Technische Universität Braunschweig

Institute of Operating Systems and Computer Networks

Data Elevators

Applying the Bundle Protocol in Delay Tolerant Wireless Sensor Networks

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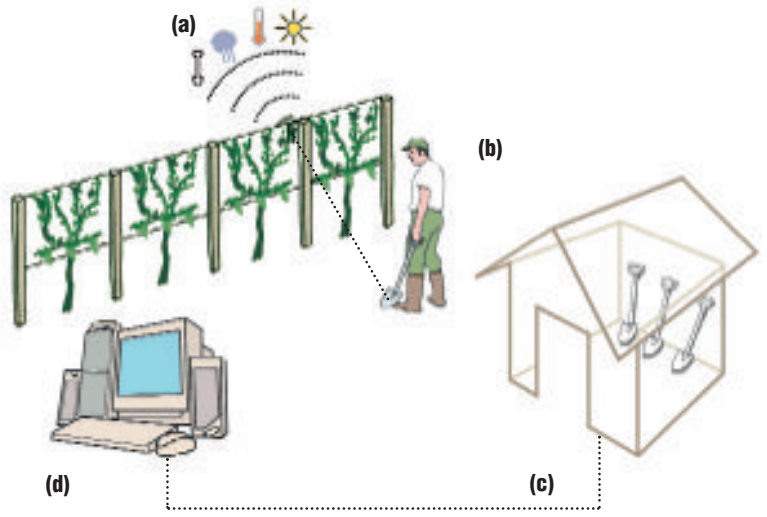
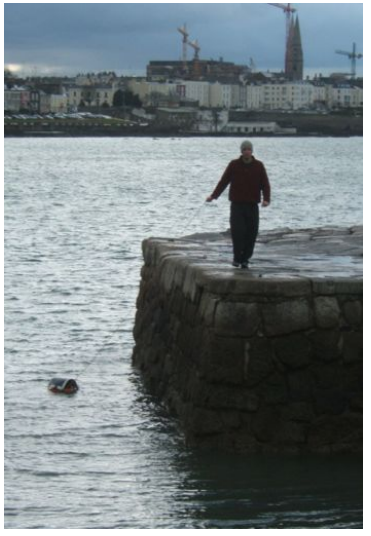
Motivation

ZebraNet



Vineyard Computing



SeNDT

Observation

Delay Tolerance is widely used (and needed) in sensor network research

Common Requirements

Measurement

- Periodic sampling of sensor values

Networking

- Multi-hop data delivery
- Disrupted links, changing topologies
- Delay is not important, reliability is

} Store, carry and forward

Hardware

- Long lifetime → Low-power
- Minimal installation effort → Wireless
- Few maintenance cycles → Robust

Wireless Sensor Networks (WSNs)

Wireless Sensor Networks

- Multi-hop wireless
- Battery powered

INGA

Wireless Sensor Nodes

- Based on microcontrollers
- IEEE 802.15.4 radios
- App. 16 kB RAM, app. 128 kB ROM
- Low-power hardware
- Storage (flash, SD, ...)

T-Mote Sky

Outline

Protocols for Wireless Sensor Networks

Predominant WSN Protocols

- *6LoWPAN*: IPv6 over low-power WPAN
- Contiki's and TinyOS' proprietary protocols

  → Not delay tolerant (not store, carry and forward)

Store, Carry and Forward Protocols

- *ZebraNET* (non-standardized)
- *Vineyard Computing* (non-standardized)
- *Seal-2-Seal* (non-standardized)
- *Bundle Protocol* (RFC 5050)

Benefits and Drawbacks of Standard Protocols

Benefits

- Seamless integration
- Lower entry barrier
- Generic solutions

Drawbacks

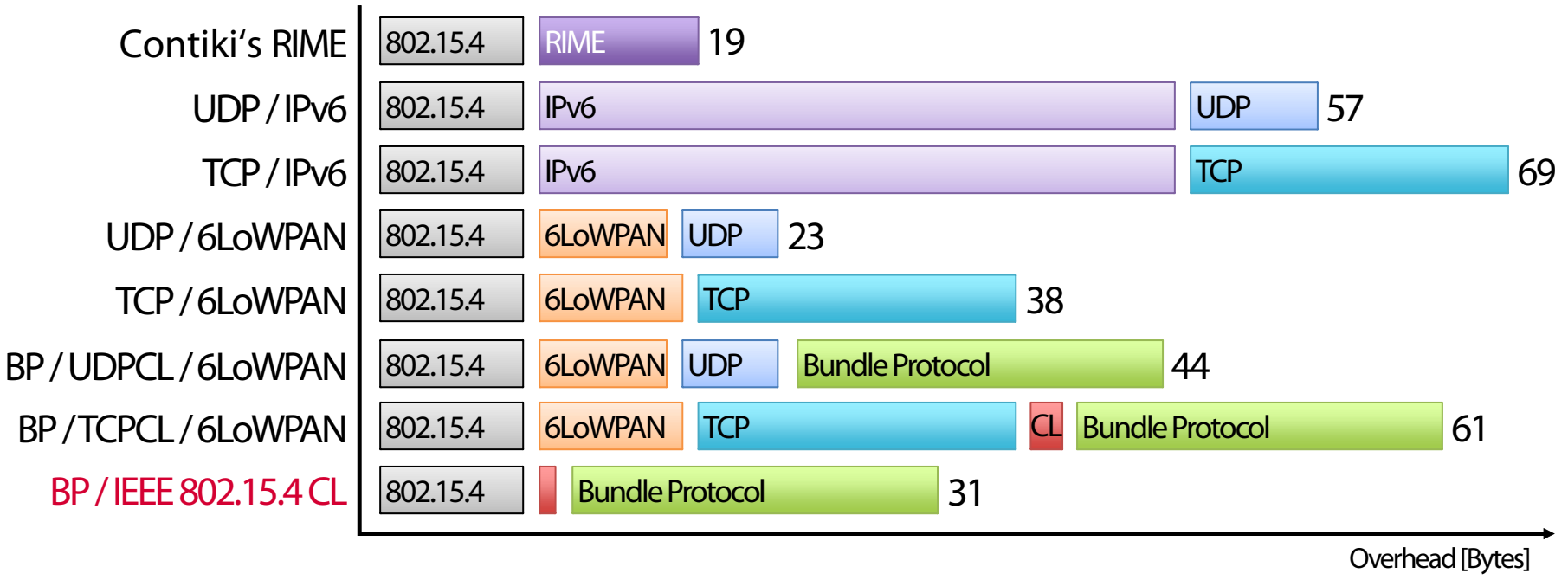
- Not optimized for use case
- Higher overhead

Benefits of the Bundle Protocol

- *Flexibility*: Variable length header fields, extension blocks, etc.
- *Overlay Protocol*: Works on top of heterogeneous technologies
- *Well suited*: Designed for unstable links and changing topologies

Q: Is the Bundle Protocol too heavy for nodes?

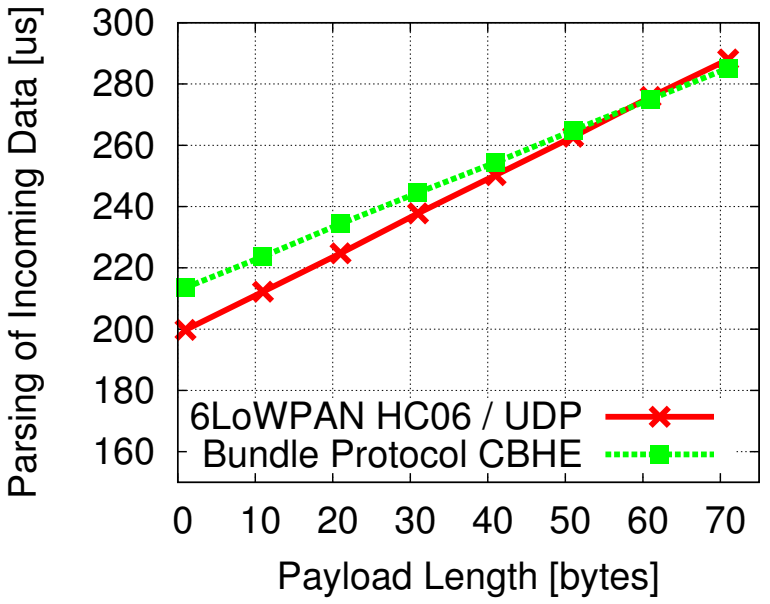
Bundle Protocol Overhead Comparison

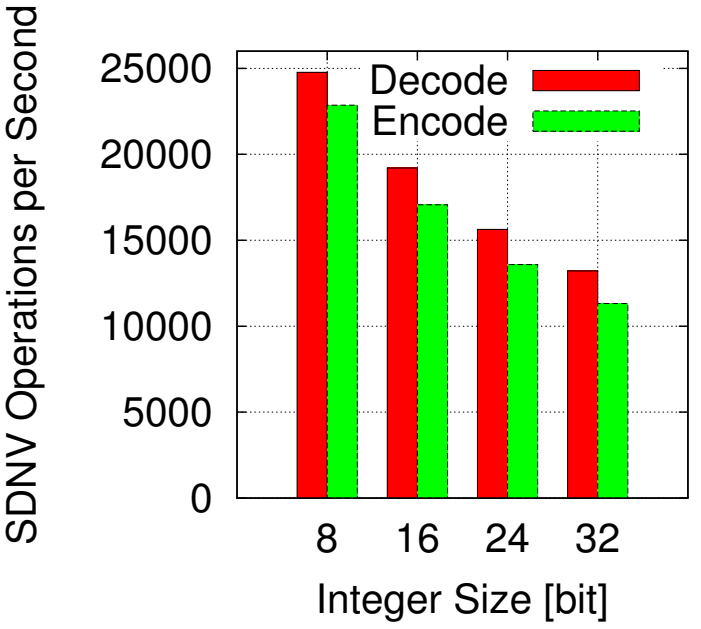


IEEE 802.15.4 maximum frame size is 127 bytes

A: Protocol overhead is higher but manageable

Bundle Protocol Complexity Comparison





Run on INGA at 8 MHz

A: Computational complexity is comparable

How can we implement the Bundle Protocol on nodes?

Literature

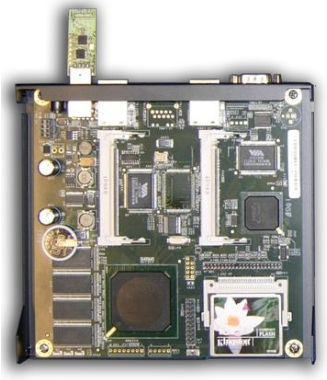
- Bundle Protocol as overlay protocol over 6LoWPAN

Our Approach on the Nodes: μDTN

- BP in IEEE 802.15.4 data frames
- Cross-layer, avoiding layers 3 and 4
- Implementation based on Contiki OS

Our Approach on the PC

- IEEE 802.15.4 radio attached to PC
- IBR-DTN software extension to handle radio



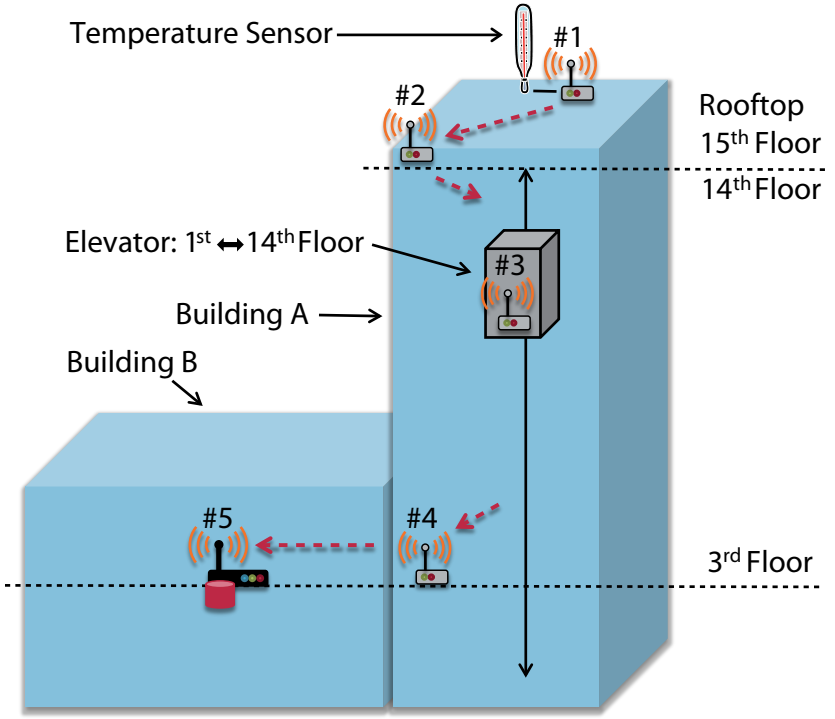
Data Elevator Application Scenario

Opening Question

How can we get temperature readings from the rooftop into our lab?

Concept

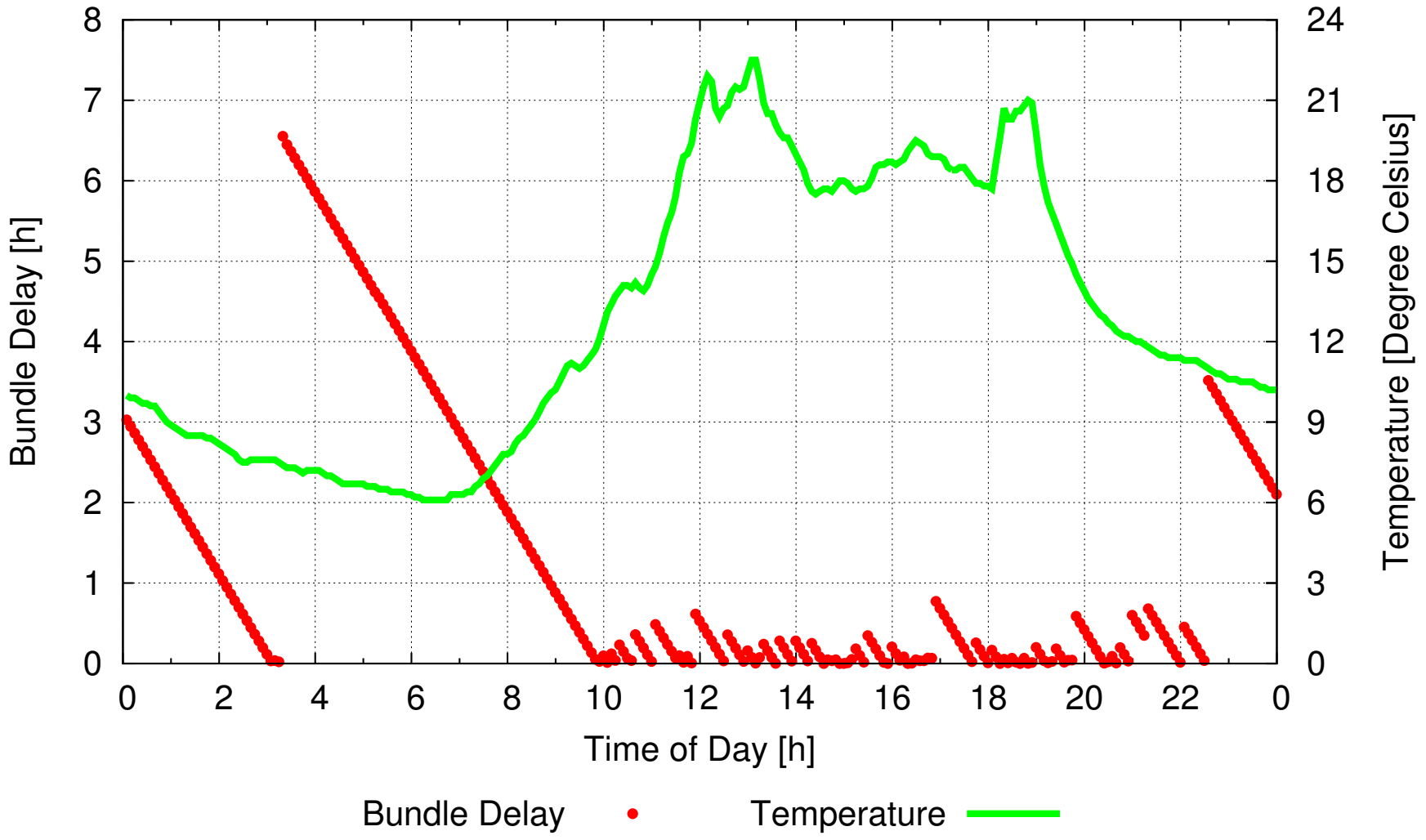
- Node with sensor on rooftop
- Elevator is data mule
- Delay tolerant network



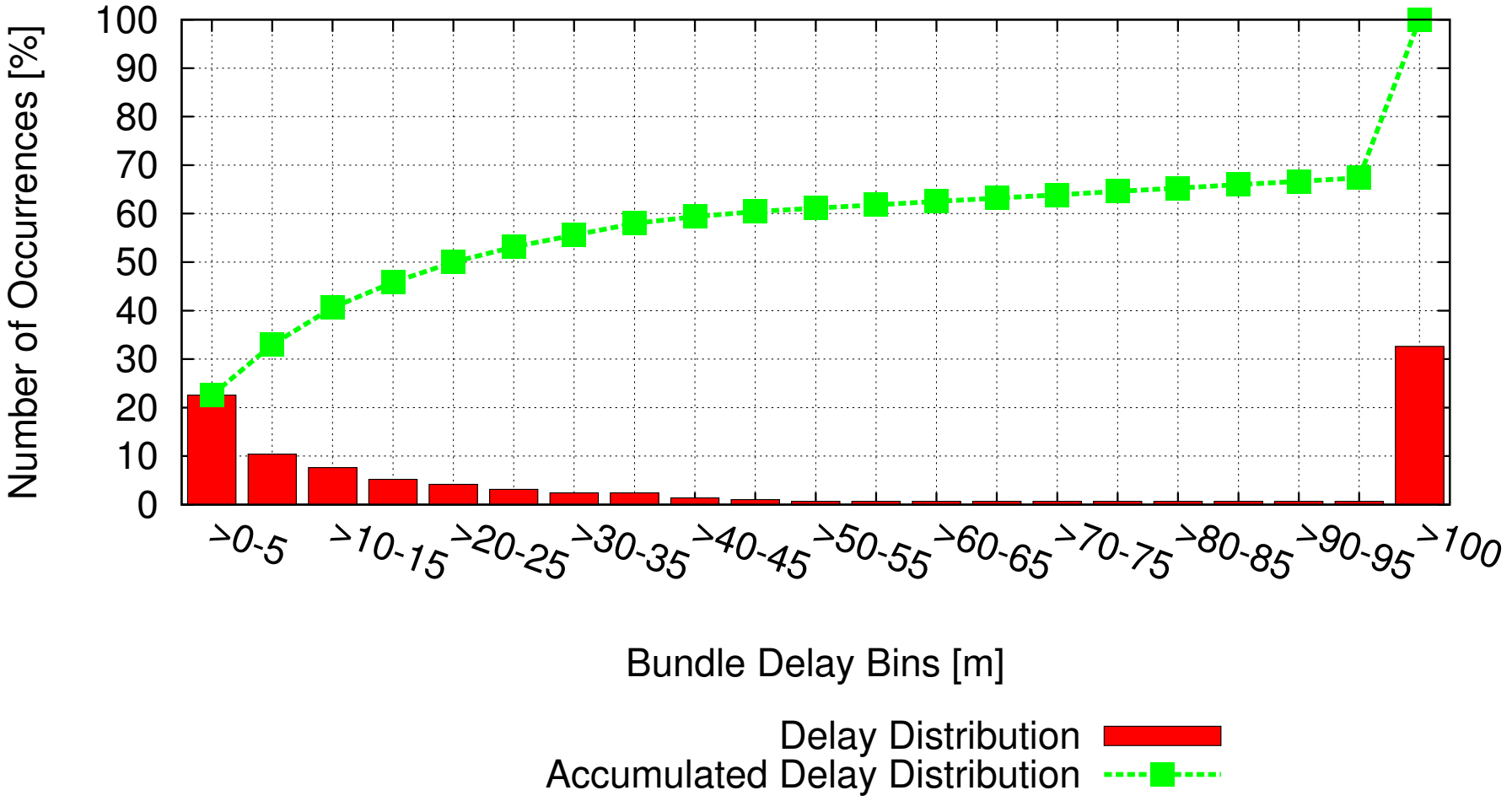
Setup

- 1 sensor, 3 relays, 1 sink
- μDTN with RAM storage

Evaluation: Temperature and Delay (Weekend)

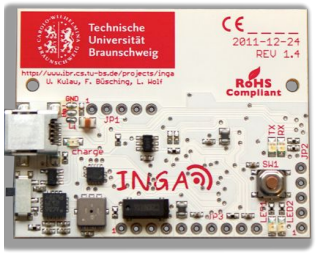


Evaluation: Delay Distribution (Weekend)



DT-WSN Capacity Model

Sender



BundleRate_i

Receiver

$S_{Cap,Send}$	Storage Capacity	$S_{Cap,\text{Recv}}$
$S_{Send,i}$	Bundles in Storage	$S_{\text{Recv},i}$

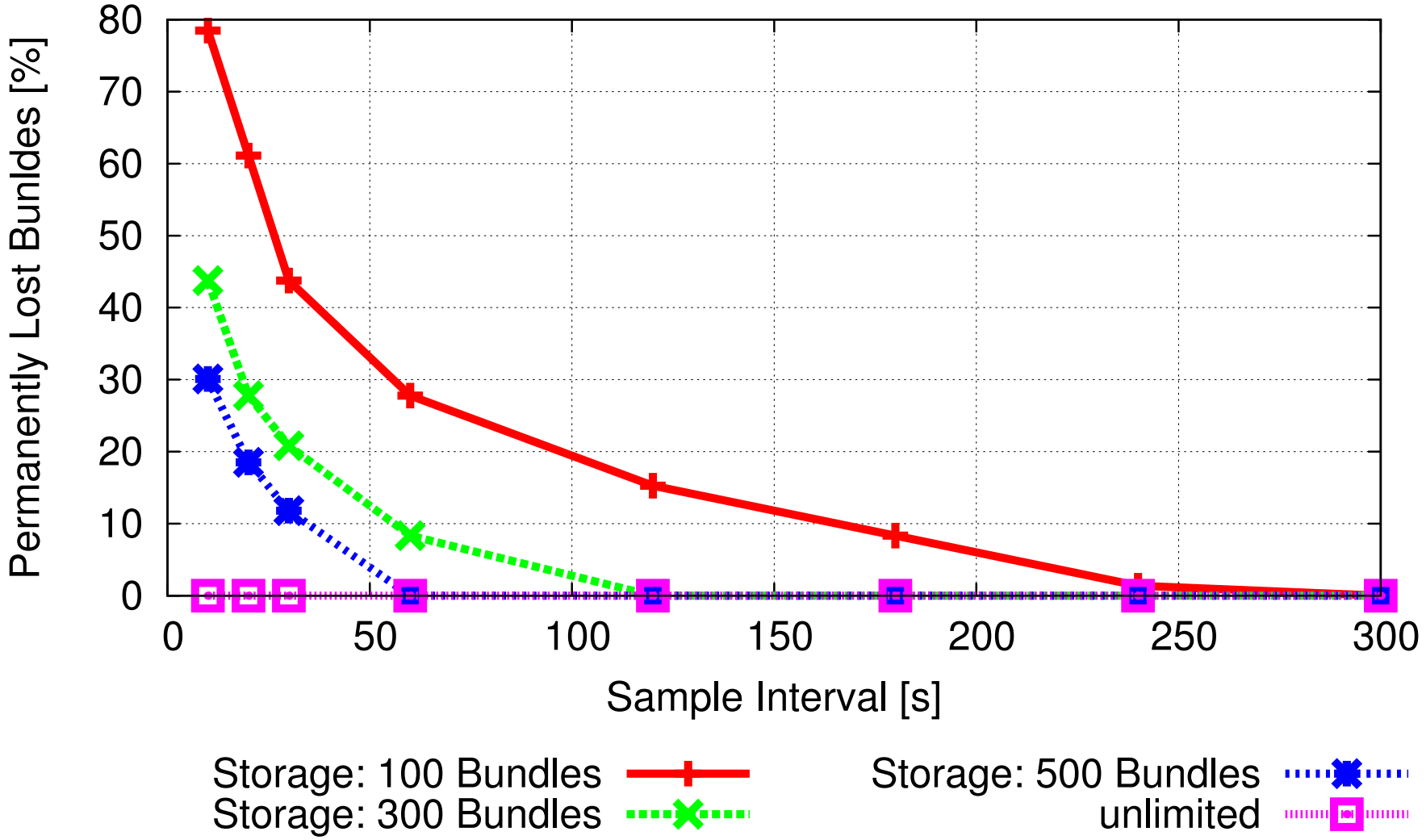
Channel Capacity: $C_{i,j} = Duration_i \cdot BundleRate_i$

Transmitted Bundles: $T_i = min(S_{Send,i}, C_{i,j})$

Storage Sender: $S_{Send,i} = min(S_{Send,i-1} - T_{i-1} + N_i, S_{Cap,Send})$

Storage Receiver: $S_{Recv,i} = min(S_{Recv,i-1} + T_i, S_{Cap,Recv})$

Evaluation: Capacity Model



Conclusions

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Protocols

- Standard protocols are generic solutions to common problems
- BP is de facto standard in DTNs and should be in DT-WSNs

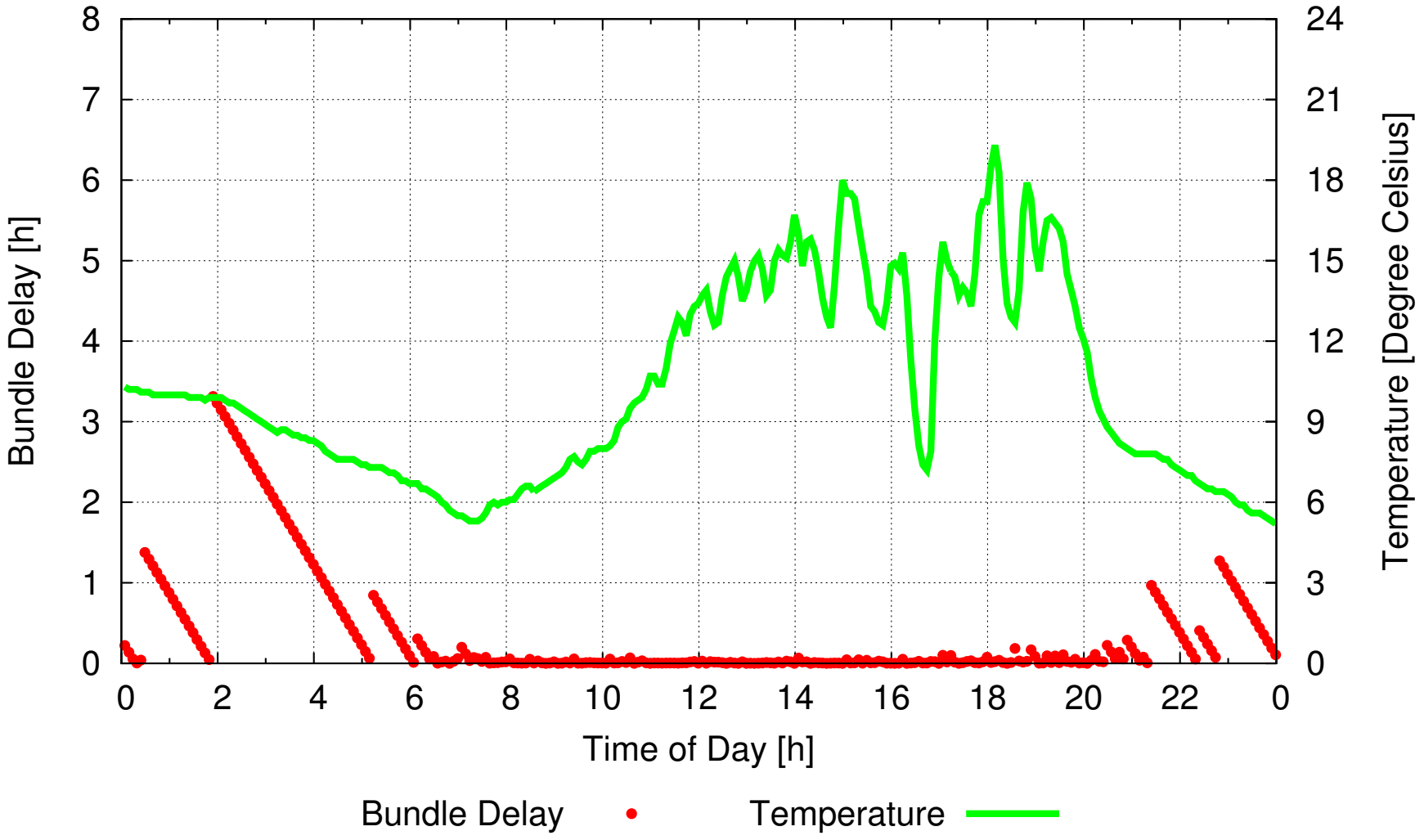
μDTN

- Bundle Protocol implementation for Contiki
- Overhead is comparable to 6LoWPAN
- Integration into existing DTNs via transparent gateway nodes

Data Elevator

- Data is delivered with delay but without loss

Evaluation: Temperature and Delay (Weekday)



Evaluation: Delay Distribution (Weekday)