IMMS

INSTITUT FÜR MIKROELEKTRONIK- UND MECHATRONIK-SYSTEME GEMEINNÜTZIGE GMBH

Wireless communication for IoT

USES2 Online Workshop#1

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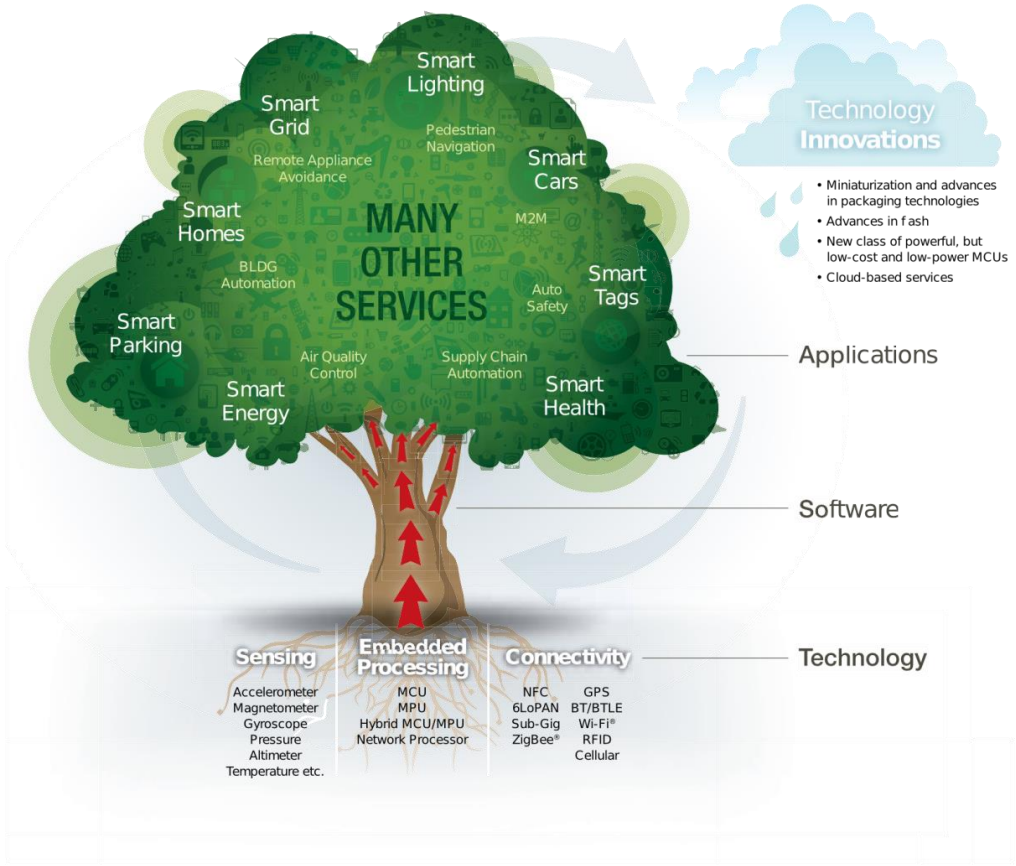
The Internet of Things

- First gained attention in 1999
  - Originally Internet for Things
  - Idea: attach RFID Tags to objects and track or customize them individually

Basic Idea

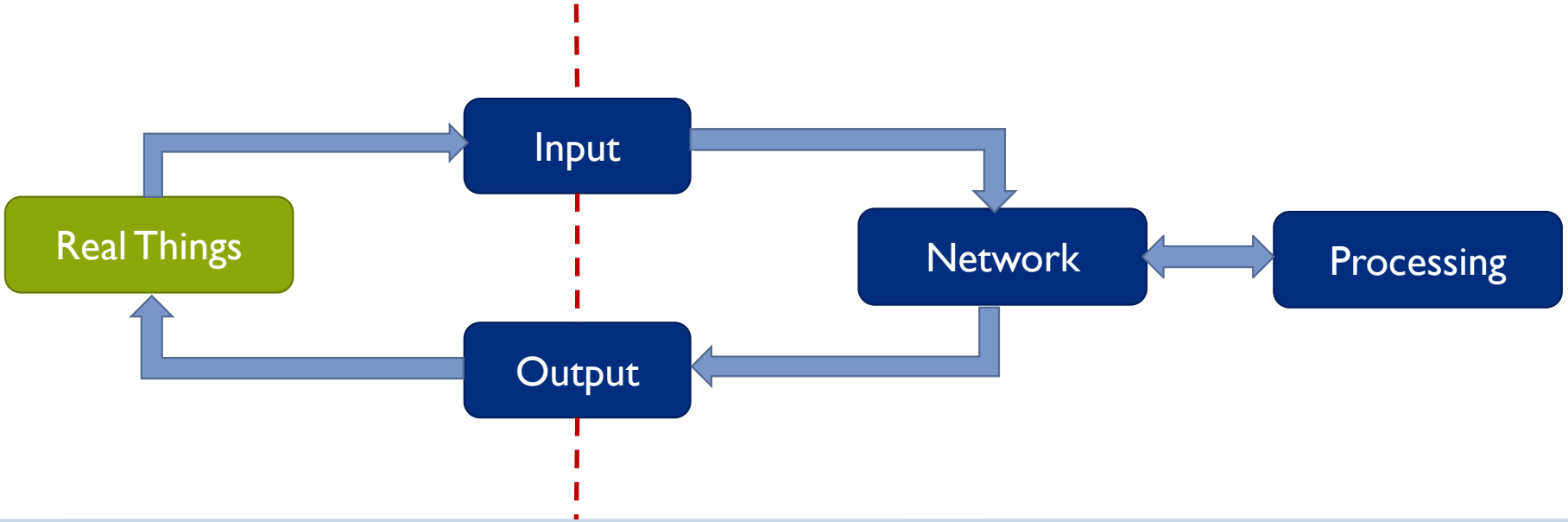
- Connect all things and areas of daily life intelligently
  - Automatically collect information from the real world
  - Interconnect different information with each other
  - Provide information within the network

➢ Allow the system to react to its environment

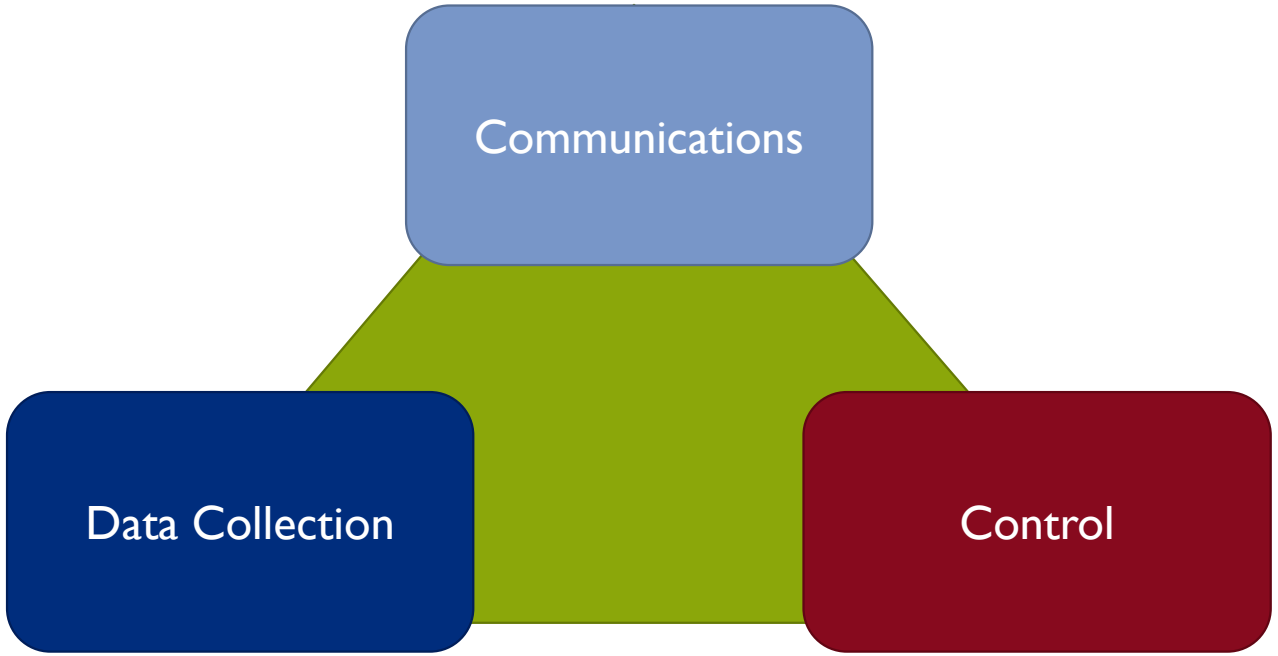


Background – Sensor nodes

- Connect the real physical world with digital virtual world
- Things
  - Communicate with
    - User
    - Each other
  - Take autonomous decisions



Basic Elements of IoT Systems



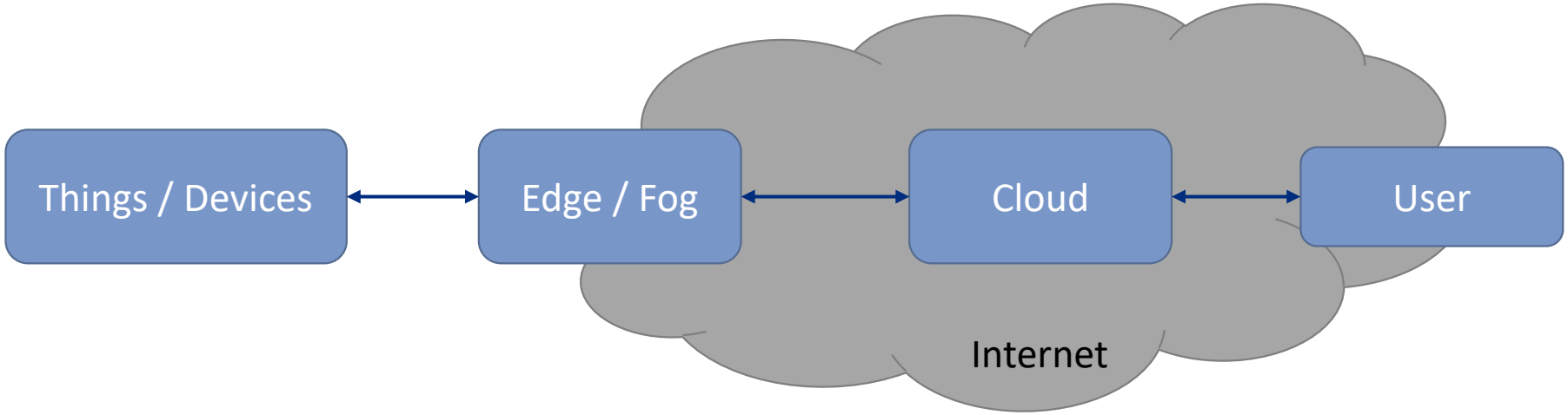
Differences to the Internet

	INTERNET	IOT
Devices	Smartpones, tablet, PCs, server	Sensor nodes, actuator nodes, gateways
Communication	Cable based, WLAN, cellular	various wireless technologies with low-power focus
Content	Human to human	Machine to mashine
Information distribution	Request-Response	Pushing information, triggering actions

- specific application protocols required

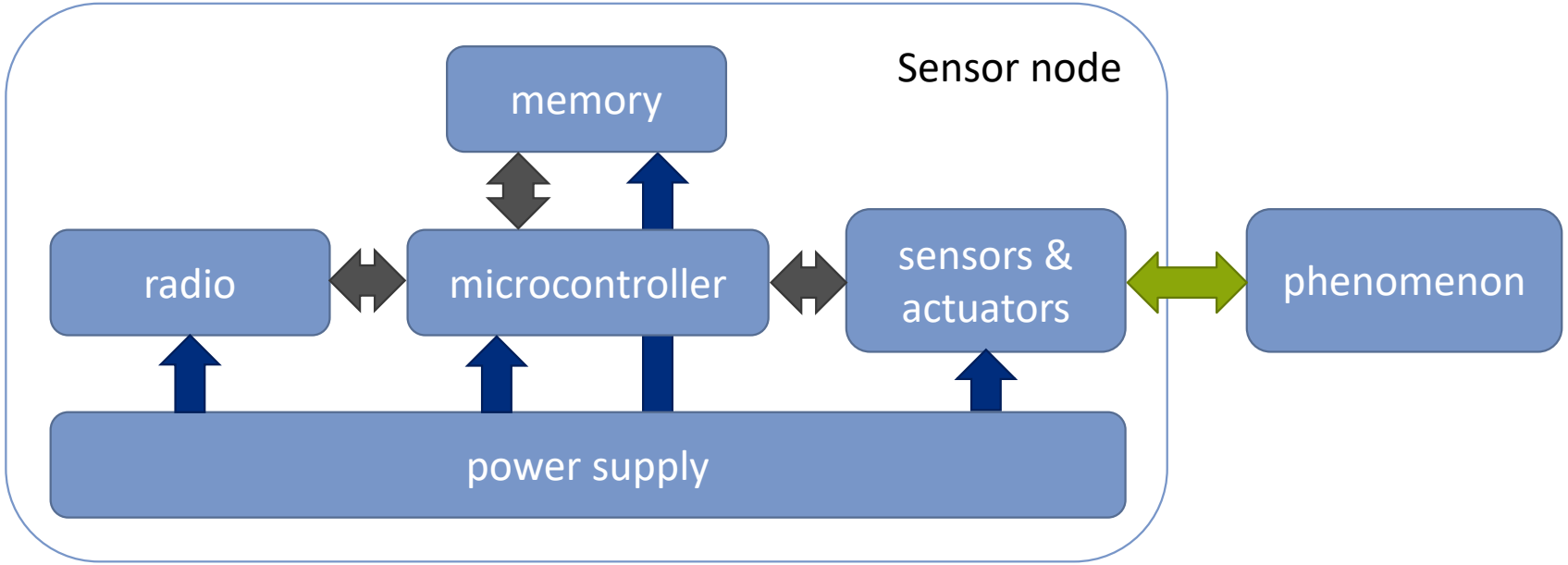
Architecture

- From sensor to the cloud
- IoT describes a complex, distributed system with many components
  - Functionality / analyses take place at different locations
  - Interactions between different system layers and devices of a layer



Sensor nodes?

— Basic components

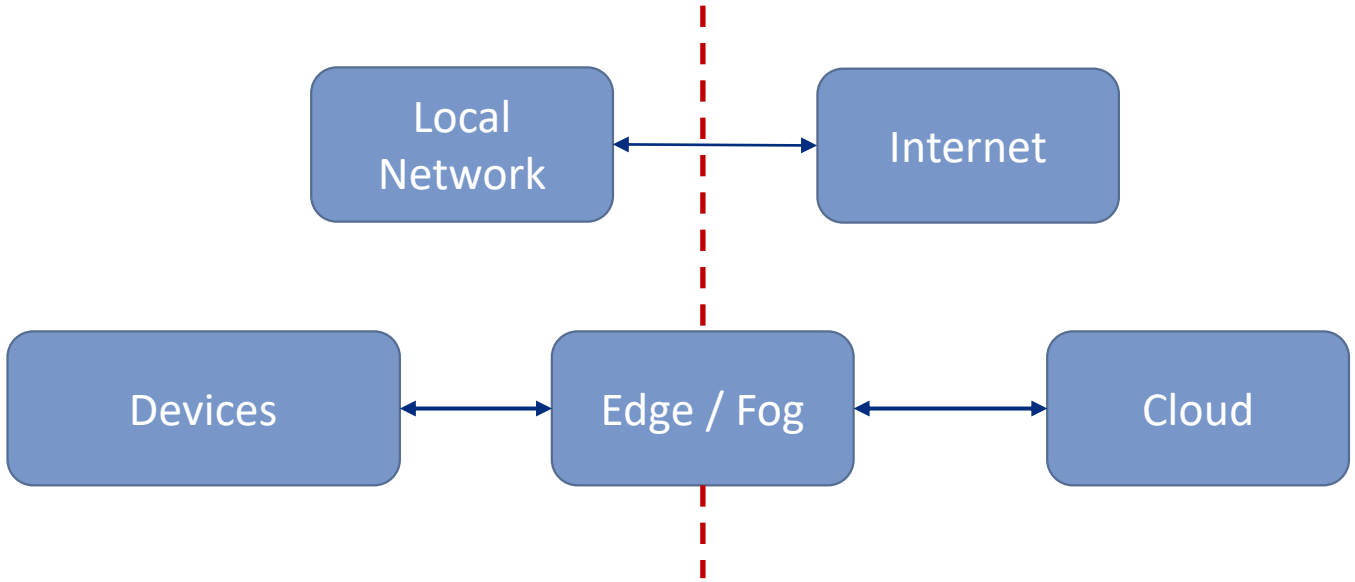


IoT Challenges

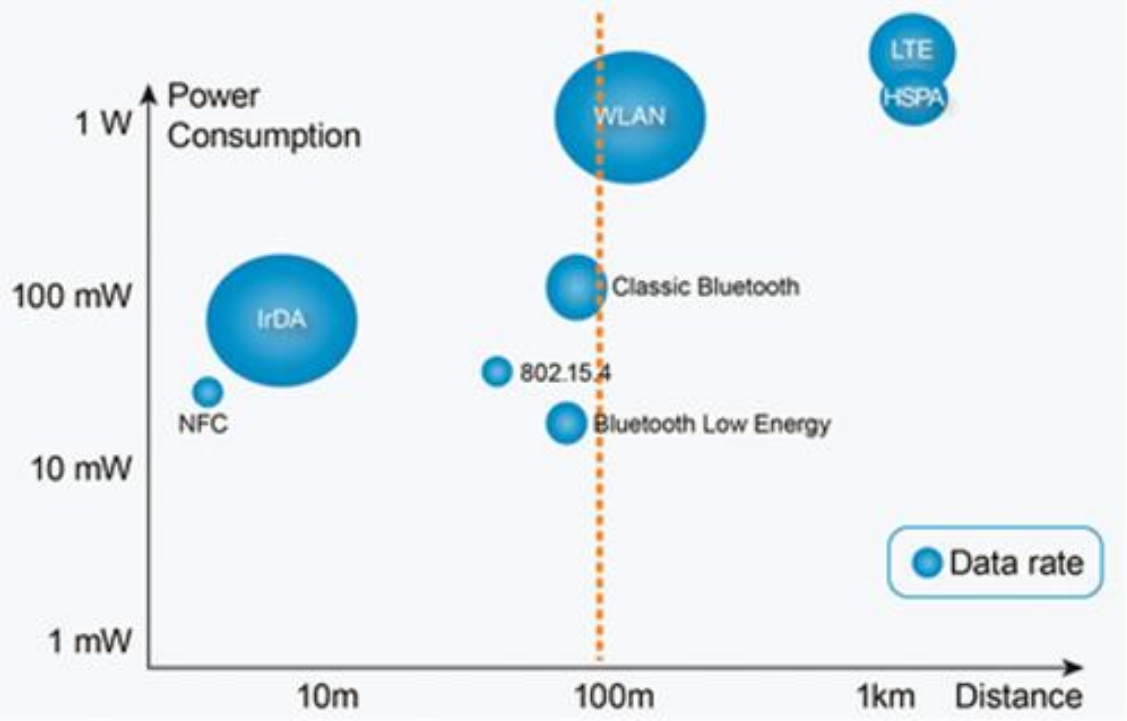
- S - scalable & robust
  - Support a large number of devices to provide information timely and in suitable formats
- M - monitored & managed
  - Recognize, manage and configure (remotely) things
- A - adaptive
  - Adapt to changing environmental conditions and requirements
  - Automatic communication
- R - reliable
  - Reliable data transmission and storage
- T - trustworthy
  - Security mechanisms to avoid data manipulations and unauthorized access

Communication

- Last Mile
  - Sensor to edge
  - Often wireless communication, but not a requirement



Network Technologies



Wireless Technologies – Overview I

Technology	Type	Topology	Frequency	Downlink	Uplink	Range	ISM	MAC	PDU Size	IP Support
NFC	PAN	Point-2-Point	13.56 MHz	< 400 kbit/s		< 10 cm	yes	slotted ALOHA	254 Byte	6Lo
RFID	PAN	Point-2-Point	860 -960 MHz	128 kbit/s	640 kbit/s	< 3 m	yes	ALOHA	254 Byte	Gateway

Wireless Technologies – Overview II

Technology	Type	Topology	Frequency	Downlink	Uplink	Range	ISM	MAC	PDU Size	IP Support
802.15.4	LAN	Mesh	2.4 GHz	250 kbit/s		100 m	yes	CSMA TDMA	127 Byte	6Lo
	LAN	Mesh	868 MHz	800 kbit/s		800 m	yes	CSMA	2047 Byte	6Lo
BLE	LAN	(Mesh)	2.4 GHz	1- 2 Mbit/s		100 m	yes	Central	27 Byte 256 Byte	Gateway
WLAN	LAN	Mesh / Infra	2.4 GHz sub-GHz	300 Mbit/s 40 Mbit/s		100 m < 1 km	yes	CSMA	2304 Byte	IPv6 IPv6 / 6Lo

Wireless Technologies – Overview III

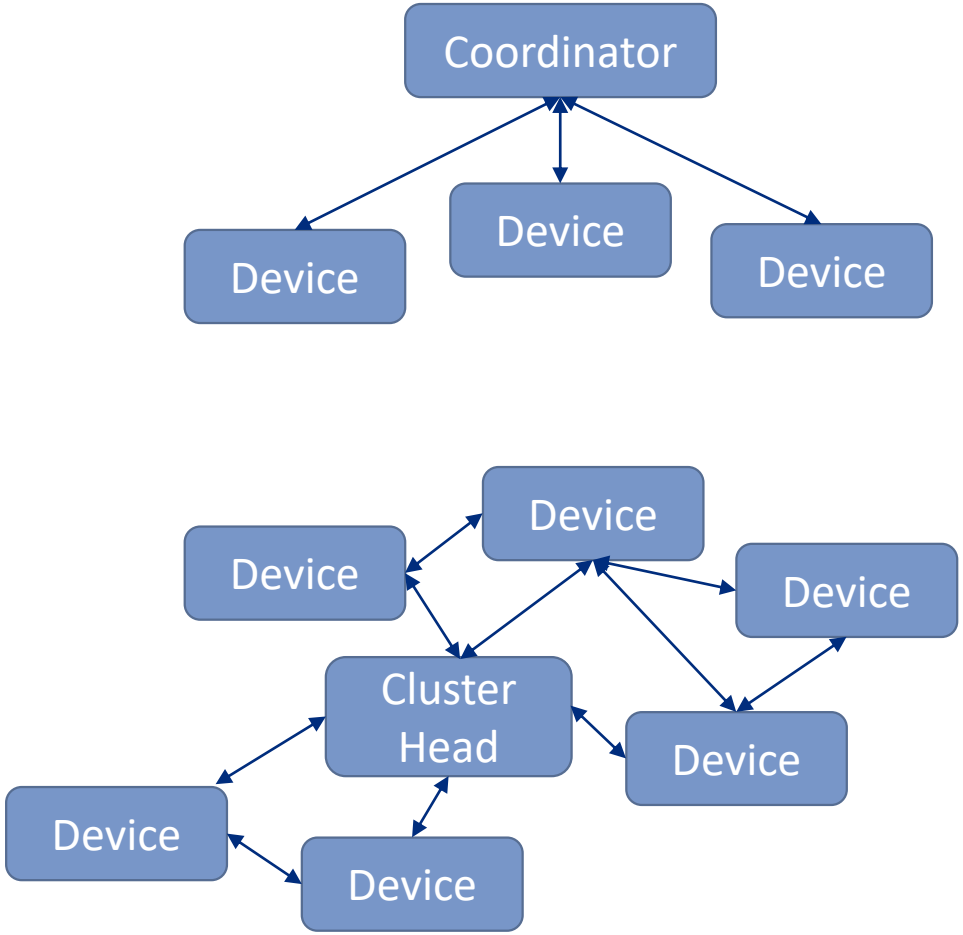
Technology	Type	Topology	Frequency	Downlink	Uplink	Range	ISM	MAC	PDU Size	IP Support
LTE	Cat 4 Cat 1	WAN	Stern	150 Mbit/s 10 Mbit/s	50 Mbit/s 5 Mbit/s	> 5 km	no	Base Station		
	Cat M NB-IoT	WAN	Stern	375 kbit/s		> 5 km	no	Base Station		
				27.2 kbit/s	62.5 kbit/s					
LoRa		MAN	Stern	50 kbit/s		<10 m	yes	ALOHA	222 Byte	Gateway
SigFox		MAN	Stern	600 bit/s	100 bit/s	< 40 km	yes	Random	12 Byte	IPv6 IPv6 / 6Lo

Selection criteria

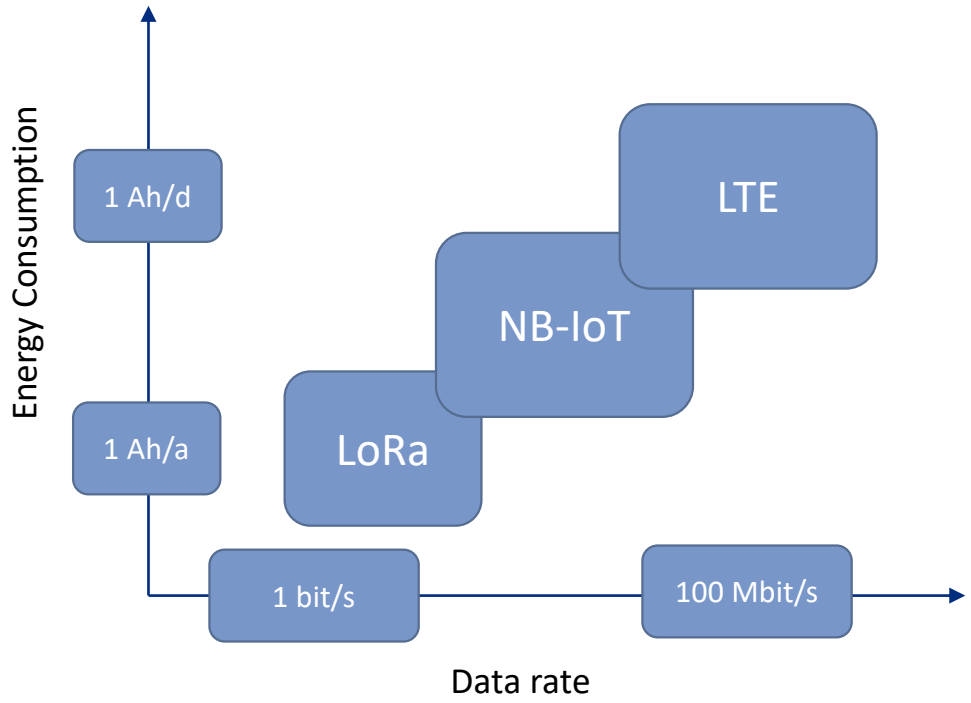
Positioning:	Range, Topology
Delay:	Data rate, Packet size, Medium access probability, distance between nodes
Fairness:	depending on medium access scheme
Scalability:	handle large amount of data / nodes
Cost:	for own infrastructure or licenses
IP Support:	required to access nodes directly via the Internet

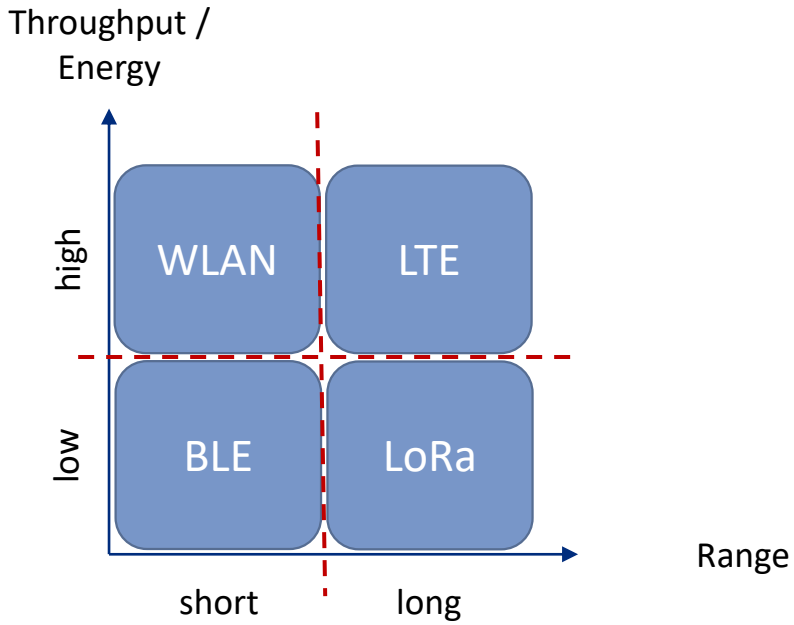
Ad-Hoc Network Topology

- Star
  - one node as coordinator
- Peer-to-Peer
  - Mesh like topology
- Cluster-Tree
  - Connecting multiple Peer-to-Peer-subnets via a node as ClusterHead



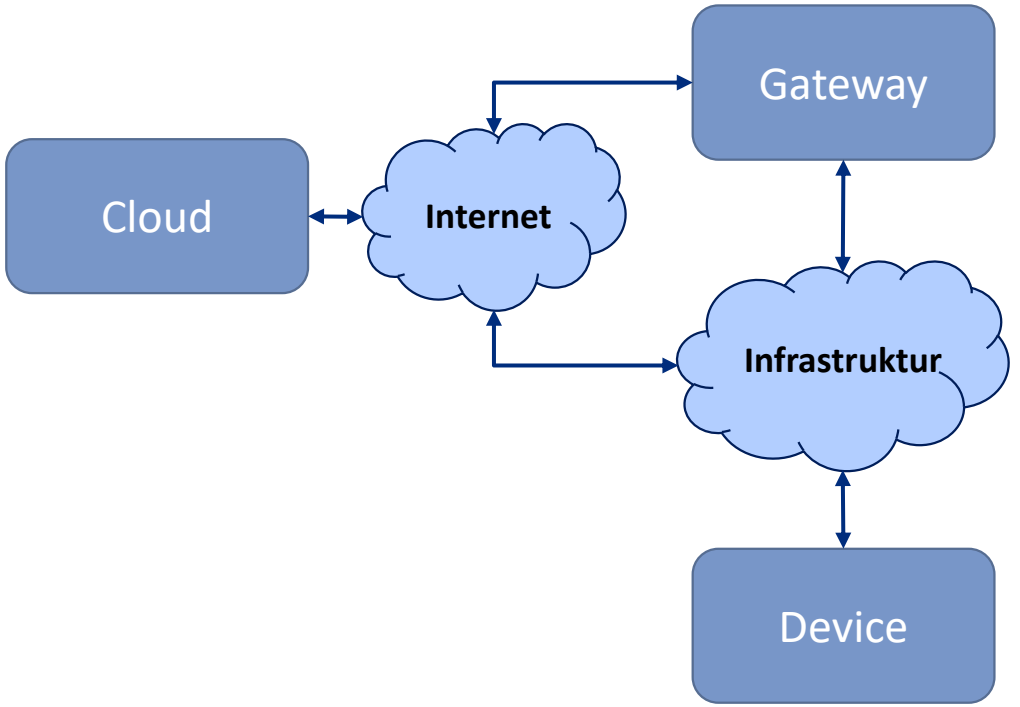
Vergleich der Technologien





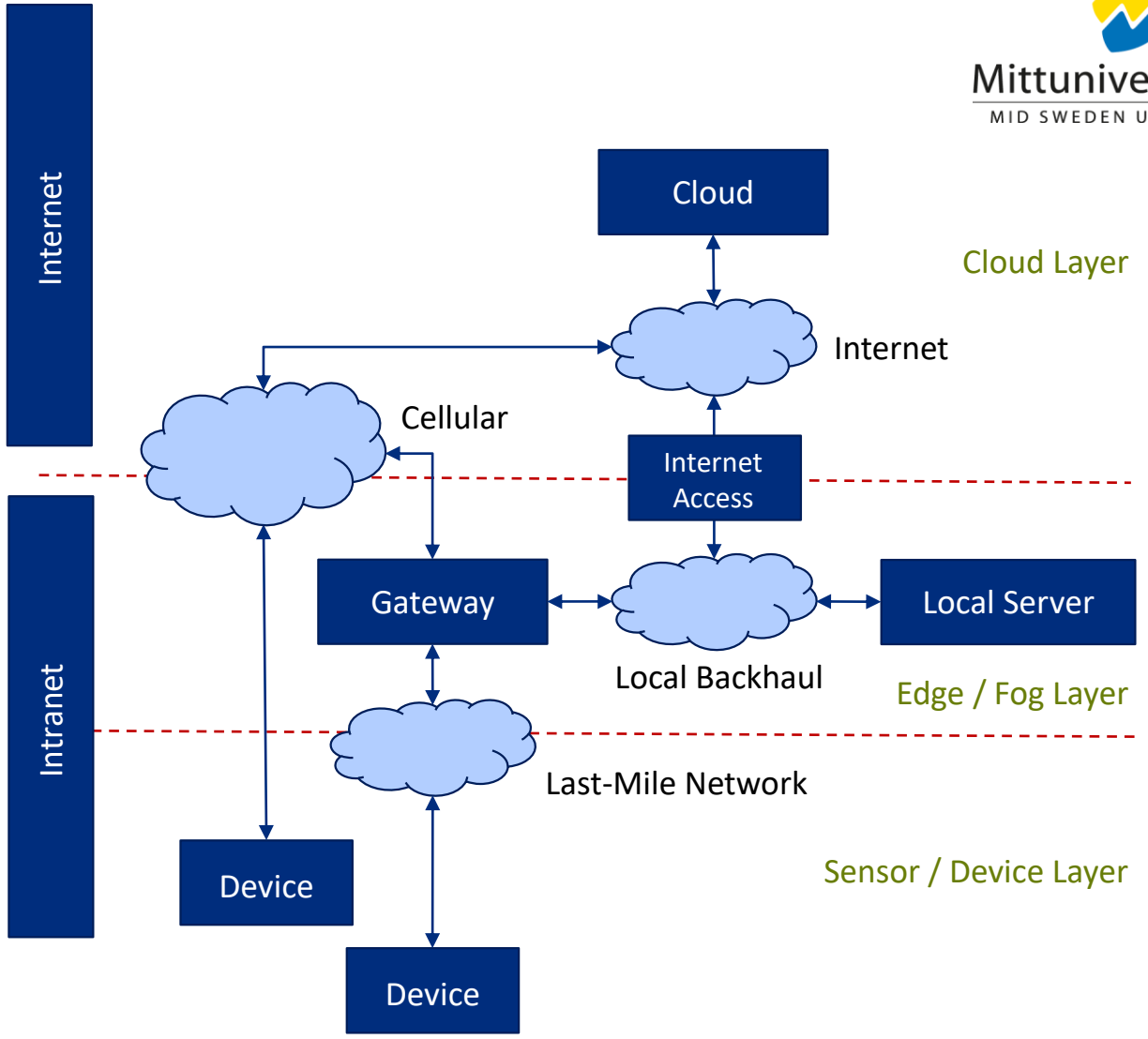
Infrastructure-based Technologies

- NB-IoT
- LoRa
- SigFox

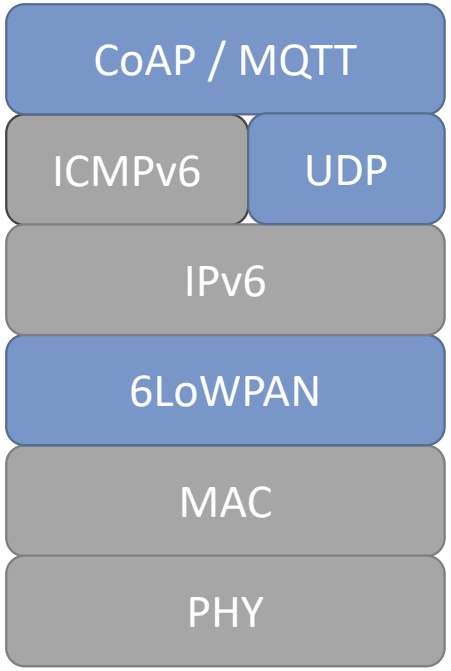


Overall System – Network Perspective

- Distributed system with
  - Multiple functional layers
  - Multiple nodes in each layer
  - Different network technologies
  - Different deployment options
- Study interests
  - System wide energy / latency trade-offs
  - Deployment options / Feature locations
    - Offloading
    - Energy-Saving / Mitigation
    - Critical Resource Identification

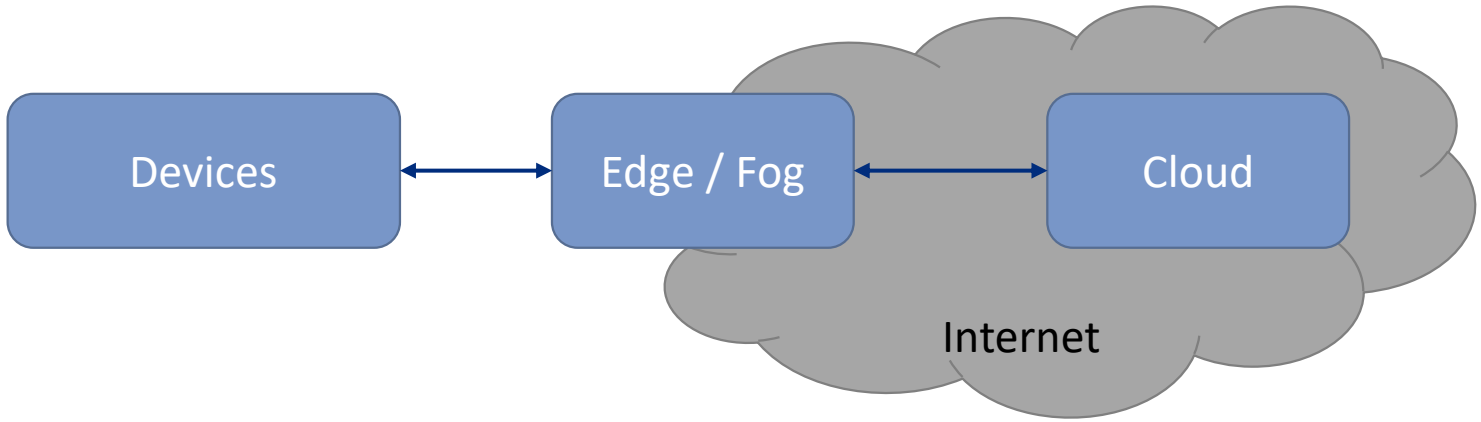


Upper Layer Protocols



Can‘t we use Internet protocols?

- TCP – IP from Edge / Fog to Cloud
- Resource optimizations required for Last Mile
  - IP Header and MTU huge compared to typical PDUs



6LoWPAN – RFC 4944

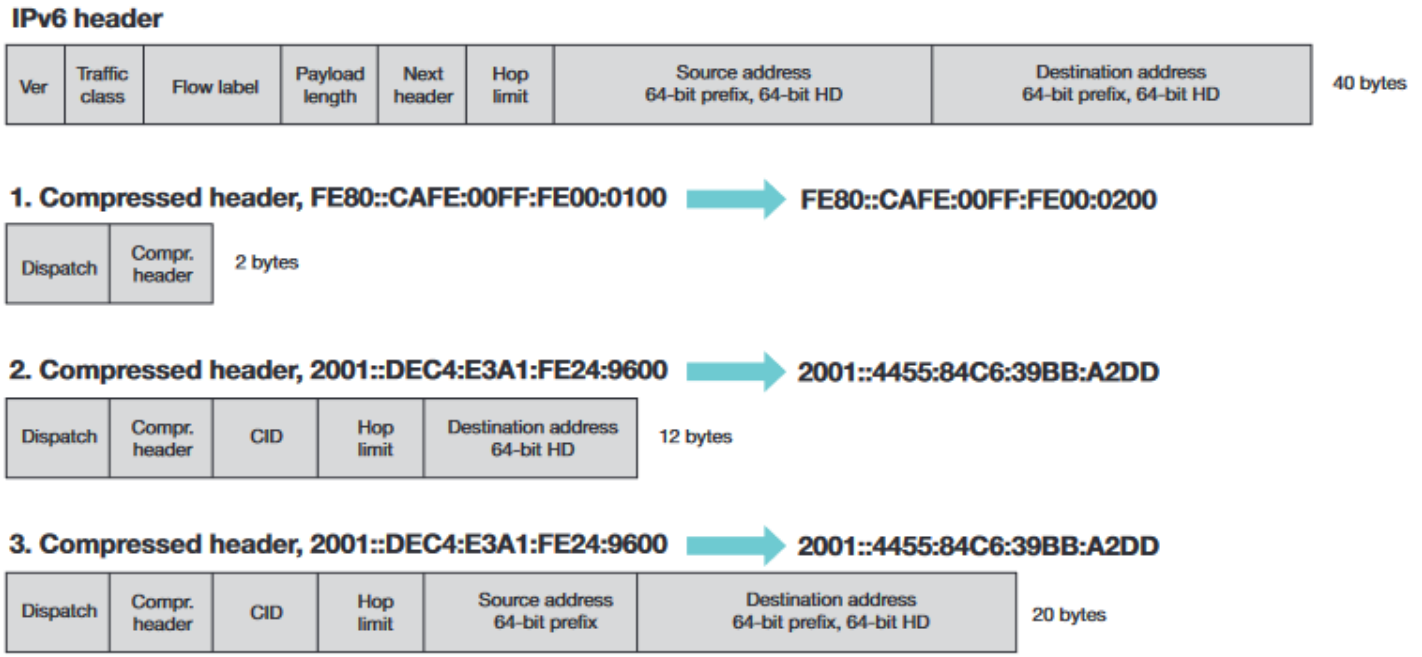
- Adaption layer between IPv6- and MAC layer
  - Enables transfer of IPv6 packets via wireless links
- Originally only for 802.15.4
  - Has been extended to other technologies (marked with 6Lo in the tables)
- 3 Tasks
  - Fragmentation and reassembly
  - stateless autoconfiguration
  - Header compression

6LoWPAN – Fragmentation

- Conflict
  - IEEE 802.15.4 PDU max 127 Bytes
  - IPv6 MTU max 1280 Bytes
- Fragmentation
  - IPv6 packets too big for single 802.15.4 packet
  - first fragment: datagram size (11 bits) and Tag (16 bits)
  - further fragments: datagram size (11 bits), Tag (16 bits) and Offset (8 bits)
- Reassembly
  - within 60 s

6LoWPAN – Header Compression

- Different options depending on requirements
  - 2 Byte – if in the same 6LoWPAN-network
  - 12 Byte – in external 6LoWPAN network, if prefix is known
  - 20 Byte – in external 6LoWPAN network, if prefix is unknown



Routing

- Goal: Find paths via a network

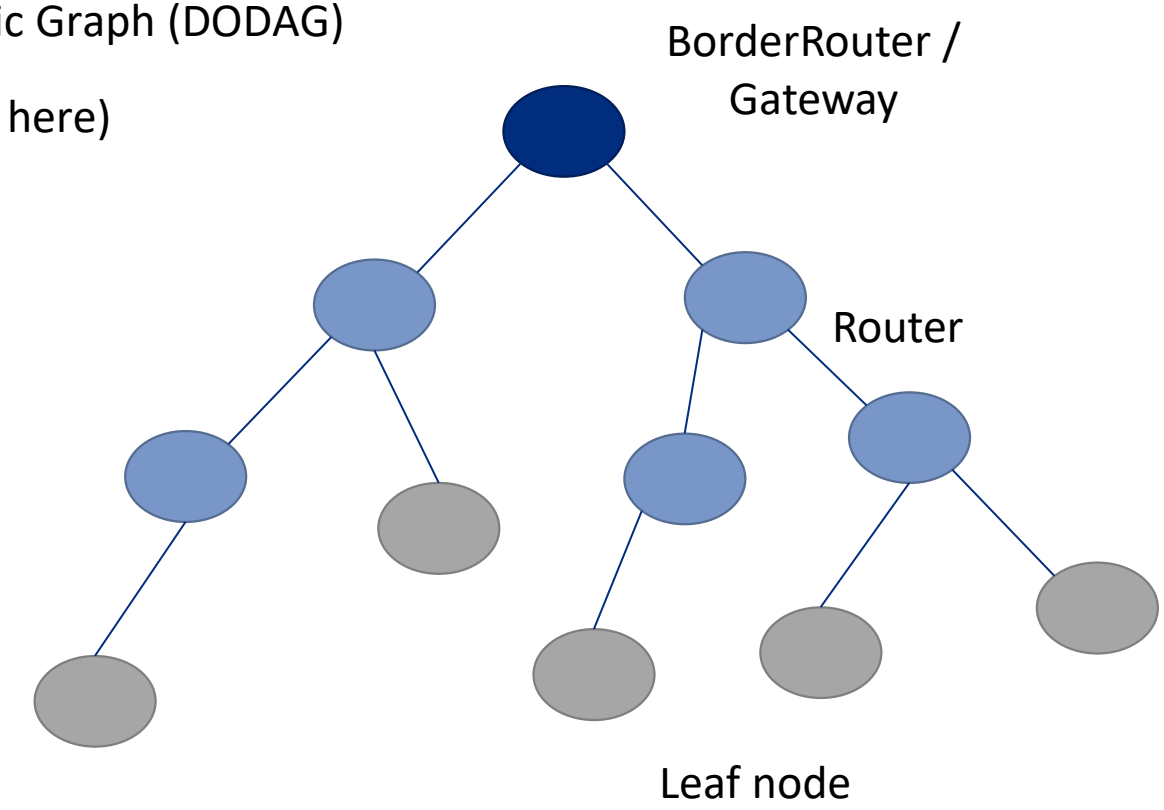
- Topology –> Connectivity –> Network graph
  - Who can communicate whit whom?
- Routing –> Define routes and select paths –> Subgraph
  - Which connections / links are actively used?
- Forwarding of packets
  - Which node receives the packet next?

Routing – Challenges in IoT networks

- Network graph not known a priori
  - Dynamic changes
  - Asymmetric links
- Lossy and instable connections
  - Low data rates
  - High packet loss
- Spatial positions partially relevant (measurement points)
  - Range of nodes not a simple function of distance between nodes
- Compared to the Internet different traffic patterns
  - Multi point-to-Point
  - Point-to-Multi point
- Potentially high number of nodes

RPL (RFC 6550)

- IPv6 Routing Protocol for Low-Power and Lossy Networks
  - Distance Vector, Source Routing
- Organizes Subgraph as Destination Oriented Directed Acyclic Graph (DODAG)
  - one root node (often the gateway, called BorderRouter here)
  - builds tree like structure to leaf nodes
- Rank as Metric
  - Position of a node in relation to the root
  - Closer to the root => small rank
  - further away => high rank



UDP as Transport Layer Protocol

- Properties of UDP
  - Unreliable, connection-less transfer
  - allows Broadcast and Multicast
  - often for streaming, VoIP and similar services
- In IoT we want reliable data reception
  - How can one achieve this using UPD?

UDP as Transport Layer Protocol

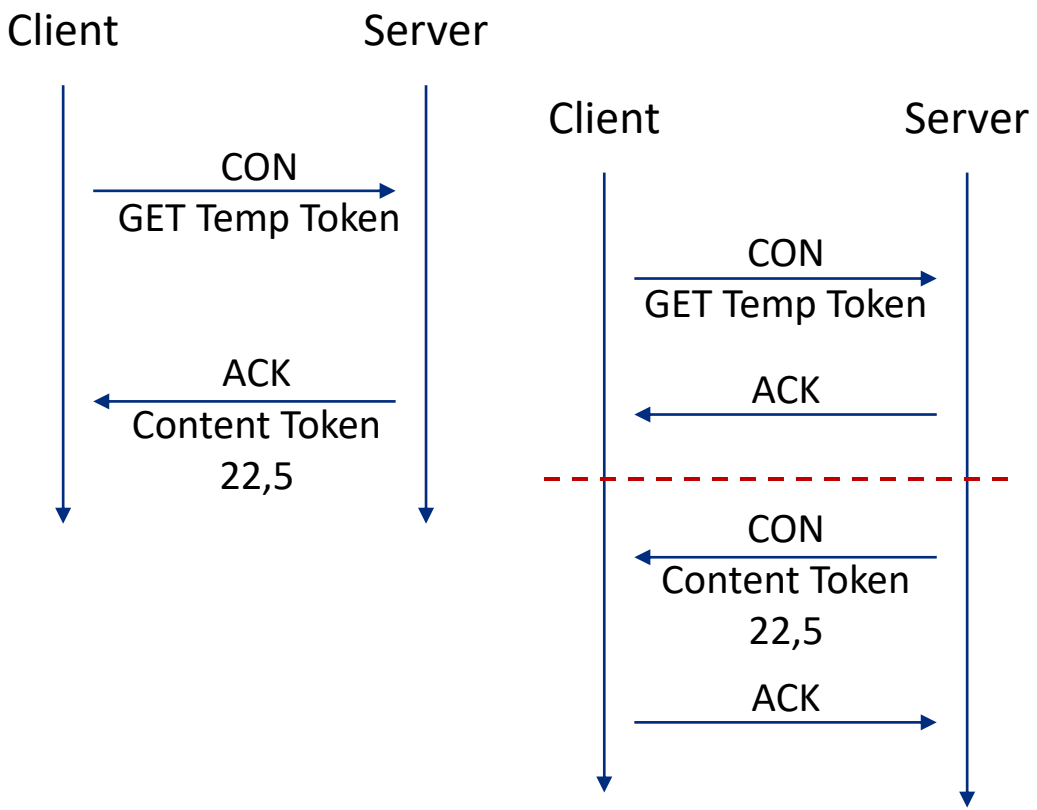
- Integrate mechanisms for reliability into the application layer
  - Sequence numbers
  - Confirmations / Acknowledgements
  - Repetitions

  ➢ Effort for reliability moved to another layer

- Employ mechanisms of the MAC Layer only
  - e.g. ACKs in 802.15.4

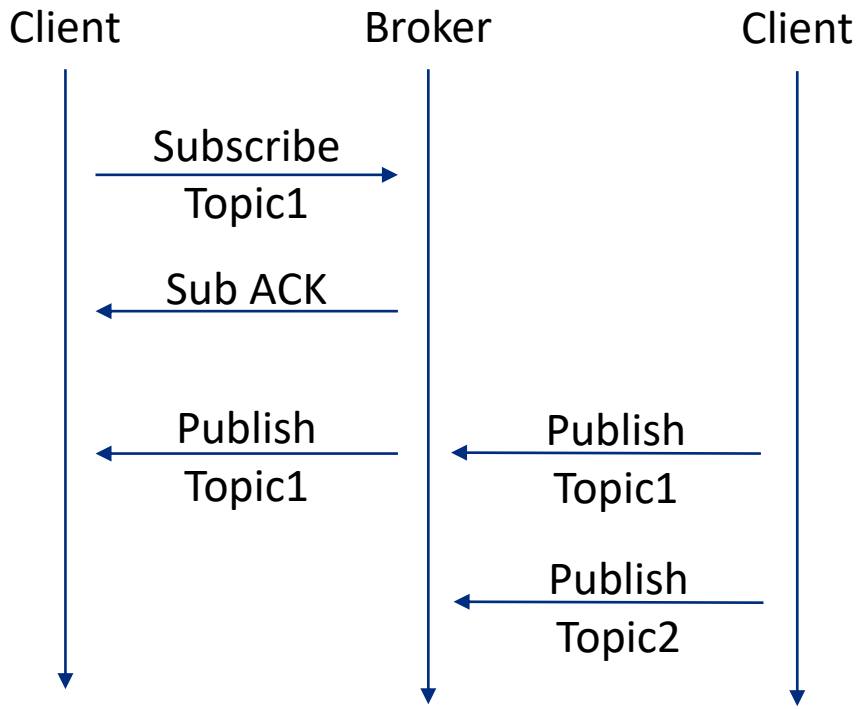
CoAP – RFC 7252

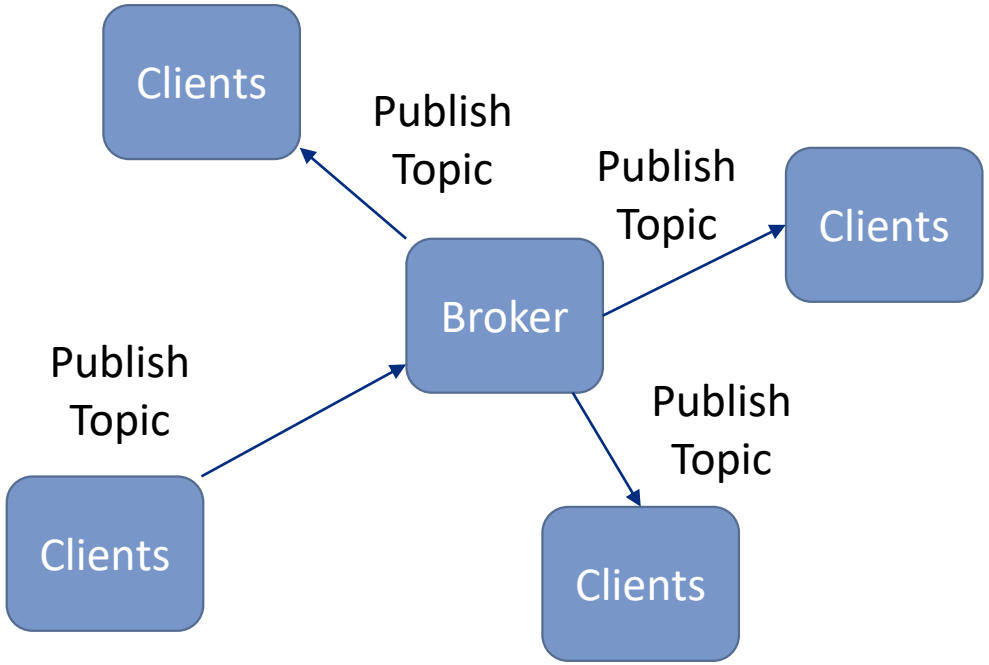
- Constrained Application Protocol
- Request–Response Schema
  - Asynchronous
  - assignment via tokens
- Reliability mechanisms required
  - Stop-and-Wait repetition with exponential backoff
  - Duplicate detection



MQTT - Message Queue Telemetry Transport

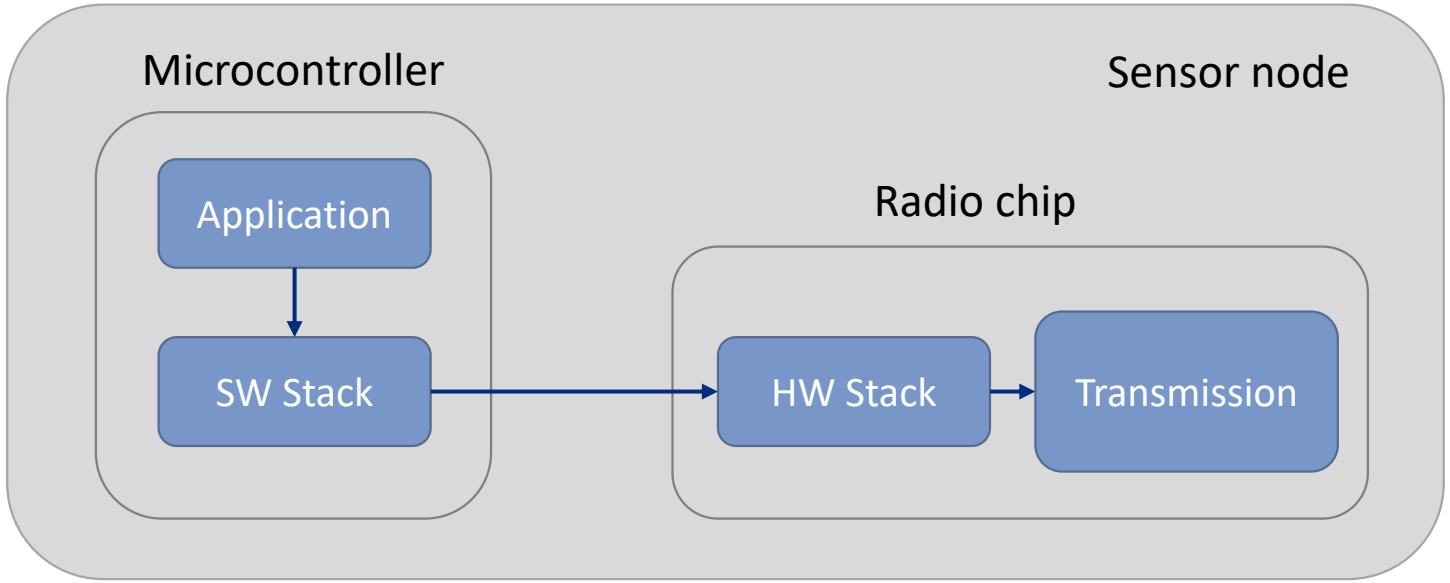
— Publish-Subscribe Scheme



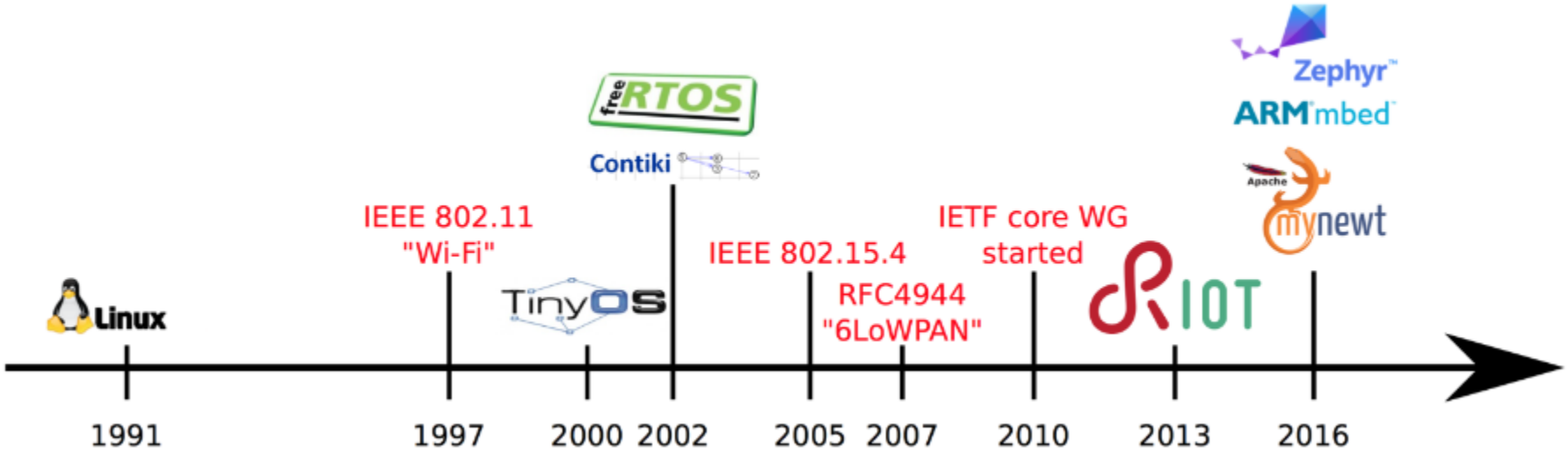


IoT Node Operating Systems - Überblick

- Why do we need to consider operating systems?
- Latency affected by
  - Processing of data
  - Transport to the actual transceiver and
  - the actual transmission



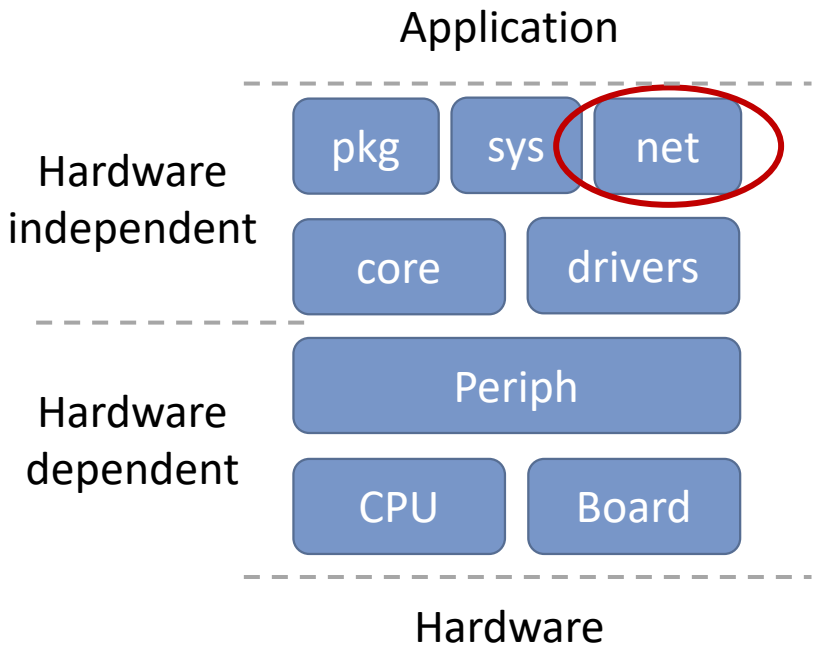
Many Options

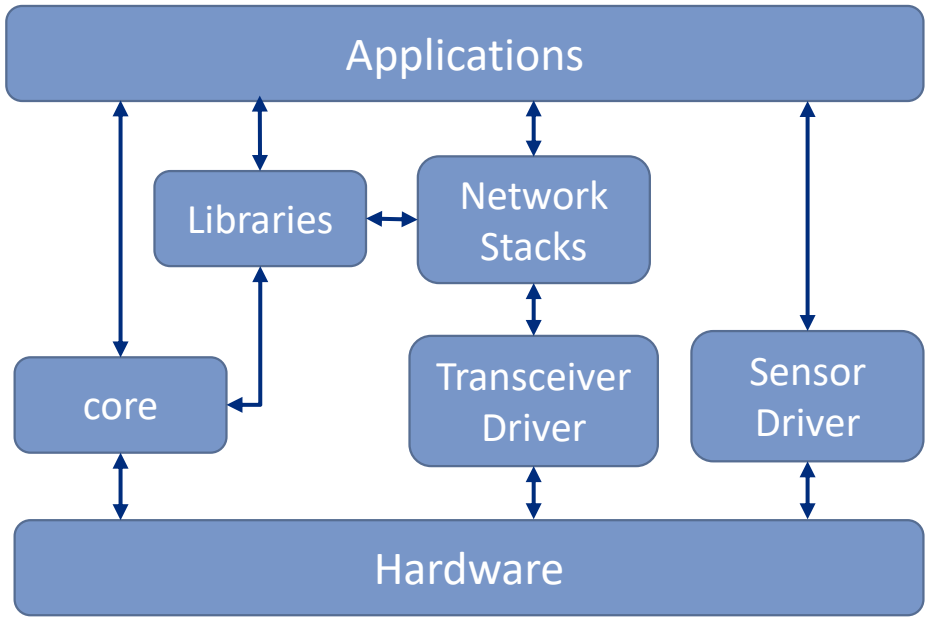


Selection Criteria – Operating Systems

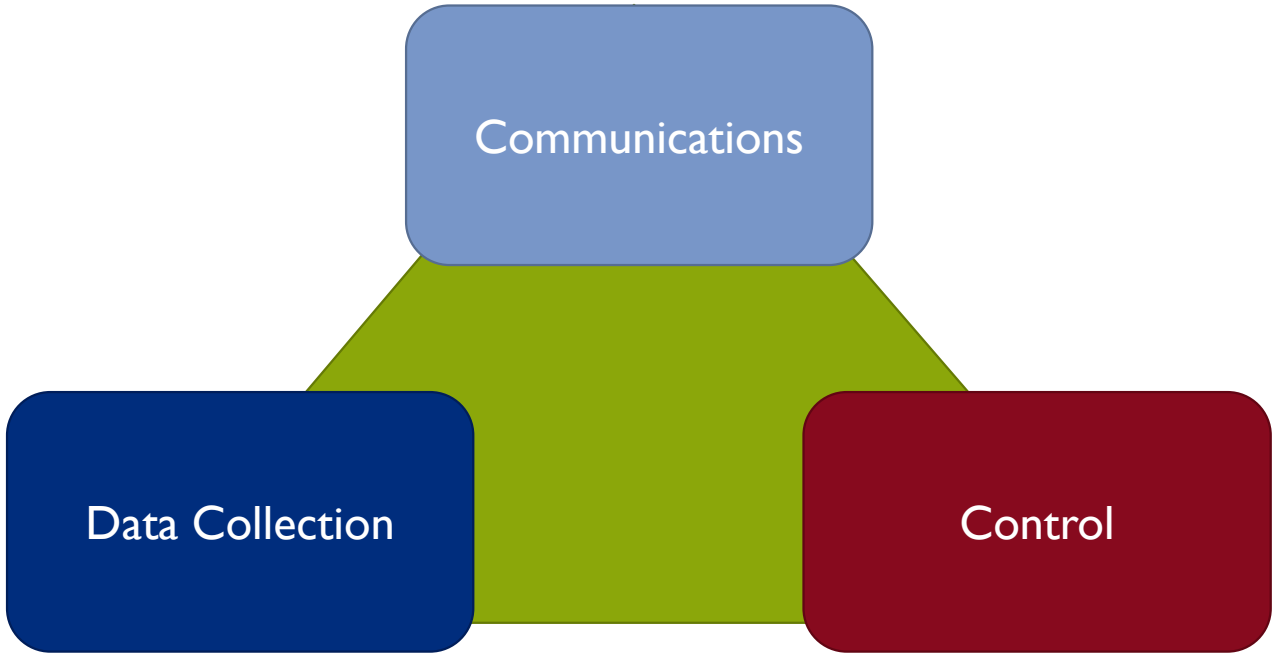
- Actuality
  - Is recent Hardware supported?
  - Are there frequent updates?
- Protocol availability
  - Are the required protocols already provided?
- Development effort
  - How difficult is it to implement custom functions?
  - How well are features documented

Structure – RIOT OS





Trade Offs



Application Requirements

Application	Sensor	Allowed delay	Measurement interval	Period
Monitoring	Vibration	s	s - d	60 s 10 s
	Temperature	ms	5 s	5 s
	Gas	ms	1 s	1 s
Control	Pressure	ms	10 – 500 ms	0,5 s
	Flow	ms	10 – 500 ms	0.1 s
	Proximity	ms	10 – 250 ms	0,25 s
	Valve	ms	10 – 250 ms	0,05 s
	Motor	ms	10 – 250 ms	0.01 s

Duty-Cycle – Impacting factors

- Energy
  - Activity of System components
  - Sleep-Current
- Data amount
  - How many Sensors?
  - How often measure and send?
  - Protocol overhead

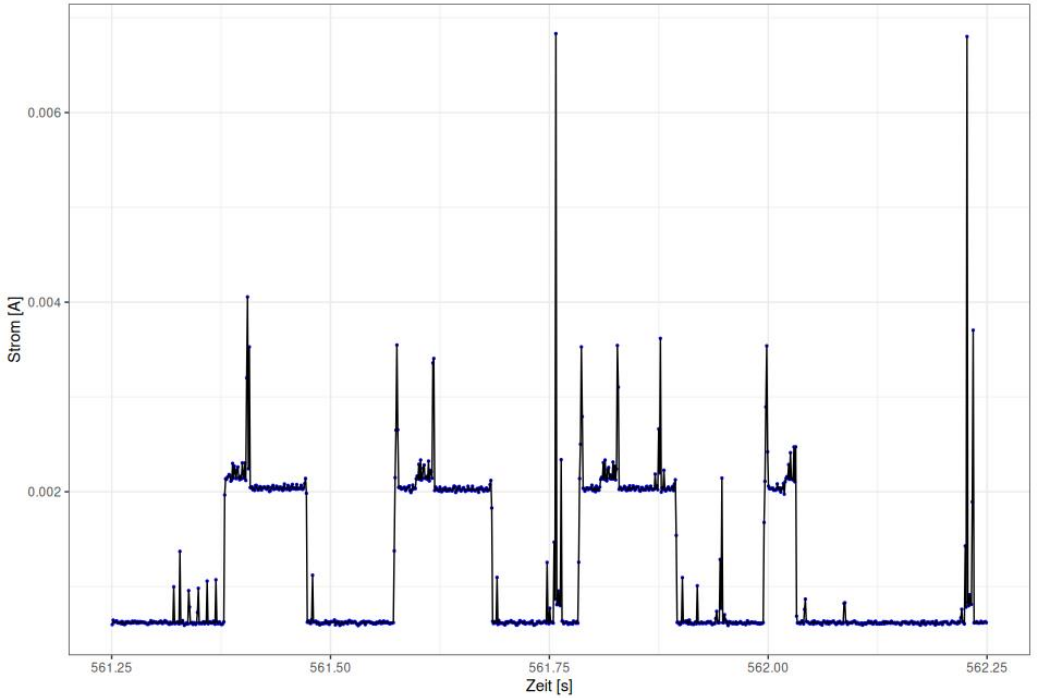
} Application data

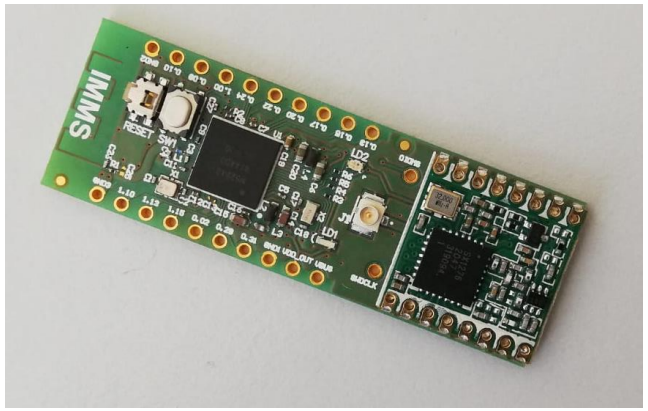
- Delay / Latency
  - Media Access
  - Data amount
  - Processing time

➢ Data rate

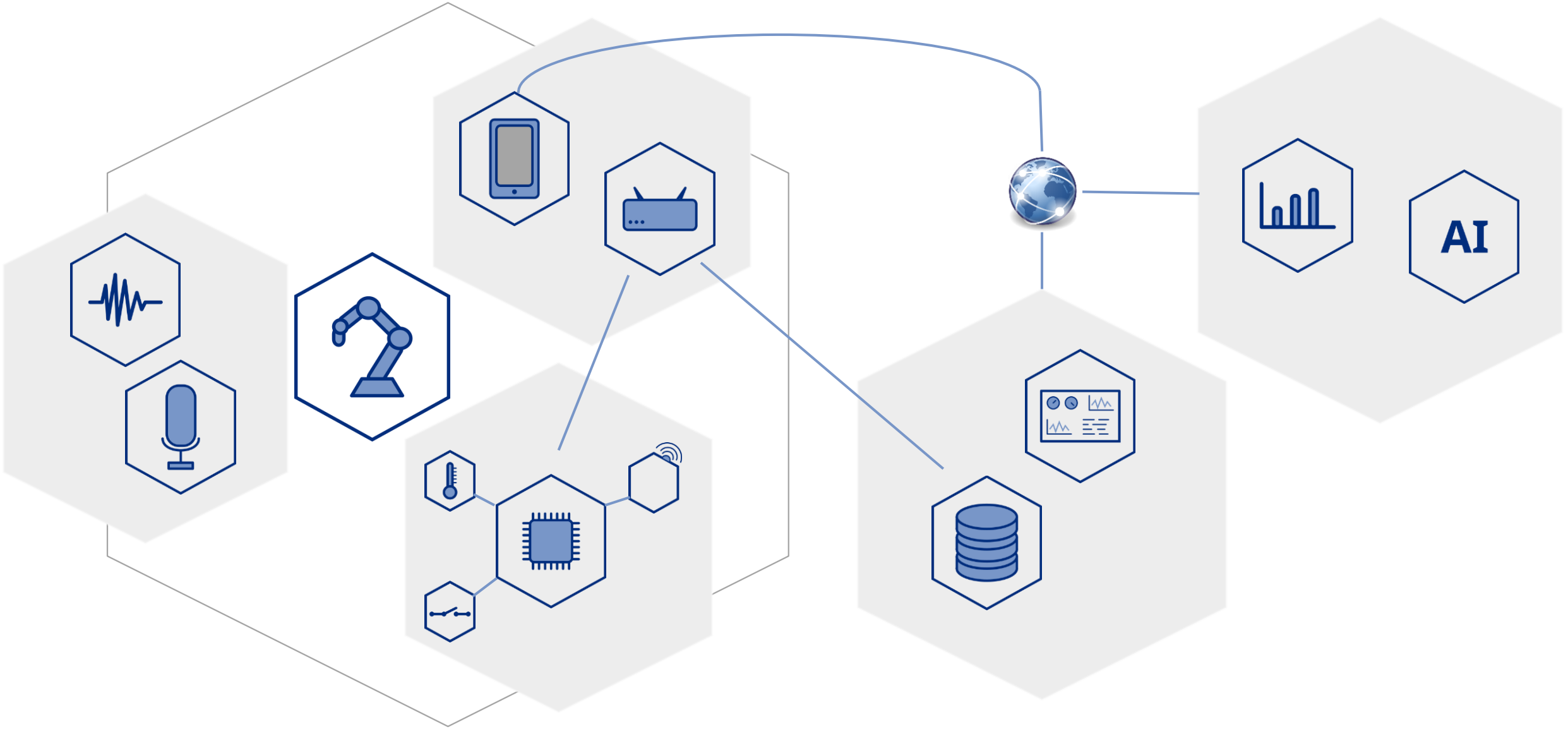
Energy-efficient communication – Where is the Energy consumption?

- Transceiver
  - Properties -> Current Consumption
  - Configuration -> TX-Power, Operation modes
  - Activity duration -> Data Amount
- Data Amount
  - Payload
  - Sending-Scheme of the application
    - How often do we transfer?
  - Protocol overhead





Intelligent Sensors – Where can the intelligence be?



Thank You! Questions?

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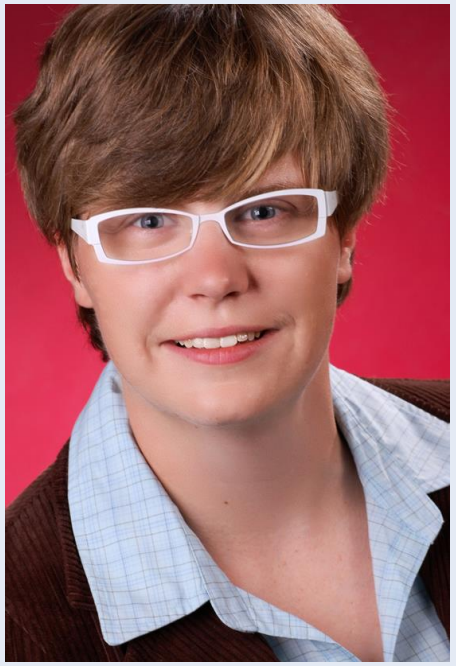

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