wireless Session Protocol) specifies interfaces for establishing and terminating sessions, and negotiate protocols
  - WTLS (Wireless Transport Layer Security) secures, authenticates, and encrypts data transmissions between the gateway and the mobile devices; it is designed to be more efficient than TLS, but does not provide end-to-end security
- WAP 2.0 is claimed to remove the need for a proxy, and enable the use of native HTTP and IP protocols

WAP Example

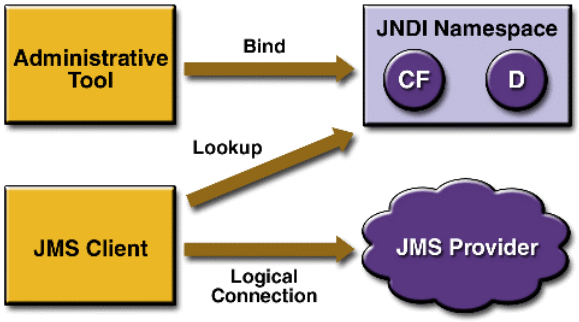
- Ski conditions is a common example
- http://www.snowreport.gr/wap
- Pages specifically designed
- Simple interface
- Simple navigation
- Multilingual
- Not a good ski day today in Greece

Java Messaging Service (JMS)

- Reliable, flexible service for the exchange of information
  - Supports synchronous, asynchronous, and publish/subscribe communication paradigms
- Defines a common set of messaging concepts and programming strategies to be supported by all JMS technology-compliant messaging systems
- Allows integration of heterogeneous clients through generic message interface

JMS

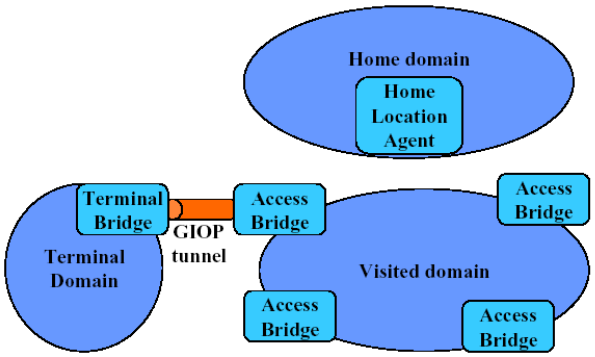
- Administrative tool: separates clients
- Namespaces: connection factories and destinations
- Clients: listeners or receive, filter optional
- Provider: e.g., J2EE, impl. admin/control



Wireless CORBA

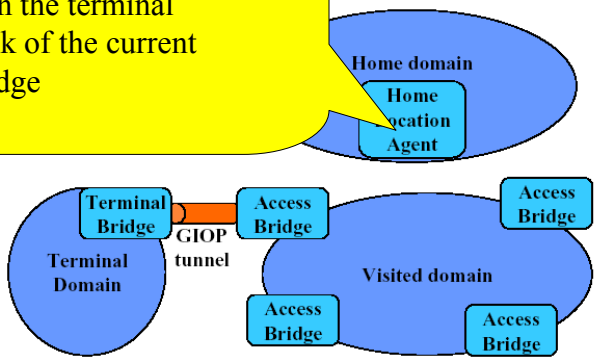
- CORBA is well accepted industry standard
  - Interoperability among multiple languages
  - Many existing CORBA objects and CORBA based systems
- In principle: access objects ignoring their location
  - Does NOT directly translate to mobile
  - What about accessing mobile objects?
- But, Wireless CORBA has a potential future
  - Mobile clients becoming more popular
  - ORB size shrinking
- Initial specification based on DOLMEN, U. Helsinki
  - Allows interoperability among mobile clients and existing objects without modification to existing infrastructure

Wireless CORBA Architecture



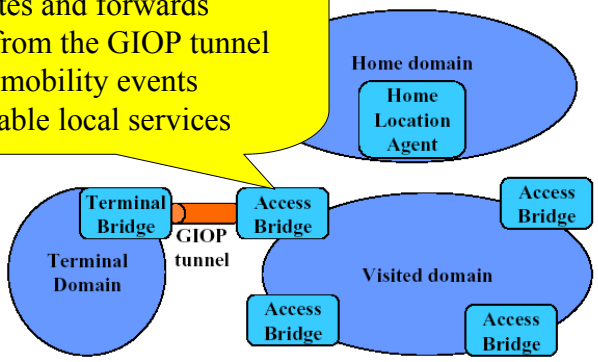
Wireless CORBA Architecture

- Redirects requests for services on the terminal
- Keeps track of the current access bridge



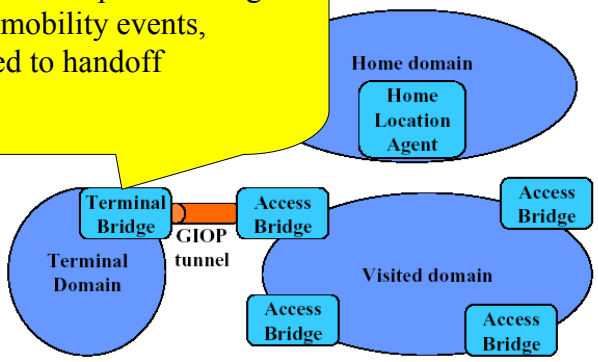
Wireless CORBA Architecture

- Encapsulates, forwards or ignores incoming GIOP messages
- Decapsulates and forwards messages from the GIOP tunnel
- Generates mobility events
- Lists available local services



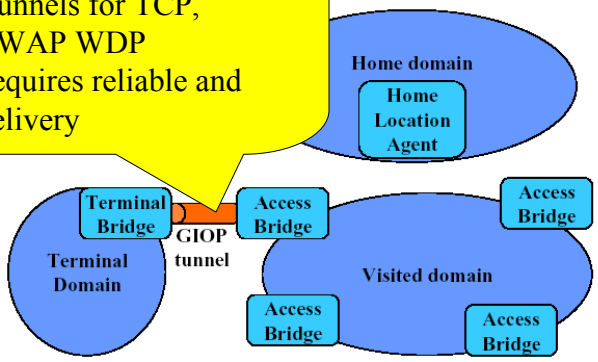
Wireless CORBA Architecture

- Other end of the Access Bridge, encapsulates/decapsulates msgs
- Generates mobility events,
- e.g., related to handoff



Wireless CORBA Architecture

- Abstract transport-independent tunnel for GIOP messages
- Concrete tunnels for TCP, UDP and WAP WDP
- Protocol requires reliable and ordered delivery



Choosing a Mobile Middelware

- What is the goal of the middleware:
- What is the expertise/exiting service base of the company?
- What is the expected application?
- How critical is multi-language interoperability?
- Message oriented or object oriented platform?

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