PSVR - A Self-Stabilizing Publish/Subscribe Middleware for Ad-hoc Networks

Gerry Siegemund and Volker Turau

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Introduction
Definition (Publish/Subscribe Model)

Publish/Subscribe is a communication paradigm that allows any number of publishers to communicate with any number of subscribers asynchronously and anonymously via an event channel.

- **Abstractions**
  - Channel $c$
  - Publication $m$

- **API**
  - `subscribe(c)`
  - `publish(c, m)`
  - `unsubscribe(c)`
Publish/Subscribe Systems

- Advantage compared to request-reply model
  - Loose coupling:
    Data producers (publishers) and data consumers (subscribers) can be added or removed dynamically

- Main body of research focuses on overlay networks such as peer-to-peer networks (e.g. Scribe)
  - Overlay networks are mainly designed for connection-oriented transport such as TCP

- Challenges for publish/subscribe systems in WANET
  - Scalability
  - Fluctuations of subscribers
  - Fault tolerance
Routing in Publish/Subscribe Systems

- Publish/subscribe middleware takes care of forwarding publications to subscribers
- Routing options
  - Tree routing
    - Publications are routed via fixed tree
    - Disadvantage: Long routes despite existence of short path
  - Steiner trees with respect to the publishers and subscribers
    - Computational unfeasible
  - Rendezvous based approaches, or informed gossiping
  - Virtual rings
Contribution

- Scalable, self-stabilizing middleware for channel-based publish/subscribe applications in WANET
- Footprint is small enough for hardware currently envisaged for IoT
- On average short routes
- Fault tolerance through leasing technique and self-stabilization
- Eventual provision of safety and liveness properties
  - Delivery of all published messages to all subscribers of corresponding channel
  - Correct handling of sub- and unsubscriptions
- Fault model
  - Message and memory corruptions
  - Network changes (node and link removals/additions)
Architecture
Layered Architecture

IoT Application

Interface

Publish/Subscribe

Virtual Ring

Spanning Tree

TCA

LQE

MAC

Physical layer
MAC Layer Network View

Bidirectional communication links
 Architecture

Neighborhood Layer Network View

Size of neighbor table $C_N = 3$
Light gray edges are none-tree links
Positions on the virtual ring

0, 8, 18, 30
2, 4, 6
1, 7, 9, 15, 17, 19, 23, 29
10, 14, 20, 22, 24, 28
25, 27
11, 13
12
21
26

Virtual Ring Layer Network View 4
Virtual Ring Graph
Routing Example on the Publish/Subscribe Layer

- tree routing (8)
- PSVR (3)
- shortest path (2)

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Concurrent Message Forwarding

- Segment: Continuous sequence of ascending positions
- Virtual ring is divided into segments s.t. either one includes the other or they are totally disjoint
- Partially ordered virtual ring

Subscribers: gray; publisher: black
Features

- Forwarding publications is highly concurrent
- Fault tolerance through leasing techniques
  - Subscriptions are periodically renewed
  - Self-stabilizing algorithm for virtual ring
- Sub-/unsubscribers require message exchange in limited region only
- Highly suitable for applications with high degree of subscriber fluctuations
Conclusion
Summary & Conclusion

- Middleware for publish/subscribe optimized for scenarios with
  - unstable communications links
  - nodes frequently change subscriptions

- Compromise between size/maintenance effort for routing tables due to sub-/unsubscriptions and length of routing paths

- Simulations against close to optimal solution show that middleware gives a fair trade-off between
  - scalability of routing structure
  - message forwarding overhead

- Real world tests in Fit-IoT Lab confirmed usability
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Volker Turau
Professor

Phone +49 / (0)40 428 78 3530
e-Mail turau@tuhh.de
http://www.ti5.tu-harburg.de/staff/turau