Long-term Reliable Data Gathering Using Wireless Sensor Networks

Volker Turau and Christoph Weyer

Institute of Telematics
Hamburg University of Technology

Fourth International Conference on Networked Sensing Systems
Braunschweig, 2007

TUHH
Technische Universität Hamburg-Harburg

Introduction

- Sensor networks are increasingly used in applications where sensors periodically measure data with high frequency

Problem

Reliable transport of sampled data through an unreliable multi-hop network

- Difficulties derive from
  - wireless communication (data loss and corruption)
  - tight resources
  - malfunction of sensors
- Focus of this work is on loss of data and tight resources

Goals & Assumptions

1. Goals: Reliable data transport
   - If data is lost, sink must be able to determine which data is missing
   - Loss of data should be balanced equally over all nodes
   - Operation time for a given energy budget should be maximized

   Minimizing delay is not a goal

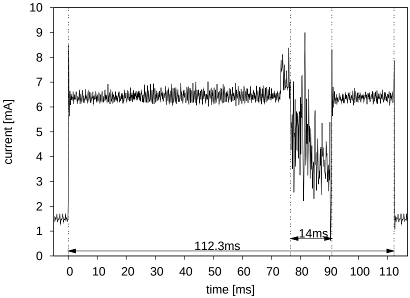
2. Assumptions:
   - MAC protocol uses TDMA
   - Sampled data is stored in buffer in EEPROM
3. Principle: Tree Routing

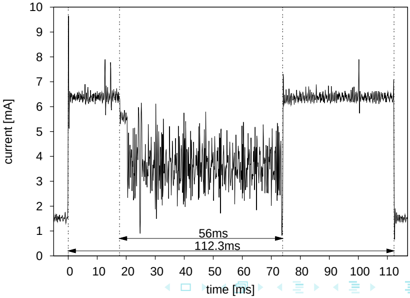
Outline

Single TDMA Time Slot

Slot length: $T_s > \frac{P_{tot}}{\gamma C} + T_a$

P_{tot}	Total packet size
C	Bandwidth
γ	Channel utilization
T_a	Time for ack.





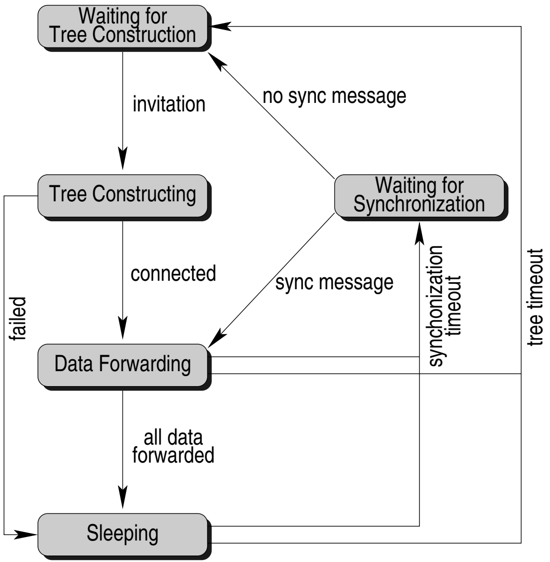
Limits of Sampling Rate s

- $s \leq \frac{\gamma C}{n}$
- $s \leq \frac{\gamma C}{\theta n_\mathrm{s}\, n}$
- $s \leq \frac{M}{\lambda \Delta\, T_\mathrm{r}\, n}$

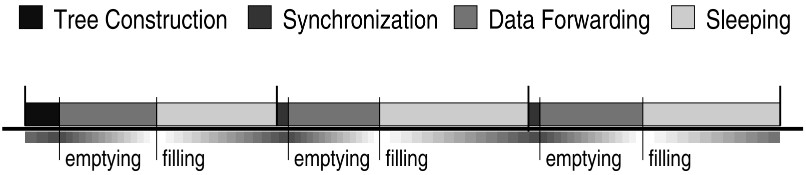
Notation

n	Number of nodes
$T_r = n_s T_s$	Length of a TDMA round
λ	Average number of retransmissions
M	Available storage
Δ	Maximal number of successors of a node
$P_\mathrm{tot} = P_p \theta$	

The different application states



Reliable Data Forwarding



- Packet is copied from EEPROM into working memory
- Node sends packet to parent
- Parent acknowledges packet once data is in its EEPROM
- Upon receiving acknowledgment, node removes packet from its EEPROM

Reliable Data Forwarding

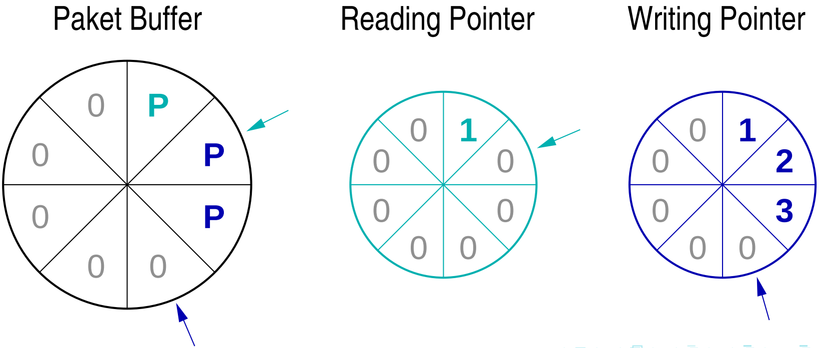
- If no acknowledgment is received, the number of failed transmission attempts is increased
- If sending repeatedly fails, node discards primary parent and selects best secondary parent
- Nodes inform parents when last packet is sent
- In future rounds:
  - Parent node does not turn on its receiver during this slot
  - Child transits into sleeping state after receiving acknowledgment

Congestion Handling

- Buffer can store f packets
  - $\lceil f / \text{sts}(v) \rceil$ packets with measurements of v itself
  - rest is reserved for packets of ancestors of v
- $\text{sts}(v)$: number of nodes in subtree with root v
- Ratio: $1/(\text{sts}(v) - 1)$
- Limits are enforced: either nodes stop taking measurements or nodes inform children and transit to sleeping mode
- $\text{sts}(v)$ is estimated: $\text{sts}^{\text{e}}(v) = 1 + \sum_{v_i \in \text{Succ}(v)} \text{sts}^{\text{e}}(v_i)$

Wear-Leveling

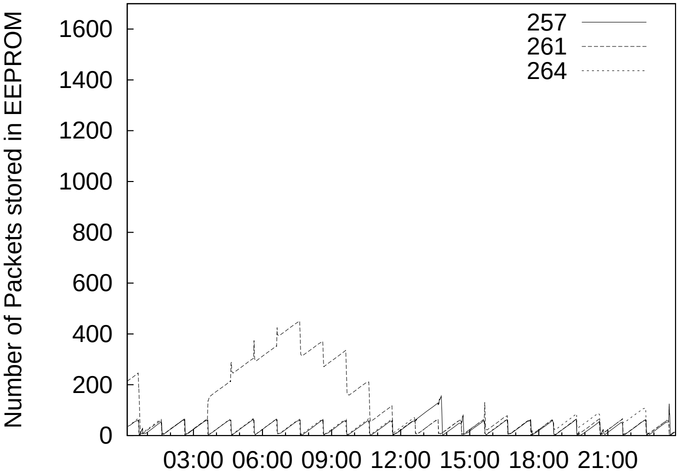
- Each EEPROM location can endure a maximum number of writes
- Repeated writes to the same location will exhaust the lifetime
- Solution: Two additional ring buffers



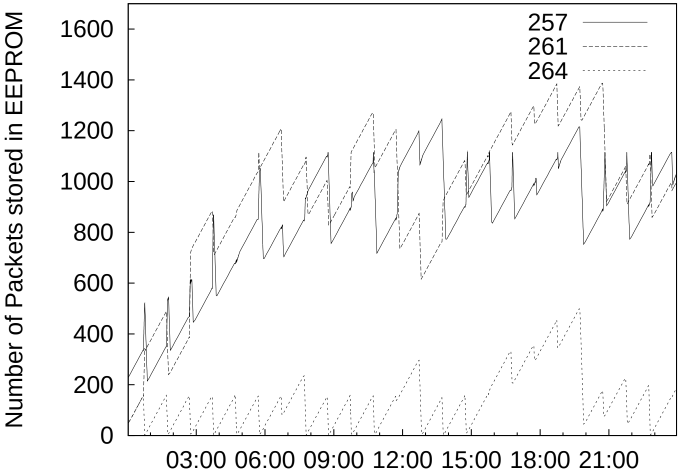
Implementation

- Prototype for office monitoring
- Hardware: 15 nodes of ScatterWeb platform
- Payload: 26 Bytes, total packet length: 111 Bytes
- EEPROM: 1600 packets
- Slot length: 120 ms
- Every 5 seconds temperature is taken (2 Bytes)
- Every 55 seconds a packet is generated

Course of EEPROM fill level - Sampling interval 5 s



Course of EEPROM fill level - Sampling interval 2 s



Power Settings

Mode	TDMA	TXPow.	LPM	Transc.	ADC	Current [mA]
Waiting			1	on	on	6.31
Data-For-warding	receiv.		1	on	on	6.31
	sending	70	1	on	on	4.05
		80	1	on	on	4.32
		90	1	on	on	5.02
		100	1	on	on	7.62
	inactive		3	off	off	0.38
Sleeping			3	off	off	0.38

Energy consumption - Sampling rate 5 s

- One month after deployment: nodes were 94.5% of time in low power mode
- No packets were lost
- On average: 0.49 mA
- Lifetime of 186 to 254 days using standard AA batteries

Conclusion

- Protocol for reliable transportation for long term data gathering
- Prototype indicates good performance
- Future work:
  - Improve throughput
  - Multiple sinks

Long-term Reliable Data Gathering Using Wireless Sensor Networks

Volker Turau and Christoph Weyer

Institute of Telematics
Hamburg University of Technology

Fourth International Conference on Networked Sensing Systems
Braunschweig, 2007

TUHH
Technische Universität Hamburg-Harburg