Nexus – A Platform for Context-aware Applications

KuVS Fachgespräch “Ortsbezogene Anwendungen und Dienste”
2004-06-24

Frank Dürr, Nicola Hönle, Daniela Nicklas, Christian Becker, and Kurt Rothermel
Overview

• Vision

• Nexus Platform
  ◦ Architecture & Core Services
  ◦ Value-added services

• Geocast based on Nexus Platform
  ◦ Location model and addressing
  ◦ Message forwarding

• Summary
Vision: Federated, Shared World Models

- Context Model: information for Context-aware applications
  - location, identity, time (primary context)
  - environment, POIs, sensor data, relevant web sites
- Shared: enables interoperability between applications
  - modeling is expensive
  - shared resources
- Federated: combining local world models to a global view
- Open
Augmented World Model

- Spatio-temporal object-oriented information model
- Real-world objects
  - Static and mobile
  - Relations
- Virtual objects
  - Metaphors for external information, e.g. Virtual Information Towers
Overview

• Vision

• Nexus Platform
  ◦ Architecture & Core Services
  ◦ Value-added services

• Geocast based on Nexus Platform
  ◦ Location model and addressing
  ◦ Message forwarding

• Summary
The Nexus Architecture

Application tier

Federation tier

Service tier

NEXUS Application Interface

NEXUS Service Interface

Area Service Register

Nexus Node 1

Nexus Node 2

Nexus Node n

App. 1

App. 2

App. m

Augmented World

Context Server 1

Context Server j

Location Service

Other Services

static objects

mobile objects

external data, e.g. WWW

static objects

mobile objects

external data, e.g. WWW

Research Group
“Distributed Systems”
Augmented Area

- Covers a certain area
- Contains only certain types of objects
- Consistent in itself
- Stored on one Context Server

- Augmented Areas may overlap
  - Multiple representations of objects
  - Relations between objects facilitate federation
Location Service

• Management of mobile objects
  ◦ Main memory based approach

• Supported queries:
  ◦ Position query
  ◦ Range query
  ◦ Nearest neighbor query

• Key issues:
  ◦ High accuracy → efficient processing of position updates and queries
  ◦ Management of large number of mobile objects → scalability
Location Service Architecture

† forwarding pointers

root server

location servers

leaf servers

position updates

tracked objects, sensor systems

service areas
Overview

• Vision

• Nexus Platform
  ◦ Architecture & Core Services
  ◦ Value-added services

• Geocast based on Nexus Platform
  ◦ Location model and addressing
  ◦ Message forwarding

• Summary
Event Service

- Distributed event observation and notification of spatial events, e.g.
  - on enter/leave area
  - on meeting
- Combination of simple events to complex events
Navigation Service

- Multimodal navigation
  - Integration of navigation data from different providers

- Context-aware navigation
  - Current traffic situation (traffic jams, train delays, etc)

Diagram:

- Application
- NEXUS Application Interface
- Nexus Node
- NEXUS Service Interface
- Area Service Register
- Navigation Service
- Augmented World
- Context Server 1
- Public Transport
- Context Server j
- Mobile Objects
- Map (streets, road works, ...)
- Location Service

Map with locations:
- U7
- Killesberg Türlenstraße
- S

Institution logos:
- University of Stuttgart
- IPVS
- Research Group Distributed Systems
Overview

• Vision

• Nexus Platform
  ◦ Architecture & Core Services
  ◦ Value-added services

• Geocast based on Nexus Platform
  ◦ Location model and addressing
  ◦ Message forwarding

• Summary
Context-aware Communication: Geocast

Send message to all hosts in geographic target area

- Message to area close to fire: “Toxic smoke. Keep windows shut!”
- Send presentation slides to everyone in conference room

Requirements

- Fine-grained addressing scheme based on Nexus location model
- Scalable geocast routing algorithms
  - small receiver groups (e.g. one room) up to large groups (e.g. a whole city)
Geocast: Addressing Schemes

- Geometric addressing
  - “Arbitrary” target areas
  - Complex location model

conference room: polygon(vertex1, …, vertexN), altitude, height
Geocast: Addressing Schemes

- Geometric addressing
  - “Arbitrary” target areas
  - Complex location model

conference room:
polygon(vertex1, …, vertexN), altitude, height
Geocast: Addressing Schemes

- **Geometric addressing**
  - “Arbitrary” target areas
  - Complex location model

- **Symbolic addressing**
  - Intuitive to use
  - Simple location model
  - Target areas dependent on symbolic location model and addressing scheme

[UbiComp ’03]

conference room:
/de/stuttgart/keplerstr/9/floor1/wing2/room1
Geocast: Addressing Schemes

- **Geometric addressing**
  - “Arbitrary” target areas
  - Complex location model

- **Symbolic addressing**
  - Intuitive to use
  - Simple location model
  - Target areas dependent on symbolic location model and addressing scheme

- **Hybrid addressing**
  - Geometric & symbolic

```
/de/stuttgart/keplerstr/9/floor1/wing2/room1: circle(X,Y)
```

Local coordinate system of room R1
Geographic Multicast

- Nexus Augmented World Model contains more than location information
  - Object classes, e.g. pedestrians, vehicles, etc
  - Object attributes
- Receiver group can be refined to address groups within geographic areas (geographic multicast)
- Examples:
  - Message to all taxis near the main station of Hagen
Simple Directory-based Geocast Message Forwarding

1. Query directory for all hosts in target area
   - static hosts: Context Server
   - mobile hosts: Location Service

2. Send message to these hosts
   - one unicast message per host

Applicable to small receiver groups → poor scalability
2-Phase Directory-based Geocast Message Forwarding

1. Query directory for all access networks intersecting target area
   • spatial model of access networks required

2. Send message to each access network’s GeoNode
   • one unicast message per access network

3. Distribute message within access network
   • broadcast or multicast

Applicable to medium-size receiver groups (small number of intersecting access networks) → medium scalability
Geocast: Geographic Routing

- Overlay network of GeoRouters
  - GeoRouters have geographic service area
  - GeoRouter hierarchy according to spatial containment relationship of service areas
Geocast: Geographic Routing

- **Overlay network of GeoRouters**
  - GeoRouters have geographic service area
  - GeoRouter hierarchy according to spatial containment relationship of service areas
- **Forwarding**: GeoRouters compare target area and service areas
  - Forwarding along hierarchy to access networks intersecting target area
  - Distribution within access networks
Geocast: Geographic Routing

- **Overlay network of GeoRouters**
  - GeoRouters have geographic service area
  - GeoRouter hierarchy according to spatial containment relationship of service areas

- **Forwarding**: GeoRouters compare target area and service areas
  - Forwarding along hierarchy to access networks intersecting target area
  - Distribution within access networks

---

**Geometric forwarding** [Navas]

- service area R3
- service area R2
- target area

R2: city router "Stuttgart"

R3: city router "Karlsruhe"

"Keplerstr. 9"

sender in Karlsruhe

access network on floor 1 covering conference room
Geocast: Geographic Routing

- Overlay network of GeoRouters
  - GeoRouters have geographic service area
  - GeoRouter hierarchy according to spatial containment relationship of service areas

- **Forwarding:** GeoRouters compare target area and service areas
  - Forwarding along hierarchy to access networks intersecting target area
  - Distribution within access networks

Symbolic forwarding:
- Baden-Württemberg: R1
- Stuttgart: R2
- Karlsruhe: R3
- room 1

access network on floor 1 covering conference room

R2: city router “Stuttgart”
R3: city router “Karlsruhe”
“Keplerstr. 9” sender in Karlsruhe

 sender in Karlsruhe
Geocast: Geographic Routing

- Overlay network of GeoRouters
  - GeoRouters have geographic service area
  - GeoRouter hierarchy according to spatial containment relationship of service areas

- Forwarding: GeoRouters compare target area and service areas
  - Forwarding along hierarchy to access networks intersecting target area
  - Distribution within access networks

- Evaluation: up to ~100,000 forwarding decisions/sec for symbolic routing algorithm → scalable to large receiver groups

Symbolic forwarding

- Baden-Württemberg: R1
- Stuttgart: R2
- Karlsruhe: R3

R2: city router “Stuttgart”
R3: city router “Karlsruhe”
“Keplerstr. 9”

sender in Karlsruhe
access network on floor 1 covering conference room
Summary

• Context-aware applications
  ◦ Require context model, but high modeling effort for global and fine-grained model

• Nexus Platform for context-aware applications
  ◦ Federation of local models → shared modeling effort
  ◦ Value added services on basis of federated context model, e.g. event service, navigation service, etc

• Geocast based on Nexus Platform
  ◦ Fine-grained addressing (symbolic, geometric, hybrid)
  ◦ Efficient message forwarding
Thank you very much for your attention!

Nexus Project: www.nexus.uni-stuttgart.de
Email: frank.duerr@informatik.uni-stuttgart.de