Systems Directions for Pervasive Computing

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The Vision

• Make computers usable for (computer) illiterate
  – Enabled by ubiquitous smart devices
• Implies a shift in focus
  – Away from devices and technology
  – Towards users and their tasks
The Reality

• Hardware is almost there
  – Handhelds, tablets, cars, fridges, dogs
  – Wireless networking
  – Location sensing

• Applications are missing
  – Too hard to design, build, and deploy in a giant, ad-hoc distributed system
    • Stuck with email and WWW
The Challenge

• Average hacker needs to develop applications that
  – Adapt to a changing environment
  – Work even if
    • Devices are roaming
    • Users switch devices
    • Network provides only limited services, or none at all
This Is A Systems Problem!

- Need dedicated systems support to make programmers’ task feasible
- But existing approaches to building distributed systems are not suitable
  - Extend single-node programming models
  - Designed for smaller, less dynamic environments
What To Do?

• Smash up and replace
  – Invoke Dawson Engler, abstraction exterminator
  – Replace with simpler, more suitable abstractions
• Pile on
  – Provide abstractions/primitives that directly help programmers
    • “Checkpoint” and “restore”
    • “Move to remote node”
    • “Find matching resource”
Smash up
Distributed Objects

• Popular in distributed systems (Legion, Globe)
• Difficult to evolve
  – Data formats set by standard bodies
  – Vendors compete on functionality
    • Many interfaces and implementations that change faster than data formats
• Difficult to control
  – Easier to provide security and resource controls for passive data

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Replace

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Separate Data and Functionality

• Tuples represent data
  – Are self-describing records
  – Define common data model, type system
  – Enable a common query language

• Components implement functionality
  – Export and import event handlers
  – Are distributed in a common binary format
  – Rely on a common core API

• But data and functionality depend on each other
  – Migrating an application and its data
Pile on
Environments

- Serve as containers for
  - Tuples
  - Components
  - Environments
- Preserve independent access
- Represent a combination of
  - File system directories
  - Nested processes
Smash up
Transparent Distribution Is Harmful

- Hides access to remote resources
  - Distributed file systems
  - Remote procedure calls
- Treats failures or unavailability as an extreme case
- But frequent changes are inherent to pervasive computing environments
  - Result: limited application availability
Replace
Expose Change

• Applications need to acquire all resources and be able to reacquire them at any time
  – Explicitly bind resources
  – Use leases to provide timeouts when accessing unavailable resources
• Programming for change shifts burden to application developer
  – Can we do better?
Pile on
Say Yes To Migration

- Moves/copies an application and its data
- Affects an entire environment tree
  - Tuples
  - Components
  - Environments
  - But nothing outside the tree
- Breaks bindings to outside
- Makes migration in the wide area feasible

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Putting It All Together

• Root of tree controls
  – When to migrate
  – Where to migrate
• Compose for migration
  – Isolate migration logic in separate environment
  – Embed application in that environment
Summary

• Challenge
  – Build applications that gracefully adapt to constant change

• Solution
  – Provide dedicated systems support
    • Separate data and functionality
    • Expose change to applications
    • Include primitives to cope with change

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