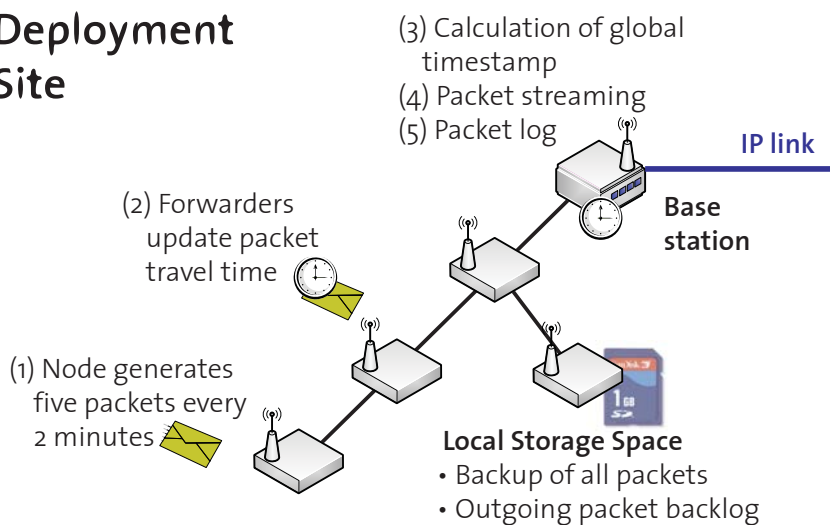


# Learning from Sensor Network Data

Matthias Keller, Jan Beutel, Andreas Meier, Roman Lim, Lothar Thiele  
Computer Engineering and Networks Lab  
Swiss Federal Institute of Technology (ETH) Zurich

## PermaSense System Model

### Deployment Site



### PermaDozer: Data Collection

- Multi-hop tree topology
- Optimized for ultra-low duty cycles
- Beacon based, 1-hop synchronized TDMA
- Round-robin scheduling with application processing window

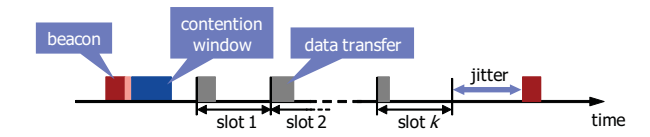


Figure 1: Beacon based synchronization in Dozer (Burri, IPSN'07)

## Analysis of Matterhorn Deployment Data

### Data Analysis Methodology

#### Assumptions from System Design

- Increasing packet sequence numbers with overroll
- Correct ordering by timestamps is not guaranteed

#### Step 1: Data Preparation

- Merging of historically emerged data representations
- Data source combination
- Data cleaning

#### Step 2: Data Downsampling and Pre-Analysis

- Received packets per day
- Computation of sequence number gaps

#### Step 3: Analysis

- Detailed examination of unexpected system behaviour



Figure 2: Matterhorn deployment site with annotated nodes

### End-to-End Data Delivery Performance

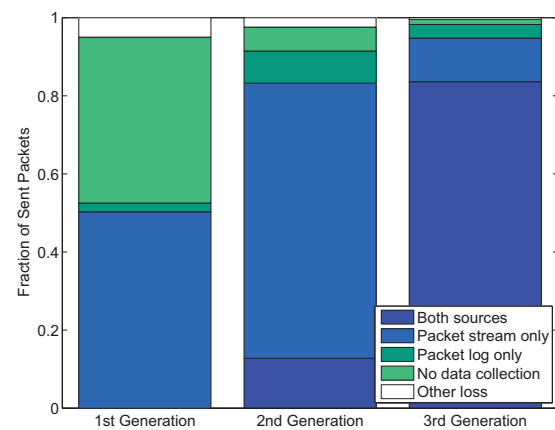


Figure 3: Data yield of three generations of deployed nodes. Nov 08 outage excluded in calculation.

#### Analyzed Data Set

- 14 million unique packets from 15 nodes

#### 1st Generation: Jul 08 - Aug 08

- Initial troubles stopped data collection for several days
- No packet logs

#### 2nd Generation: Aug 08 - Nov 08

- Nov 6-19: Outage of base station and backend
- No packet logs from Sep 09 to Nov 20

#### 3rd Generation: Nov 08 - May 09

- Nodes equipped with SD cards
- Jan 17-19: Backend server outage

### Detailed Analysis of 3rd Generation Data

- Data collection stopped due to problems with base station and/or backend
- Performance degradation with steadily increasing number of packets lost per day

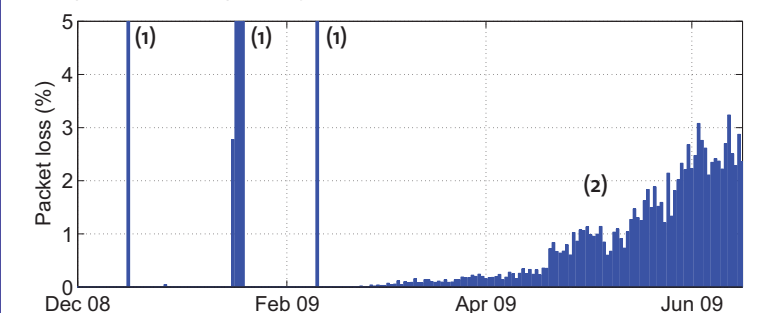


Figure 4: Packet loss over time per day

## Performance Degradation: What Happened After 3.5 Months of Flawless Operation?

### Loss Pattern Reveals Node Reset Problem

- Five subsequent packets lost in >99%
- Loss of five subsequent packets refers to node reset
- Similar pattern for all nodes

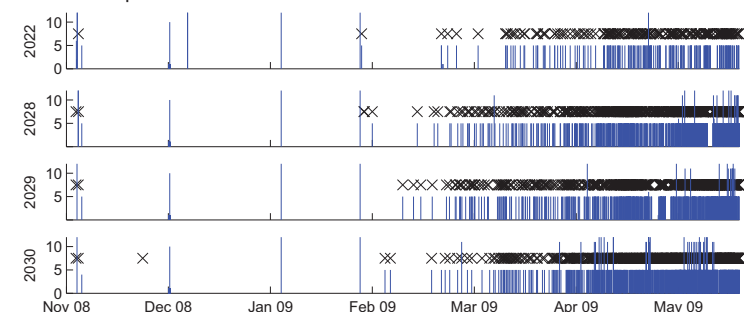


Figure 5: Packet losses (blue) and node resets (black) of four representative nodes.

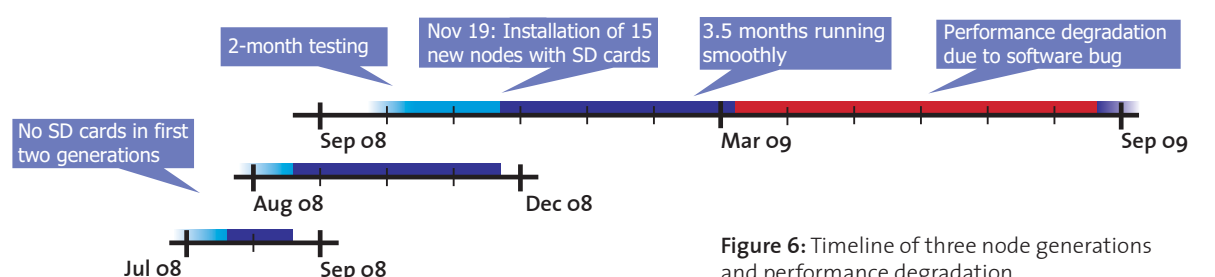


Figure 6: Timeline of three node generations and performance degradation

#### Node Reset Cause

- Increasing execution time of task that reads and writes from and to SD memory card
- Software forced reset due to task queue overrun

#### Successful Error Analysis

- Recovery of affected nodes
- Analysis of memory dumps taken after last node reset

Data Collection Does Not Stop at the Access Node

Design Data Structures for Usability

Long-term Effects Are Hard to Test and Predict