

Distributed Event Management

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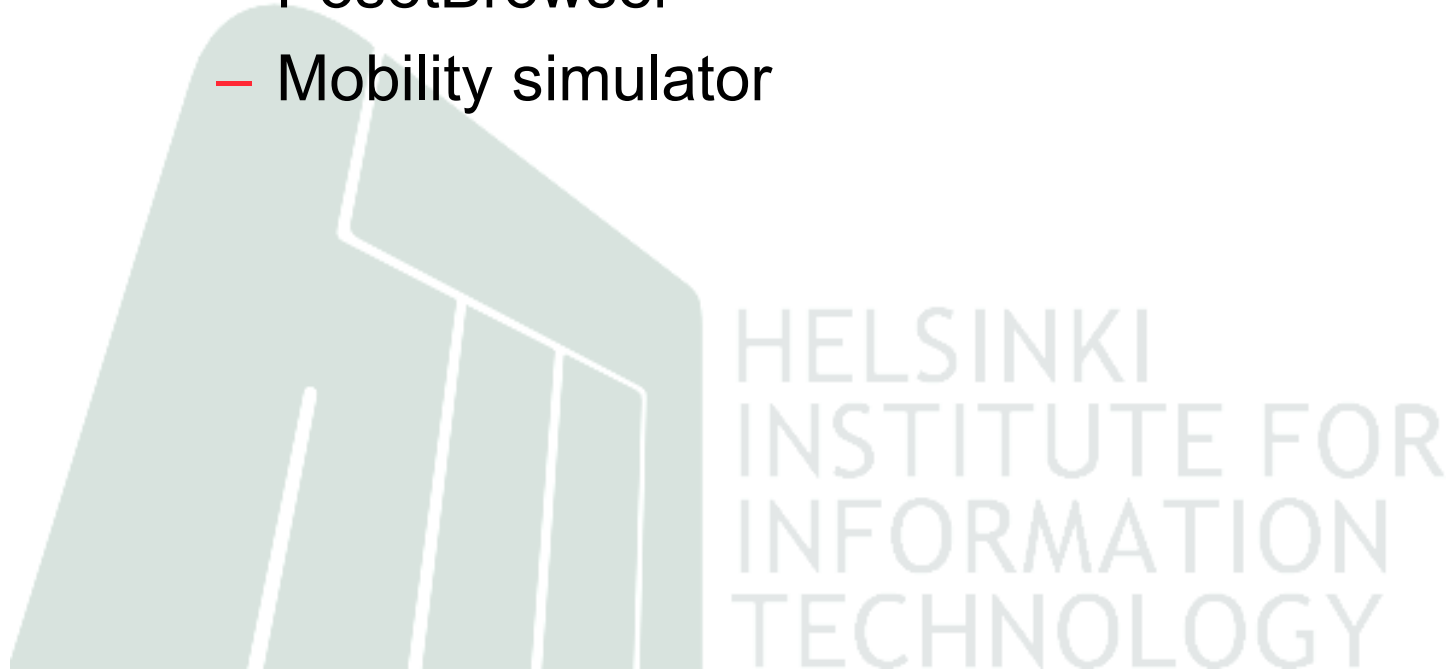
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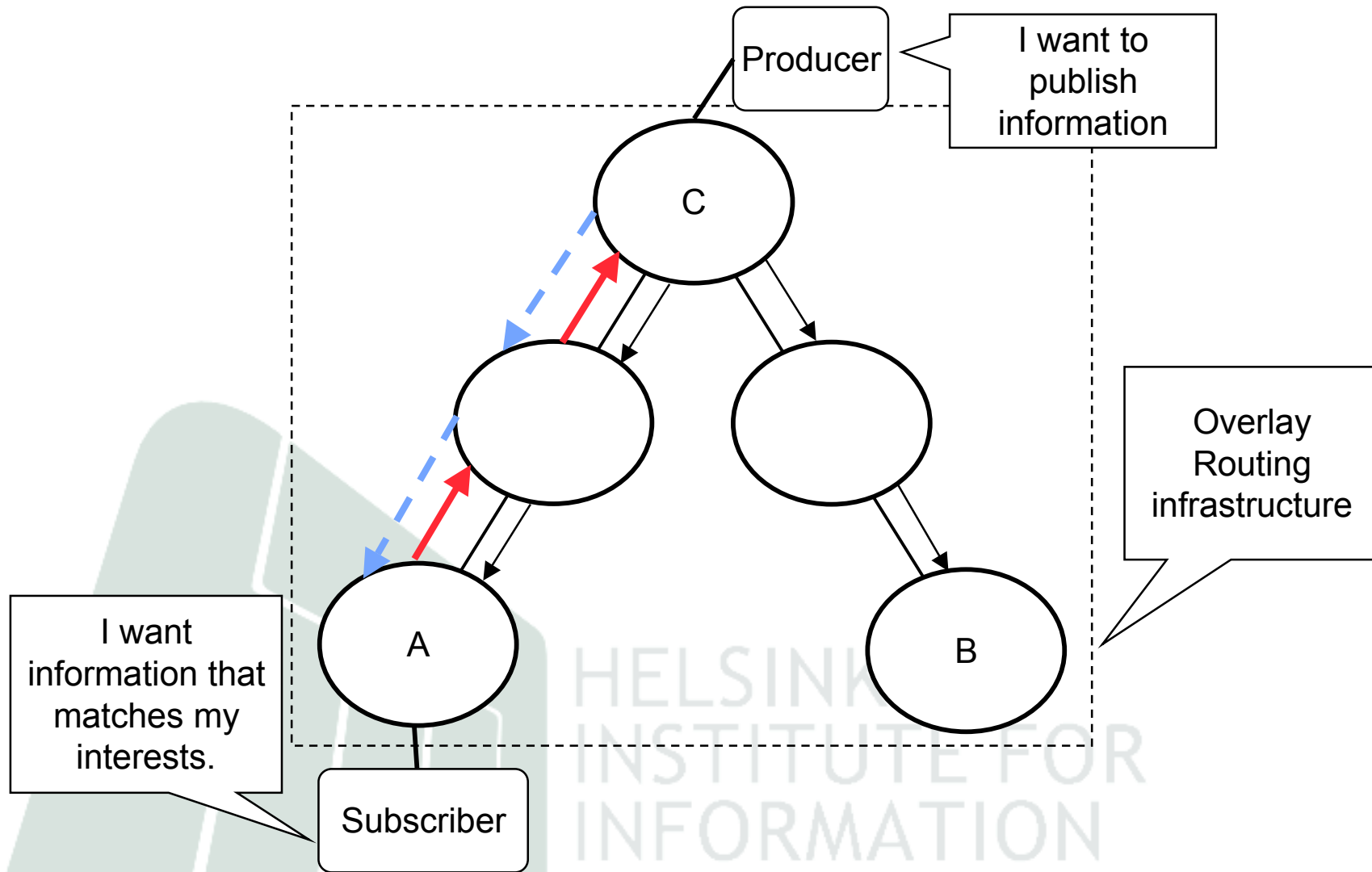
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Introduction

- Event-based systems and publish/subscribe
 - Events (or notifications) are propagated from publishers to subscribers (sinks).
- A frequently used communication paradigm
 - Proposed for mobile computing
 - Current Web lacks publish/subscribe support
 - RSS feeds use HTTP and polling.
- Subscriptions are described using filters.
 - Filter: a stateless boolean function.
 - Selects a subset of events.
 - Expressive interest definition and content-matching
- Content model typically typed tuples or XML.
- The event service is a logically centralized service
 - Basic primitives: *sub*, *unsub*, *pub*
 - Various routing topologies and semantics
 - Reverse-path routing

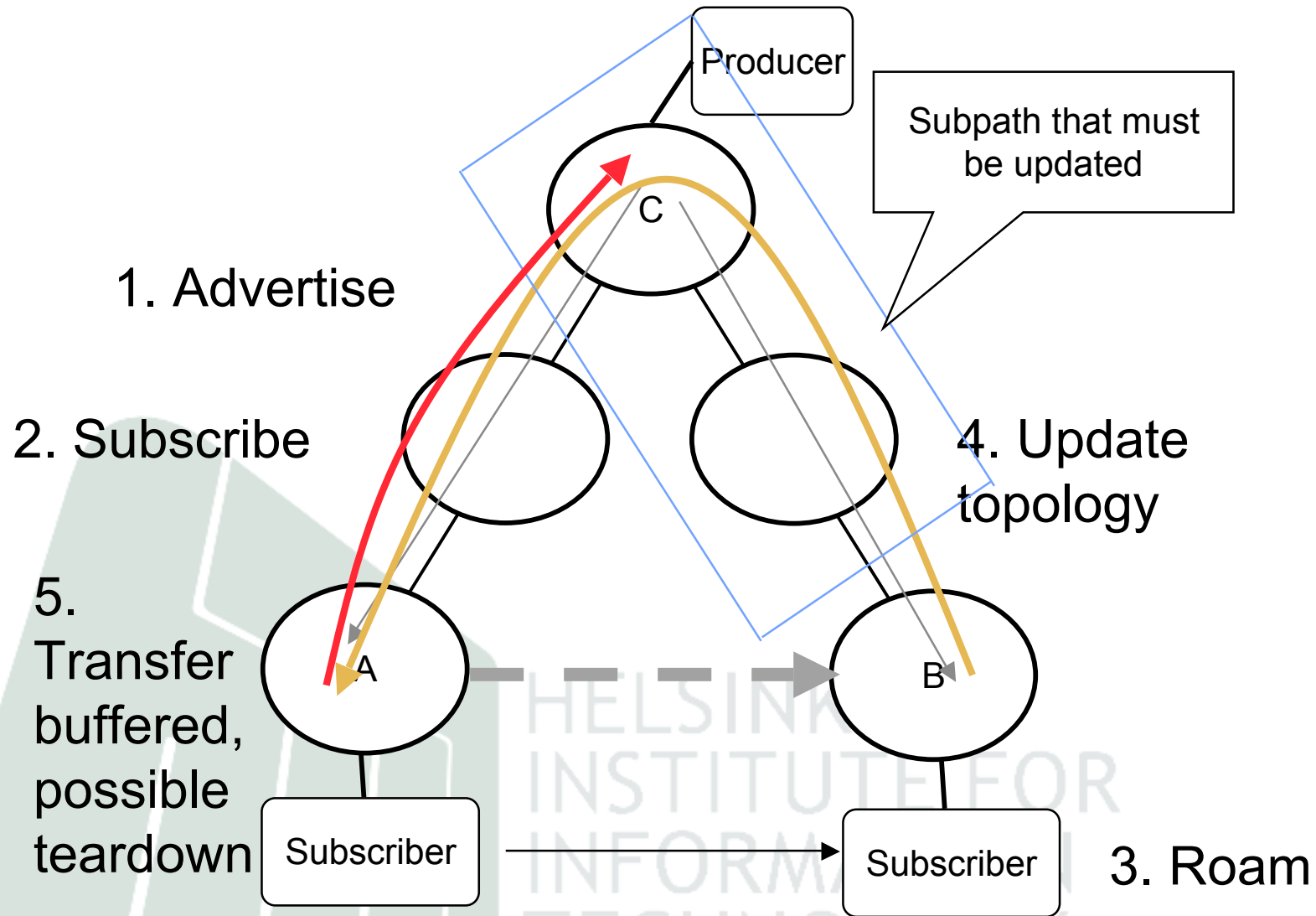
Example of Publish/Subscribe



Challenges

- How to cope with mobile users?
 - Disconnected operation
 - Buffering and queue management
 - Mobile subscribers / producers
 - Handover protocol for relocating subscriptions and updating the topology
 - Multiple indirection points
- How to manage large numbers of filters?
 - Covering relations, filter merging
 - $[0, 10]$ covers $[2, 5]$
 - $[0, 10]$ or $[9, 20]$ can be merged to $[0, 20]$
 - These optimizations complicate mobility support
- General requirements
 - fast convergence of the subscription topology
 - mobility-safety: no false negatives

Example Handover



Fuego Event System

- Scalable distributed event framework for mobile computing
- The Fuego event router consists of two parts:
 - access server functionality with buffering and handover support for mobile clients, and
 - extensible routing core for distributed operation
- New data structures for efficient content-based routing:
 - poset (partially ordered set)-derived forest
 - the forest is considerably more efficient than dag (directed acyclic graph) - based structures
- Rendezvous-based mobility support for fast handovers and subscription topology updates
 - RP or paths to RP are updated instead of the whole topology

Summary of Data Structures / Models

- Data structures for cover-based routing
 - Poset-derived forest and variants
- A formal framework for filter merging
 - Both dynamic and static merging
- A discrete model for pub/sub mobility
 - Costs for handovers, simulation results
- Data structures for context-aware operation
 - DoubleForest for matching between context queries and context profiles (cover, overlap)
- The algorithms are useful for different filter and cover-based applications
- We use the DoubleForest in context-based collection and object synchronization
- Live demos on the web: www.hiit.fi/fuego/fc/demos

PosetBrowser

Filters poset (FP)
Colored Forest (CF)
Balanced Forest (BF)
Non-redundant BF (NRBF)

Combined view

Forwards sets (FP,NRBF)
Filter Merging

Filter Generation
Execute general tests
Delete test (FP,NRBF)

Number of filters shown
1 11 21 31 41 51 61 71 81 91

Created by Sasu Tarkoma 2005

Filters poset

(val2/rn... (val2/n... (val1/n... (val1/n... (val1/ft ... (val0/n... (val0/n... (val0/gr...
(val1/rn... (val1/rn... (val1/n... (val0/ft ... (val0/gr... (val0/e... (val0/e... (val0/e...
(val0/rn...

Colored forest

(val2/rng 33.0 97.0);[iface1]FW:[iface0, iface2, iface3, iface4] n... (val0/n... (val0/gr...
(val2/rn... (val1/rn... (val1/rn... (val1/n... (val0/ft ... (val0/gr... (val0/e... (val0/e... (val0/e...
(val0/rn...

Balanced colored forest

(val2/rn... (val2/n... (val1/n... (val1/n... (val1/ft ... (val0/n... (val0/n... (val0/gr...
(val2/e... (val1/rn... (val1/n... (val1/n... (val0/ft ... (val0/gr... (val0/e... (val0/e... (val0/e...
(val0/rn...

Non-redundant balanced colored forest

(val2/rn... (val2/n... (val1/n... (val1/n... (val1/ft ... (val0/n... (val0/n... (val0/gr...
(val1/rn... (val1/rn... (val1/n... (val0/ft ... (val0/gr... (val0/e... (val0/e... (val0/e...
(val0/rn...

Mobility Simulator

The screenshot displays the Mobility Simulator interface, which is divided into several sections:

- Network Topology:** A central window showing a network graph with nodes (V0-V99) and edges. Nodes are represented by circles, some in red and some in grey. The graph is interconnected, showing a complex network structure.
- Control Panel:** Located at the bottom left, it includes a dropdown menu for "Select protocol" (set to "PingPong"), sliders for "Subscribers" (1), "Producers" (1), "Active types" (1), and "UI Delay" (1). There are checkboxes for "Show all edges?", "Only edge mobility?" (checked), and "Force x,y?". A "Generate Script" button is also present. Below these are buttons for "Simulate", "Stop", "Pause", "Step", "Routing tables", and "Script".
- Replay Script Events:** A window on the right side showing a list of events. The events are timestamped and include details such as "type", "source", and "target". The events listed are:

```
0.0 type: TYPE_SET_LOC source: V61 target: V61
0.0 type: sub_source: V61 target: V61
0.0 type: TYPE_SET_LOC source: V48 target: V48
0.0 type: adv source: V48 target: V48
65.01619913074279 type: TYPE_RESET_COST source: V81 target: V81
100.01619913074279 type: mobstart source: V61 target: V61
200.0161991307428 type: mobend source: V61 target: V2
400.0161991307428 type: mobstart source: V2 target: V2
500.0161991307428 type: mobend source: V2 target: V74
700.0161991307427 type: mobstart source: V74 target: V74
800.0161991307427 type: mobend source: V74 target: V13
1000.0161991307427 type: mobstart source: V13 target: V13
1100.0161991307427 type: mobend source: V13 target: V41
1300.0161991307427 type: mobstart source: V41 target: V41
1400.0161991307427 type: mobend source: V41 target: V2
1600.0161991307427 type: mobstart source: V2 target: V2
1700.0161991307427 type: mobend source: V2 target: V53
1900.0161991307427 type: mobstart source: V53 target: V53
2000.0161991307427 type: mobend source: V53 target: V64
2200.0161991307427 type: mobstart source: V64 target: V64
2300.0161991307427 type: mobend source: V64 target: V9
2500.0161991307427 type: mobstart source: V9 target: V9
2600.0161991307427 type: mobend source: V9 target: V31
2800.0161991307427 type: mobstart source: V31 target: V31
2900.0161991307427 type: mobend source: V31 target: V53
3100.0161991307427 type: mobstart source: V53 target: V53
3200.0161991307427 type: mobend source: V53 target: V13
3400.0161991307427 type: mobstart source: V13 target: V13
3500.0161991307427 type: mobend source: V13 target: V2
3700.0161991307427 type: mobstart source: V2 target: V2
3800.0161991307427 type: mobend source: V2 target: V40
4000.0161991307427 type: mobstart source: V40 target: V40
4100.016199130743 type: mobend source: V40 target: V85
4300.016199130743 type: mobstart source: V85 target: V85
4400.016199130743 type: mobend source: V85 target: V53
4600.016199130743 type: mobstart source: V53 target: V53
4700.016199130743 type: mobend source: V53 target: V48
4900.016199130743 type: mobstart source: V48 target: V48
5001.562602419984 type: mobend source: V48 target: V29
5201.562602419984 type: mobstart source: V29 target: V29
5301.562602419984 type: mobend source: V29 target: V46
5501.562602419984 type: mobstart source: V46 target: V46
5601.562602419984 type: mobend source: V46 target: V48
```
- Status Log:** A window at the bottom left showing simulation status and statistics:

```
***** topology is complete *****
Total cost of signalling traffic: 112
Avg handover latency: NaN +/-0.0
65.01619913074279 type: sub_source: V47 target: V48 0
60.74869920593049 type: sub_source: V35 target: V47 0
```

Future Work

- Ad hoc and peer-to-peer routing
- Massive scalability
- Applications
- Load balancing



Recent Papers on Events

- Sasu Tarkoma, Tancred Lindholm, and Jaakko Kangasharju. Collection and Object Synchronization Based on Context Information. In Second IEEE/IFIP International Workshop on Mobility Aware Technologies and Applications, October 2005.
- Sasu Tarkoma and Jaakko Kangasharju. Handover Cost and Mobility-Safety of Content Streams. In Eighth ACM/IEEE International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems, October 2005.
- Sasu Tarkoma and Jaakko Kangasharju. Filter Merging for Efficient Information Dissemination. In 13th International Conference on Cooperative Information Systems, October 2005.
- Sasu Tarkoma and Thalainayar Balasubramanian Ramya. A Gateway for SIP Event Interworking. In Third Workshop on Applications of Wireless Communications, August 2005.
- Sasu Tarkoma and Jaakko Kangasharju. A Data Structure for Content-based Routing. In IASTED EuroIMSA 2005, February 21-23, 2005, Grindelwald, Switzerland.
- Sasu Tarkoma and Jaakko Kangasharju. Mobility and Completeness in Publish/Subscribe Topologies. In IASTED International Conference on Networks and Communication Systems, ACTA Press, April 2005