

# XMIDDLE & Mobile Healthcare Applications

1. XMIDDLE, a Data Sharing Middleware for Mobile Computing.

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# Outline

- XMIDDLE
  - Motivation
  - The Goal and Our Approach
  - Example / Case Study
  - Assumptions
  - Primitives & Architecture
  - Evaluation
  - Future Work / Ideas
  - Summary
- Mobile Healthcare Applications

# Motivation

- Proliferation of mobile devices
  - Limited processing power
  - Limited memory
- Built in networking hardware
  - e.g. 802.11b, Bluetooth, IrDA
  - Error prone, battery hungry, (some are) short ranged, perhaps expensive (GSM modems)
- Need to share information with other hosts
  - From classical PDA synchronisation paradigms (e.g. PalmOS hotsync)
  - Exploitation of limited peer resources

# Motivation (2)

- Problems with existing middleware
- Fixed network (wired) infrastructure middleware too heavy
- Existing mobile networking middleware problematic
  - Bayou (Xerox PARC): mobility is an exception
  - Lime & TupleSpace Based Systems: unstructured data

# The Goal

- Provide a middleware for data sharing in mobile computing environments, supporting disconnected operations through replication and providing for the dynamic nature of ad hoc networks
- Provide a framework for the automatic reconciliation of shared information
- The application should be able to guide the middleware as to how to resolve conflicts

# The XMIDDLE Approach

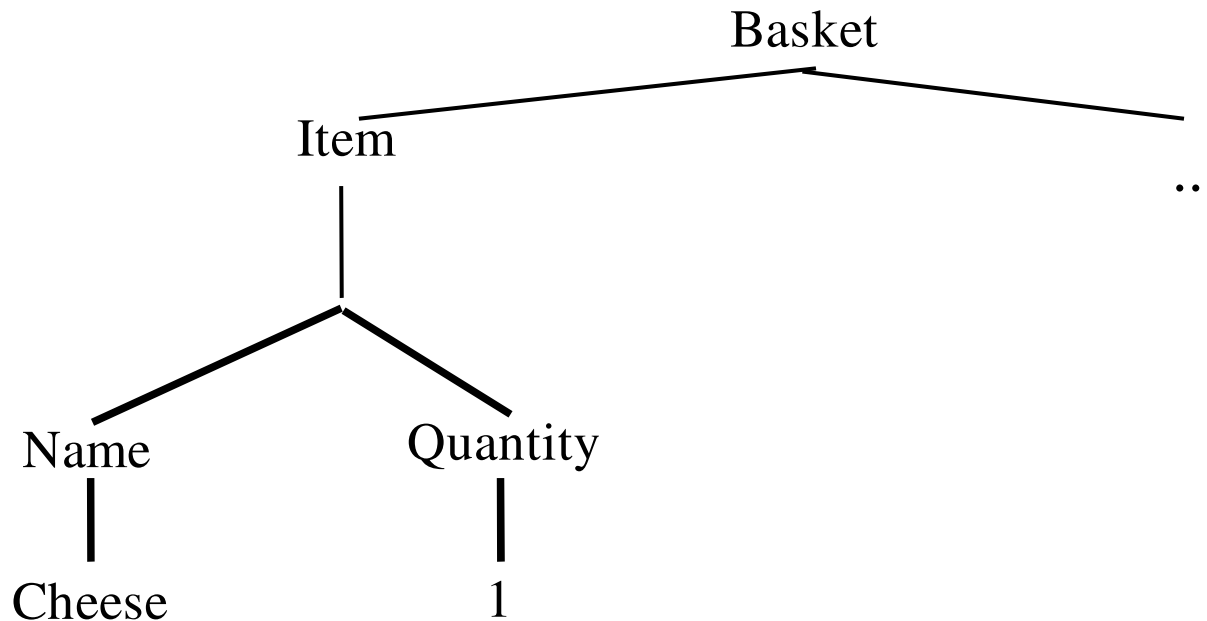
- Completely decentralised (peer to peer) operation
- Geared for non-continuous & low bandwidth networking hardware
- Fine-grained application control of what is being shared
- Concurrently supporting multiple applications
- Applications store their data in XML format (i.e. a tree)
- Provides an API to access data, hiding any replication information
- Lightweight and fast!

# A Simple Example

- A household, with one home computer (A) and a PDA (B), both running XMIDDLE and a e-shopping application.
- Connected, when in reach, via a wireless link.
- Family wishes to use both A and B to do their shopping

# A's Data

- Encoded as XML





# Exporting and Linking

- A exports basket.
  - Data available for sharing
- B links to the exported branch
  - The data are copied to the local shopping tree and are readily available to the application

# Remote Access

- A & B are separated
- Both have access to the catalog and the shopping basket
- B changes quantities and adds another item...

# Reconciliation

- A & B come in reach again.
- The middleware detects that they are sharing data
- It determines that there have been changes to the data
- A diff of the changes is computed and transferred.
  - Any conflicts are resolved via the use of application-specific policies
- A & B end up with the same consistent tree

# Complexity

- Scenario can be more complex
- Multiple hosts sharing information
- Hosts reconciling shared data even if none of the involved hosts “own” the data
- Larger data
- Online collaboration

# Basic Assumptions

- Availability (non constant) of networking hardware (TCP/IP stack) and network connection
- Each application stores its data on an XML document, accessible via DOM operations (tree based format)
- XML validation a non-issue for the middleware (disabled).
  - Deemed an application issue.
  - Can be enabled (work in progress)

# XMIDDLE Primitives

- **Connection:** hosts can be connected to/participating in the ad hoc network, allowing them to share data and to trigger the transparent data reconciliation process
- **Disconnection:** hosts can choose to explicitly disconnect from the network, in which case they will not have access to the networked facilities that the middleware provides, although they will still be able to access shared data that has already been replicated. A host can explicitly request disconnection, to conserve battery power, etc.

# XMIDDLE Primitives (2)

- **Exporting:** applications can specifically define which local data elements they allow to be shared with other devices, by exporting elements of their data tree.
- **Linking:** In order to share information, applications need to link to data exported by applications in other hosts. Once linked the middleware allows disconnected operation on that data, and the reconciliation of changes when connected & in reach
- **Unlinking:** data can also be unlinked when sharing and reconciliation is not needed anymore

# Hosts

- Hosts are defined by two ids
  - PrimaryID: Assumed to be unique. Used to identify hosts.
  - SecondaryID: Human-readable identification of a host (does not have to be unique)
- Receive information in two ways
  - IP Multicast (for information broadcast to all hosts)
  - UDP Sockets (each host has a socket open for receiving information specifically addressed to it)



# Versioning & Reconciliation

- In order to reconcile information, XMIDDLE uses the concept of versioning
- A version is a “snapshot” of the shared data tree.
  - Can either be a full snapshot, or a diff pointing to a previous version
- The first version (version 0) is created when a branch is first exported by the owner, and is always transferred to the host that links to it (along with the latest version available).
  - So all hosts sharing a branch have at least one common tree to reconcile data from

# Versioning & Reconciliation (2)

- New versions are released when two hosts reconcile a branch that they are sharing
  - The “snapshot” of the reconciled branch
- Each version has a version identifier attached, which contains three elements:
  - The PrimaryIDs of the two hosts involved, and a version number starting from 0 (when the branch is first exported)
- The hosts reconciling the branch automatically compute the same version identifier
- Reconciliation always starts from the most recent (i.e. largest version number) version common to both hosts

# Installing Applications

- Applications must register with the Application Manager in order to have access to the services of the middleware.
- When registering, they are assigned a unique ID (integer).
  - Used to distinguish which application is exporting which element
  - IDs are unique on each platform – The same application can be assigned a different ID when installed on a different platform

# Installing Applications (2)

- The Application Manager creates an Application Profile for each application.
  - Contains references to the data tree etc.
- The application accesses its data via the Application Profile through the Application Manager

# XMIDDLE, DOM and XPath

- Exported elements are encoded using XPath
  - Advertising and requesting such elements is done via XPath
- XMIDDLE provides an API where applications can request local data using XPath and are returned DOM Elements

# Peer Discovery

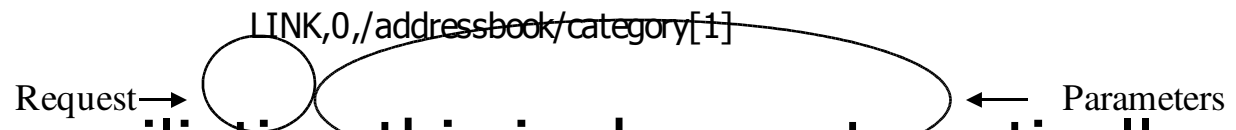
- Upon connecting to the network, XMIDDLE hosts join an IP Multicast group
- Send information like their ids, their exports, items they're linking to, private port number...

```
<online> <primaryID> 1352591906 </primaryID> <secondaryID> musakas </secondaryID> <address>
128.16.10.65 </address> <port> 1439 </port> <segmenSize> 2048 </segmentSize> <linktable> < export
> <appID> 0 </appID> <branch> /addressbook/category[1]
</branch> </export> </linktable> <services> </services> </online>
```

- Amount of data currently sent needs optimisation
- Other hosts detect and analyse this
  - If they stop receiving it, they consider that the host is off-line or out of reach

# Protocols

- Reconciliation, Linking (can be extended)
- The host that wishes to initiate a session (e.g. Linking) with another host, sends a protocol request to the UDP socket of the latter...



– For reconciliation this is done automatically

- Both hosts then launch what we call the ProtocolChooser...

# Protocols, the ProtocolRegistry & the ProtocolChooser

- What is a protocol?
  - Linking, reconciliation... But there can be many ways to do those, depending on the context etc...
  - How about new ideas such as simple copying of data?
- On a basic level, a Class implementing a specified Protocol interface
- Protocols need to register with the XMIDDLE ProtocolRegistry



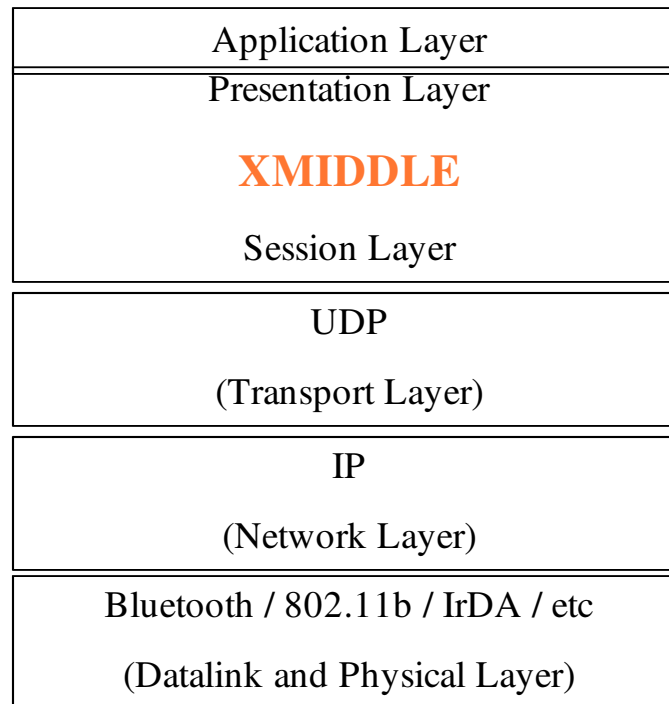
# Protocols, the ProtocolRegistry & the ProtocolChooser (2)

- ProtocolRegistry is a repository of Protocols (algorithms)
- Protocols have a unique (String) id.
  - e.g. LINK
- They register with the ProtocolRegistry giving their full class name and their id.
  - e.g. `edu.UCL.xmiddle.lib.protocols.Linkin`

# Protocols, the ProtocolRegistry & the ProtocolChooser (3)

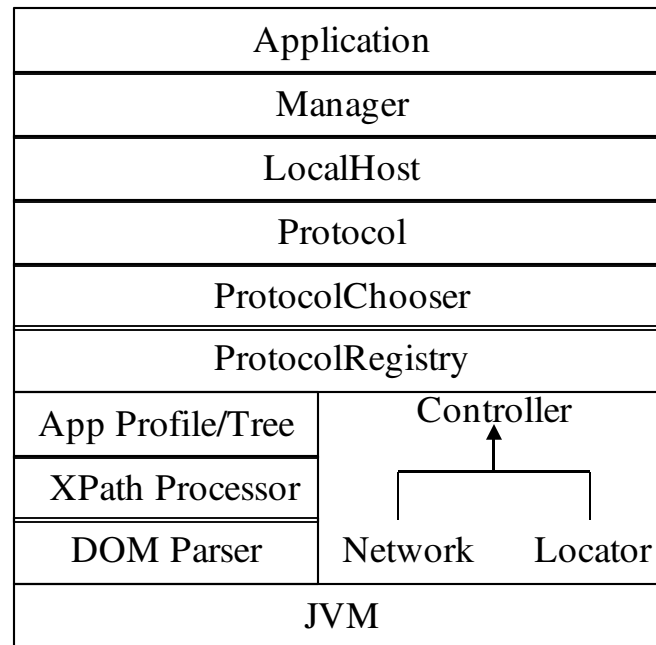
- When the ProtocolChooser is launched, it checks the registry for the specified protocol.
  - If it is not found then it has the option of requesting the given protocol from the other host
  - Dynamic code update
- It then negotiates dedicated UDP sockets (which we call Listener and Sender objects) for communicating directly with the other host for this session
  - Faster processing, possibilities of encryption etc
- Synchronises the hosts involved and
- Finally, using the Java Class Loader, it launches the Protocol giving it any parameters and data it requests

# XMIDDLE and the Protocol Stack



# Brief Overview of Architecture

- Modular & Reusable



# Some Numbers

- XMIDDLE has been installed on Compaq iPAQ H3660 (64MB memory) running Linux (familiar 0.4, kernel 2.4.3)
  - Intel StrongARM CPU (206MHz)
- Lucent Orinoco Silver cards (802.11b)
- Java (1.3.1-rc1 from Blackdown ~15MB) & XML Parser & Xpath Processor(Xerces 1.4.1, Xalan 2.2.D6, ~2.5MB)
  - No JIT for ARM (yet)
- XMIDDLE (~250KB)

# Evaluation

- Biggest bottlenecks were found to be Apache Xerces and Xalan.
  - Xerces 2.0 supposedly much faster
- Fast but can become faster
  - e.g negotiation of UDP sockets for transferring information during protocol sessions needs to be faster

# Future Work

- Reconciliation of reconciliation policies!
- Dynamic Code Update
- Access rights
  - Framework already exists
- Examine the use of other XML parsers and XPath processors
  - Considering development of parser and processor specifically targeted at mobile devices

# Conclusion

- Presented our motivation and the problem
- Highlighted XMIDDLE's approach
- Presented an overview of our architecture



# Mobile Healthcare Applications

- Case Study – Mprescribing
- Joint work between UCL and Elan Technologies
- Uses XMIDDLE

# Agenda

- Motivation
- Solution and Architecture
- Constraints and Requirements
  - Mobility
  - Healthcare environment
- How were the requirements met
  - Role of XMIDDLE

# Motivation (1)

- Grim statistics

“Blunders in giving medicine are killing 1,100 hospital patients a year, five times more than a decade ago...”

“...The audit commission report showed that, aside from the human toll, the mistakes were costing the NHS £500million a year. Nick Mapstone who compiled the report said that 7,000 individual doses of medicine were administered daily in a typical hospital, taking up 40% of nurses’ time”

“...Mr Mapstone said three-quarters of medication errors could be avoided if hospitals used central electronic health records and computerised prescriptions.”

**SOURCE: London Metro newspaper 18-12-01**

# Motivation (2)

- Remove prescribing mistakes
  - Lack of information
  - Paper based approach
- Looking to empower Medical Professionals at 'point of care'
- Improve efficiency of the prescribing process
- Data Integration
- Create Framework to develop further mobile applications.

# Solution (1)

- Client Server Model
  - Server
    - Connects to back end database which contains all the data
    - Responsible for 'flooding' changes throughout system.
  - Client
    - Personal Digital Assistant (PDA)
    - Requests and submits data to the server
- XMIDDLE used for transparently sharing data between client and server
- Wireless LAN used as communication medium.

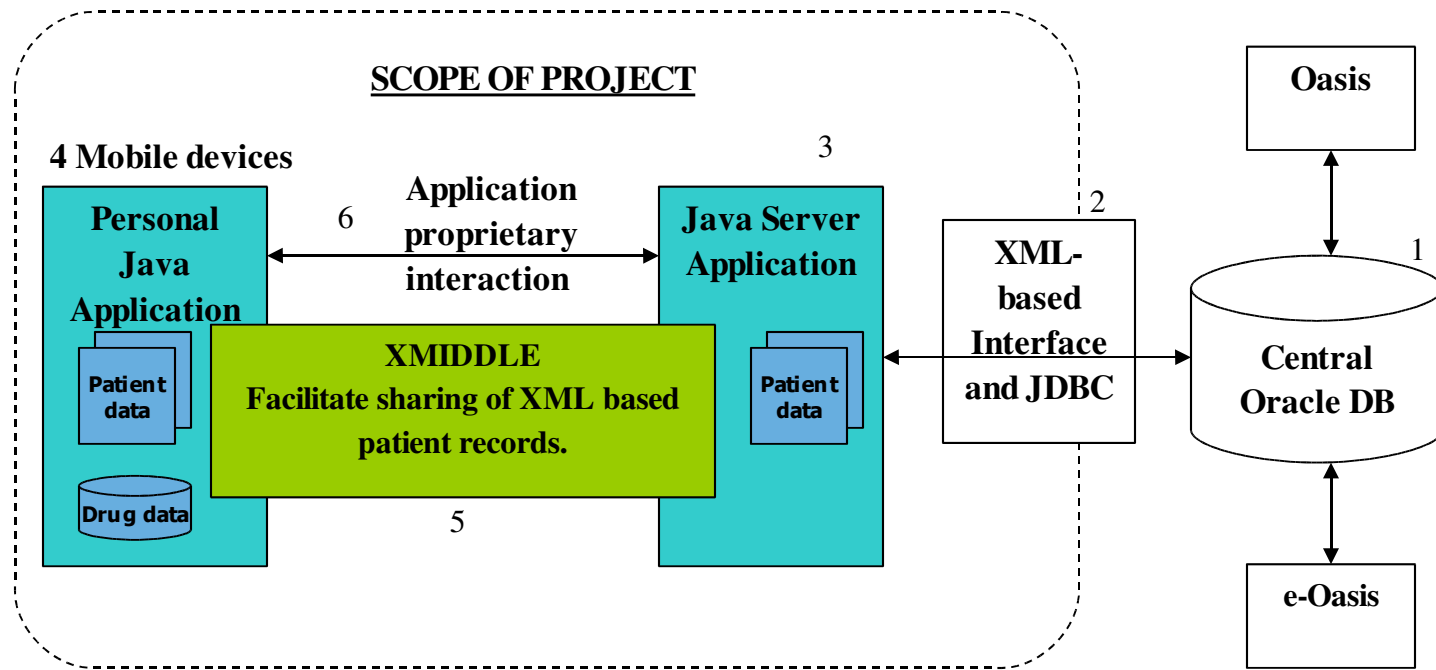
# Solution (2)

- Types of records
  - Patient records
  - Drug Information records
- Usage Scenario
  - Doctor logs on and downloads his/her patient's records onto the PDA.
  - The doctor proceeds on a ward round and for each patient reviews that patient's record
  - The doctor can prescribe drugs/makes changes to each patient if necessary.
  - Any changes made are communicated back to the server and flooded throughout the system.

# Technologies

- Xmiddle originally developed on Linux (familiar 0.4, kernel 2.4.3) using Java (1.3.1-rc1 from Blackdown ~15MB)
- Xerces XML Parser, Xalan Xpath processor
- Ported to Microsoft PocketPC platform running Insignia's Jeode java Virtual Machine
- Existing backend database is Oracle 8

# Architecture





# Constraints & Requirements (1)

- Mobility constraints
  - Disconnections
  - Slow, low-bandwidth comms.
  - Battery Power
  - Low memory
  - Lack of processing power
  - Limited size screen

# Constraints & Requirements (2)

- Healthcare environment
  - Security
  - Highly Mobile working environment (POC)
  - Ease of use
  - Data Integrity – Mission Critical
  - Standardisation (HL7 and XML)
  - Delivery at Point of Care

# Mobile comms. in healthcare

- EMI concerns
- NHS report DB9702 'EMC of medical devices with mobile communications'
- WLAN deployment
  - Wide scale in the US (Proxim)
  - Sheffield Children's hospital (Entrasys)
  - Guy's and St. Thomas's hospital
- EMC Standards
- Bluetooth and IrDA solutions deployed

# Role of XMIDDLE

- Suitability of XMIDDLE
  - Nomadic as opposed to ad-hoc
  - Client-Server as opposed to peer-to-peer
  - XML based documents (HL7 Standardisation)
- Share Patient Records
  - Server Exports
  - Clients Link
- Provides transparency to network comms.
  - Changes are made locally and committed when Server is reachable.
  - User is unaffected by state of network

# Role of XMIDDLE (2)

- Conflict and reconciliation
  - Configurable reconciliation policies
- XMIDDLE drawbacks and modifications
  - Overhead of XML Parsers
  - Communication Overhead (data transfer)
  - Multithreading on PocketPC and Jeode
  - XMiddleApp interface.

# Data Types

- Patient Records
  - Dynamic
  - Shared by XMIDDLE
- Drug Records
  - Static
  - Stored Locally
  - Use of memory vs. Communication overhead

# Addressing mobility constraints

- Memory
  - Session based downloads
  - remove unnecessary data and replication
- Processing power
  - Migrate computation to server
  - Xmiddle reconciliation should be done at server
- Weak comms.
  - Send minimal information over network
    - Changes only and not whole XML document
- Small Screen size
  - New UI Models and navigation techniques

# Tradeoffs

- Where to store information ?
  - Locally and use up memory or remotely at server and deal with communication overhead
- Where to execute processes ?
  - Locally at the cost of time and multithreading constraints or remotely at server and deal with communication overhead



# Addressing Healthcare Req. (1)

- Security
  - Patient Confidentiality
  - Security of PDAs
  - Wireless LAN security
  - Ideally Middleware should provide some security.
- Data Integrity
  - Mission Critical environment
  - Middleware should guarantee delivery of uncorrupted data
  - Wireless LAN coverage

# Addressing Healthcare Req. (2)

- Highly Mobile environment
  - Doctors constantly on the move
  - Use of small, Lightweight PDAs
- Ease of Use
  - UI models
  - Transparency from middleware

# Project Status

- Moved away from XMIDDLE
  - Principals are the same
  - Concentrating more on Nomadic Client-Server model
- Using a more lightweight, small footprint XML Parser for the client

# Summary

- Affect of Mobility constraints
  - Unreliable communications
  - Weak network nodes (PDAs)
  - Tradeoffs
- Middleware and XMIDDLE
  - Transparency to the user
  - Disconnected operation
  - Reconciliation
- Case Study
  - Requirements in a healthcare environment
  - Ease of use and transparency

# Questions ?