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Connectivity

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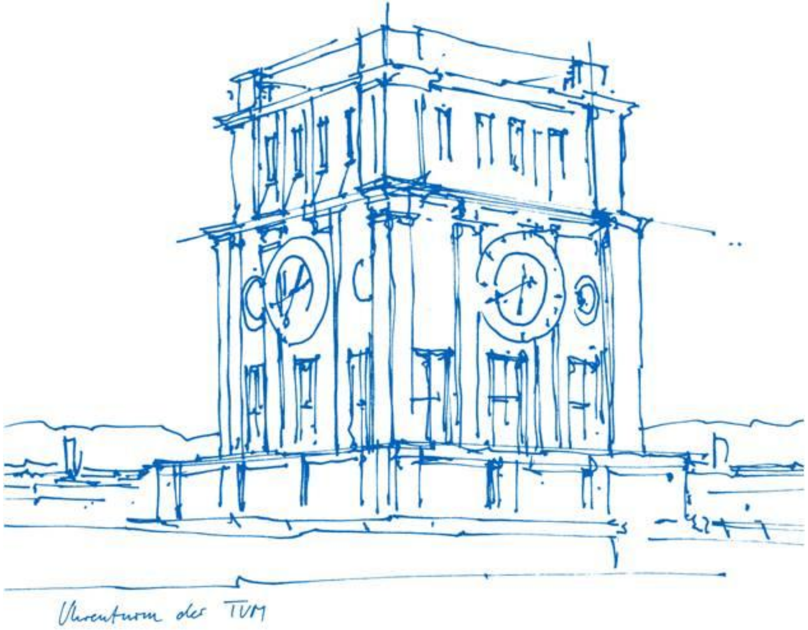

Structure

1. Recap IoT Stack
2. Challenges of Connectivity in agriculture
3. Categorization of networking technologies
4. Examples for networking technologies
5. System comparison
6. LoRa-Deepdive
7. Use-cases in agriculture

Recap IoT Stack

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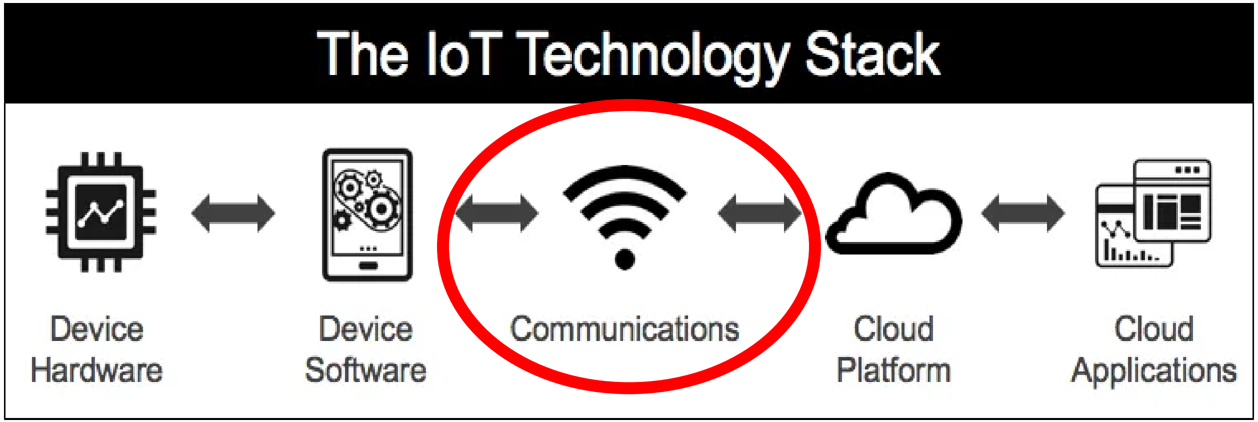
Where today's lecture fits in



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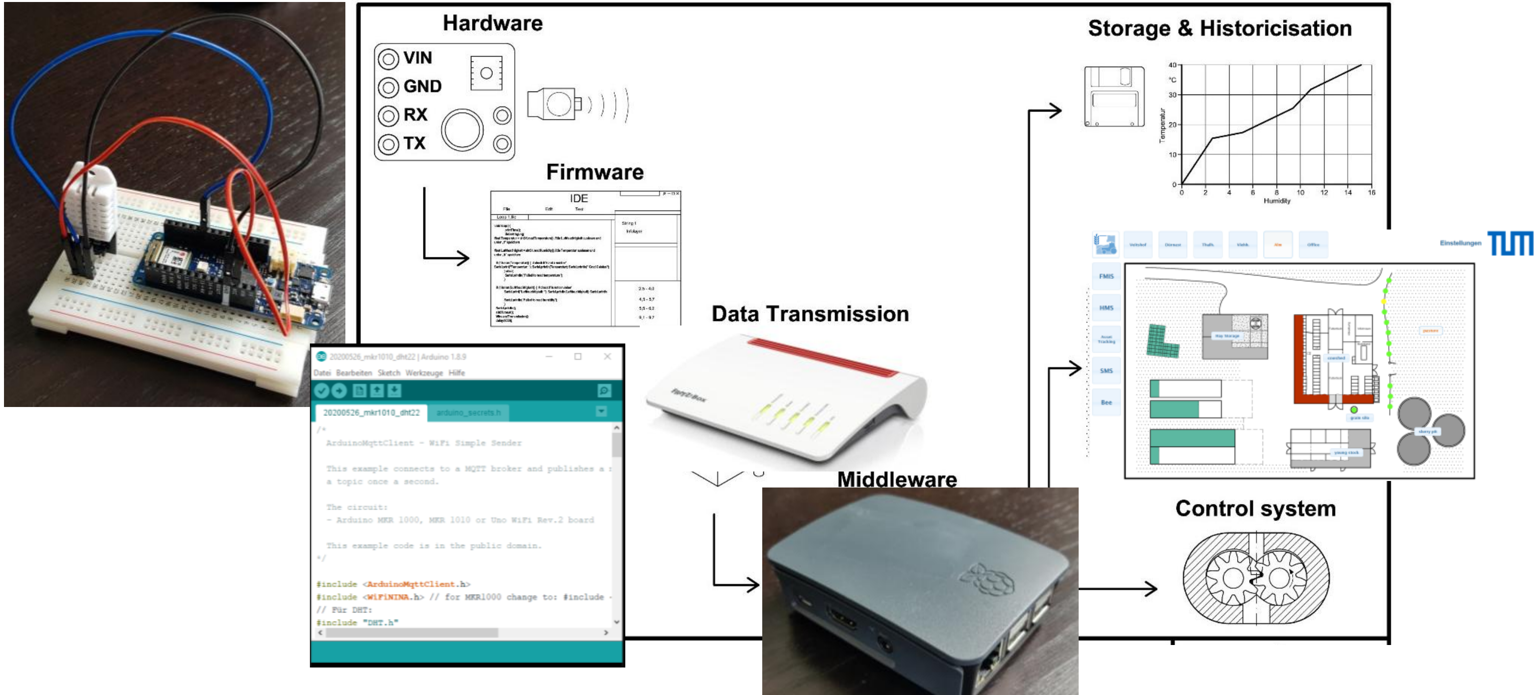
Where today‘s lecture fits in



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Technologies for wireless data transfer

Bluetooth
NB-IoT™
mioty
zigbee
5G
LoRa™
sigfox

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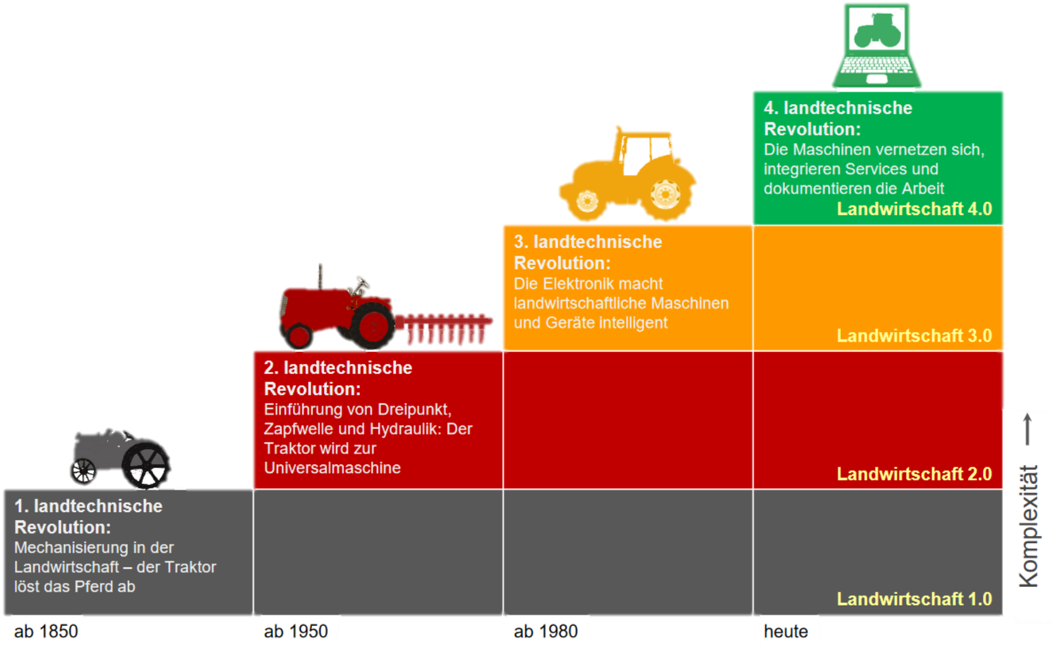
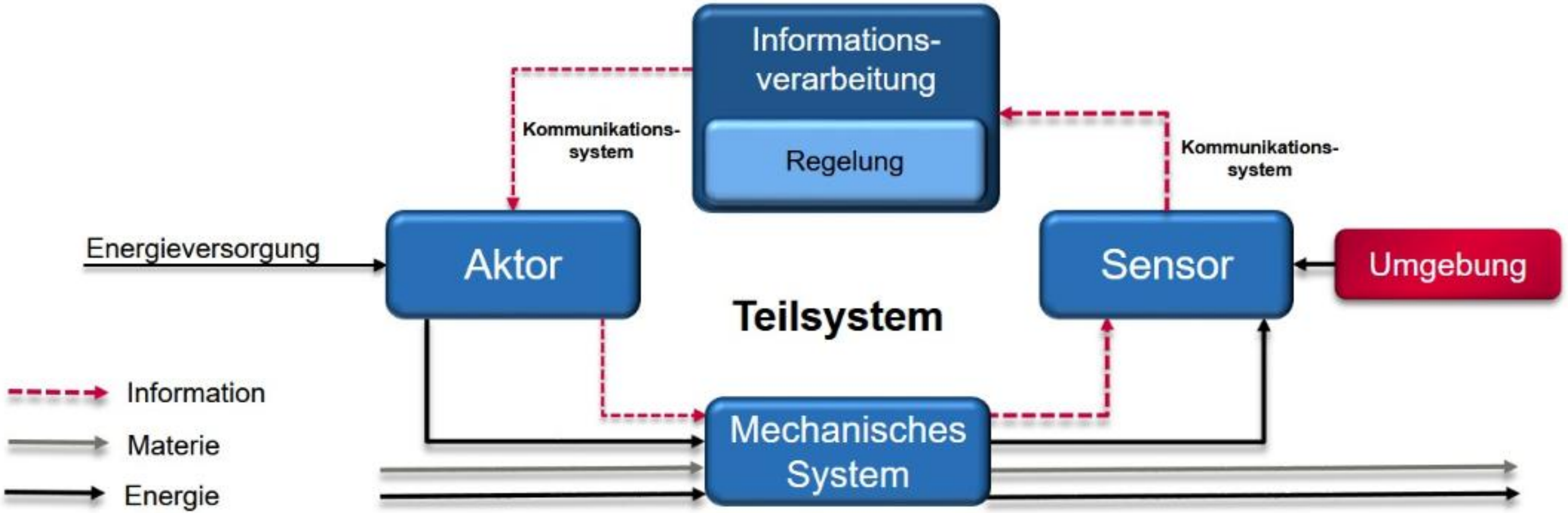
Challenges of Connectivity in agriculture

Landwirtschaft 1.0 - 4.0



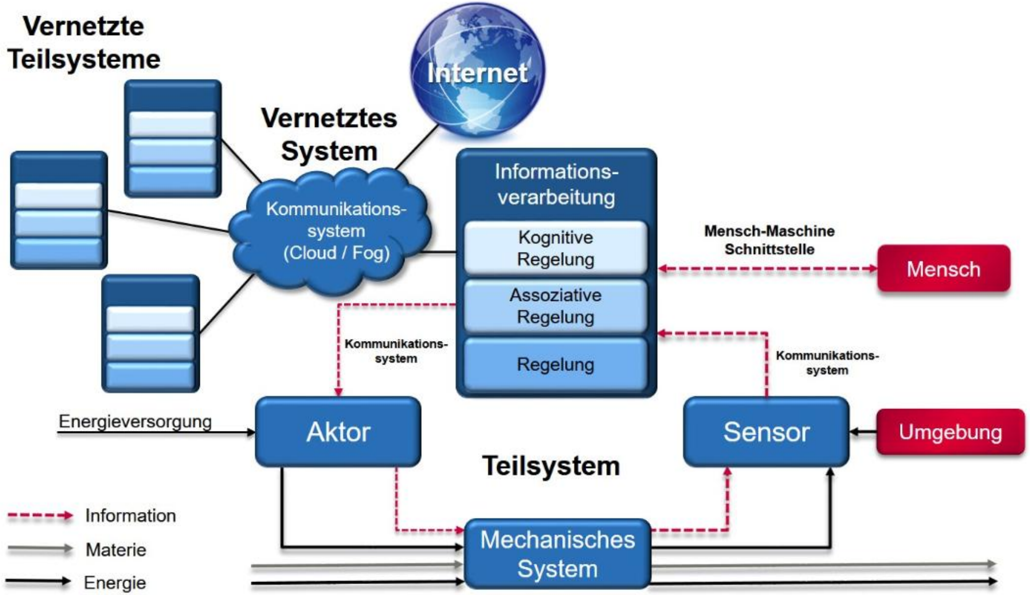
Heinrich Prankl: „Landwirtschaft 4.0“ ÖKL 24.5.2016

Mechatronical systems



Quelle: Züricher Hochschule für Angewandte Wissenschaften (2017)

Cyber-physical Systems



Quelle: Züricher Hochschule für Angewandte Wissenschaften (2017)

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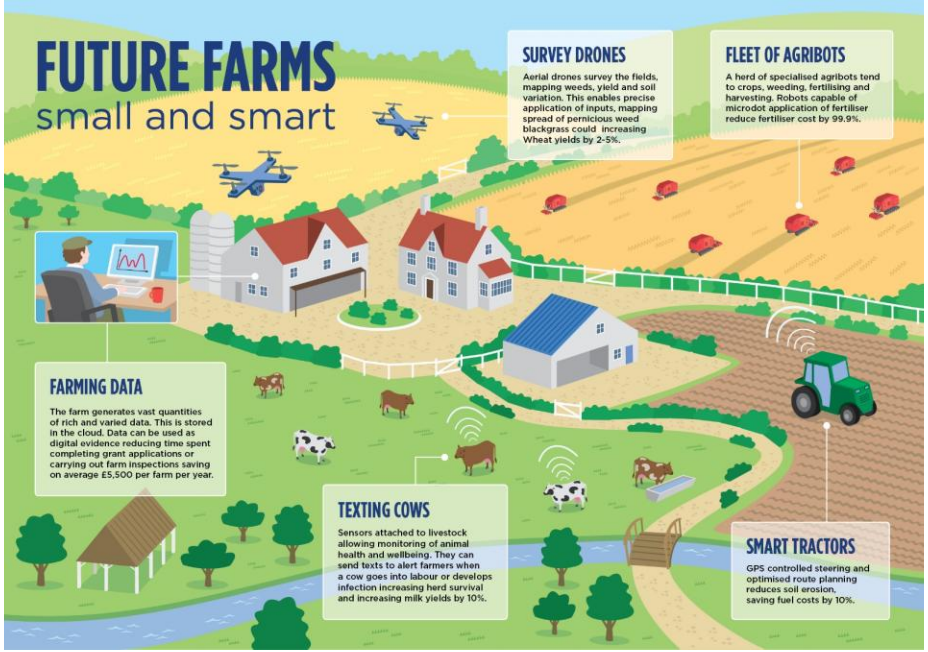
Wireless Data transfer is a necessity for the „Future Farm“



Source: NESTA (2015)

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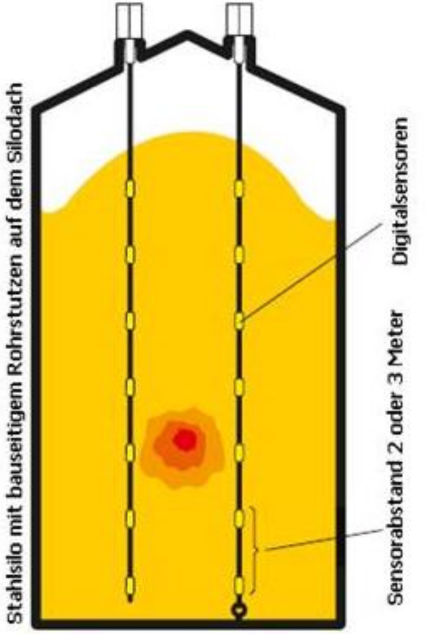
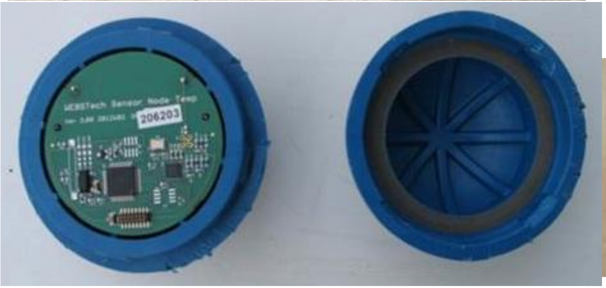
Typical „nodes“ and their Agricultural Environment





Challenges for our wireless sensor networks

Livestock Farming	Crop Farming
dust, dirt, abrasion, vibration	dust, dirt, abrasion, vibration
high humidity	weather (sun, rain…)
corrosive environments	extreme temperature changes
animal's urge to play	high external forces (vibration, pressure, impact…)
requirements of different species	heterogeneity of conditions (calibration)
signal transmission despite of big concrete walls, large roofs, interference with metal structures in the barn	**signal transmission** (through surrounding biomass, dust, fog, long distances, moving machines)
energy supply (long term attached-to/inside the animal)	**energy supply** (short high intensity campaigns, long storage times)

Political debate

„5 G available at every milk can…"

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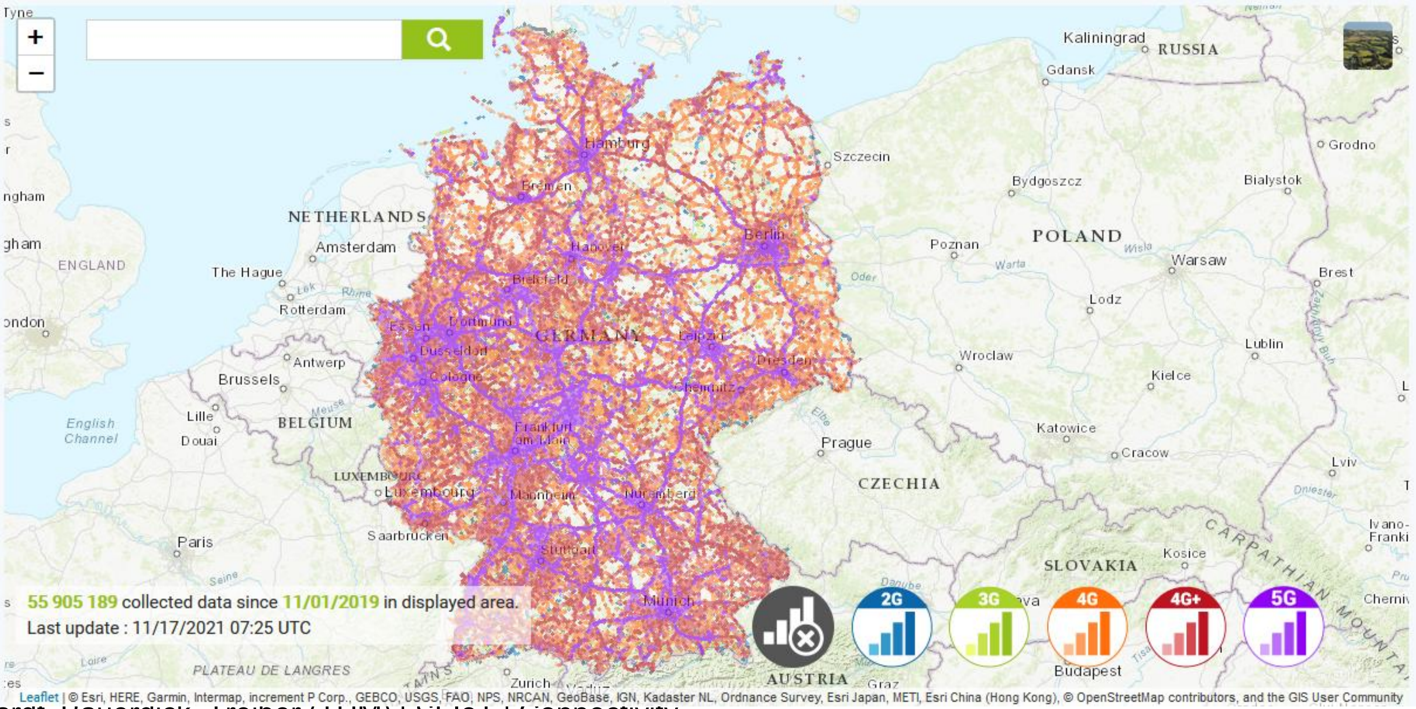
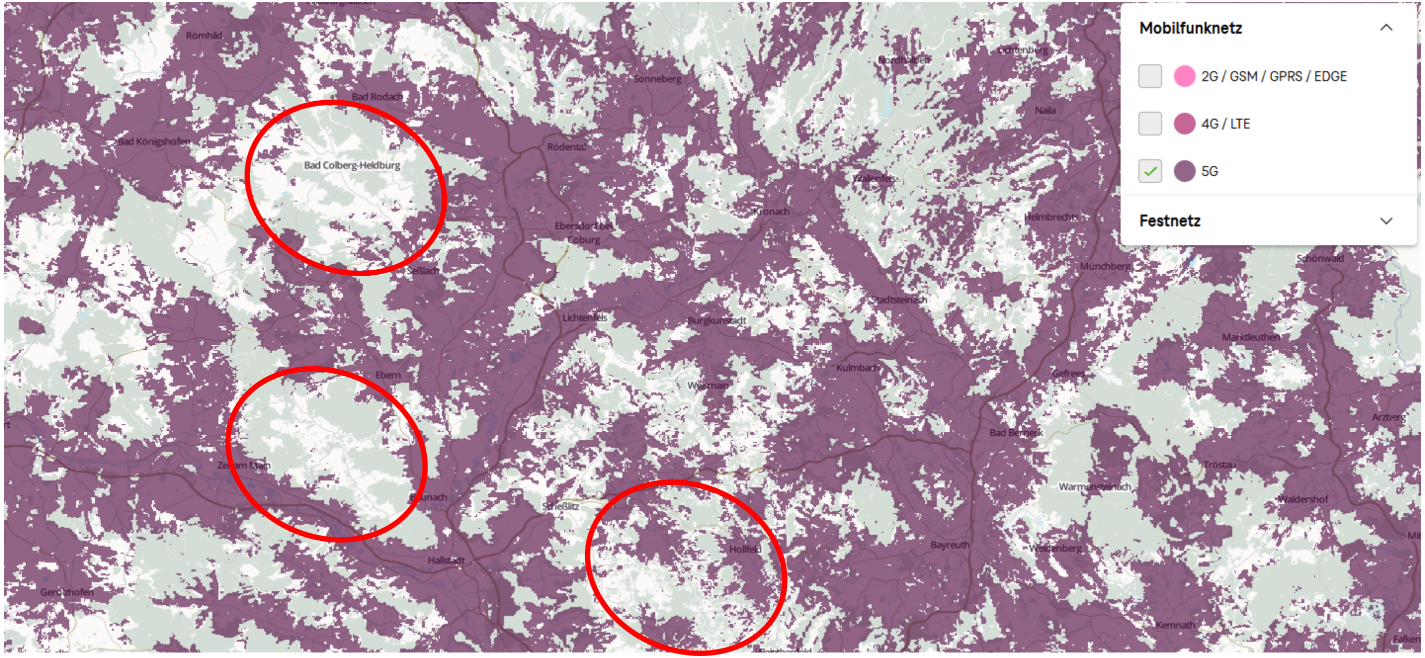
Reality check



Guess where agriculture happens:



Source: Telekom Netzausbau (2021)

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How to solve this?

For IoT in Agriculture we need

the right Connectivity for the desired use-case

in a real-world applicable network-provider structure.

Categorization of Networking Technologies

-

How to choose the right networking technology for my projects?

Definitions & Decision factors

„[While choosing a network technology] it is important to balance range, data transfer rate, latency, data availability and energy consumption.“
(Haenel, 2017)

Term	Definition
range	Maximum distance for successful signal transmission
data transfer rate	(vulgo: bandwidth); amount of data that can be transferred in a defined timeframe over a certain channel
latency	timespan between sending a message and receiving the first bit of the according response at the terminal
data availability	Probability of the network transmitting the desired data in a certain timeframe or on a certain point in time
energy consumption	Requirements of the network and the participating units in regard to energy supply

Categories of networking technologies

	Local Area Network (LAN)	Low Power Wide Area Network (LPWAN)	Cellular network
advantages	• Established standards • Wide adoption • High data-rates	• Low energy consumption • Low cost • Easy to build own network (rel. High range)	• Good coverage available • High data rates
shortcomings	• Low range • High energy consumption • Partly high cost & manufacturer dependence	• Low data rate • Standards still under development • Network provision more difficult than one might think	• Provider dependence • Total cost of ownership (subscription fees)
examples	Bluetooth, zigbee, WiFi	LoRa, Sigfox	GSM, 3G, 4G, 5G

Network topologies

Network topologies

Low-power wireless technologies support up to five main network topologies:

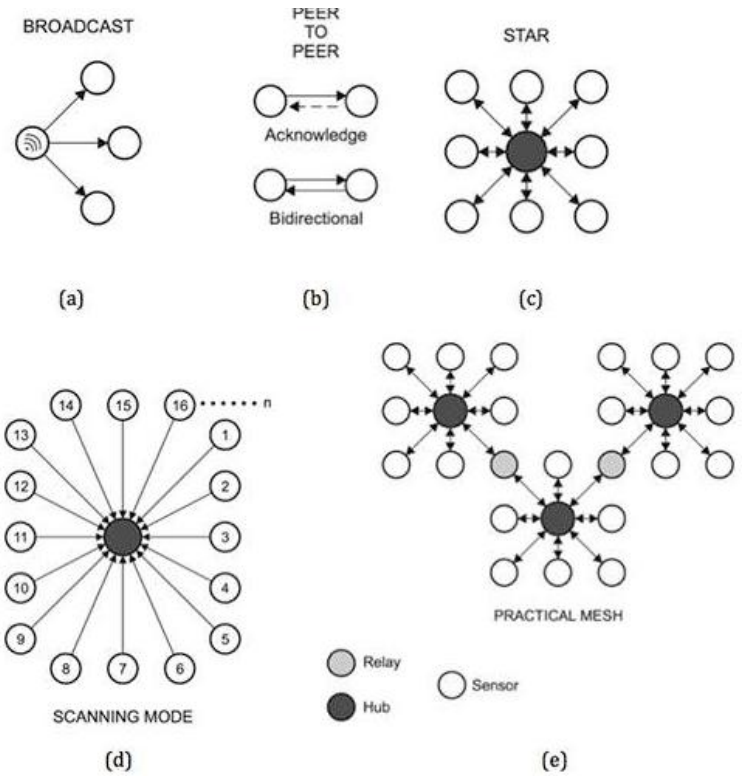
Broadcast: A message is sent from a transmitter to any receiver within range. The channel is unidirectional with no acknowledgement that the message has been received.

Peer-to-peer: Two transceivers are linked on a bi-directional channel whereby messages can be acknowledged and data can be transferred both ways.

Star: A central transceiver communicates across bi-directional channels with several peripheral transceivers. The peripheral transceivers can't directly communicate with each other.

Scanning: A central scanning device remains in receive mode, waiting to pick up a signal from any transmitting device within range. Communication is in one direction.

Mesh: A message can be relayed from one point in a network to any other by hopping across bi-directional channels connecting multiple nodes (typically using the services of nodes with additional functionality such as hubs and relays).



Quelle: Digikey Electronics (2017)

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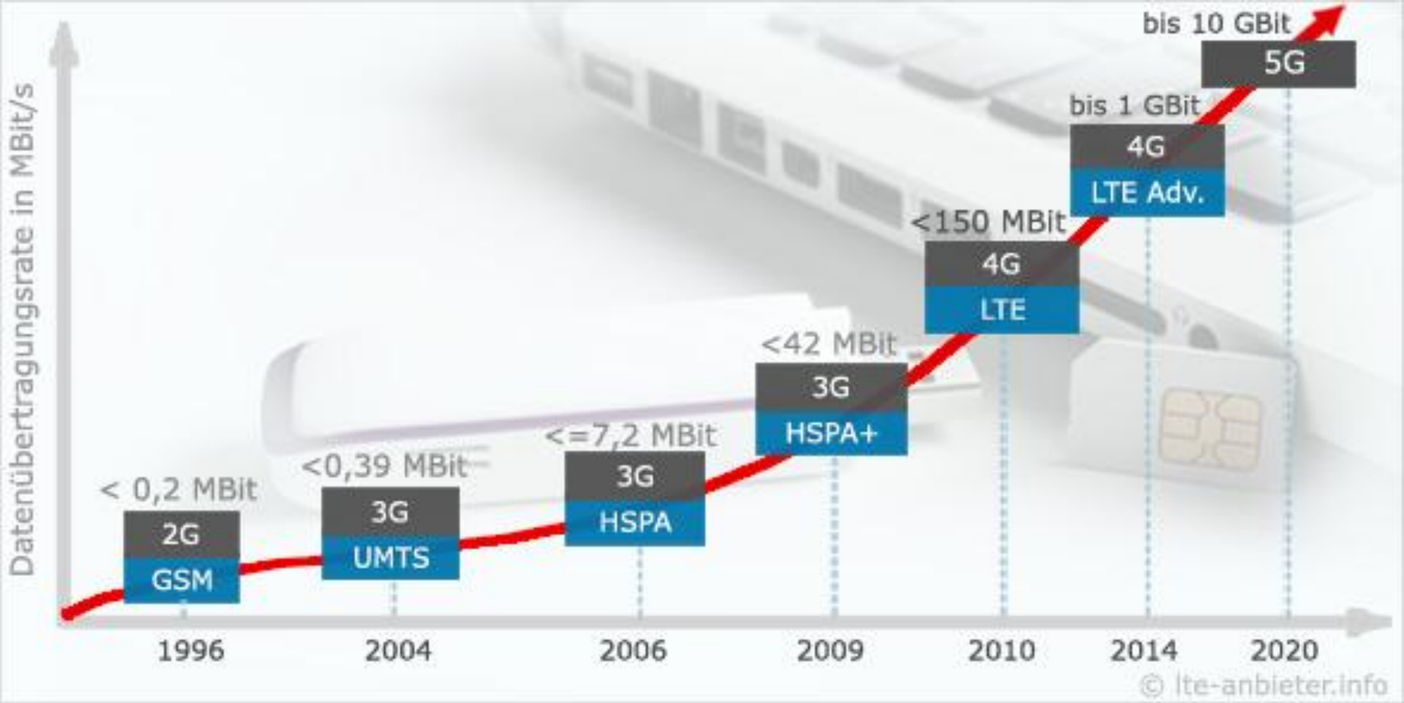
Spotlight on important networking technologies

History of cellular network in Germany



Quelle: lte-anbieter.info (2018)

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WiFi

- High data rates in up- and download
- For short distances only (up to 100 m – read: around the farm main building)
- Bad penetration of building structures (walls/ceilings/roofs)
- Ubiquitous availability on most end devices
- High energy consumption
- Mostly used for high-speed access to the internet

Bluetooth

- High data rates in up- and download
- Data transmission over short distances (up to 30 m – read: close proximity to operators smartphone)
- Bad penetration of building structures (walls/ceilings/roofs)
- Ubiquitous availability on most end devices
- High energy consumption (exception Bluetooth low-energy devices)
- Mostly for data transmission of nodes and mobile devices with each other

zigbee

zigbee

- Low data-rates
- Short distances (up to 100 m)
- Medium penetration of building structures (Walls/ceilings)
- Good security standards
- Good proprietary and well integrated smart home solutions available
- Low energy consumption (long term battery powered nodes possible)
- Mostly in integrated smart home solutions

sigfox

- Low data-rates
- Short distances (up to 100 m)
- Medium penetration of building structures (Walls/ceilings)
- Good security standards
- Good proprietary and well integrated smart home solutions available
- Low energy consumption (long term battery powered nodes possible)
- Mostly in integrated smart home solutions

LoRa

- Low data rates (think of an old-school sms)
- High range (**3-5 km no problem** in practice, up to 10 km and more possible in perfect conditions)
- Very good penetration of building structures and biomass
- Data availability limited (messages can be lost)
- Safety standards still evolving
- Modular open-source solution for makers (lots of cheap hardware available, quality is a problem)
- Very low energy consumption (long term battery powered nodes are the norm)
- Many applications in agriculture (well suited for surveillance tasks)

Mioty

mioty

- Low data rates
- High range for long distances (**up to 15 km**)
- Very good penetration of structures and biomass
- Very low energy consumption
- High robustness in comparison to LoRa (better for industry applications, high prices for hardware)
- Developed by Fraunhofer ILS
- Robustness comes from Telegram-Splitting Technology – LoRa loses messages, mioty does not
- -> like LoRa on steroids for professional applications (expensive!)

NB-IoT

- 3GPP-Industry standard
- Substandard of LTE, (so a cellular networking technology)
- Bandwidth limited to a single 200kHz Band
- Can be used with existing cellular network infrastructure (if there‘s LTE/3G -> there also is NB-IoT)
- providers -> no hassle to build own network but subscription fees
- Low data rates
- Very good penetration of structures and biomass
- Very low energy consumption (battery powered nodes!)

System comparison

Technische Parameter	LTE (4 G)	Wi-Fi	Bluetooth	Bluetooth LE	zigbee	LoRa
Frequenz	700/800/1800/2600 mHz	2,4/3,6/5,8 GHz	2,4 GHz	2,4 GHz	2,4 GHz, 868 MHz	433 MHz; 868 MHz
Datenübertragungsrate	LTE: 1 Gbit/s 5 G: 10 Gbit/s	600 Mbit/s	2,1 Mb/s	125 kbit (0,125 Mbit/s)	250 kbit/s	27 kbit/s
Reichweite	< 10 km	32 m (Innen) 100 m (Außen)	5-30 m	Max. 100 m	10-100 m	Ca. 5 km
Energiebedarf	hoch	hoch	116 mA	<15 mA	Peak: 12 mA Normal: 2 μA	Peak: 12 mA Normal: 2 μA
Latenz	2-8 s	1,5 ms	2,5 ms	6 ms	20 ms	1-2 s
Kosten	Hoch (laufende)	Hoch	Mittel	gering	Sehr gering	Sehr gering
Standards	3GPP	IEEE, WECA	Bluetooth SIG, IEEE 802.15.1	Bluetooth SIG, IEEE 802.15.1	Zigbee Alliance, IEEE 802.15.4	LoRa Alliance
Sicherheit	Relativ sicher, gute Standards, Probleme bei Umgang/Kundensoftware	Sicherheitslücken sind bekannt/ Schutzmaßnahmen verfügbar	Riskanter als WiFi	Riskanter als WiFi	Gute Standards, Key Management System	Standard noch in Entwicklung, eigene Lösungen notwendig

Deepdive LoRa

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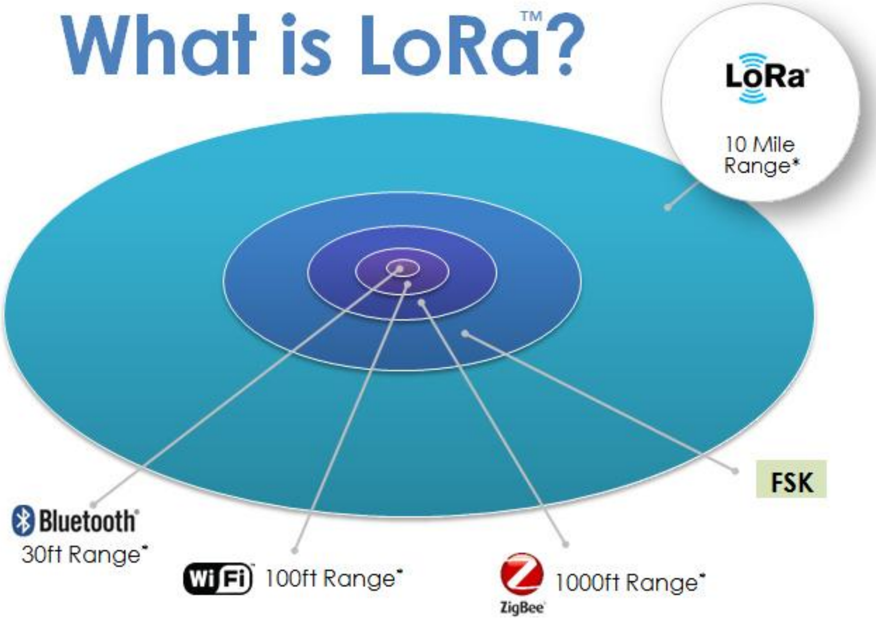
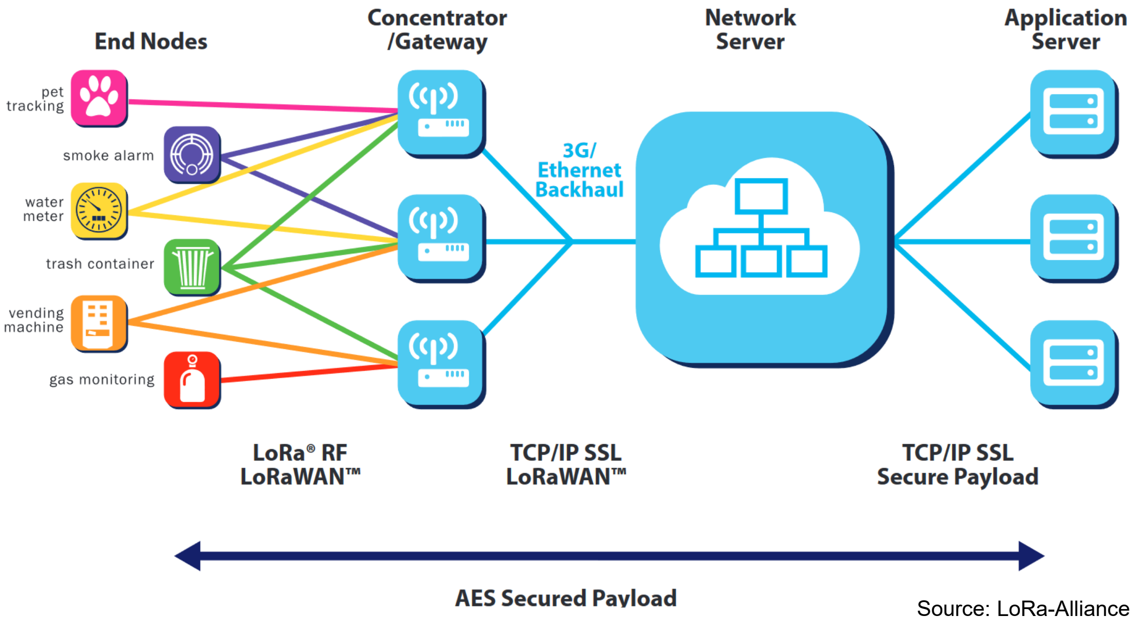
What is LoRa?



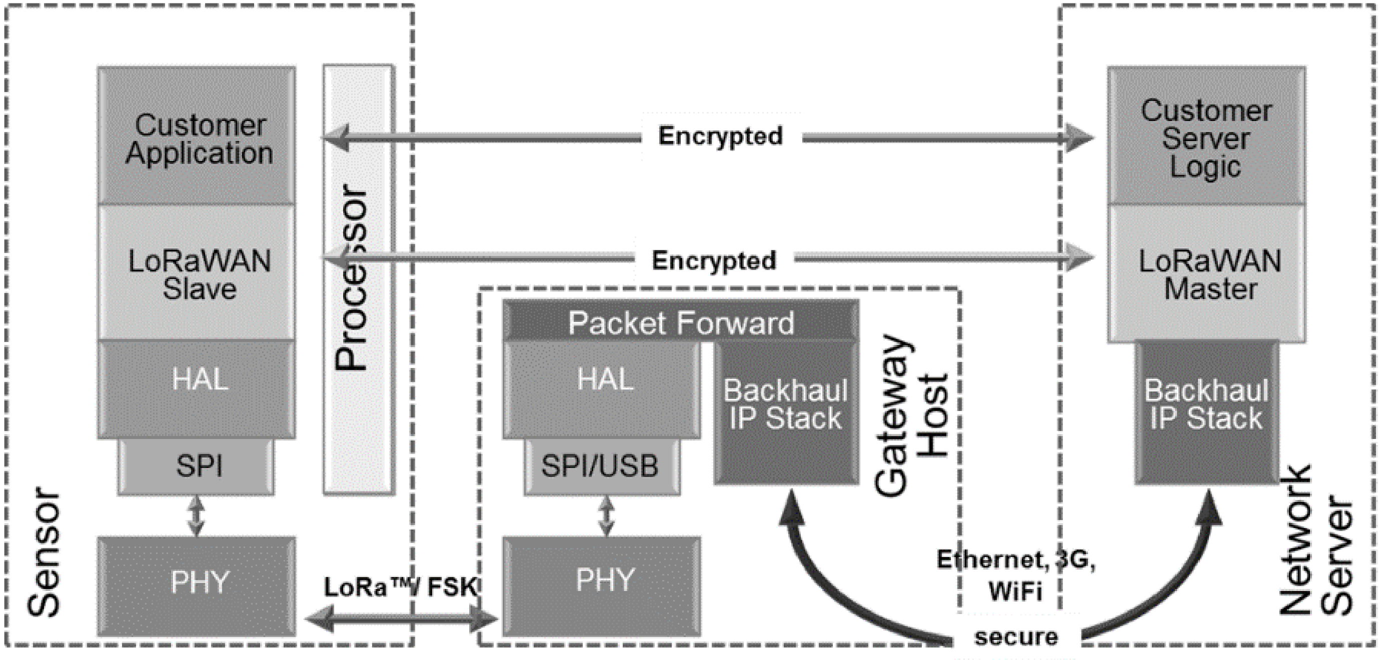
Source: LoRa-Alliance (2015)

LoRa network architecture



Source: LoRa-Alliance (2015)

LoRa Backbone



Source: LoRa-Alliance (2015)

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LoRa Gateway and Nodes

<< 2017 << 2016 << 2015

Excursus: Power Supply

4,50 €

10,50 €

15 €

Excursus: Power Supply

1s lithium-polymer
4,21 €

The all-mighty 18650
(aka „the pocket bomb“)
7,99 €

Excursus: Energy Supply – Power Telegram

- Price & lifespan of Batteries have significant influence to the TCO (total cost of ownership) of a wireless sensor network
- Working time for battery changes must not be underestimated
- Unneccesary disposal of batteries is not environmently friendly!

-> LoRa WAN supports Power Telegram (Battery status of nodes sent in messages)
-> energy-consumption calculators are available
-> plan accordingly: energy supply and maintenance scheme, when designing a wireless sensor network!

LoRa - downsides

- LoRa is just the transmission technology -> additional Sensor Node firmware, Middleware & Cloud Application Software for Data Management & Analytics needed
- When using one LoRa module with multiple sensors -> Middleware/Backend need to do the „information splitting“
- A lot of thought has to be put into Power Supply strategy
- Data availability is low (messages can be lost -> no highly critical nodes with LoRa!)
- Many low quality and unreliable nodes in the market (choose with caution!)

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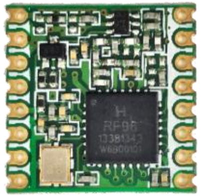
LoRa vs. LoRa WAN
-
the difference between
network technologies and networking protocols

LoRa vs. LoRa WAN



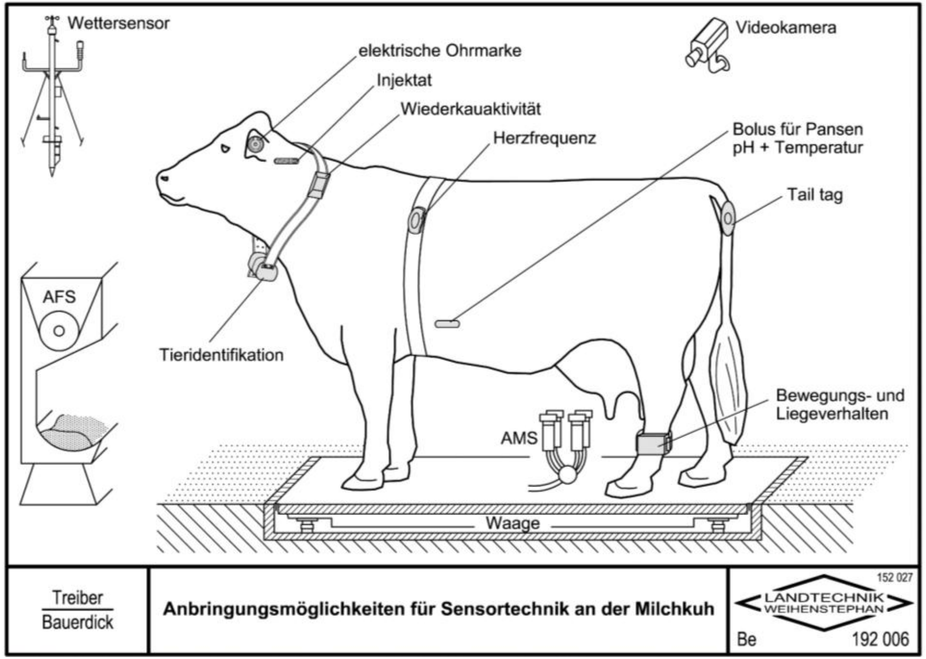
- LoRa: **wireless radio frequency technology** -> physical layer (frequency + Semtech chips)

- LoRa WAN: **networking protocol** developed by the LoRa Alliance -> media access control layer protocol which leverages and includes the physical LoRa modulation of Semtech

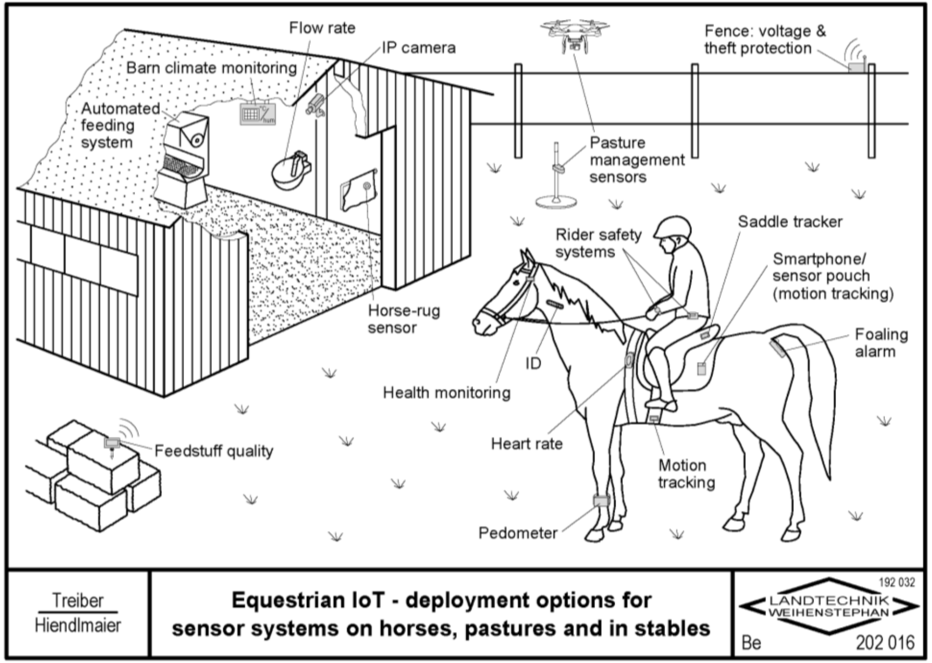
LoRaWAN networks, using the LoRaWAN protocol, are offered by over 70 network operators and there are LoRaWAN IoT deployments in more than 100 countries (private ones included)

Use-Cases

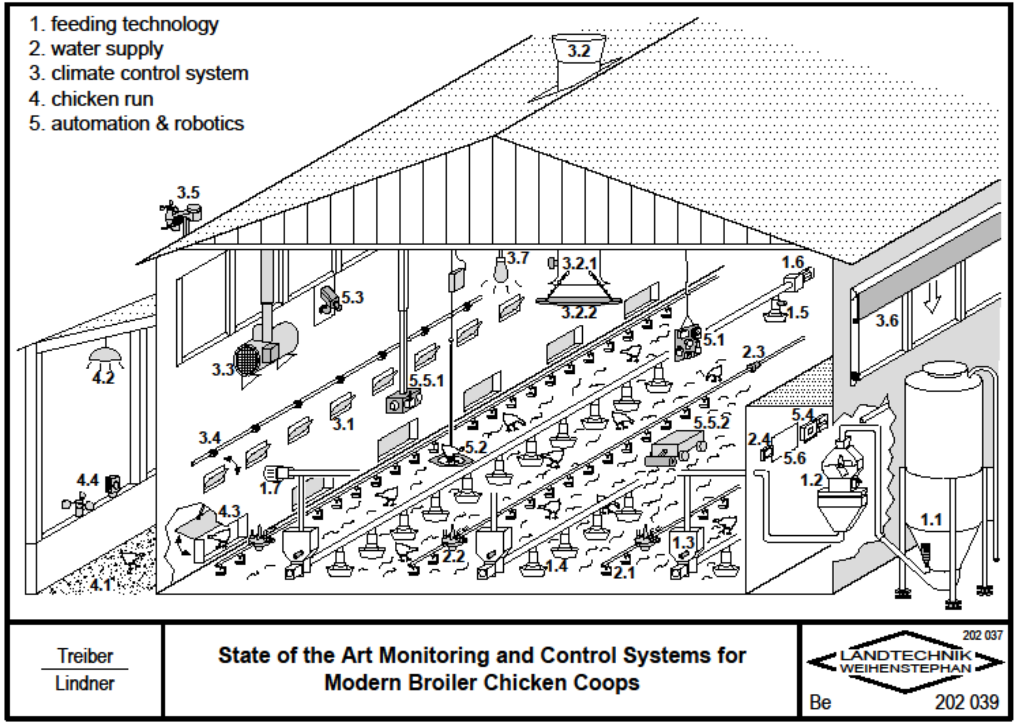
Use-Cases Rinderhaltung



Use-Cases Pferdehaltung



Use-cases Geflügelhaltung



Questions to remember

- Which aspects to consider when choosing a transmission technology?
- Examples for wireless transmission technologies
- Benefits and shortcomings of wireless transmission technologies in regard to agricultural use-cases
- Examples for use-cases