Internet of Things

Lecture 3

Application Areas 2

Healthcare and Smart Home

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Course overview (all included in DVAD70)

1. **Areas of application** (DVAD71)

   Health, smart homes, smart cities, industry 4.0, …

2. **Infrastructures** (DVAD72)

   Online sensors, gateway connections, mesh networks.
   Technologies such as NB-IoT, ZigBee, 433MHz, Z-Wave, LoRa, WiFi, Bluetooth, CoAP, MQTT

3. **Data management** (DVAD73)

   collection, storage, processing, analysis, automation, presentation)

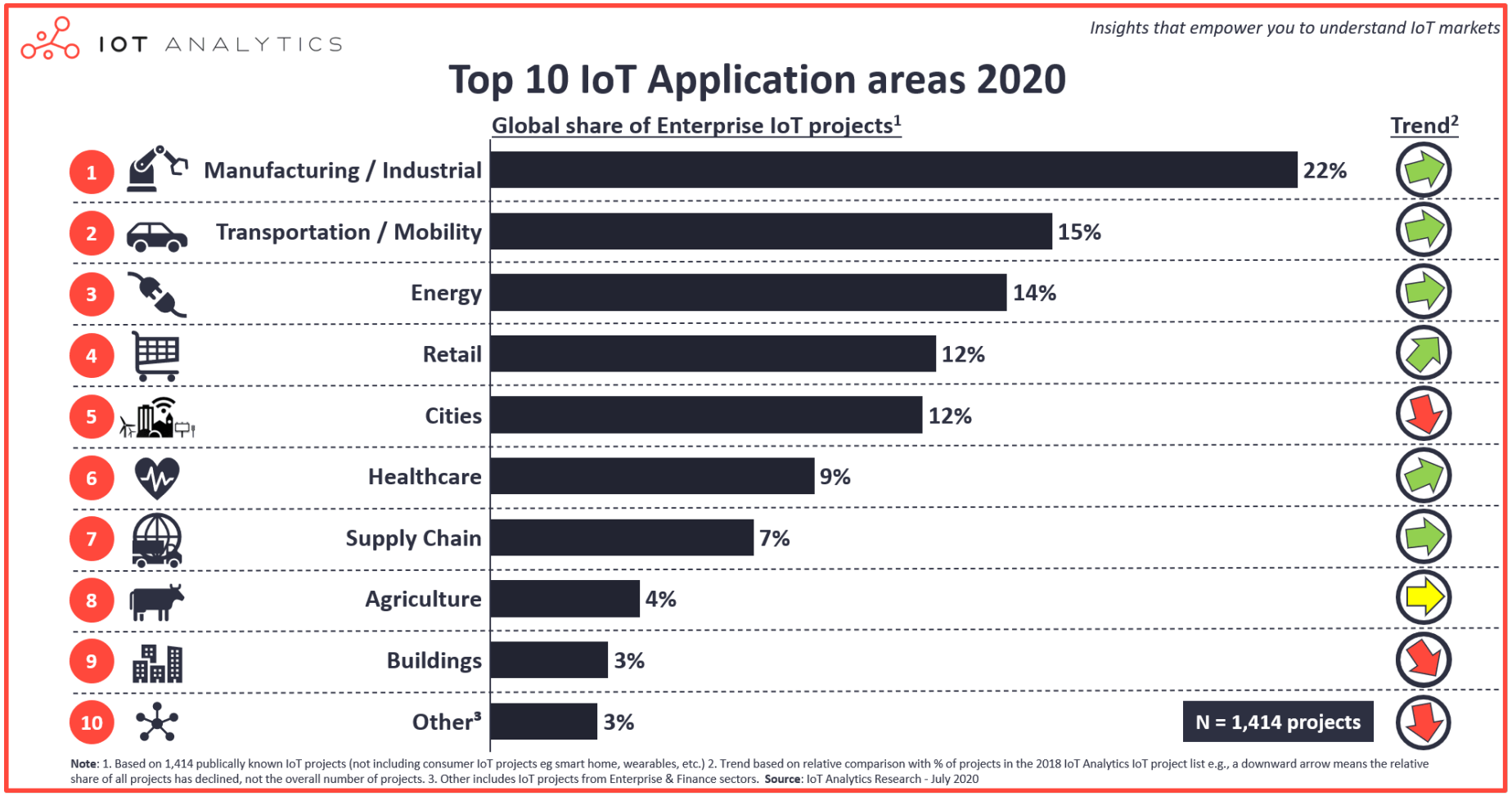
4. **Privacy and security** (DVAD74)

   surveillance, behavioral patterns, encryption, firmware updates, attack vectors

5. **Energy optimisation** (DVAD75)

   10 years of battery life – how can we achieve this?
   What can influence energy consumption?
   How can we minimize energy consumption?

IoT application areas



Most relevant IoT application areas 2020
(by https://iot-analytics.com)

IoT Application Areas

- IoT technologies are relevant in a large number of areas:
  - *Manufacturing/Industry 4.0*
  - Transportation/Mobility
  - *Energy*
  - Retail
  - Smart Cities
  - **Healthcare**
  - Supply Chain
  - Agriculture
  - **Smart Homes/Smart Buildings**

- What are IoT challenges, features and infrastructure components common to these areas?
- What are specific IoT properties relevant to a specific area?
- Example use cases

Healthcare and Well-Being

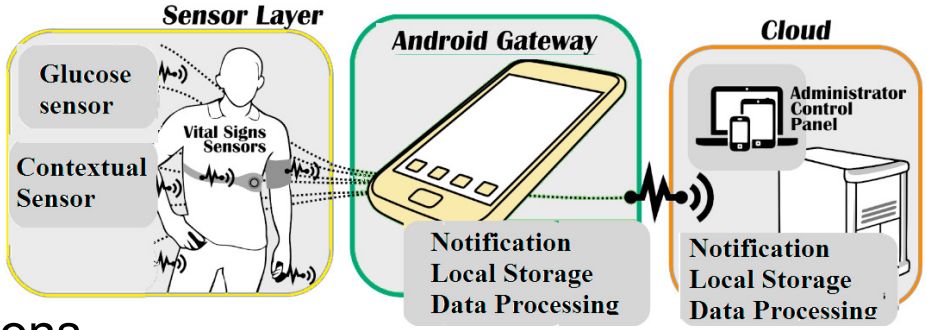
- How can IoT help in with healthcare and personal well-being?
- User groups in healthcare:
  - Physicians
    - keep track of patients' health
    - track patients' adherence to treatment plans
    - track any need for immediate medical attention
  - Hospitals
    - track real time location of medical equipment
    - analyze and control deployment of medical staff
    - hygiene monitoring
  - Health insurance companies
    - incentives for customers to using and share health data
    - validate claims through data captured by IoT devices

Healthcare and Well-Being

- In addition, personal well-being helps patients with
  - Exercise and training supervision and planning
  - Group exercises
  - Supervision of health parameters
    - e.g. heart rate, glucose level and depression and mood monitoring, support for elderly persons

- Common challenges
  - Size and energy
  - Reliability
  - Data protection and security

Glucose monitoring

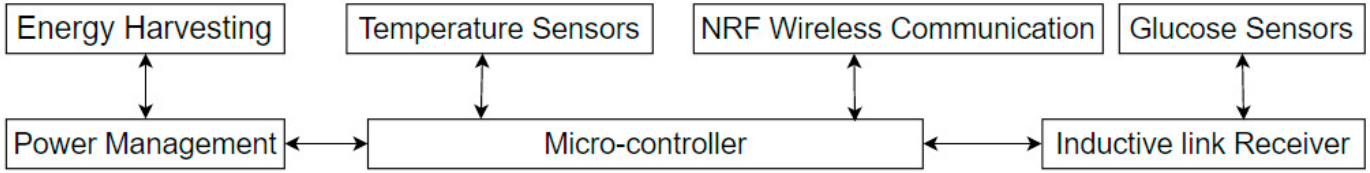


Figures from [1]

- Diabetes patients require monitoring of blood glucose levels to determine required insulin injections
  - Traditionally, a manual, analog, error-prone process
  - Patients endangered by operating errors or carelessness
- Real-time remote IoT-based continuous glucose monitoring systems [1] enable automatic monitoring, history, supervision by a physician
  - Sensors for glucose, body temperature, environmental data
  - NRF to smartphone
    - Cloud gateway
  - Energy efficiency enables energy harvesting

Table 3: Power consumption of nRF transceiver, sensor node and gateway

Device	Voltage supply (V)	Average Current (mA)
nRF transmitter (nRF + ATMEGA328P)	2	0.5
nRF receiver (nRF + ATMEGA328P + FTDI board)	5	5
Sensor node	2	1.4
gateway(Android phone without nRF receiver)	5	70
Android phone with nRF receiver	5	75



Glucose monitoring: commercial system

Example: *Ericsson Actiste* [2]

- combined product and service
  - preventing both hypo- and hyperglycemia
- brings together a blood sampler, blood glucose meter and insulin pen
- objective: minimize the number of actions needed for diabetes control
  - combined functions for sampling, measurement and insulin injection
- additional features in companion app
  - provide the user with insights into how lifestyle factors impact blood glucose control
  - download reports of all recorded treatment to determine opportunities to improve blood glucose control

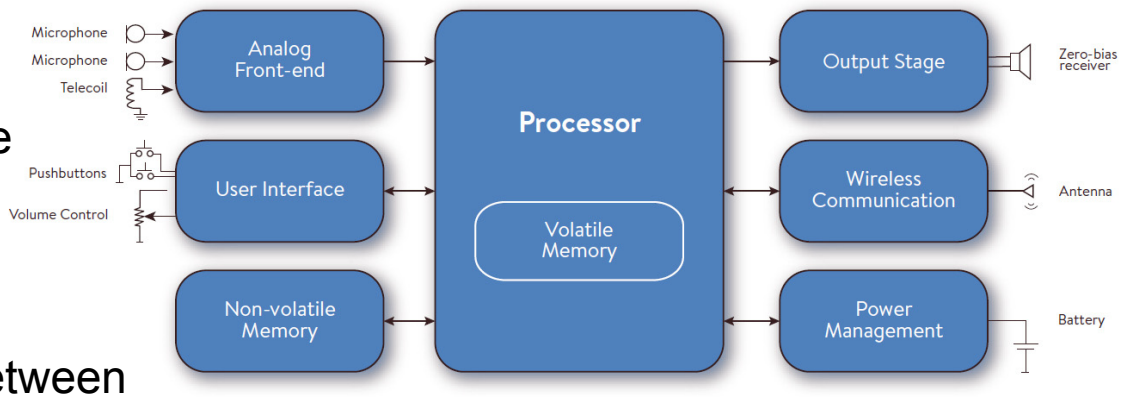
Figures from Actiste

IoT-connected hearing aids

- Challenges: [3]
  - Traditional hearing aids are problematic with some external audio sources – phones, TVs, etc.
  - ***Adaptation*** to changing hearing characteristics
  - ***Energy efficiency*** and ***real-time*** signal processing
  - ***Size*** constraints
- Additional application use cases
  - Audio noise cancellation
  - Personal sound zones
  - Audio broadcast
  - Audio alerts
  - Sound streaming

Example: IoT-connected hearing aid [4]

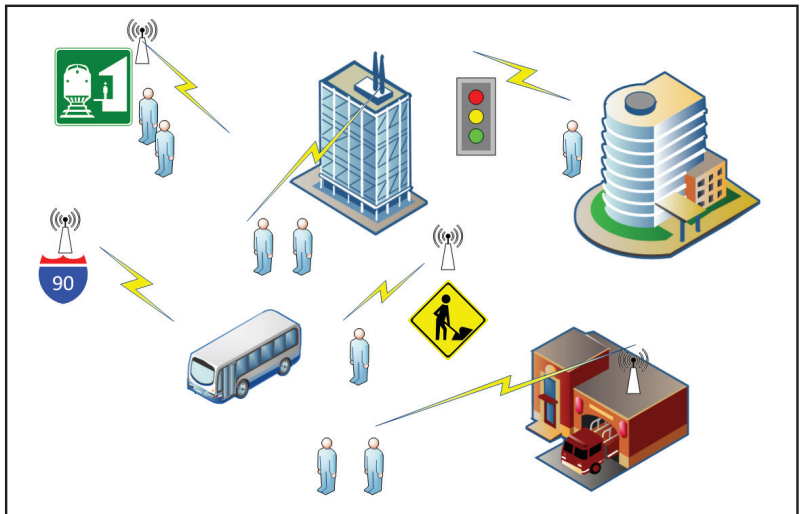
- Analog Front End
  - conditioning and converting the signal from analog to digital
- Processor with volatile memory (to store samples, runtime data)
  - performs signal processing and controls various tasks
  - DSP functionality required for real-time signal processing
- Output stage
  - Pulse width modulation (PWM) technology is used as a digital amplifier technique
- User interface
  - enable input from a volume control, push buttons or sensors
- Wireless communication
  - enables communication between the hearing aid and external devices used to control the hearing aid
  - send data between hearing aids or other devices (smartphone, etc.)



Functional blocks of an IoT-based hearing aid (from [4])

IoT hearing aid and Smart Cities

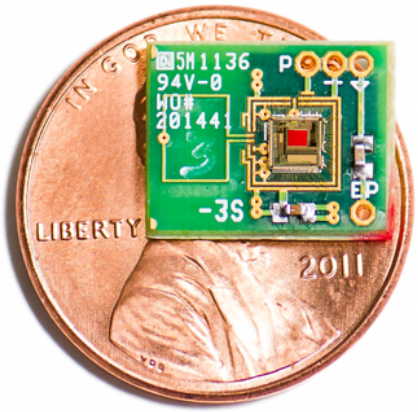
- Internet connectivity enables IoT-based hearing aids to provide additional functionality
- Integration with a Smart City environment enables the sending of information [5]
  - bus/train departure times
  - warnings (traffic lights, construction, alarms)
- Enabled by near-range communication
  - Bluetooth Low Energy (BLE)
- Early work for smart information integration e.g. at TU Dortmund



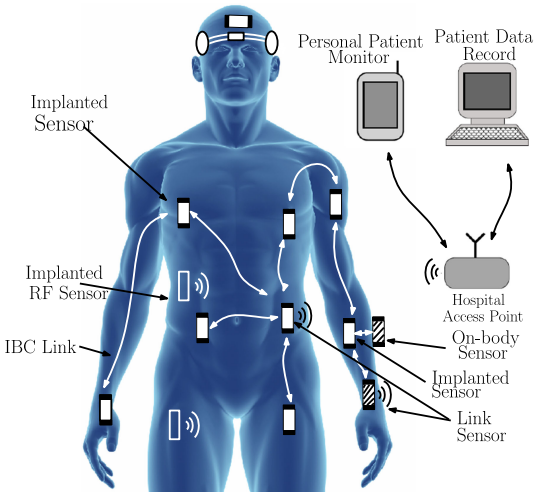
Integration of IoT-connected hearing aids into a Smart City environment (from [5])

https://ess.cs.tu-dortmund.de/Teaching/PGs/dovinci/

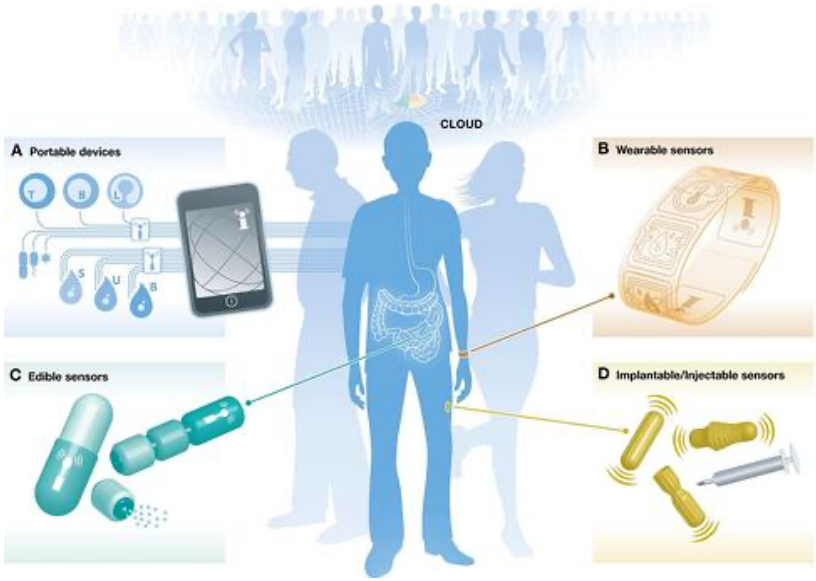
Implanted Medical Sensors



- Applications:
  - monitoring and controlling body parameters and functions
  - e.g. subcutaneous glucose sensor transmitter, oximeter, pH sensor, pacemaker, nerve/brain stimulator [6]
- Challenges: energy, size, communication
- Wireless body area network (WBAN) [6]
  - uses tissues as part of its transmission channel
  - 10–500 kbit/s possible



WBAN network (from [8])



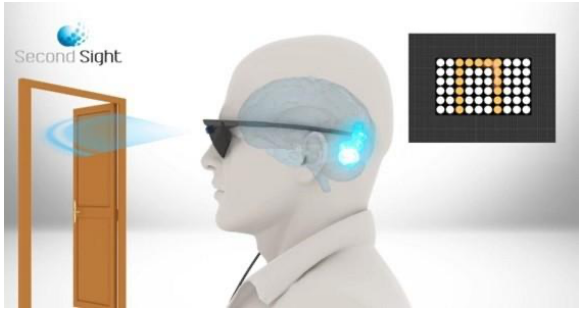
In-body sensor infrastructure

Problem: obsolescence

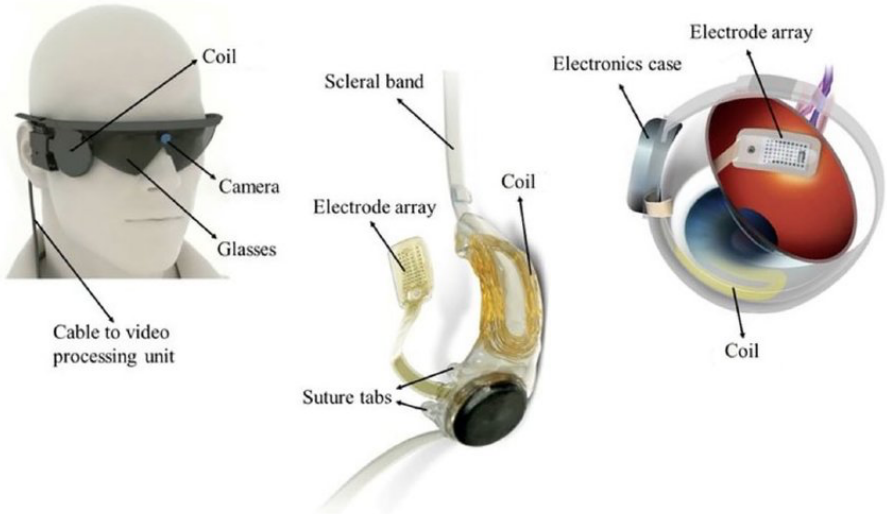
- *Bionic eyes* – retinal implant to partially restore vision for blind patients
- Argus I and II products by Second Sight Medical Products [6]
- Provides low-resolution view of physical environment
  - Useful to navigate e.g. doors
- Company went bankrupt in 2020, products are now unsupported [8]
  - No fixes, problems with medical analysis due to missing information

Patients wearing Argus retinal implants

Images from [6,7]



Quality of vision example



Argus system overview

Smart Home

- Idea: equip homes with sensor and actuator technology
  - Connected using near-range networks
  - Gateway to the internet
- Application areas
  - Energy saving
    - Turn lights and heating on/off on demand/weather conditions
  - Safety
    - Smart smoke detectors
  - Security
    - Intrusion detection
    - Remote surveillance
  - Comfort
    - Door sensors/cameras
    - Automatic window blinds

IoT devices in the Smart Home
from https://iot5.net/iot-applications/smart-home-iot-applications/

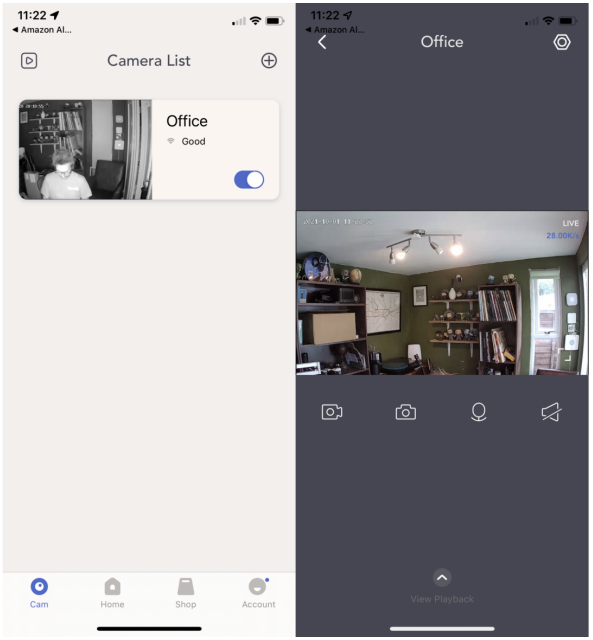
Smart Home Example: Nest

- Smart device designed to control a central air conditioning unit based on heuristics and learned behavior
- Connect to home/office network, interface with the Nest Cloud for remote control
  - ZigBee module for communication with other Nest devices
- Uses machine learning
  - first weeks: set the thermostat manually to provide the reference data set
  - Nest can then learn schedules, which temperature they are used to and when
  - energy-saving mode when nobody is at home
    - determined using built-in sensors and phone locations
- Dual-processor solution
  - TI Sitara AM3703 ARM Cortex-A8 system-on-chip
    - 64 MB RAM, runs Linux
  - ARM Cortex-M3 microcontroller (128 kB flash, 16 kB RAM)
    - control few driver circuits and SHT20 temp. / humidity sensor

Nest thermostat front and back (from [9])

Smart Home Example: video surveillance

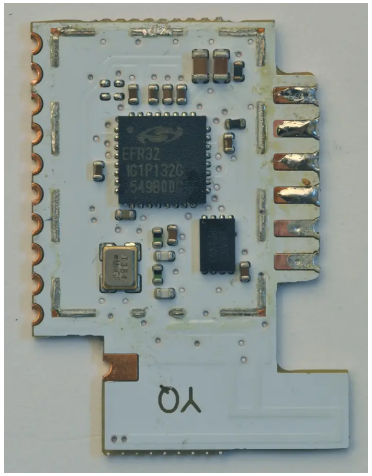
- Security focus
  - Monitor video (and audio) streams in your home when you are away
  - Smart cameras: motion detection, internet connectivity
  - Smart phone/tablet/browser application to watch live stream
- High bandwidth requires Wifi or Ethernet connection
  - Live stream: 1–2 Mbit/s for 1080p video with 6–10 fps
- "Intelligent" camera functionality
  - motion and person detection
  - avoid false alarms (e.g. due to sunlight)



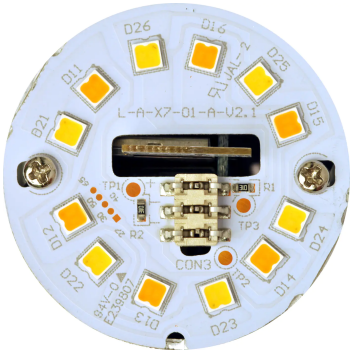
Example from https://www.trustedreviews.com/reviews/nooie-cam-360

Smart Home Example: light bulb

- Component of energy saving infrastructure
- Example: IKEA trådfri
  - "Smart" LED light bulb, ca. 100 SEK
  - Manual control via wireless switch/dimmer
  - Automatic control via gateway
- Six cold white + six warm white LEDs
  - Individually controllable via PCM
- ARM Cortex-M4 microcontroller
  - SilLabs Mighty Gecko EFR32MG1P132GI
  - 40 MHz, 256 kB flash, 32 kB RAM (!)
  - ZigBee wireless radio
- Interface to gateway via ZigBee
- Part of a whole family of smart home devices [11]
  - window blinds, motion sensors, dimmers, …



Trådfri light bulb digital PCB



Trådfri light bulb LED PCB

From https://www.heise.de/make/artikel/Das-steckt-in-Ikea-Tradfri-3597295.html

Conclusion

- IoT in medical applications
  - internal or external to the body
  - low-power, small size, high reliability requirements
  - monitoring and control of vital parameters

- IoT in the smart home
  - large number of sensors and active devices
  - low cost, flexible, heterogeneous systems and networks
  - reduce energy consumption, increase safety and security, convenience functions

- IoT benefit: ***Interoperability***
  - Connect medical devices to smart home and city environments
  - E.g. hearing aid integration with home and city networks

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[6] A. K. Teshome, B. Kibret, and D. TH Lai. *A review of implant communication technology in WBAN: Progress and challenges*, IEEE reviews in biomedical engineering 12 (2018): 88-99

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[11] IKEA trådfri hacking – https://github.com/basilfx/TRADFRI-Hacking