Technische Universität Braunschweig

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Flow Control Mechanisms for the Bundle Protocol in IEEE 802.15.4 Low-Power Networks

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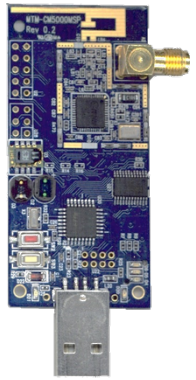
CHANTS 2012 (ACM MobiCom), Istanbul, Turkey, August 2012

Motivation



Wireless Sensor Networks (WSNs)

- Battery-powered nodes, limited hardware capabilities
- Wireless communication, usually IEEE 802.15.4
- Unstable links, changing topologies
- **Many publications use DTN, but not Bundle Protocol**

Delay Tolerant Wireless Sensor Networks (DT-WSNs)

- Sensor Networks using store, carry and forward protocol
- Bundle Protocol allows seamless backend integration

Bundle Protocol over IEEE 802.15.4 Wireless Links

- Bundle Protocol designed as overlay protocol on Layer 5
  - But: Significant overhead

IEEE 802.15.4 Convergence Layer

- Transports bundles inside IEEE 802.15.4 MAC frames
  - Avoids network and transport layer, has to handle their tasks
  - IEEE 802.15.4 MAC does CRC, ACKs, retransmissions,...
- **Flow Control** necessary to avoid overrunning receivers
  - WSN nodes are slow due to limited resources

Problem Statement

Assumptions

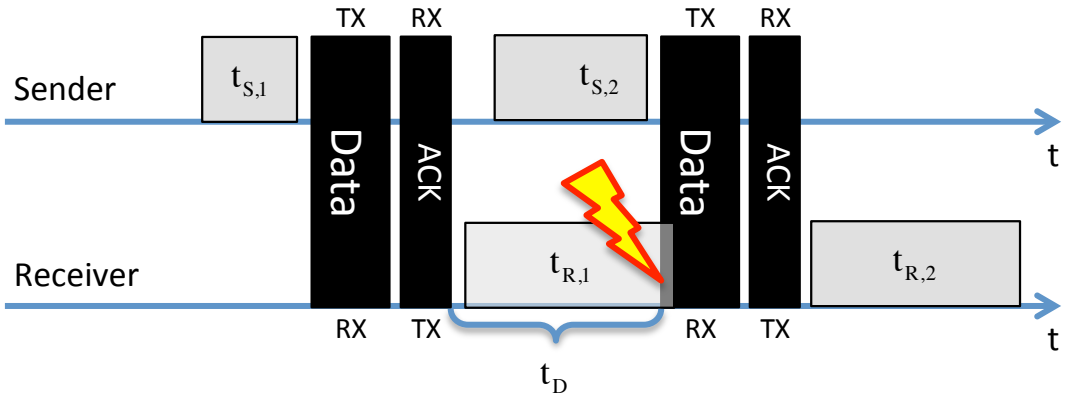
- Persistent bundle storage in flash (not enough RAM)
- Writing a page (0.5 - 5ms) slower than reading (<<1ms)
- File systems and OS make the delay variable over time

Problem Statement

- Ensure inter-packet-delay t_D is large enough to give sender and receiver time.
- Or: $t_D \geq \max(T_R, T_S)$

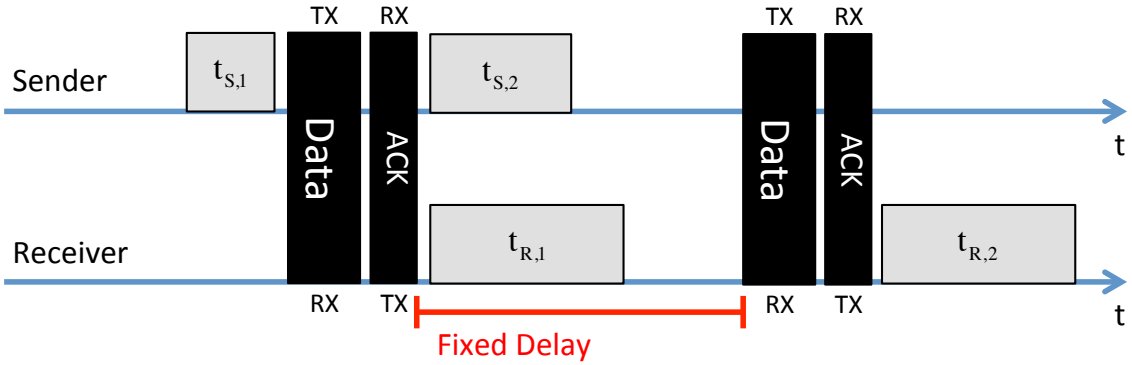
Goal

- Minimize t_D

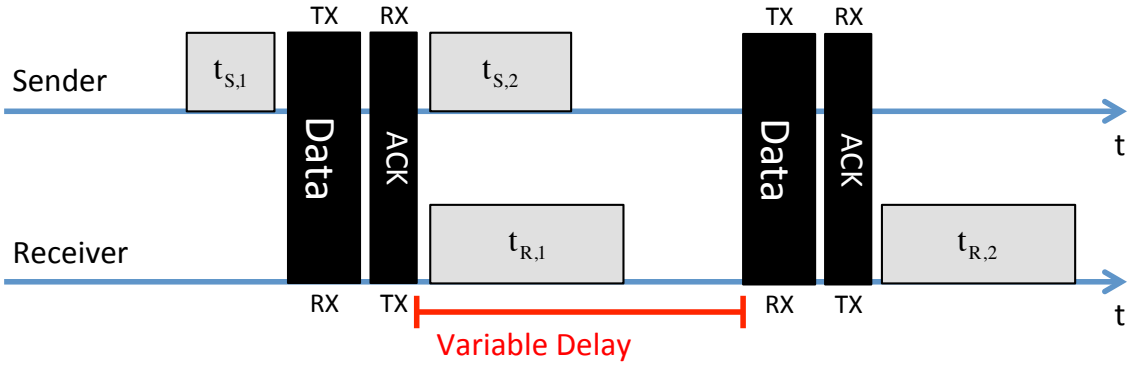


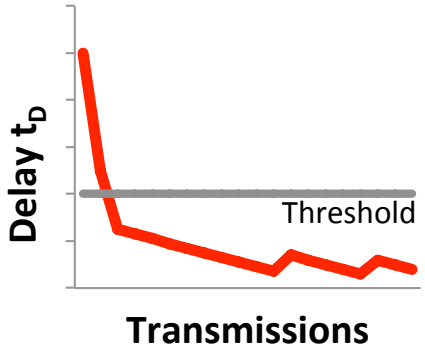
Four Different Flow Control Mechanisms (1/2)

- **Fixed Delay** between outgoing packets



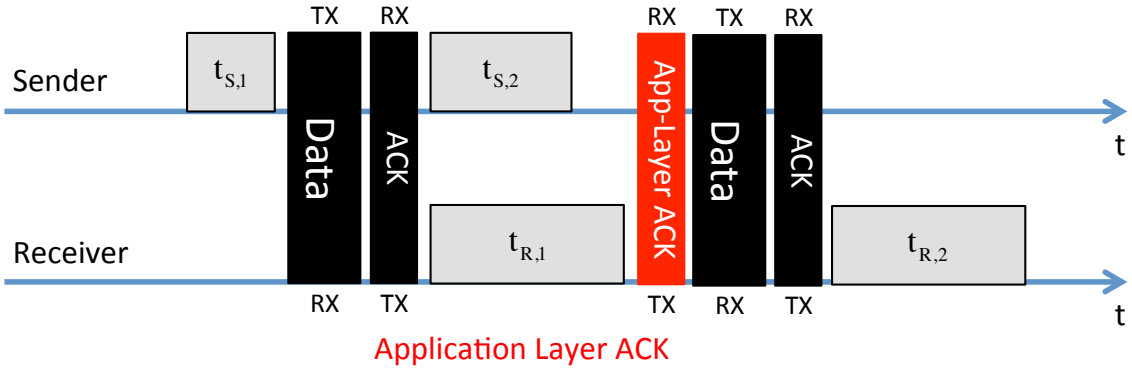
- **TCP-inspired** approximation of processing time



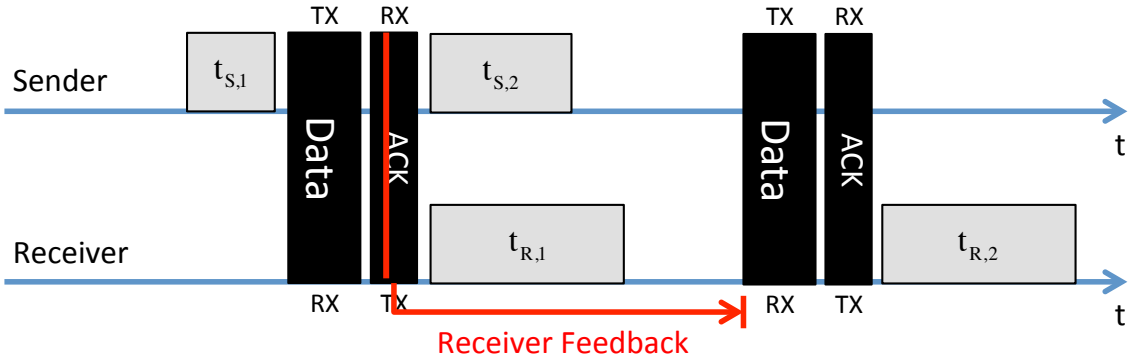


Four Different Flow Control Mechanisms (2/2)

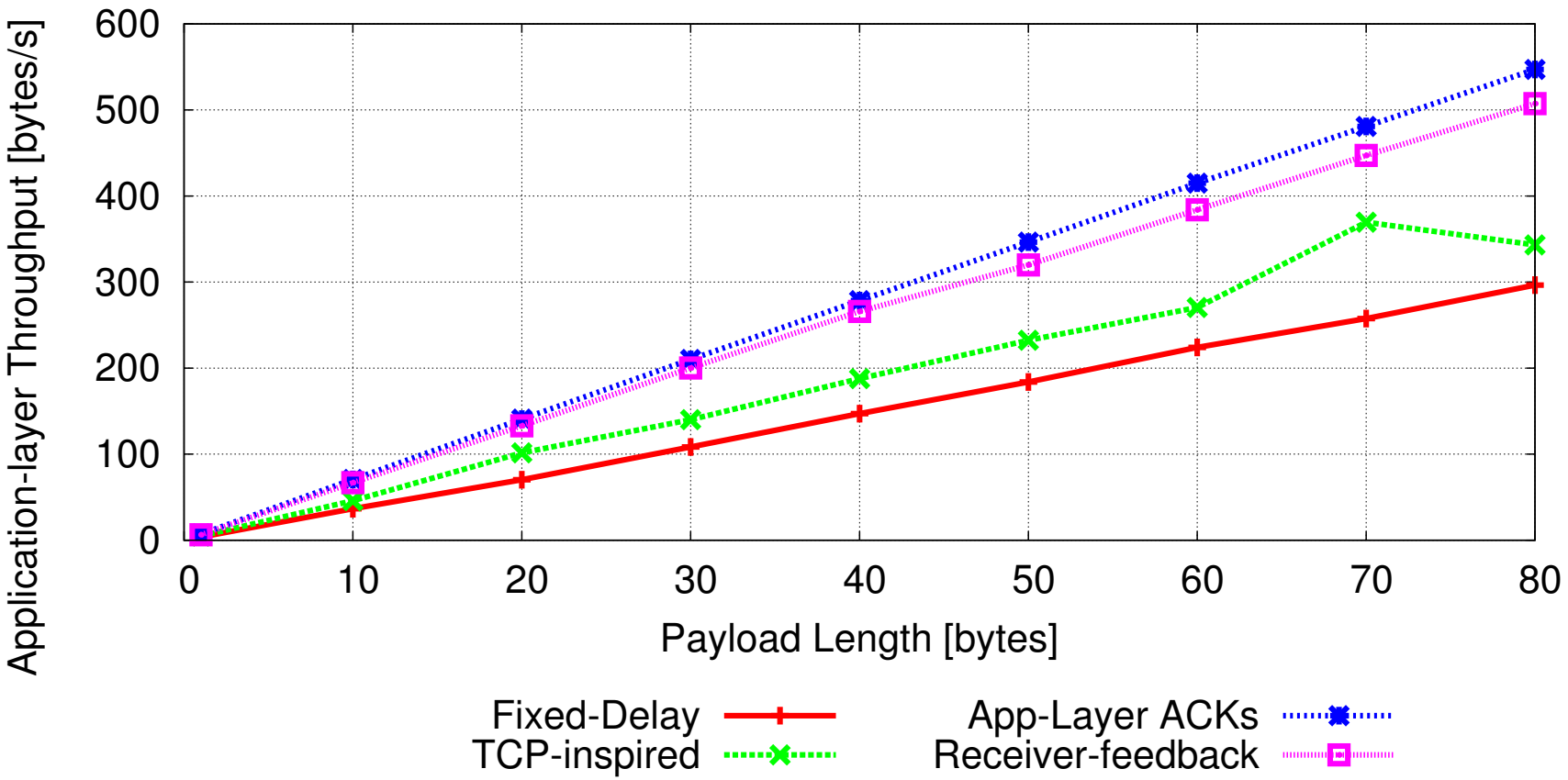
- **Application-Layer ACKs** when processing is done



- **Receiver-feedback** on estimated processing time

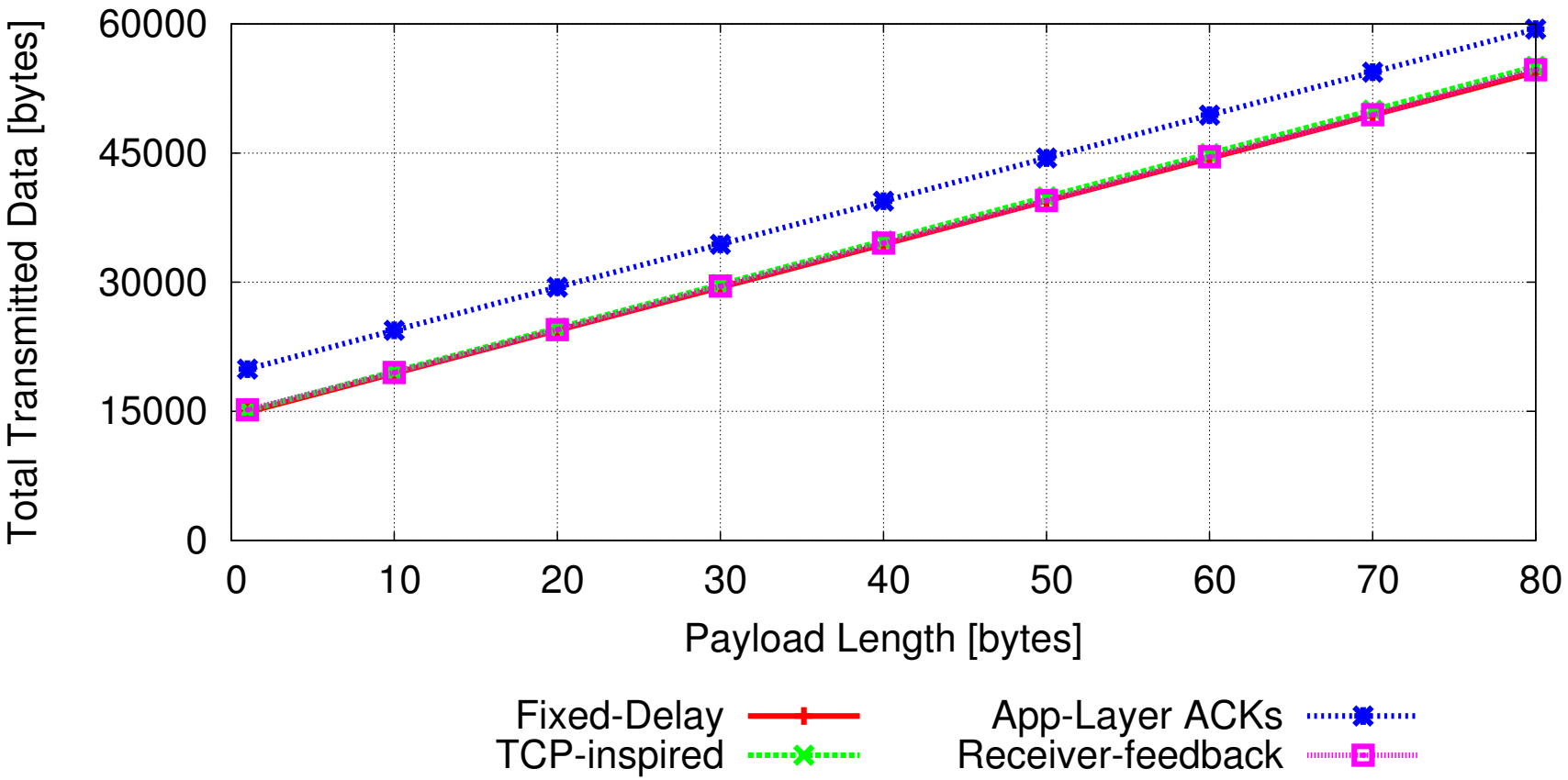


Evaluation: Application Layer Throughput



- App-layer ACK & Receiver-feedback show highest throughput

Evaluation: TX Energy Consumption (via transmitted data)



- App-Layer ACK shows highest energy consumption because additional ACK packets have to be transmitted

Conclusions

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http://www.ibr.cs.tu-bs.de/projects/mudtn/

- Delay Tolerant Wireless Sensor Networks (DT-WSN)
  - Low-Power nodes built around µC running on batteries
  - IEEE 802.15.4 as predominant wireless communication
- IEEE 802.15.4 Convergence Layer
  - Operates directly on top of MAC layer to reduce overhead
  - Takes care of typical L3+L4 duties. Here: Flow Control
- Flow Control for IEEE 802.15.4 CL
  - App-Layer ACK: high throughput and energy consumption
  - Receiver-feedback: Energy efficient but platform specific
- µDTN is available as open-source software