Synchronization with Guarantees

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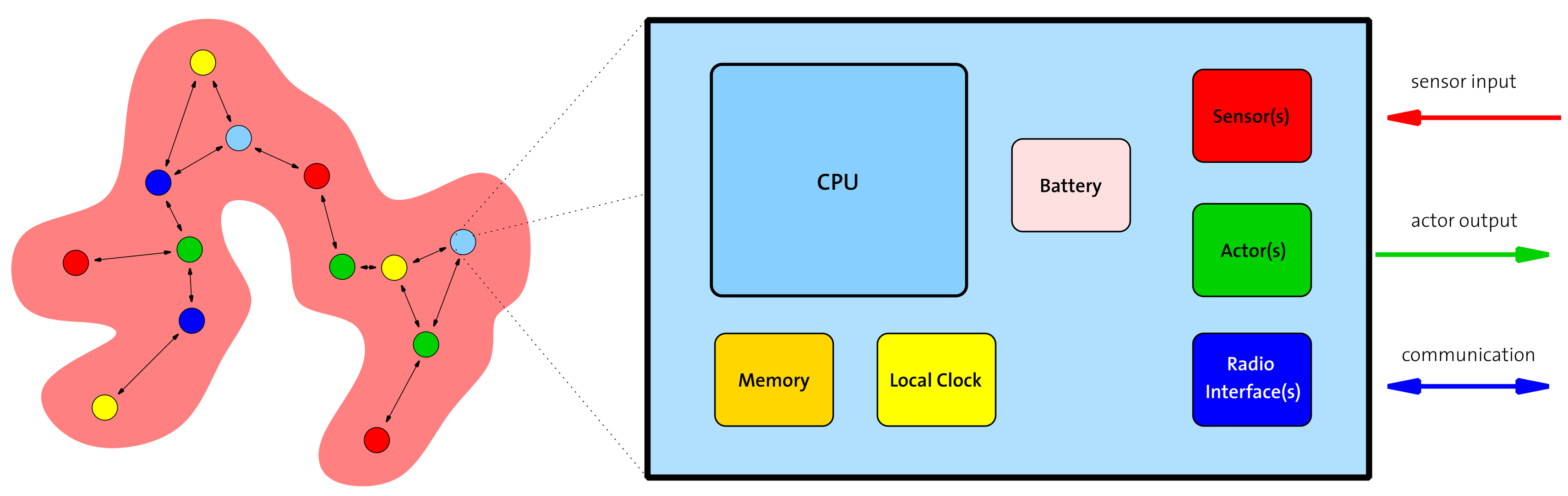
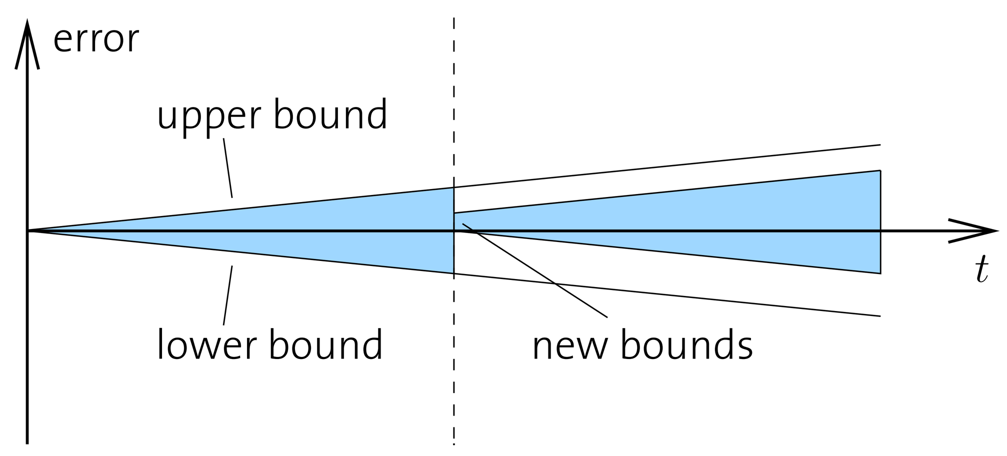
Goal and Motivation in the Context of Ad-Hoc Networks

Goal: Find efficient algorithms that provide tight and deterministic time bounds in ad-hoc networks



Network of heterogeneous nodes



Deterministic time bounds on the real time t

Use of synchronization

- fusion of distributed sensor data
- coordination among distributed actuators
- energy-efficient communication

Peculiarities of ad-hoc networks

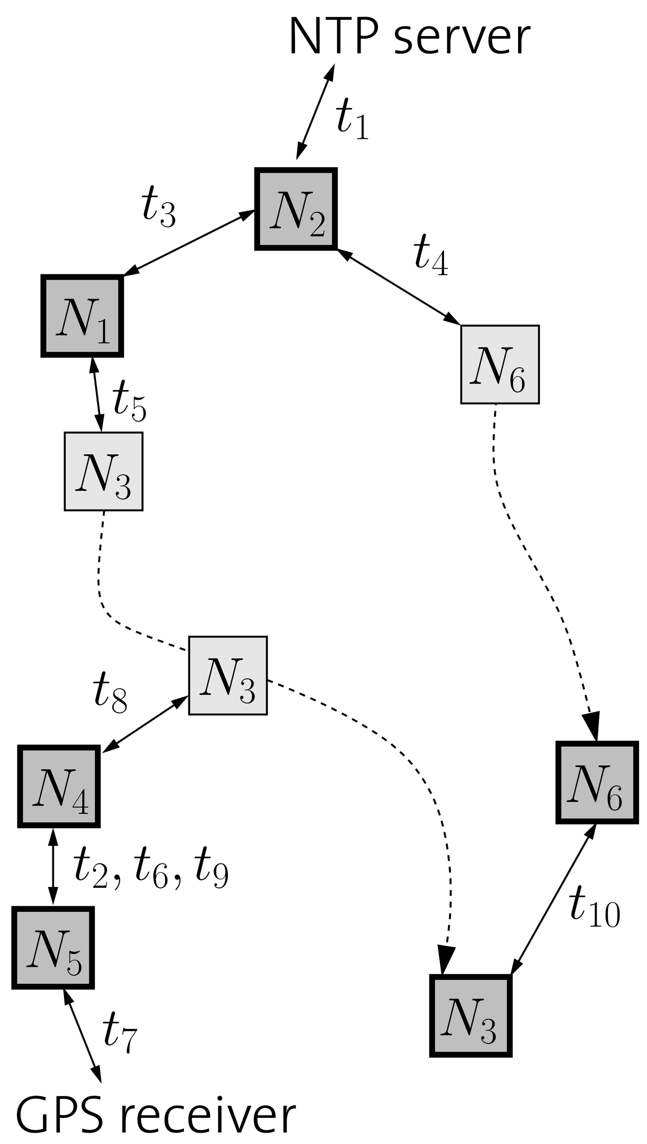
- no configuration or infrastructure
- stable connectivity cannot be assumed
- energy is a scarce resource

Advantages of guaranteed bounds

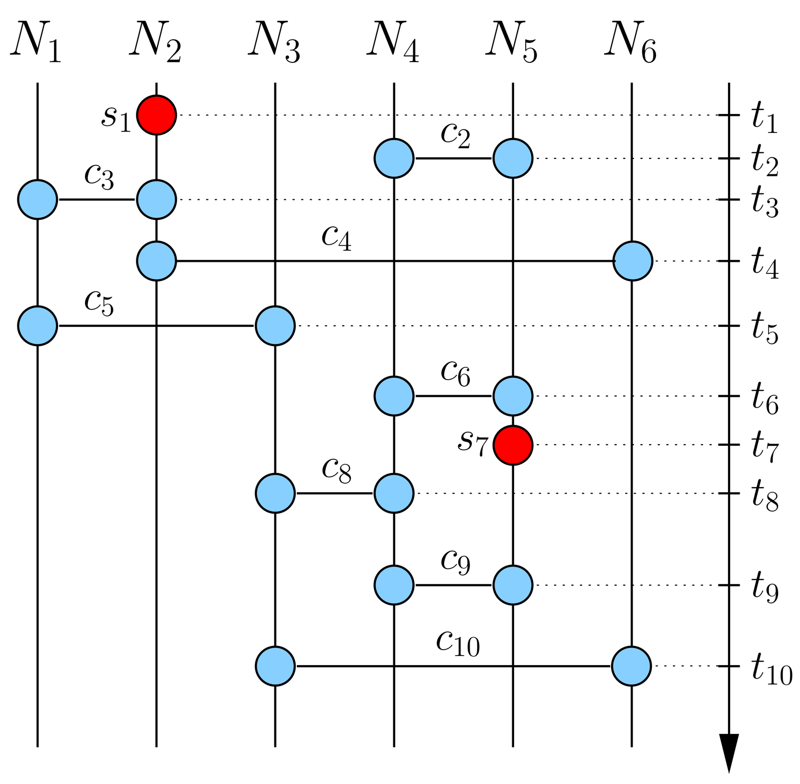
- unambiguous combination of time information
- guaranteed data-fusion results
- fail-safe state if bounds drift too far apart

Results

Scenario



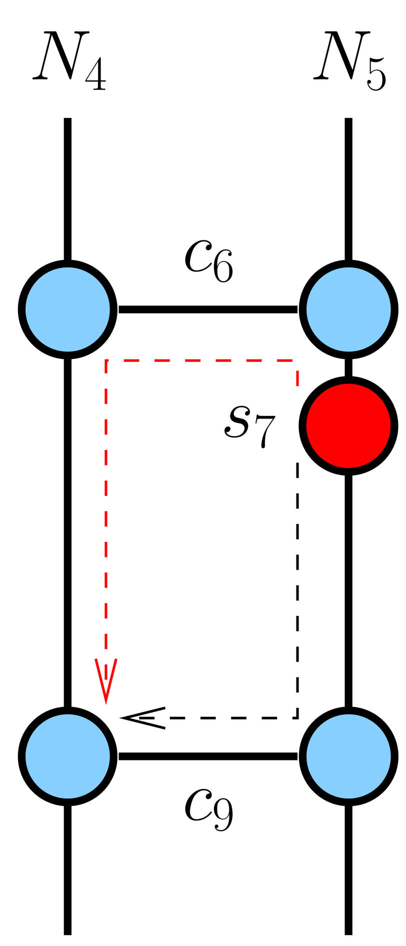
Model



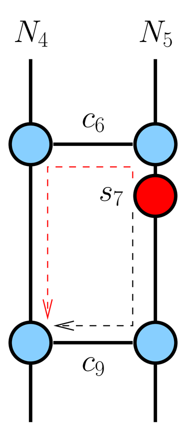
Corresponding event chart

Path-based analysis

- intersecting intervals is worst-case optimal
- worst case = equal drifts
- including backward paths can lead to improvements in the general case
- conjecture: this is optimal in the general case
- analysis is also applicable to internal synchronization

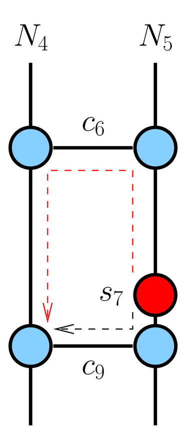


Basic principle



Early source event

Using backward path yields reduction of uncertainty between 0 and 100 %, depending on the drift difference



Late source event

No reduction of uncertainty by using backward paths

Simulation

- duration 1800 seconds, 50 nodes in a square with edge length x
- each node has constant clock drift $\rho \in_R [-100\text{ppm}, 100\text{ppm}]$
- nodes communicate with all reachable neighbors c times
- s source events occur at randomly chosen times and nodes
- **we are interested in the average gain of using backward paths**

x	s	c	range	average # of comm.	average gain
10000	10	100	5000	157268	26.3 %
10000	10	100	2500	51348	18.9 %
10000	10	100	1000	9503	2.3 %
10000	40	100	5000	156808	27.3 %
10000	10	400	5000	640263	50.6 %
10000	10	400	2500	203879	29.6 %
10000	10	400	1000	37709	1.7 %
1000	10	100	250	50946	19.1 %

Work in Progress

- investigate whether the improved algorithm is generally optimal
- extend simulation framework: varying drifts, node mobility, and communication patterns
- adapt simulation framework to internal synchronization
- show worst-case optimality of simple algorithm for internal synchronization and find generally optimal algorithm
- implement and compare the algorithms on the BTnode platform

Related Work

Maintaining the Time in a Distributed System: An Example of a Loosely-Coupled Distributed Service, Keith Marzullo, Ph.D. thesis, 1984, Dept. of Electrical Engineering, Stanford University, USA.

Interval-based Clock Synchronization, Ulrich Schmid and Klaus Schossmaier, Journal of Real-Time Systems **12** (1997), no. 2, 173–228, Kluwer Academic Publishers.

Time synchronization in ad hoc networks, Kay Römer, ACM Symposium on Mobile Ad Hoc Networking and Computing, October 2001, Long Beach, California, USA, ACM Press.