Technische Universität Braunschweig

DT-WBAN: Disruption Tolerant Wireless Body Area Networks in Healthcare Applications

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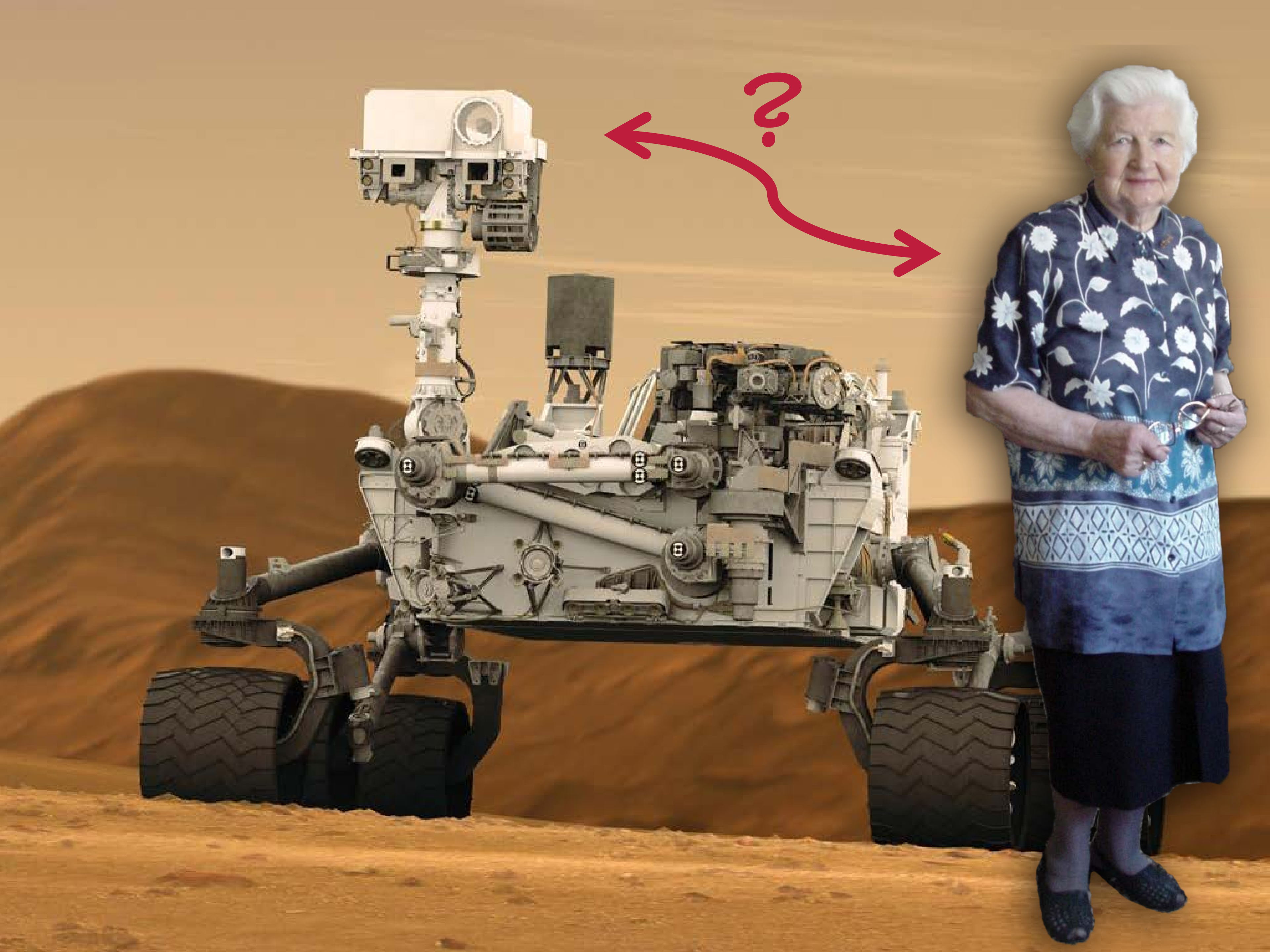
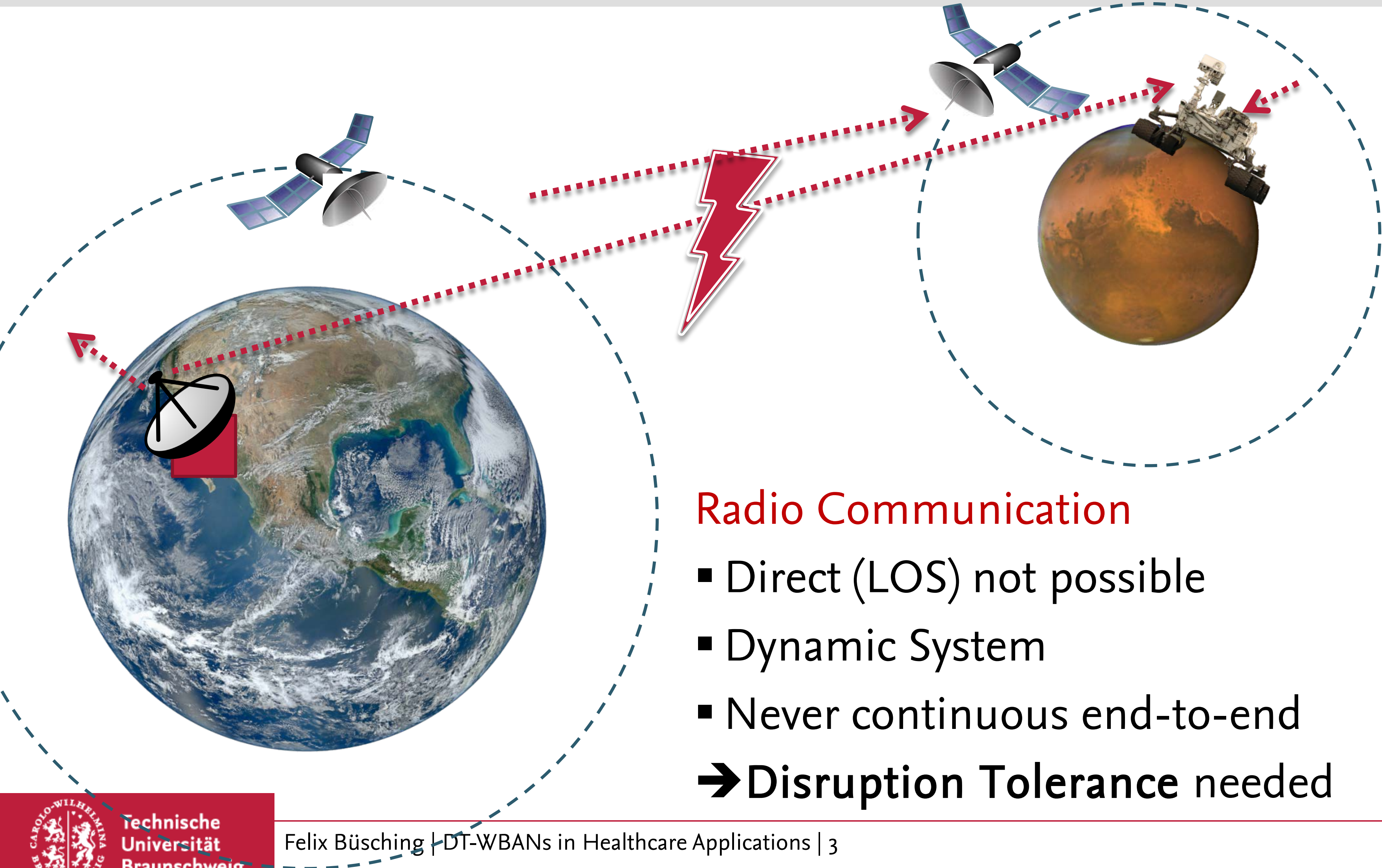


Interplanetary Communication

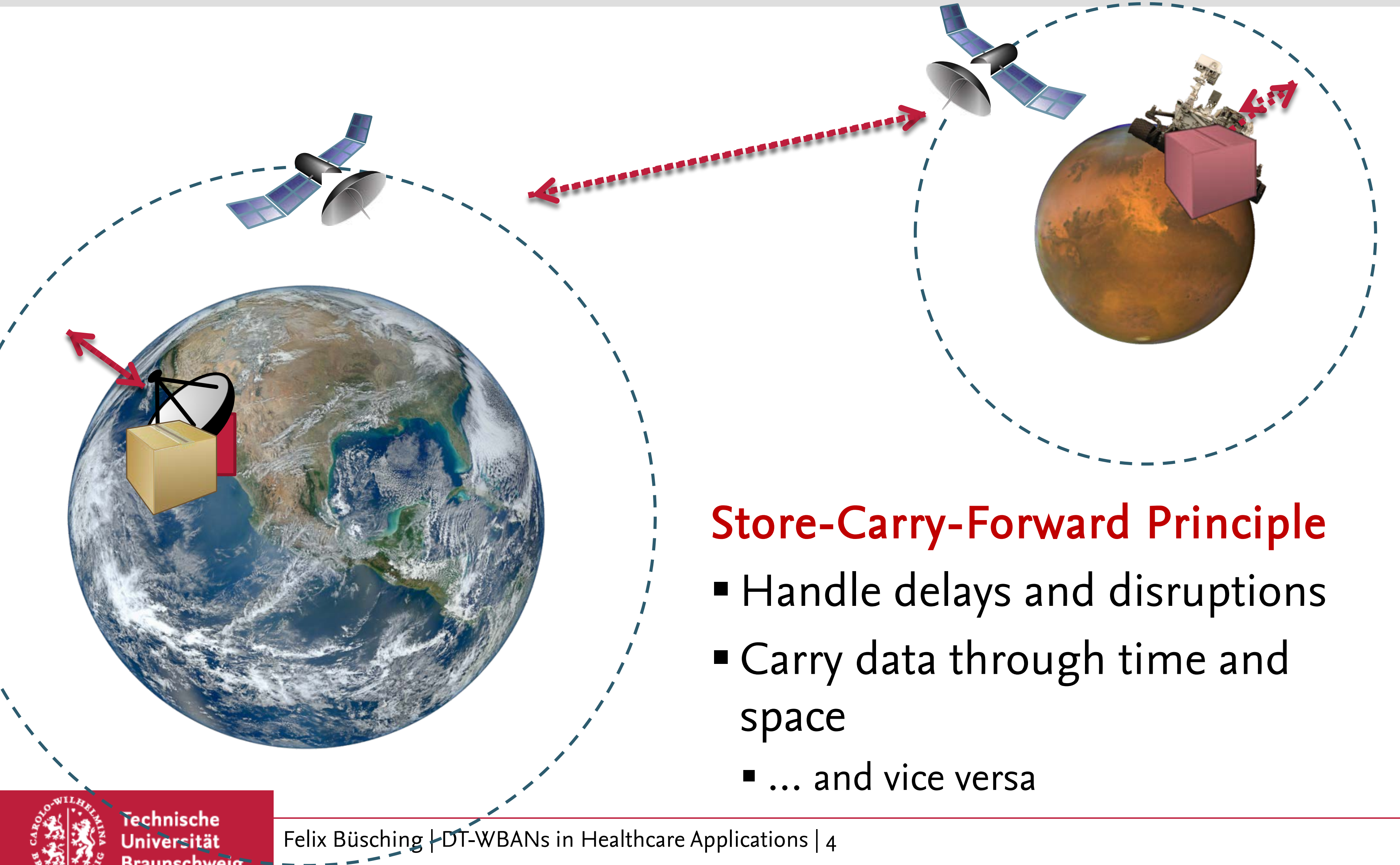


Radio Communication

- Direct (LOS) not possible
- Dynamic System
- Never continuous end-to-end

➔**Disruption Tolerance** needed

Disruption Tolerant Networks (DTN)



Store-Carry-Forward Principle

- Handle delays and disruptions
- Carry data through time and space
  - … and vice versa


CURIOSITY

Summary: Interplanetary Communication – e.g. Mars Rover "Curiosity"

Aim

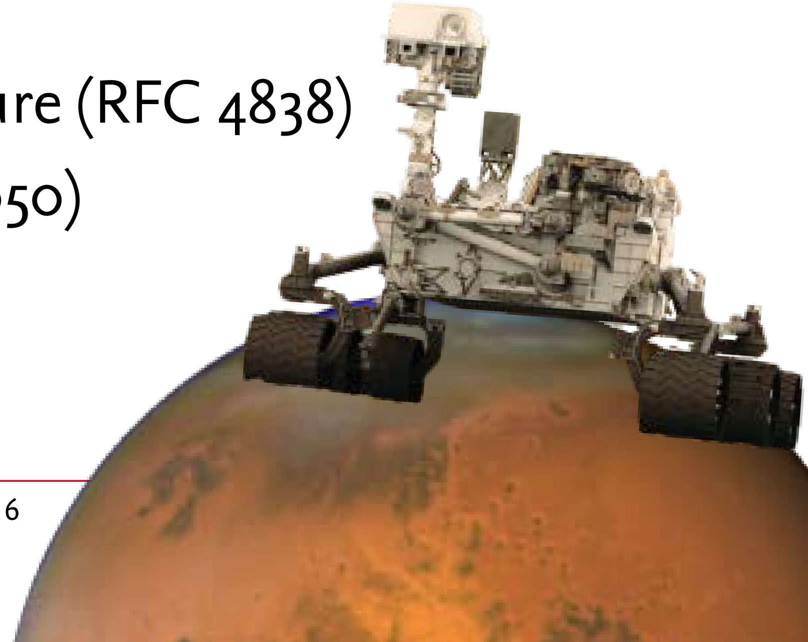
- Collect data, transfer it to earth

Challenges

- Harsh environment
- Huge delays
- No continuous end-to-end connection

Solutions: Store – Carry – Forward

- Delay-Tolerant Networking Architecture (RFC 4838)
- Bundle Protocol Specification (RFC 5050)



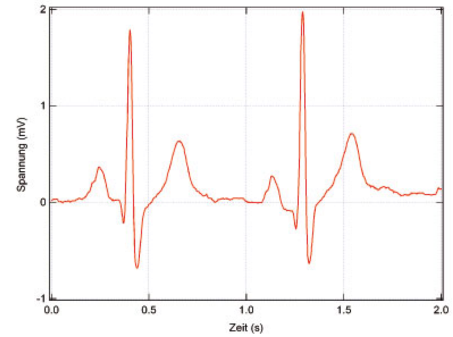
DT-WBAN: Disruption Tolerant Wireless Body Area Networks

- What is a DTN?
- How do DTNs work?
- Motivation & Use Case: Long Term Monitoring
- Multiple Scenarios Covered
- Sensors and Data Rates
- Opportunity for DTNs?!
- Experiments & Evaluations

Health and Activity Monitoring

Sensors for vital parameters

- ECG
- Blood pressure
- Acceleration
- Temperature, Air Pressure



Long term monitoring – today

- Data is either
  - Stored on memory card or
  - Transmitted wirelessly to base station

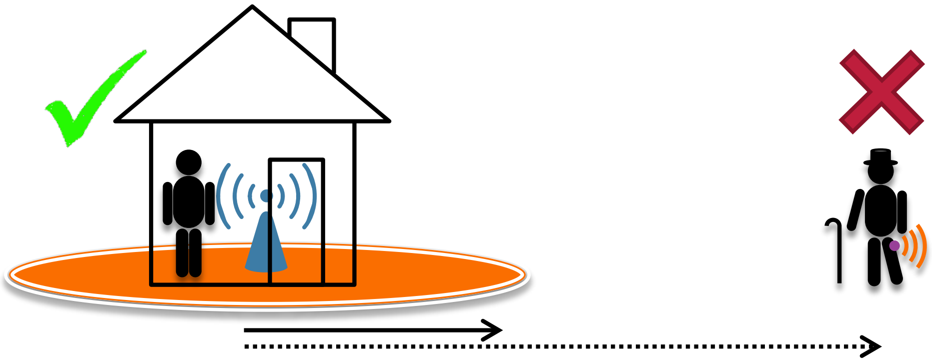
Drawbacks of Local Storage and Wireless Transmission

Local Storage (Body Device)

- Robust, but
  - Limited capacity
  - Interaction required (exchange cards)
  - No remote configuration possible

Constant Wireless Transmission to Sink

- Comfortable
  - Data available in “realtime”
  - Remote configuration, but
- Unstable links
- Data loss



Summary: Wireless Monitoring in Health Care

Aim

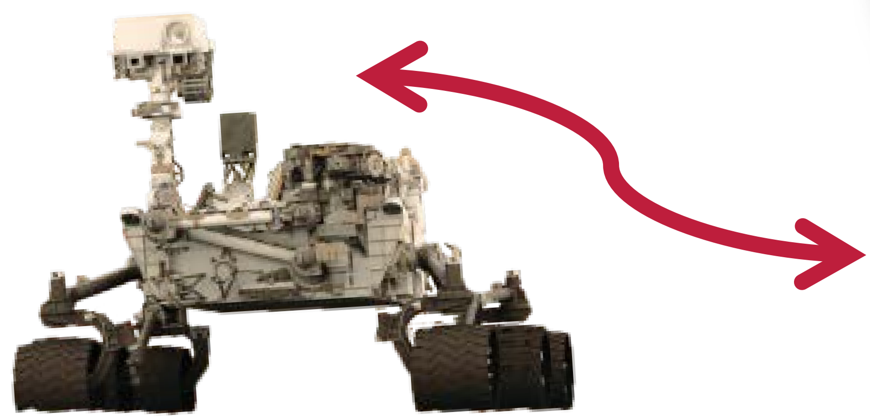
- Collect data, … , transfer it somehow to physician

Challenges

- Harsh environment (elderly)
- Huge delays
- Often disrupted connection

Solutions

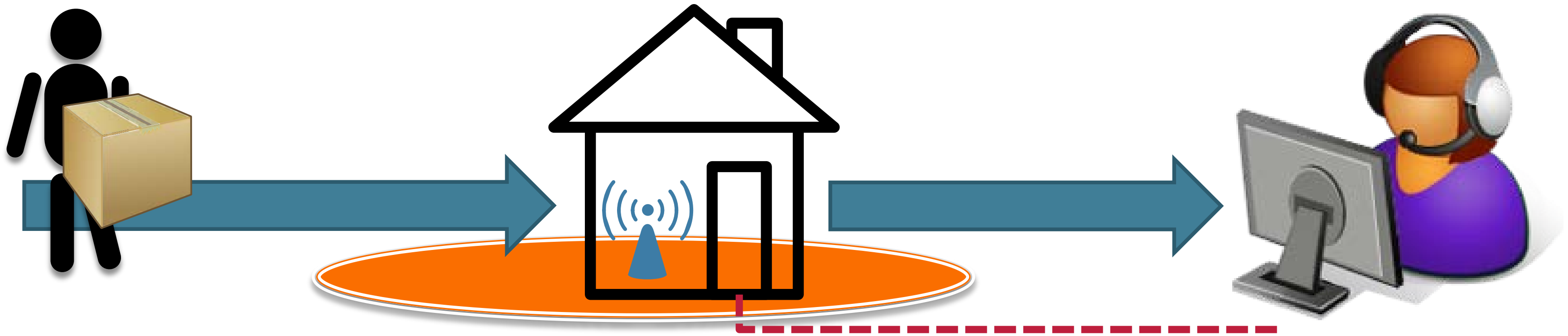
- Look up!



Opportunity for DTN techniques

Adopt "Store – Carry – Forward" Principle

- Store – while "on the road"
- Carry – data home
- Forward – to base station at home



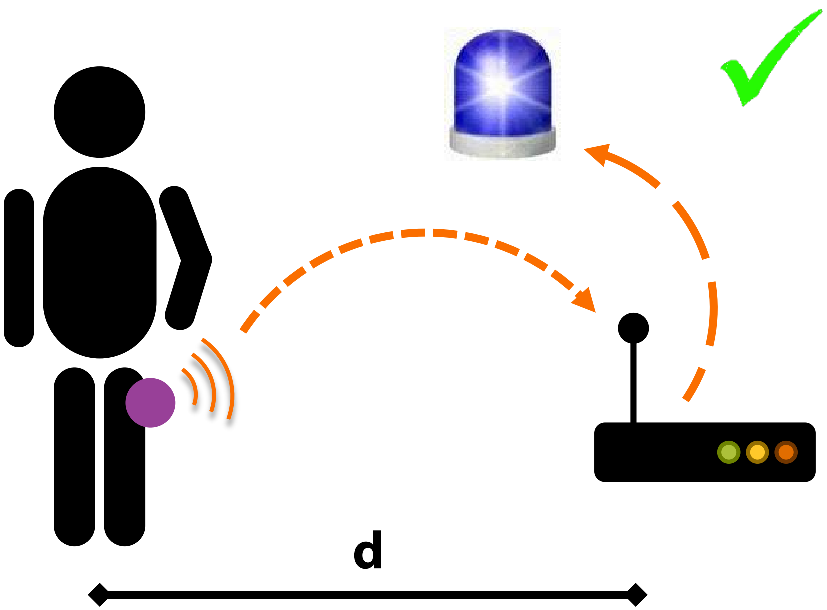
Implicit Synchronization

- No data get's lost
- Seamless handover from "online" to "offline"

Additional Benefit: One Sensor Supporting Multiple Scenarios

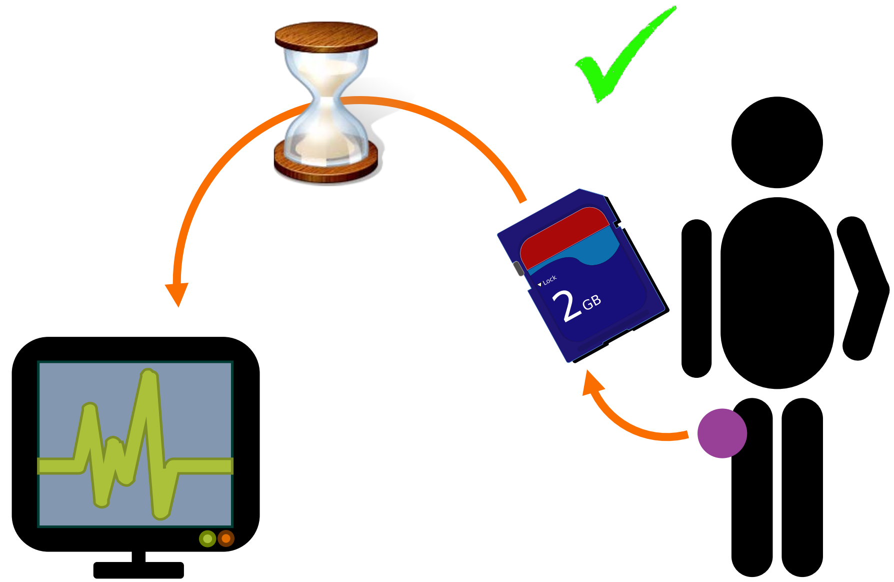
Fall Detection

- Based on Accelerometer Data
- Instant alarm by base station
  - Within communication range



Health & Activity Monitoring

- Multiple Sensors
- Cover huge periods
  - Without data loss



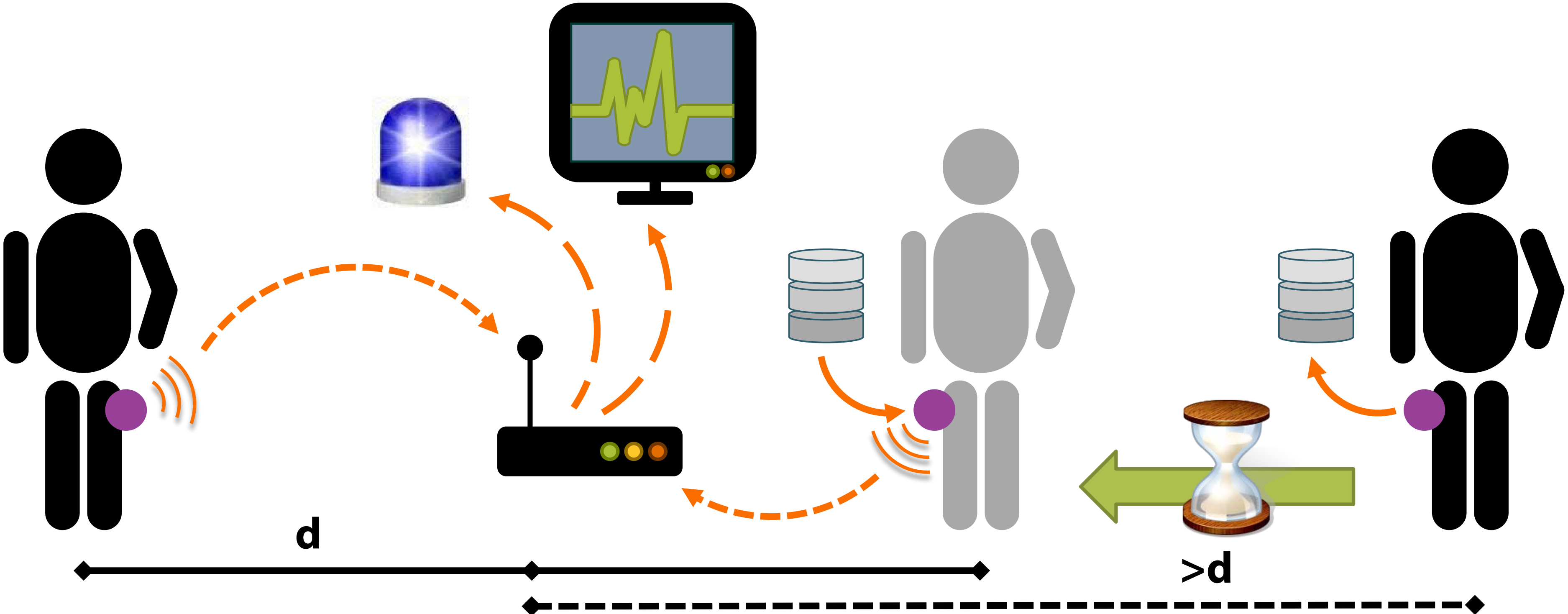
Combined Use Case

Online Fall Detection

- Normal function
  - Within range of base station

Health & Activity Monitoring

- No lost data
- Implicit Synchronization



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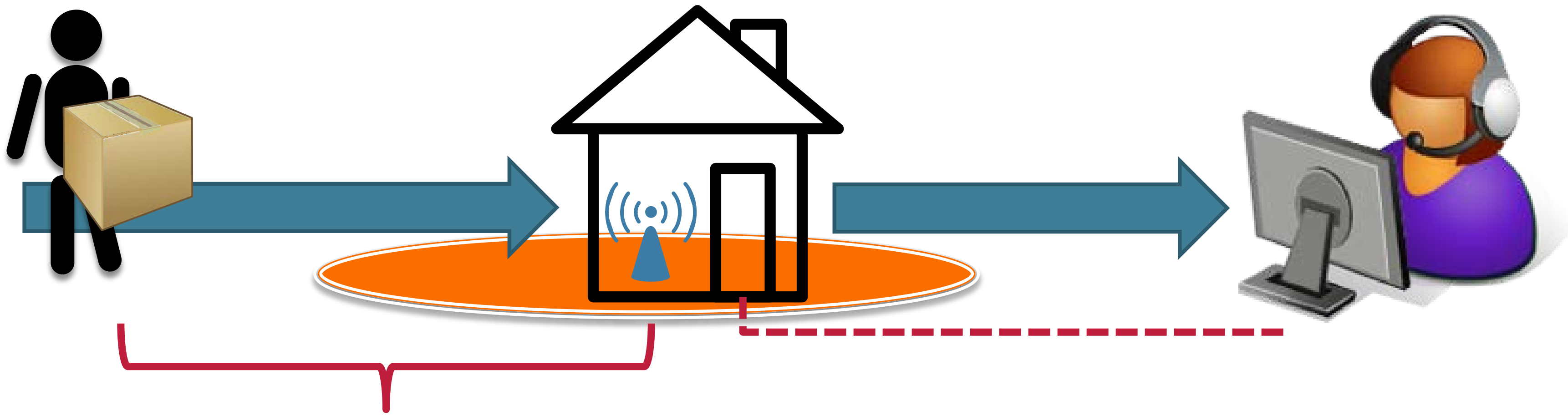
3 Limiting Factors for DTN Usage

Person

- Generator data rate, D_{gen}
- Stored data capacity, S_{fill}



Network

- Transmission throughput, goodput, D_{good}

→ $D_{gen} < D_{good}$

Generated Data: Expected Data Rates

Typical Sensors

Sensor	D_{min}	D_{max}	D_{typ}	Configuration f. D_{typ}
Accelerometer	3 Bit/s	124 800 Bit/s	**1 500 Bit/s**	10 Bit, 50 Hz, 3 axis
Gyroscope	4 800 Bit/s	38 400 Bit/s	**9 600 Bit/s**	16 Bit, 200 Hz, 3 axis
Air Pressure + Temp.	35 Bit/s	4 392 Bit/s	**70 Bit/s**	19 Bit + 16 Bit, 2 Hz
Pulse	8 Bit/s	32 Bit/s	**16 Bit/s**	8 Bit, 2 Hz
EKG	800 Bit/s	96 000 Bit/s	**8 400 Bit/s**	14 Bit, 200 Hz, 3 Channel

- INGA Wireless Sensor Node
  - Designed for human activity monitoring
  - IEEE 802.15.4 radio interface
  - Micro-SD card slot

Benefit: Implicit Synchronization

Storage fills when disruption occurs

- $S_{fill} = t_{disrupt} \cdot D_{gen}$

Synchronization time depends on fill level and data rates

- $t_{sync} = \frac{S_{fill}}{D_{good} - D_{gen}}$

Assumptions

- Accelerometer
  - 3 axis, 50 Hz, 10 Bit
  - → 1500 Bit/s
- IEEE802.15.4 radio
  - DTN implementation on INGA
  - →50 KBit/s DTN goodput

$t_{disrupt}$	t_{sync}	S_{fill}
1 second	0.03 seconds	< 200 Byte
1 minute	1.86 seconds	< 12 KByte
1 hour	< 2 minutes	< 1 MByte
1 day	< 45 minutes	< 17 MByte
1 month	< 5.2 hours	< 500 MByte
1 year	< 11.5 days	< 6 GByte

General Solution

Special solution

- $S_{fill} = t_{disrupt} \cdot D_{gen}$
- $t_{sync} = \frac{S_{fill}}{D_{good} - D_{gen}}$

Combine

- $t_{sync} = \frac{t_{disrupt} \cdot D_{gen}}{D_{good} - D_{gen}}$

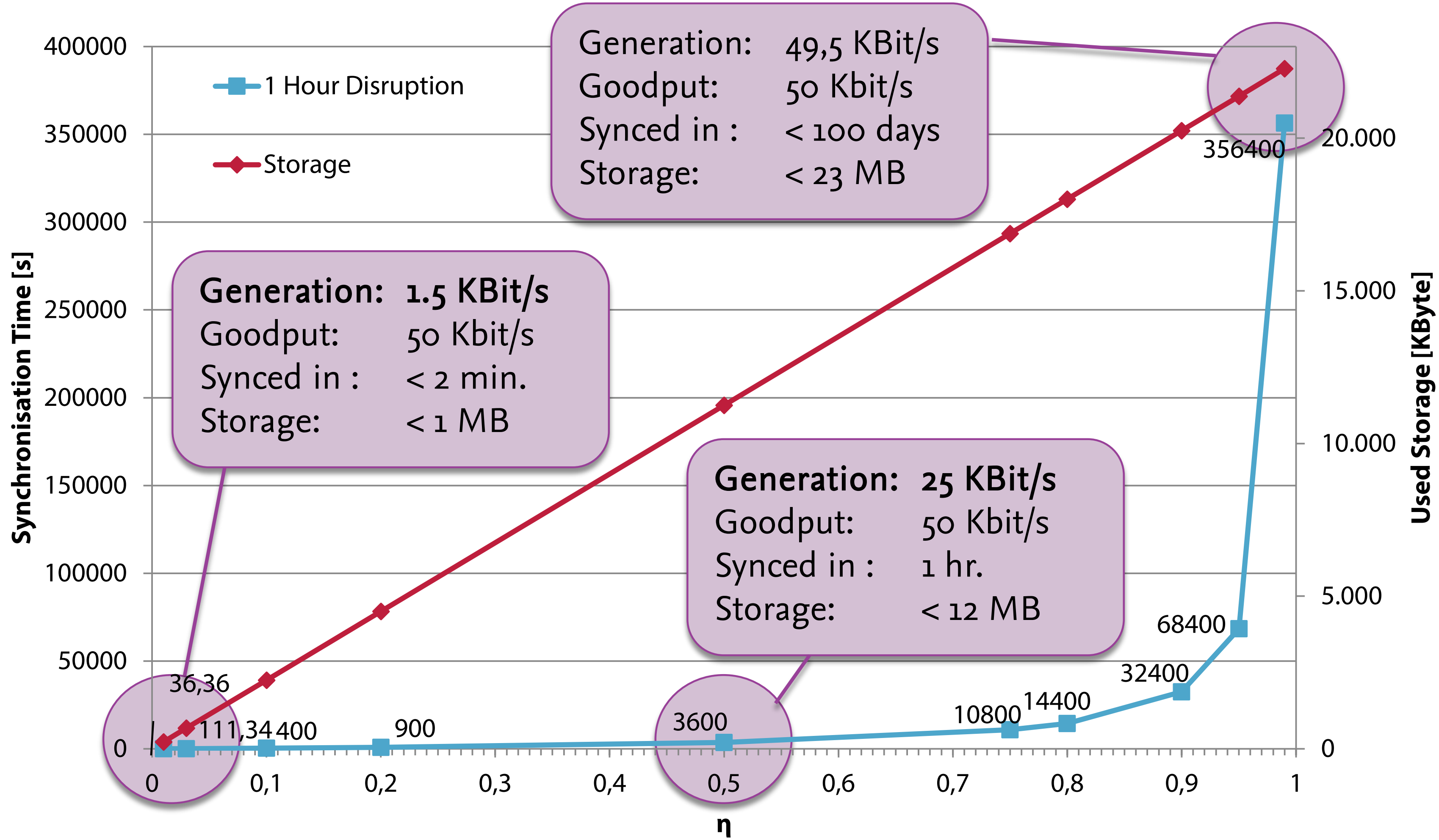
Substitute

- $\eta = \frac{D_{gen}}{D_{good}}$
- $t_{sync} = \frac{\eta \cdot t_{disrupt}}{1 - \eta}$

Synchronization time depends

- Duration of Disruption
- Ratio
  - Generated data
  - Throughput

Synchronization after 1 Hour Disruption, different η



Summary: Opportunity for DTNs?!

General requirement

- Generated data < throughput

Long disruptions require huge amount of storage

- SD cards can handle this: 128 GB microSD available
  - 20 years of accelerometer data
  - 4 month of 12-channel ECG (500 Hz, 16 bit)

Throughput depends on used sensor

- Will work for all mentioned using slow 802.15.4 radio

Sensor	D_{min}	D_{max}	D_{typ}	Configuration f. D_{typ}
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System Setup

1 PC

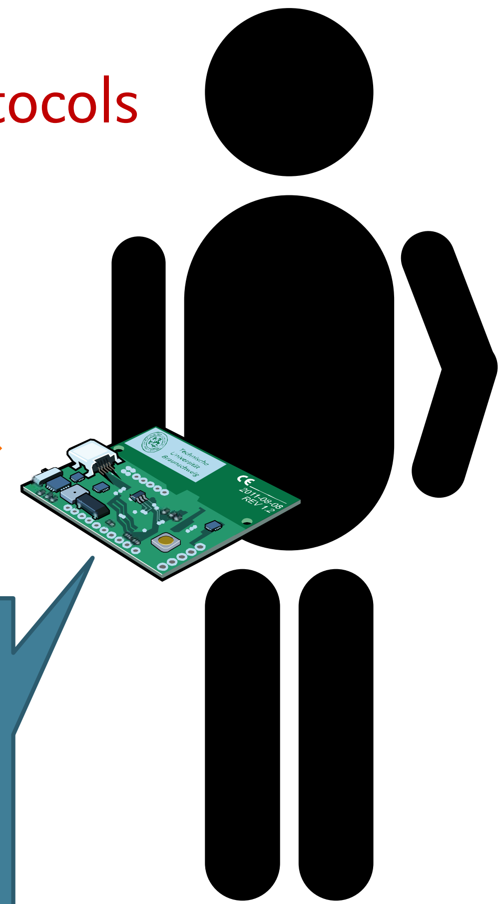
2 INGA Wireless Sensor Nodes

Transport Protocols

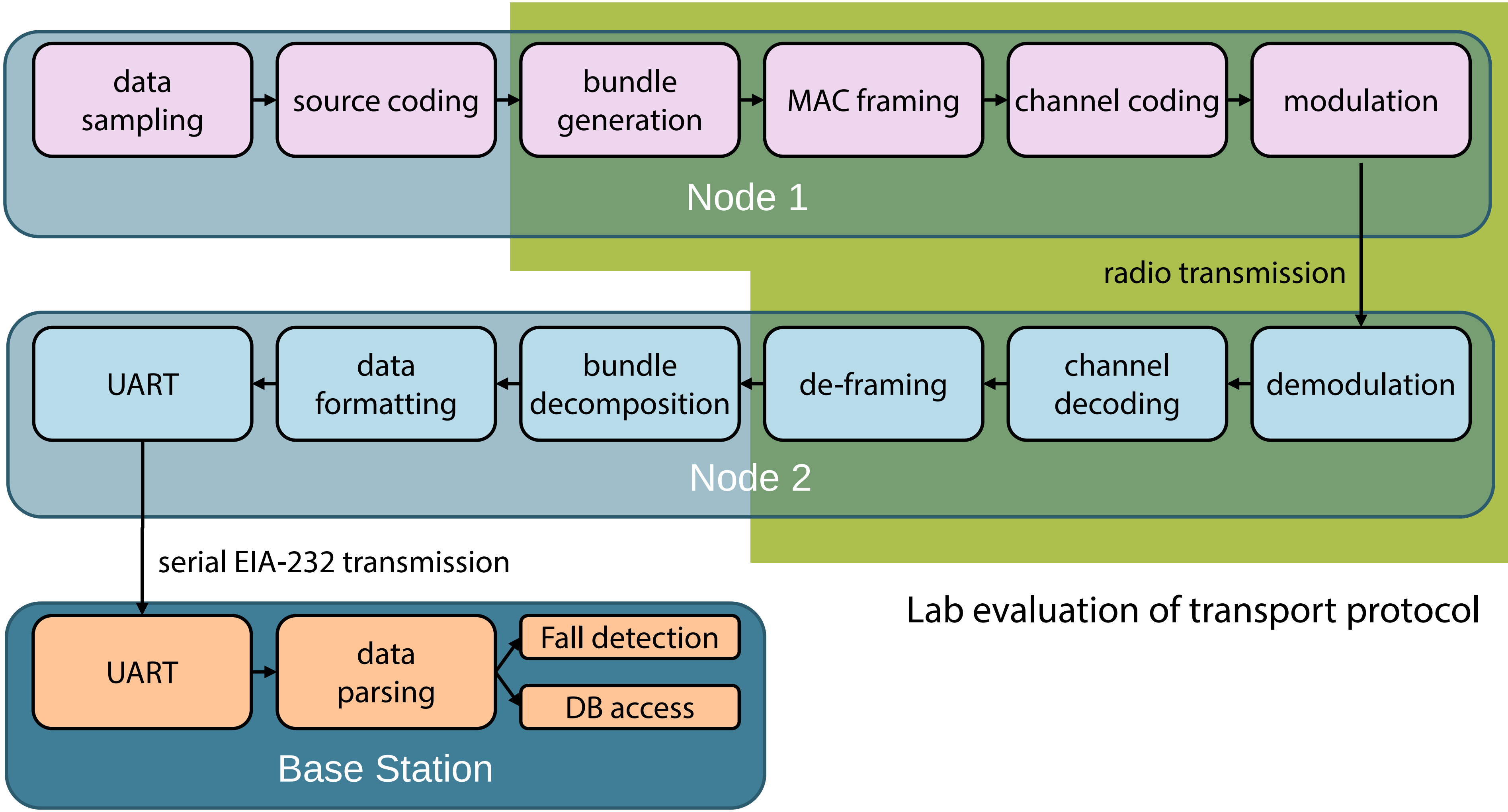
- µDTN
- UDP

- Acceleration
- Pressure
- Temperature
- Channel characteristics

1 Human

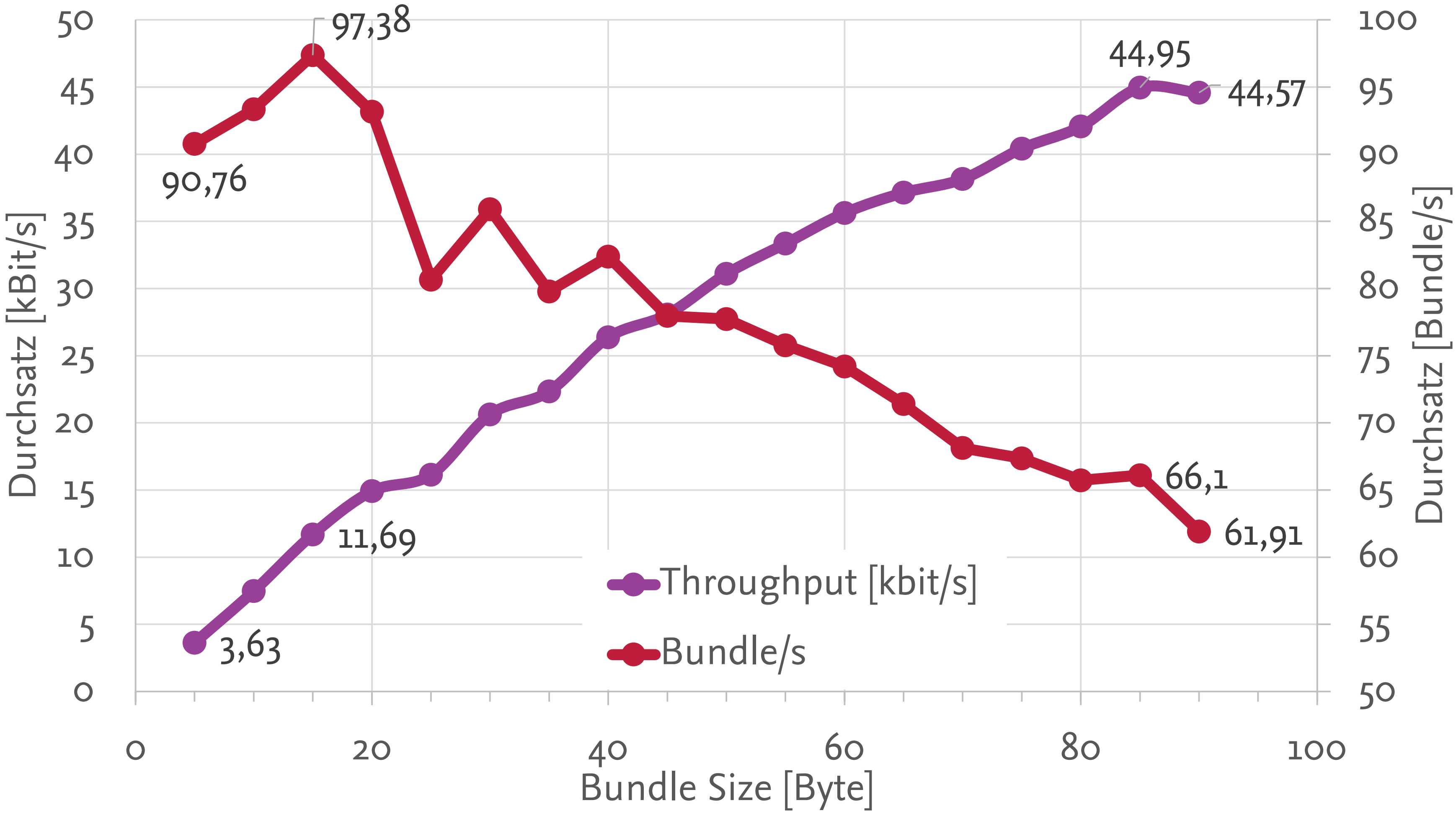


Evaluated System



Lab evaluation of transport protocol

Lab Evaluation: µDTN



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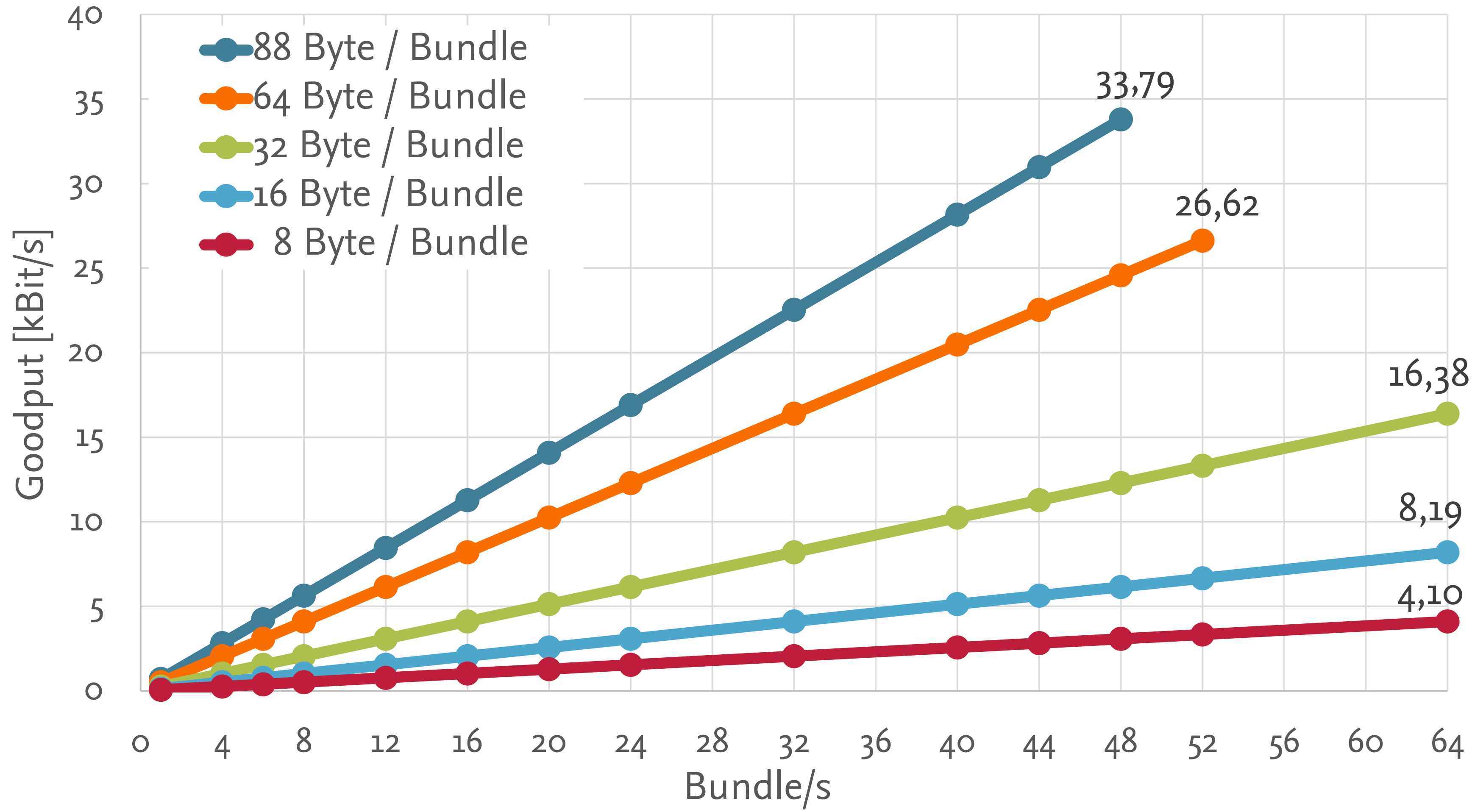
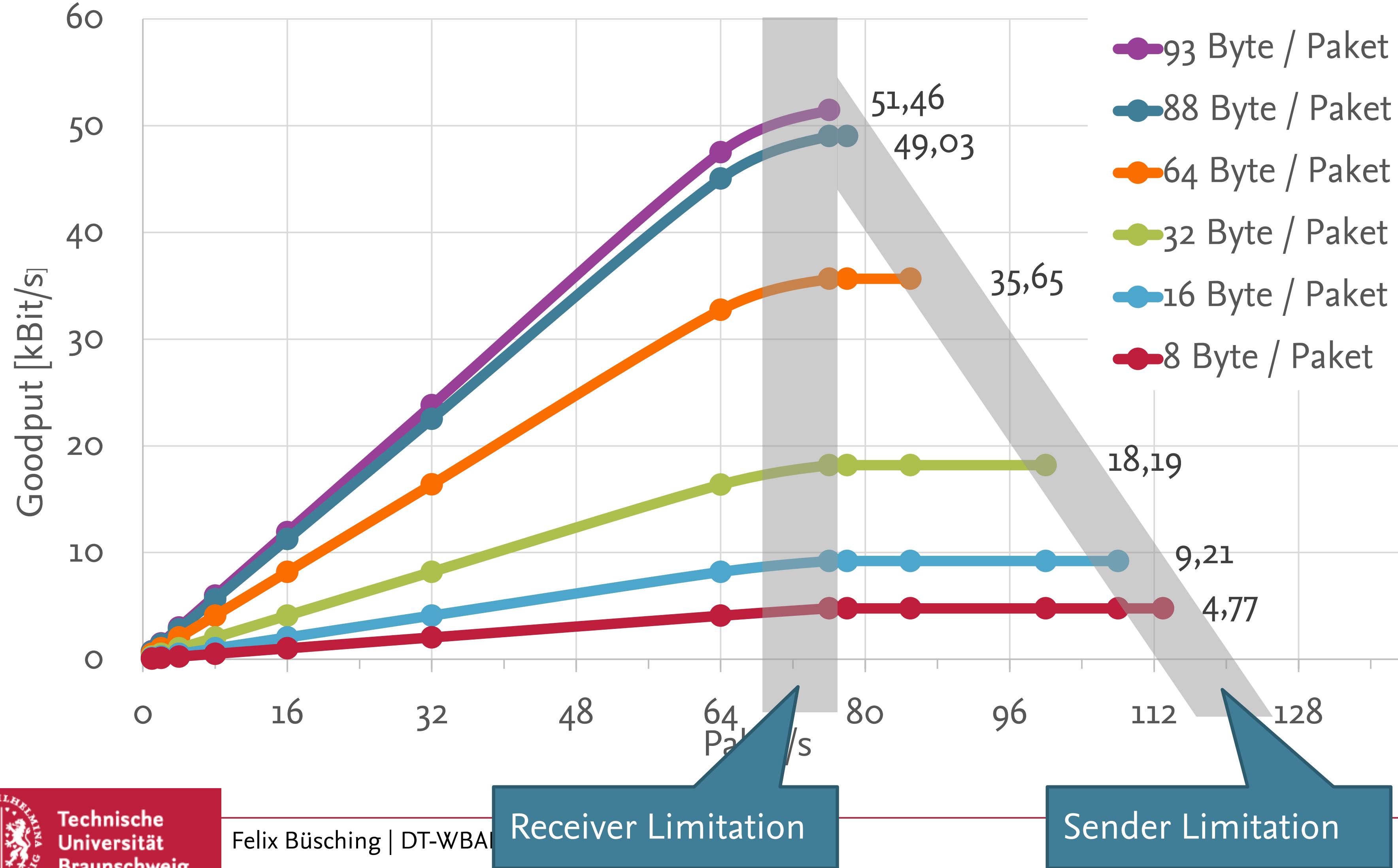
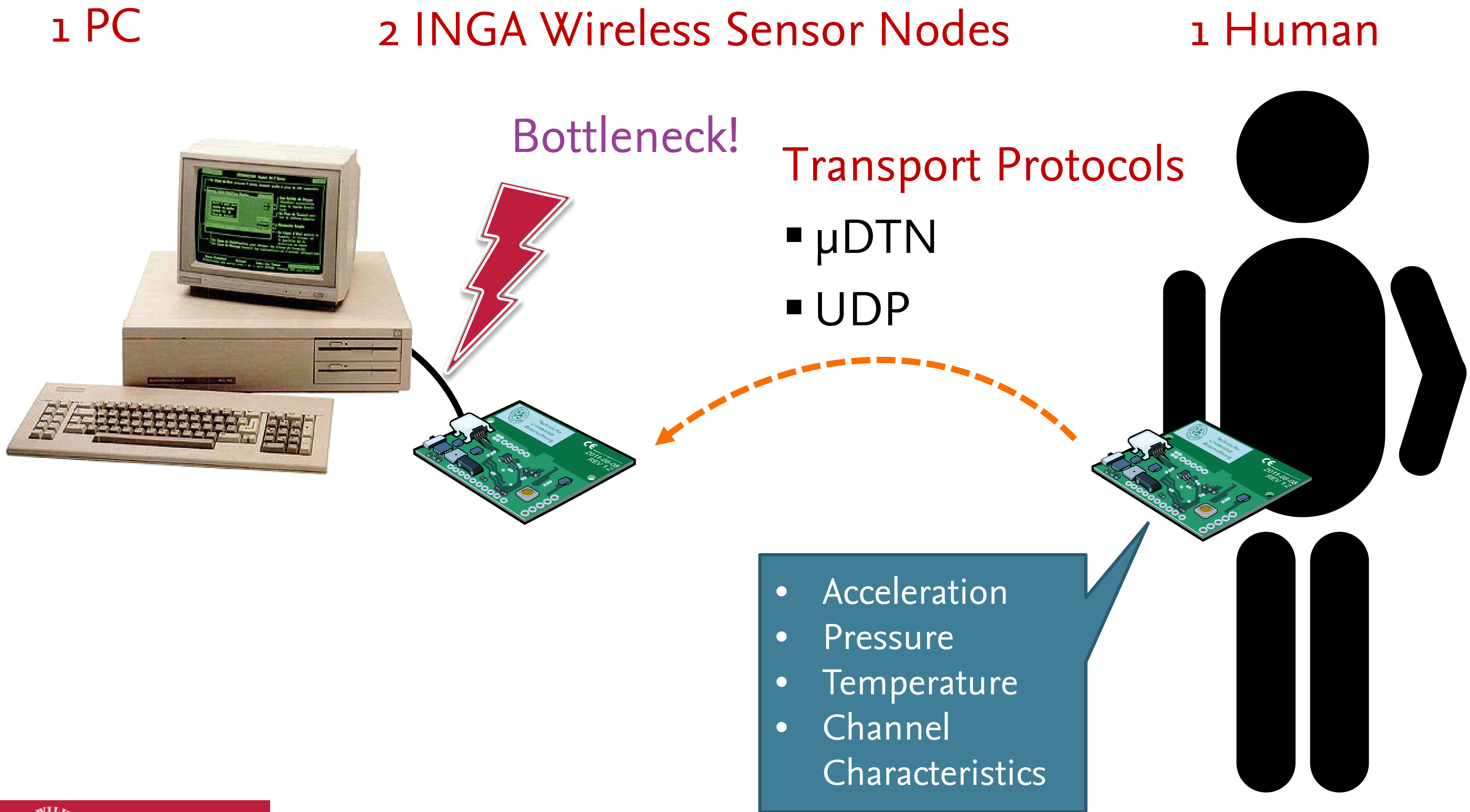
µDTN Application Layer Throughput



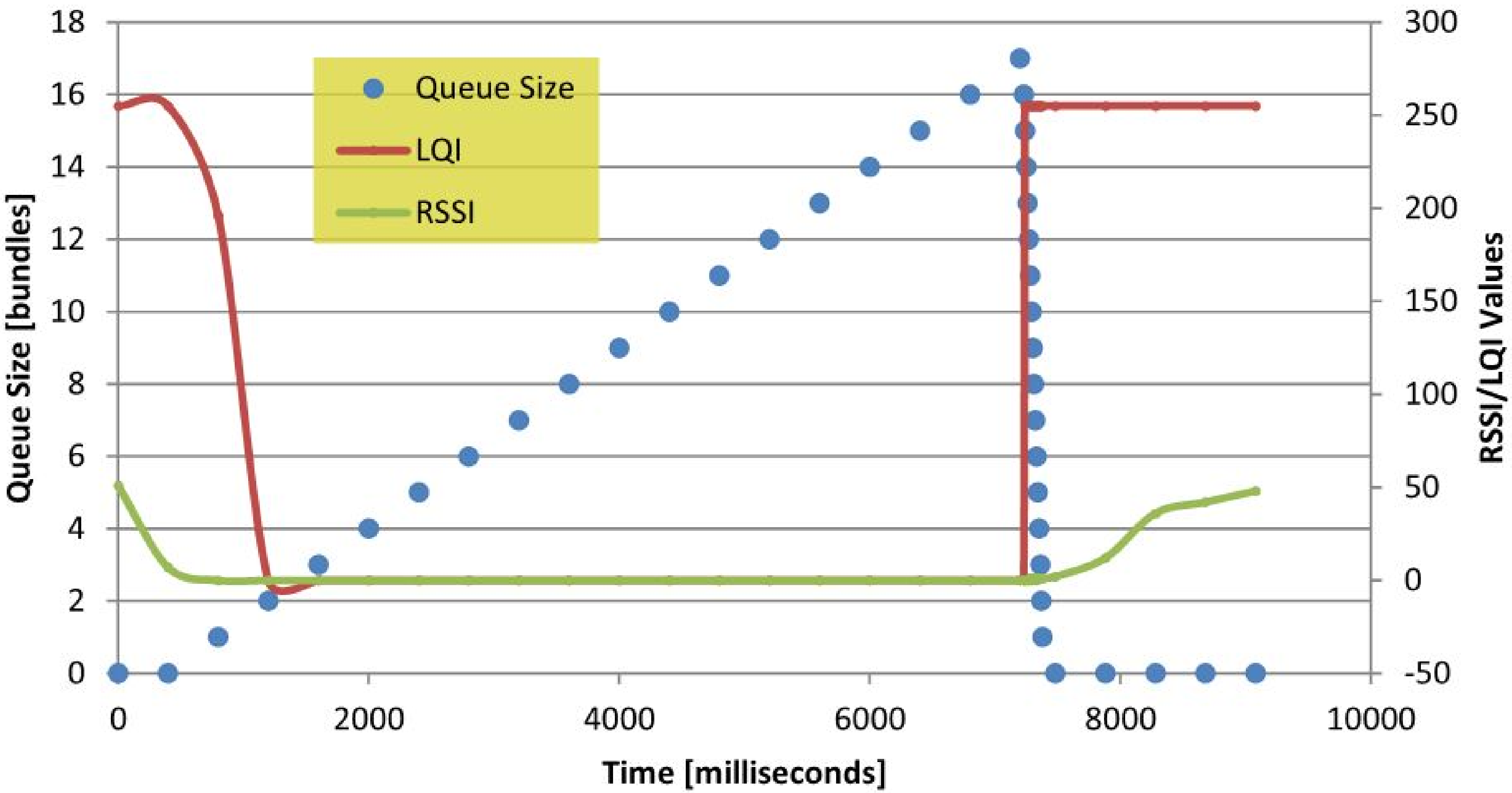
System Evaluation of Transport Protocol: UDP



System Setup



Synchronization: Channel Characteristics vs. Storage Fill Level



μDTN-Source Code:
www.ibr.cs.tu-bs.de/projects/mudtn

Similar requirements in space and healthcare

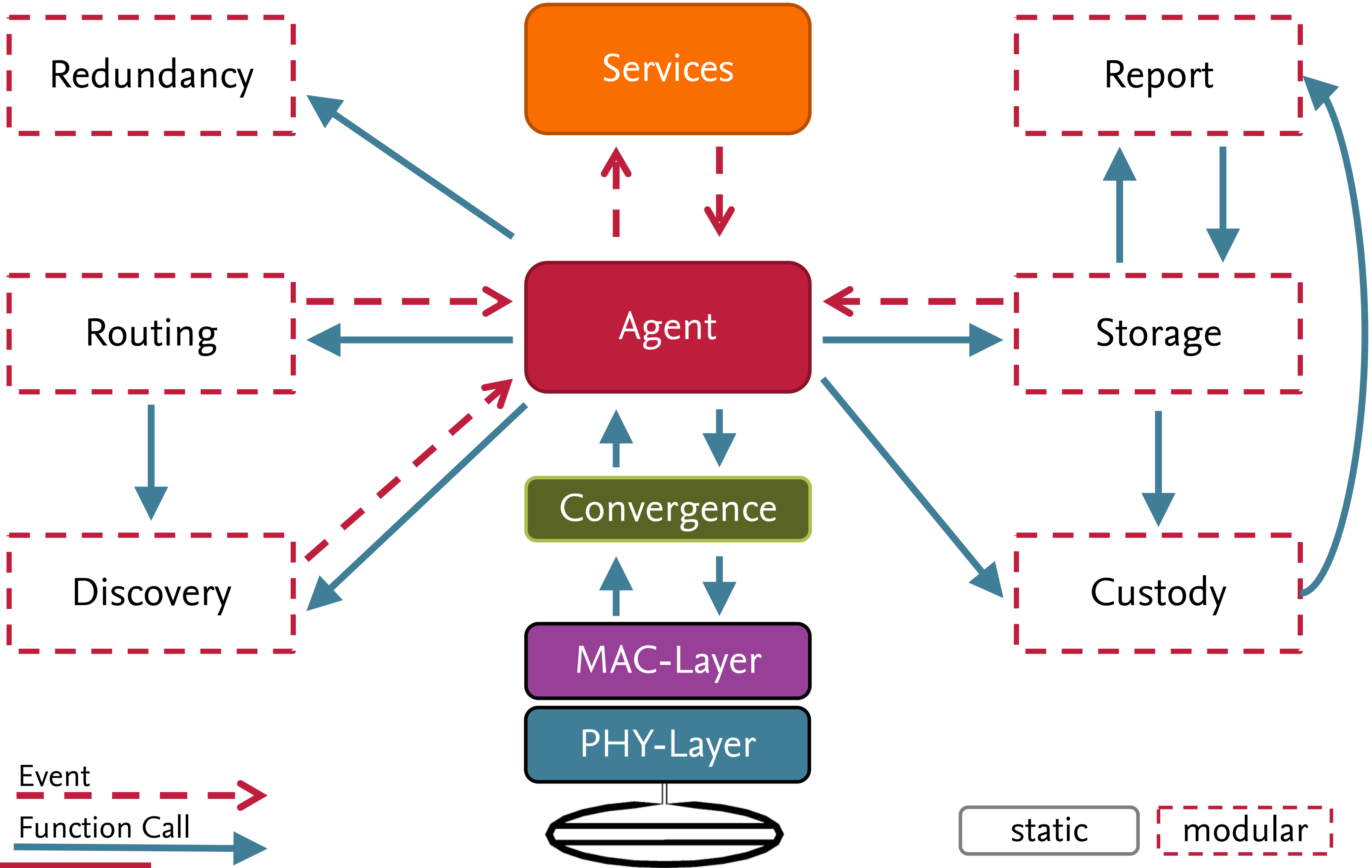
- Demand of robust and reliable communication
  - Handle delays and disruptions
- Use standards, wherever applicable
  - DTN & Bundle Protocol at least “RFC-Status”

Use DTNs …

- … in long term monitoring applications
  - if throughput > generated data
- … to combine online and offline scenarios
  - and achieve implicit synchronization

Thanks for your attention!

- Felix Büsching, buesching@ibr.cs.tu-bs.de


Redundancy
Services
Report
Routing
Agent
Storage
Discovery
Convergence
Custody
MAC-Layer
PHY-Layer
Event
Function Call
static
modular

Disruption and Synchronization Time for Different η ϵ {0.01..0.99}