Context-aware Migratory Services in Ad Hoc Networks*

Rutgers-Helsinki Ph.D. Student Workshop on Spontaneous Networking
8-12th May 2006

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Connecting to Internet through ad hoc networks

How else can we exploit the ad hoc network characteristics to support a new class of applications?
Ad hoc networks as service providers

- Enable a new class of services specific to ubiquitous computing environments
- Acquire, process, disseminate real-time information
- Targets: region, activity, entity

Traffic Information from region at constant distance in front of the driver

- Requirements:
  - Service must be aware of its context
  - Service must adapt to user’s context
Entity Tracking Service

Requirements:
• Service must be aware of its target
• Service must preserve its execution state over time

Spontaneous Monitoring Service

Requirements
• Transfer code from node to node
• The service must be aware of its context
Requirements for services in ad hoc networks

- Context-awareness
  - dynamism of services and request targets

- User-driven adaptability
  - dynamism of user needs and operational context

- Service continuity
  - due to context changes, a node may become incapable of hosting a service any longer
  - need to support stateful interaction

- On-demand code distribution
  - nodes do not possess the code for any type of service

Outline

- Motivations
- Context-aware Migratory Services
- Migratory Services Framework
- Evaluation
- Conclusions & Future Works
Migratory Services Model

- MS migration
- Physical client-service interaction
- Virtual client-service interaction

One-to-one mapping between clients and migratory services

Migratory Services Model - cont’d

Client end-point

MS State

Meta-service

MS State

Migratory service

MS State

Migratory service end-point

MS State

Migratory service end-point

One-to-one mapping between clients and migratory services
Example: Region monitoring Service

Key ideas in Migratory Services

- Capable of migrating to different nodes in the network in order to effectively accomplish their function
- 3 basic mechanisms:
  - Monitor the context of interacting entities
  - Specify in context rules how the service execution is context-dependent
  - Migrate the service from node to node and resume its execution once migrated
- Service migration is triggered by context changes
- Service migration is transparent to the client
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Migratory Services Framework

- Client Application/Service
  - Context Manager
  - Monitored Cxt
  - Communication Manager
  - Reliability Manager
- InCtxRules
- OutCtxRules
  - Validator

Smart Messages Platform

Operating System/ Wireless Communication / Sensors
Migratory Service Implementation using Smart Messages

Smart Messages
- implemented on a modified version of Sun’s Java K Virtual Machine

Migratory Services
- clients, migratory services, and meta-services are Java programs that register with the framework
- the framework maps these programs onto lower-level SMs
- SM self-routes using geographical and content-based routing

Context Manager
- Context data provided by the SM platform
  - location, time, speed using GPS
  - device status information
  - neighbors list
- MonitoredCtx identifiers are translated into SM I/O tags
- Access to context data by polling or blocking on corresponding SM tags
Context Rules and Validator

- Evaluate if a service computation can be “correctly” carried out on the current hosting node
- If not, trigger migration

CxtRules are service/client-specific policies
- inCxtRules – control on incoming data
- outCxtRules – control on outgoing data

CxtRules are condition/action statements
- Conditions are full binary trees of Boolean expressions (comparisonNodes + combinationNodes)
  - Ex: < OR, <batteryLevel, EQUAL, low>, <responseLocation, OUT_REGION, userRegion> >
- Actions: migrate service, send update, accept/refuse response, ...

Communication Manager

- Tasks:
  - Discover meta-services
  - Route messages between communicating end-points
  - Carry out service migration

- Use naming conventions defined by SM

- Two basic SM routing algorithms:
  - geographical routing (similar to GPSR)
  - region-bound content-based routing (similar to AODV)
Reliability Manager

- Fault-tolerance to one failure
- Inactive version of the service on a secondary node
- In case of failure of the primary version, the secondary version can take over the service provisioning

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Prototype Migratory Service: TJam

- Predict traffic jams in real-time
- Traffic jams are locally congested phases in which cars travel at slow or zero velocity
- TJam utilizes two types of information that every car owns:
  - number of one-hop neighboring cars
  - speed of one-hop neighboring cars

\[ P_{\text{number}} = \max P_{\text{number}} \times \frac{\text{avg speed} - \text{min speed}}{\max \text{num} - \text{min num}} \]
\[ P_{\text{speed}} = \max P_{\text{speed}} \times \frac{\text{avg speed} - \text{max speed}}{\min \text{speed} - \max \text{speed}} \]
\[ P'_{\text{tjam}} = \alpha \times P_{\text{number}} + (1 - \alpha) \times P_{\text{speed}} \]
\[ P_{\text{tjam}} = P'_{\text{tjam}} \times \frac{N_{\text{tjam}}}{N_{\text{total}}} \]

TJam: Testbed Experiments

- Ad hoc mobile network of 11 HP iPAQs with 802.11 cards and GPS
- Use mobility traces
- 1-2 hops communication
- 2/3 neighbors
TJam constantly executes in the user-specified region

TJam: Simulations

- ns-2 simulator with the CMU-wireless extensions
- microscopic traffic generator tool Micro-VTG
- Goal: Investigate the scalability of migratory services in large scale networks
- Study based on the comparison of
  - TJam-Smart: migratory service model implementation
  - TJam-Base: baseline centralized approach
- Metrics
  - inter-response time
  - correct response generation time
  - packet utilization rate
  - response packets overhead
Simulations: effects of number of clients

- highway of length 25km with 3 lanes
- vehicles avg speed is 30m/s with a gap of 150m
- 800 vehicles (500 vehicles active and 50 service nodes)

Simulations: effects of vehicles speed

- 150 clients
Outline

Motivations
Context-aware Migratory Services
Migratory Services Framework
Evaluation
Conclusions & Future Works

Conclusions

Migratory Services enables a new class of services in ad hoc networks

- services quickly adapt to changes in the physical environment, in the node capabilities, and network topology
- service continuity to the client

Experimental results demonstrate the feasibility of our approach
Simulation results demonstrate the scalability and efficiency of migratory services compared to a traditional centralized approach
Future Works

- Extend migratory services to smart phones using Portable Smart Messages (J2ME CDC)
- Experimental testbed of nokia 9500
- Use migratory services to collect context information of entities and environments
  - Integration with the Contory middleware
  - Contory is a middleware for the provisioning of context information on smart phones

Thank you!

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