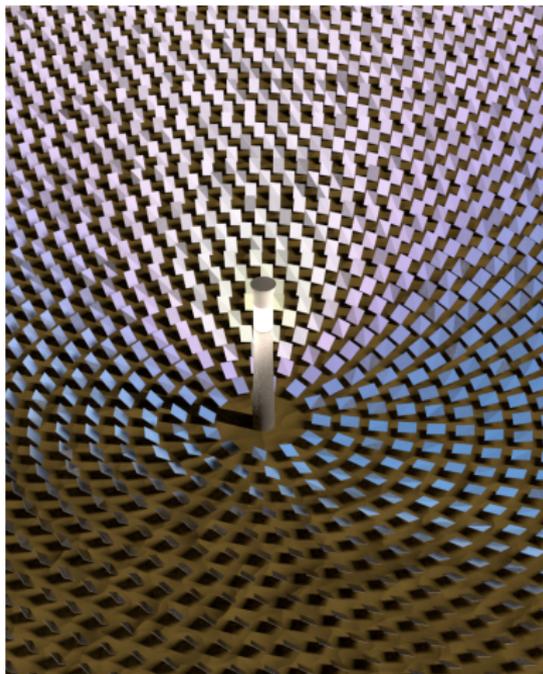


A Holistic Solution for Reliable Over-the-Air Software Updates in Large Industrial Plants

Florian Kauer, Florian Meyer, Volker Turau

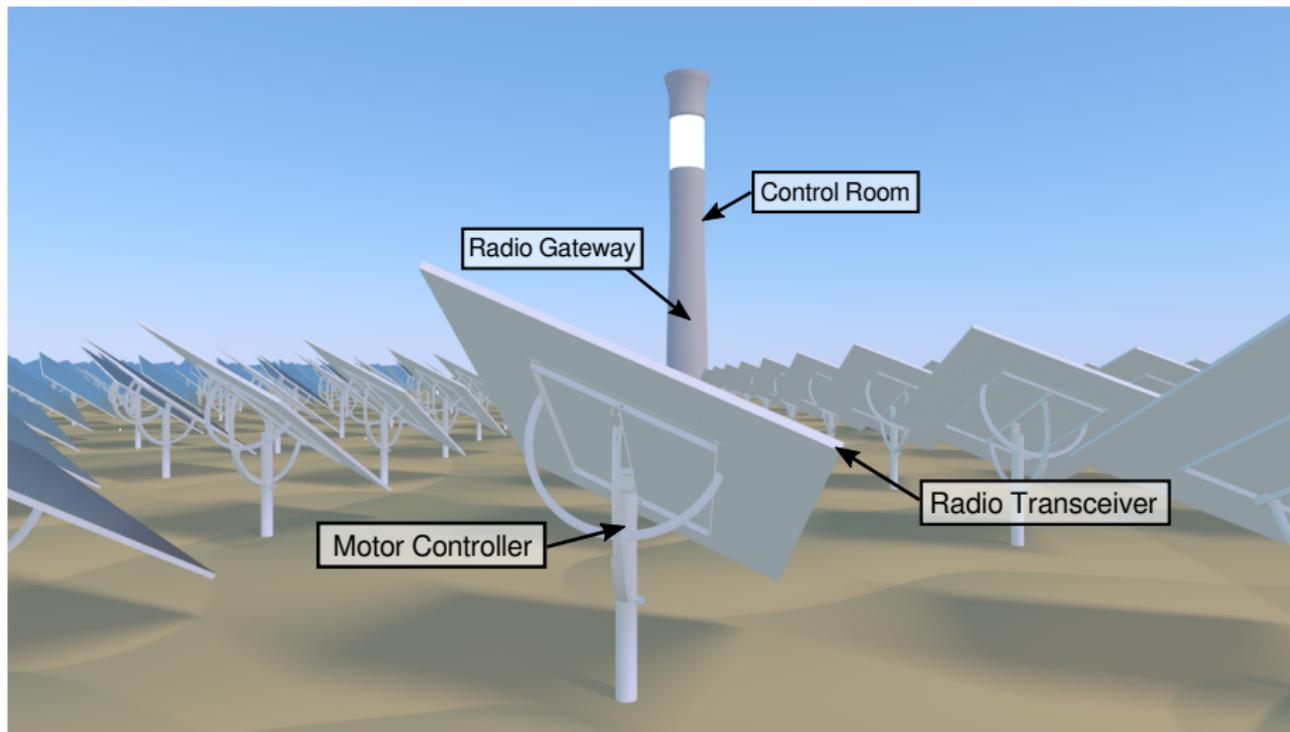
June 13th, 2017

Motivation

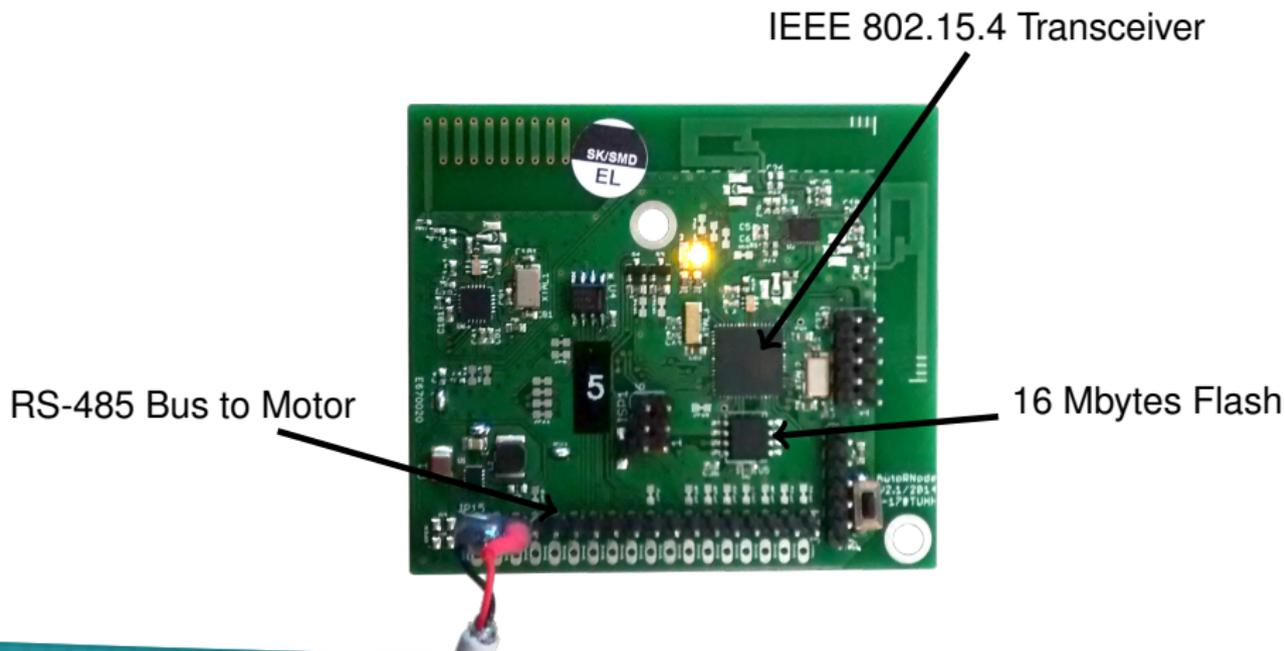


- Industrial Wireless Networks
- Concentrated Solar Power Plants
 - ◆ 1,000 - 1,000,000 heliostats
 - ◆ Wired → Wireless Field Bus
⇒ Cost reduction
- Software maintenance required for
 - ◆ Network components
 - ◆ Third-party devices

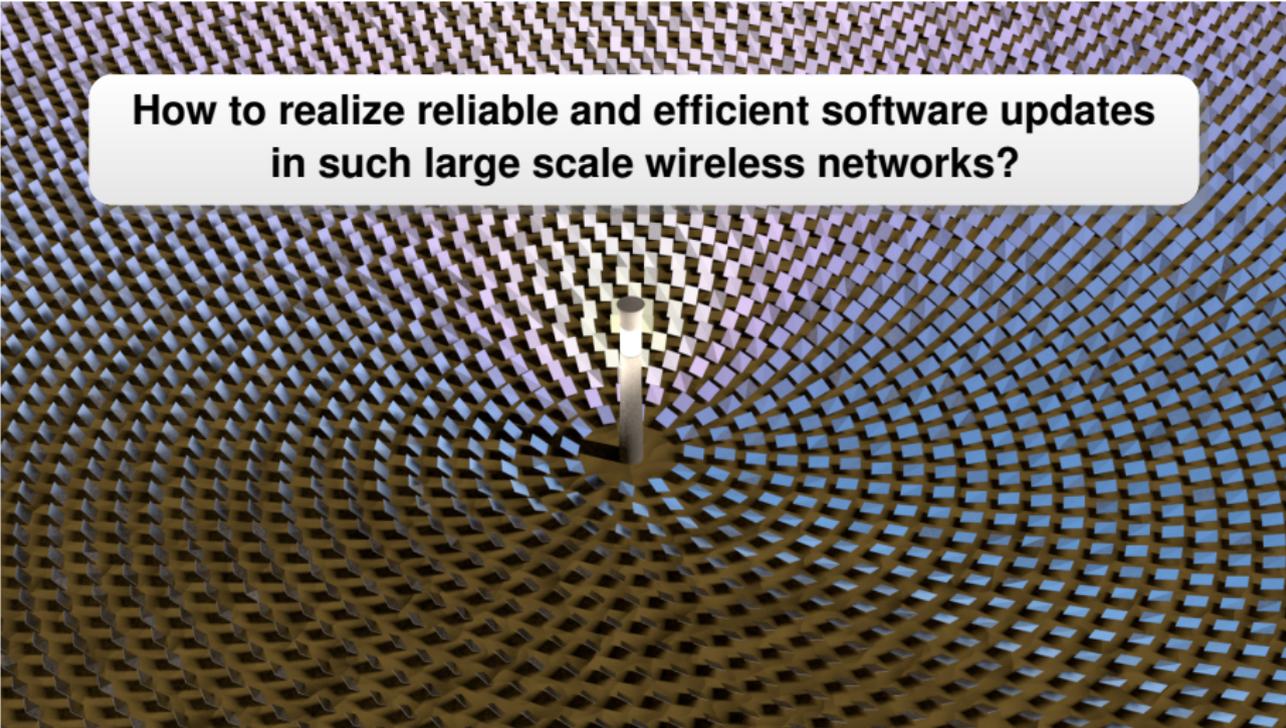
Components



Radio Transceiver



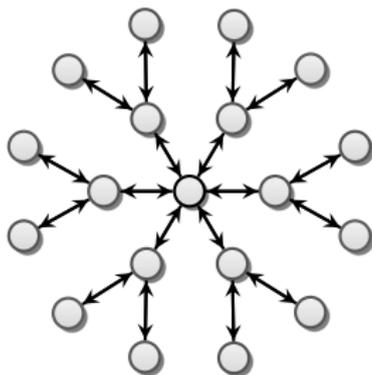
Motivation



**How to realize reliable and efficient software updates
in such large scale wireless networks?**

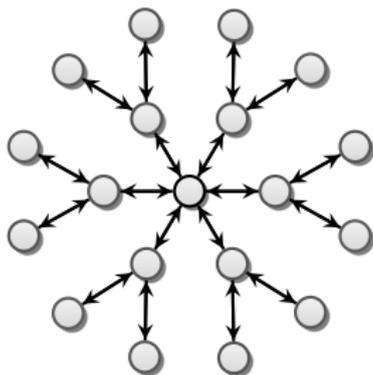
Requirements

- Scalable to thousands of devices
- Suitable for a IEEE 802.15.4 network
 - ◆ Low data rate (250 kbit/s)
 - ◆ Small packets (< 127 Bytes)
 - ◆ Forwarding over multiple hops
- Sufficiently fast
 - ◆ Updating the whole plant over night
- Fail-safe
 - ◆ Maintain a working system if something goes wrong



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S. Unterschütz and V. Turau, "Fail-Safe Over-The-Air Programming and Error Recovery in Wireless Networks" in *Proceedings of the 10th International Workshop on Intelligent Solutions in Embedded Systems (WISES)*. Klagenfurt, Austria, Jul. 2012.

Deluge

- Fast and efficient data dissemination for multi-hop networks
- Split large file into multiple pages
- Exchange page informations via Trickle algorithm
- Send pages via link-layer broadcasts
- Pages can be redirected before whole file was received
 - ⇒ Spatial multiplexing



J. W. Hui and D. Culler, “The Dynamic Behavior of a Data Dissemination Protocol for Network Programming at Scale” in *Proceedings of the 2nd International Conference on Embedded Networked Sensor Systems (SenSys)*. Baltimore, MD, USA, Nov. 2004.

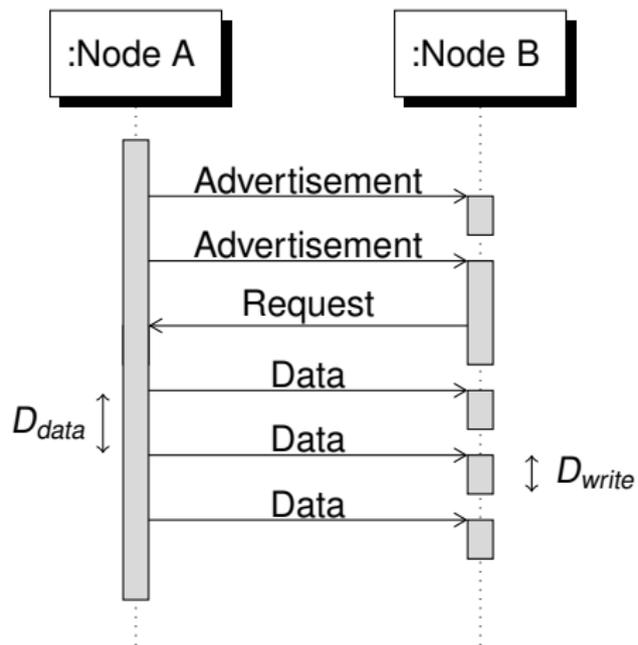
Coffee File System

- File system abstraction for resource-constraint devices
- Efficient usage of Flash storage
 - ◆ Problem: Overwriting data only possible by erasing whole sector
 - ◆ Solution: Micro Logs
 - Write to empty memory first, write back occasionally

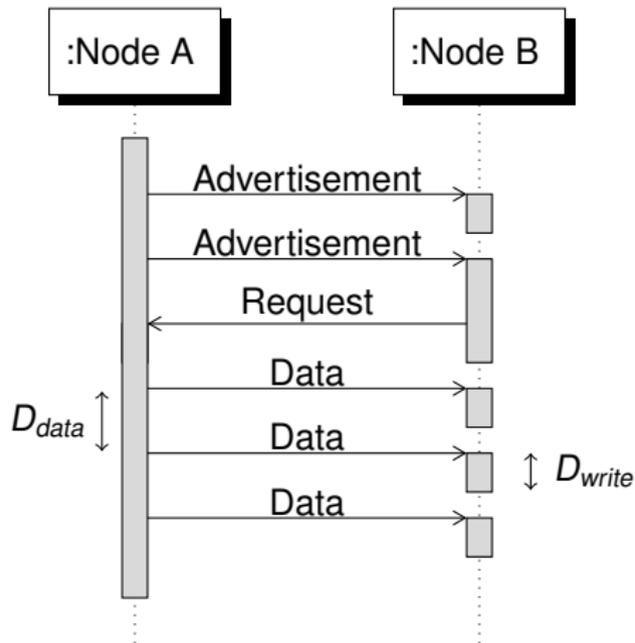


N. Tsiftes, A. Dunkels, Z. He, and T. Voigt, “Enabling Large-Scale Storage in Sensor Networks with the Coffee File System” in *Proceedings of the 8th International Conference on Information Processing in Sensor Networks (IPSN)*, San Francisco, CA, USA, Apr. 2009.

Interplay of Deluge and Coffee

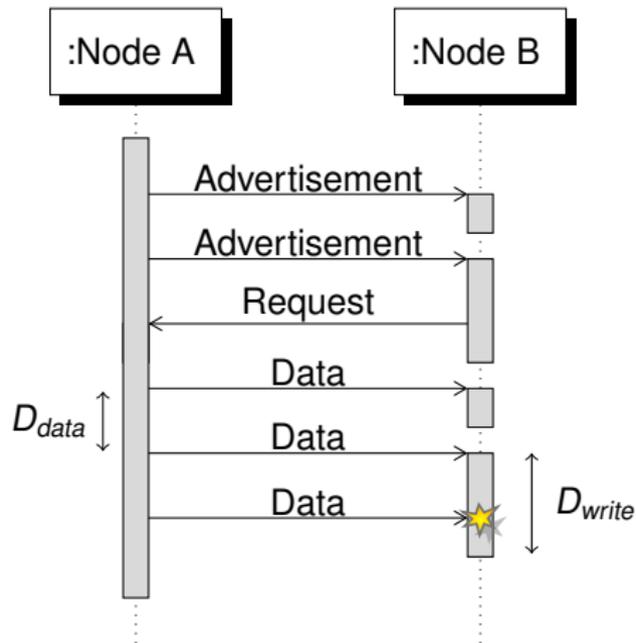


Interplay of Deluge and Coffee



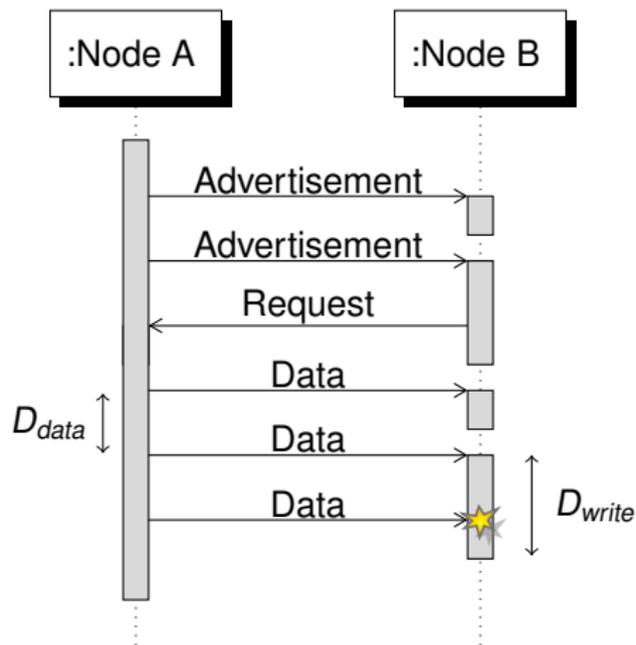
- D_{data} too high
 ⇒ Transmission takes too long

Interplay of Deluge and Coffee



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Interplay of Deluge and Coffee

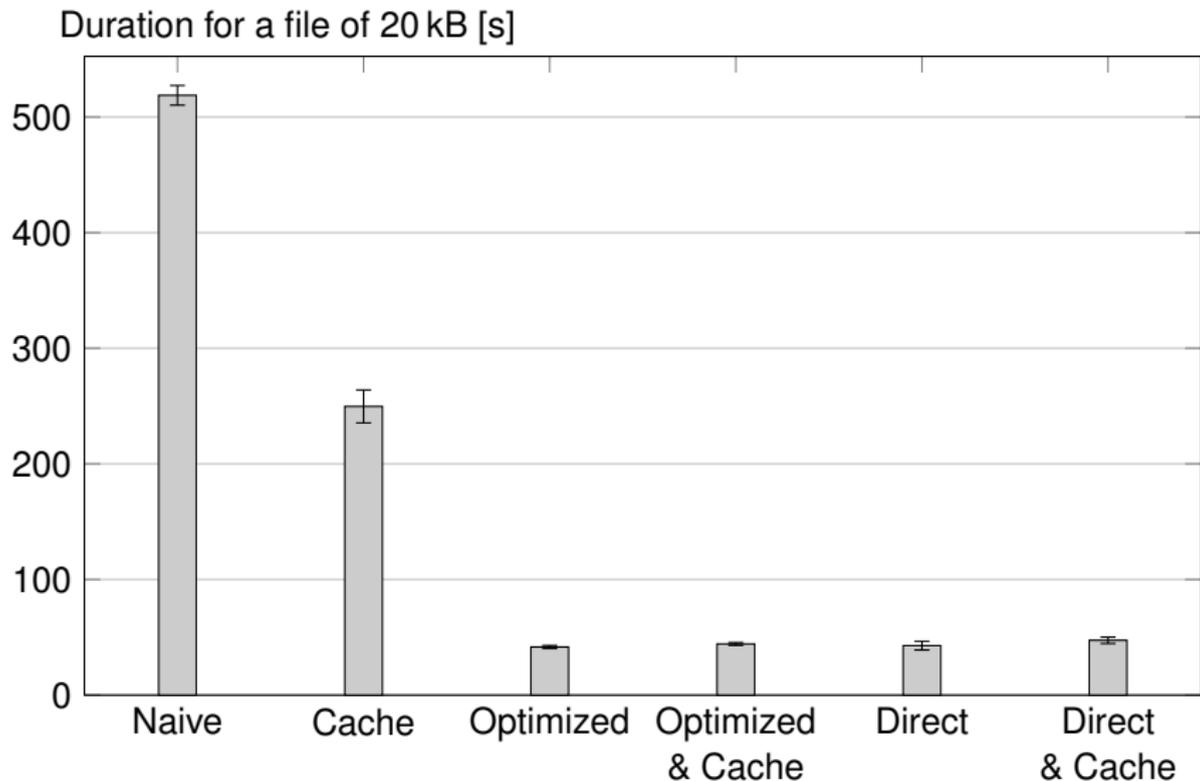


- D_{data} too high
 - ⇒ Transmission takes too long
- D_{data} too low
 - ⇒ Sometimes writing not finished
 - ⇒ Retransmissions required
 - ⇒ Transmission takes too long

Interplay of Deluge and Coffee

- Repeated writes to file when new packets arrive
 - ⇒ Micro Logs grow fast
 - ⇒ Write-back can occur at any time and takes very long
 - ⇒ Severe delays for data dissemination
- Proposed Solutions:
 - ◆ **Cache** larger chunks in RAM
 - ◆ **Optimize** the write back
 - ◆ Selective **direct** memory access

Comparison of Flash Access Techniques

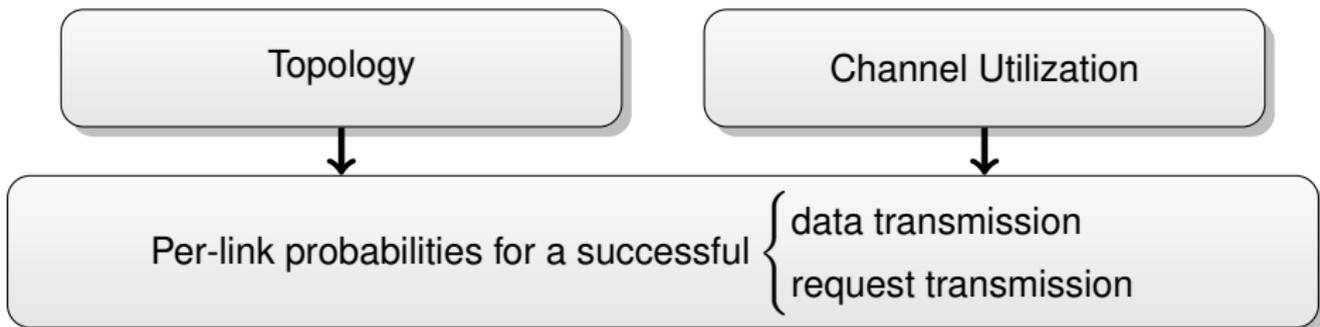


Analytical Model

Topology

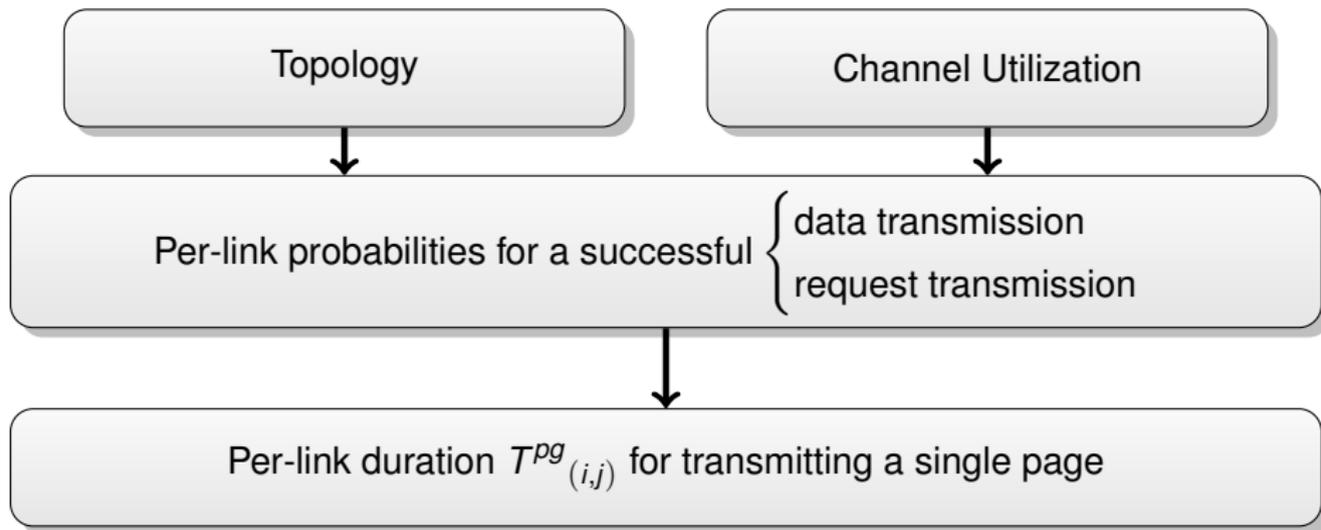
Channel Utilization

Analytical Model

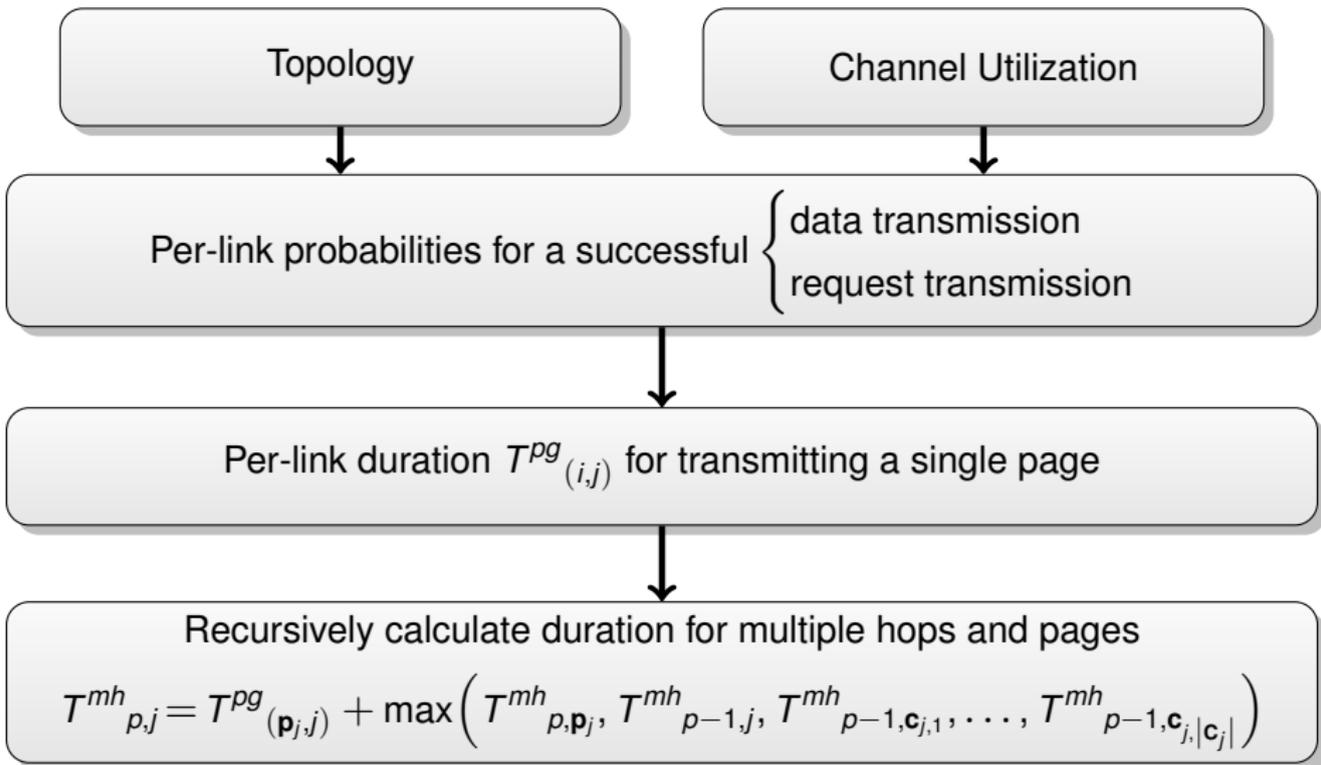


F. Meier and V. Turau, "An Analytical Model for Fast and Verifiable Assessment of Large Scale Wireless Mesh Networks," in *Proceedings of the 11th International Conference on the Design of Reliable Communication Networks (DRCN)*, Kansas City, MO, USA, Mar. 2015.

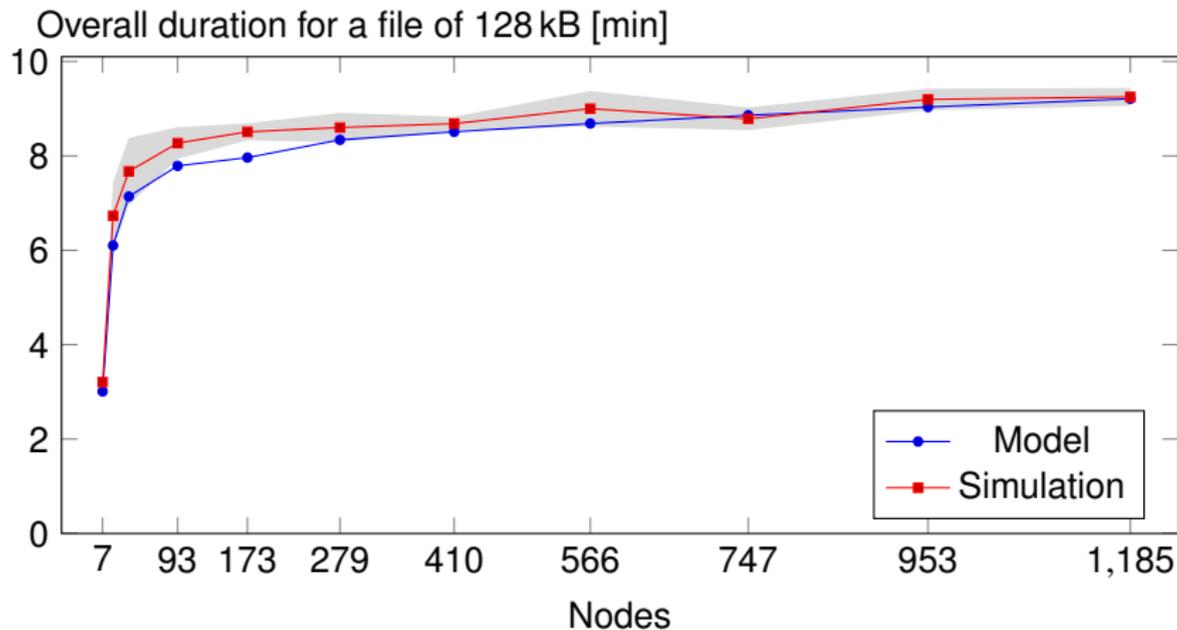
Analytical Model



Analytical Model



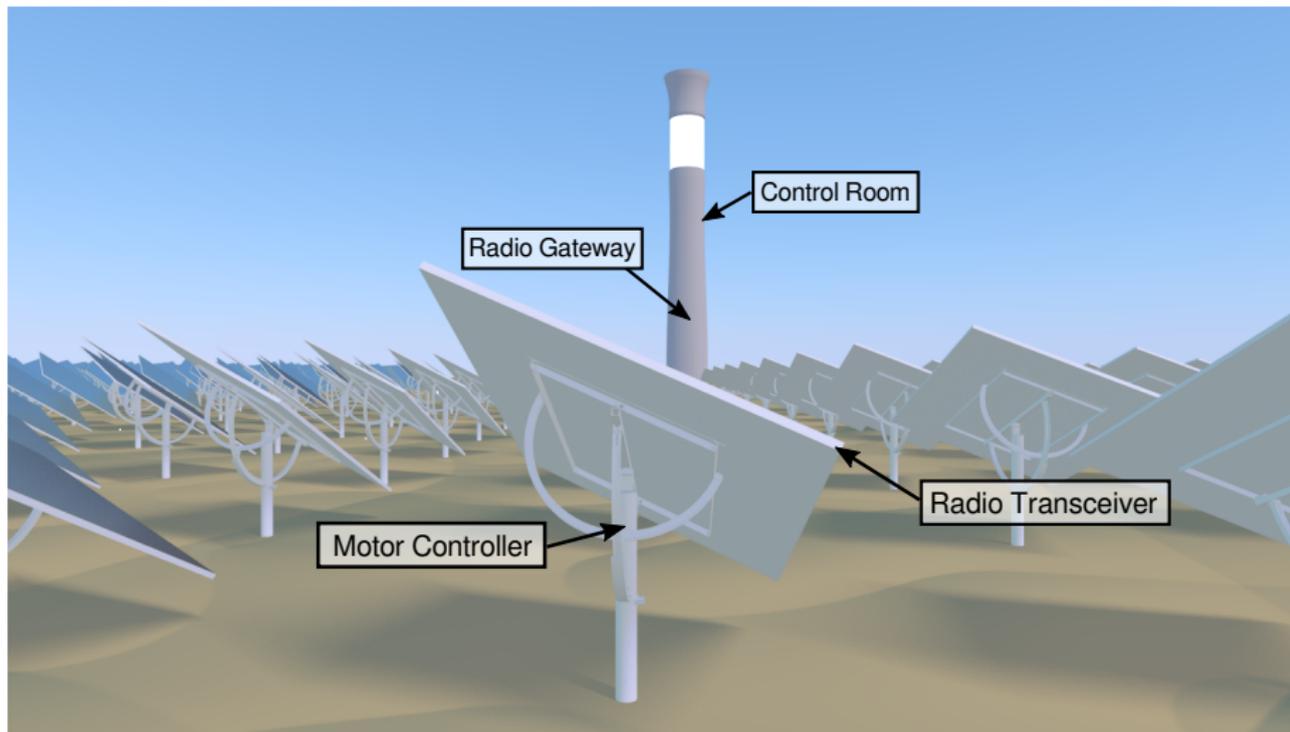
Duration of Firmware Distribution



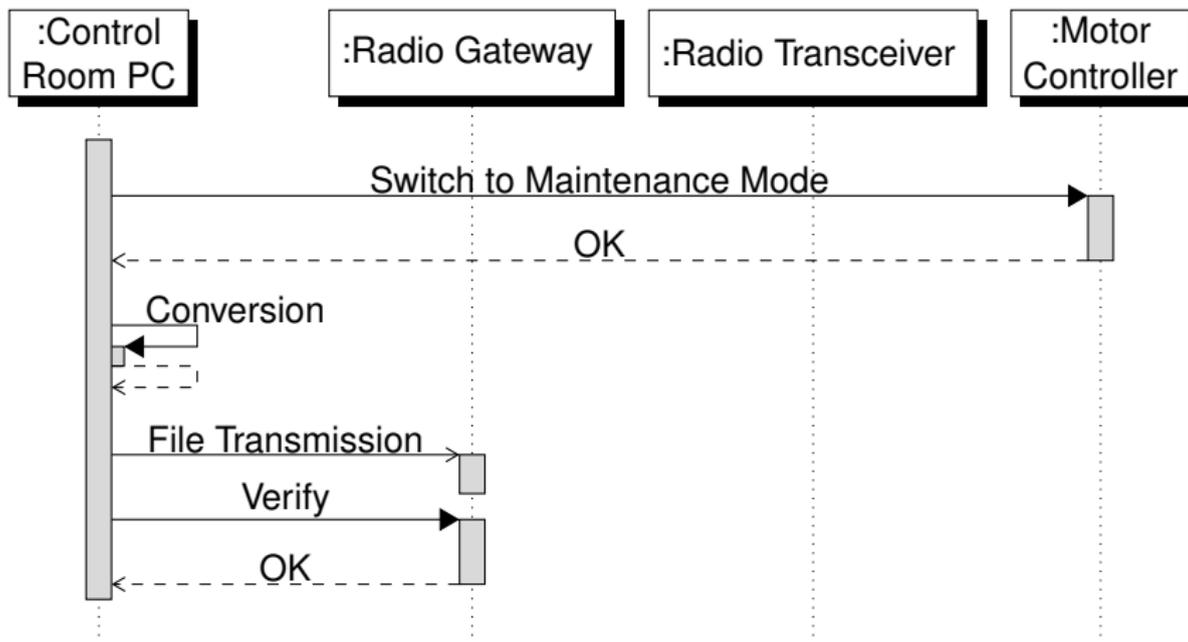
⇒ Analytical model matches simulation

⇒ Spatial multiplexing allows for fast firmware distribution

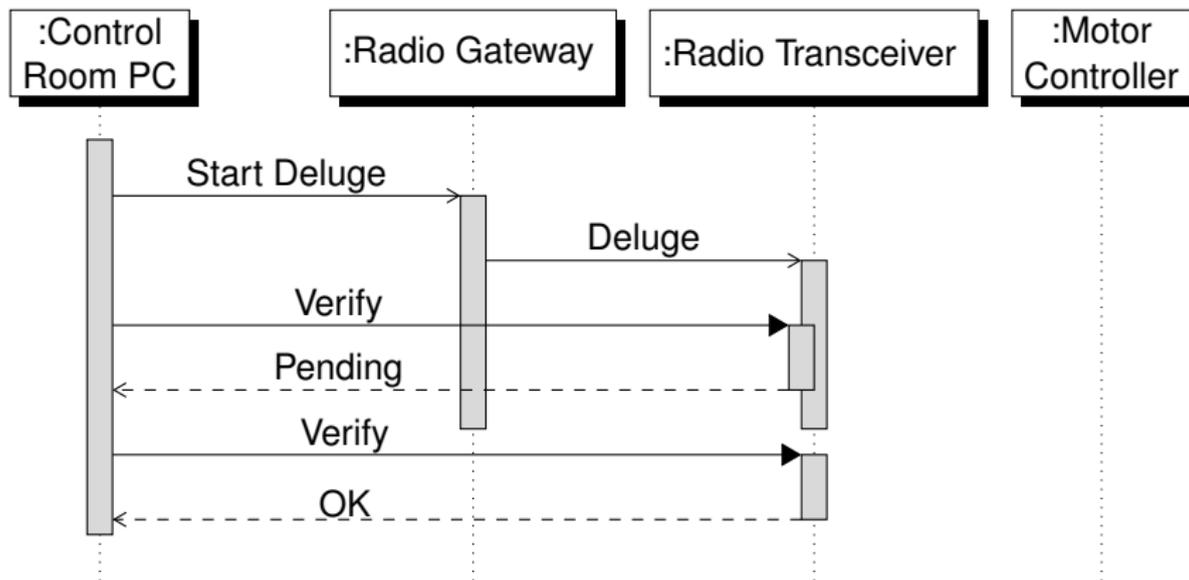
Components



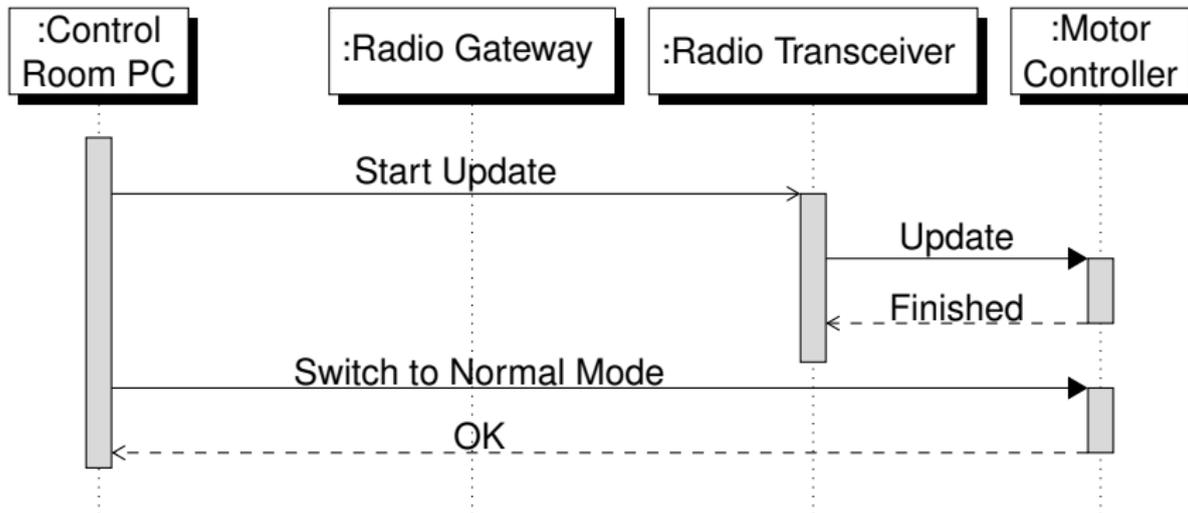
Procedure - 1. Phase



Procedure - 2. Phase



Procedure - 3. Phase



Summary

- Software updates in large-scale industrial wireless networks
- Using Deluge and the Coffee File System
 - ◆ Interplay optimized
 - ◆ Delay largely reduced
- Analytical model developed
 - ◆ Shows good conformance to the simulation
 - ◆ Spatial multiplexing allows for fast firmware distribution
- Holistic approach tested with real-world components

A Holistic Solution for Reliable Over-the-Air Software Updates in Large Industrial Plants

Florian Kauer

Florian Kauer

Ph.D. Student

Phone +49 / (0)40 428 78 3746

e-Mail florian.kauer@tuhh.de

<http://www.ti5.tu-harburg.de/staff/meier>