Ultra-low Power Wireless Communication for Medical Implants

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Outline

- Why use wireless communication for medical implants?
- Efficient communication system integration with implant
- Feasibility and use cases:
  - Battery-free Capsule Endoscope
  - Multichamber leadless cardiac pacemaker
- BCRATOS: Brain Machine Interface

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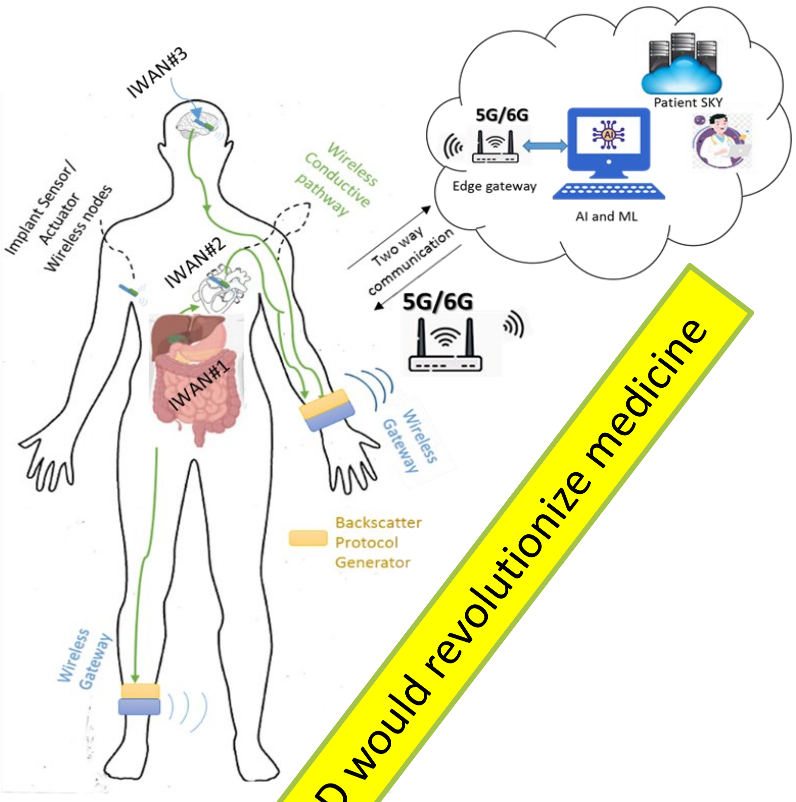
Internet of Implant Medical Devices(IOIMD) for Future Medicine

Aim: Early detection early treatment

- **Sensors for detection and recording**
- **Information exchange**
    - Intra-body
    - On-body
    - Body area
- **Data fusion to networks (WPAN, WLAN and Intranet, Internet)**
- **Access to the sensor's data from the network**
    - Two way communication
    - Addressing
    - Localization
- **Implementation of ML, AI models, Cloud computing for detection and treatment plans**
- **Actuation, treatment delivery systems**



IOIMD would revolutionize medicine

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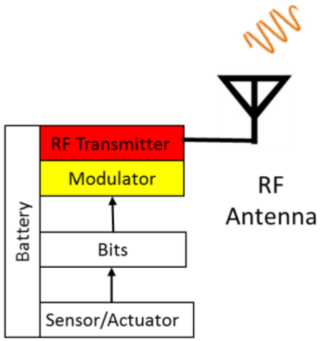
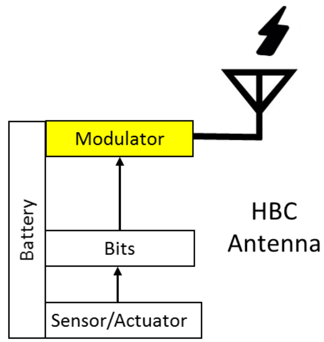
Communication Technologies for Implants



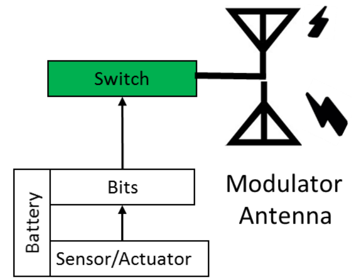
Implant Device
RF transmitter

Power consumer



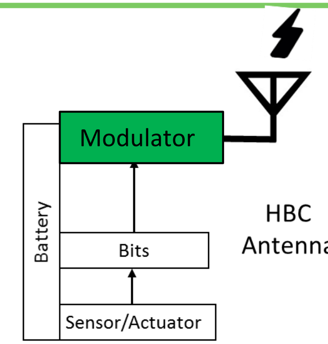
Implant Device
HBC

Moderate Power



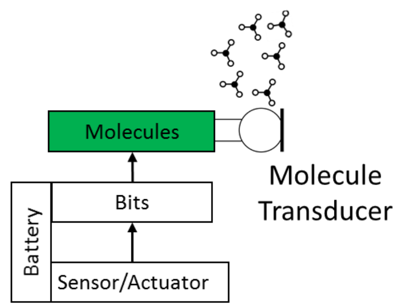
Implant Device
HBBC

Ultra low power



Conductive Impulse

Ultra low power



Implant Device
Molecular

Ultra low power

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Comparison Table

Implant Communication Technology	Transmitter Electronics	Power Consumption (mW)	Path loss (dB/cm)	Antenna Efficiency (%)	Antenna Miniaturization (mm)	Data rate	Integration within node	Communication distance (cm)	Research Status
Radio Frequency (MICS bands)	Yes	High (25-35)	High (5-6)	Very Low (2-5)	Limited (efficiency loss)	< 2 Mbps	Difficult	< 20	Established Technology
Electric signal (HBC)	Yes	Moderate (10-20)	Low (2-3)	Moderate (10-20)	> 10 mm (Matching loss)	< 100 kbps	Easy	< 10	Research Area
Backscatter (HBBC)	No	Very Low (10-30 nW)	Moderate (4-6)	High (60-70)	> 5 mm	< 30 Mbps	Easy	<20	Near Future Technology
Molecular	No	Ultra Low	High	No Antenna	Ultra small (nm?)	< 10 bps	Very Easy	<0.1	Future Technology

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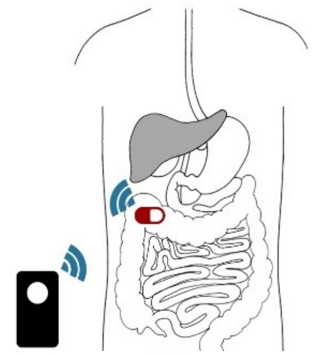
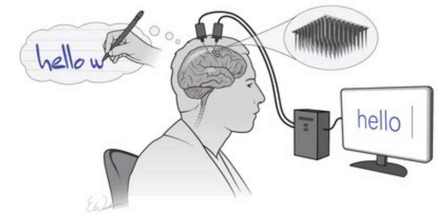
Main limitations with Implant communication

- **Energy resource and device lifetime**
  - Battery, local harvesting, wireless charging
- **Size (use case → micro to Cms)**
- **Bio-compatibility (usually metal casing)**
- **Electronics integration and EMC**
- **Safety, Trust, Identity**
- **Security, authenticity, reliability**

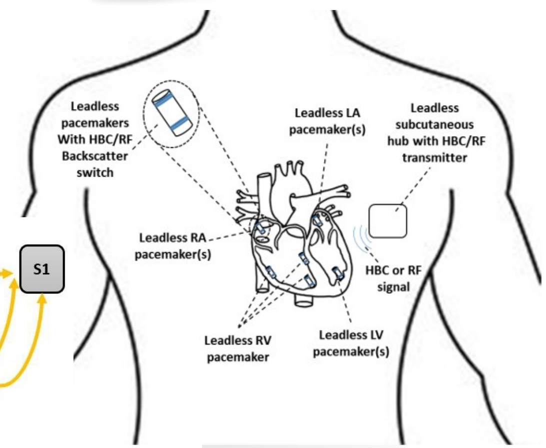
Implants Powered by Wireless Communications

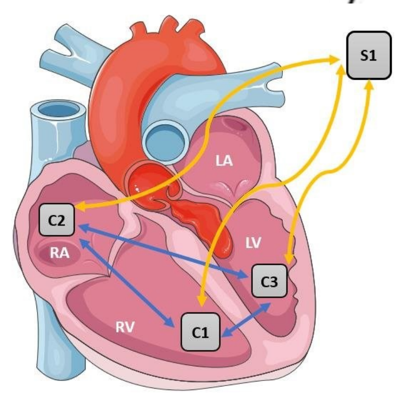
- **High data rate sensors**
  - Wireless capsule endoscopy (WCE)
  - Brain machine interface (BMI)





- **Low to moderate rate sensors**
  - Multichamber Cardiac pacemaker capsules
  - Biological chemical sensors





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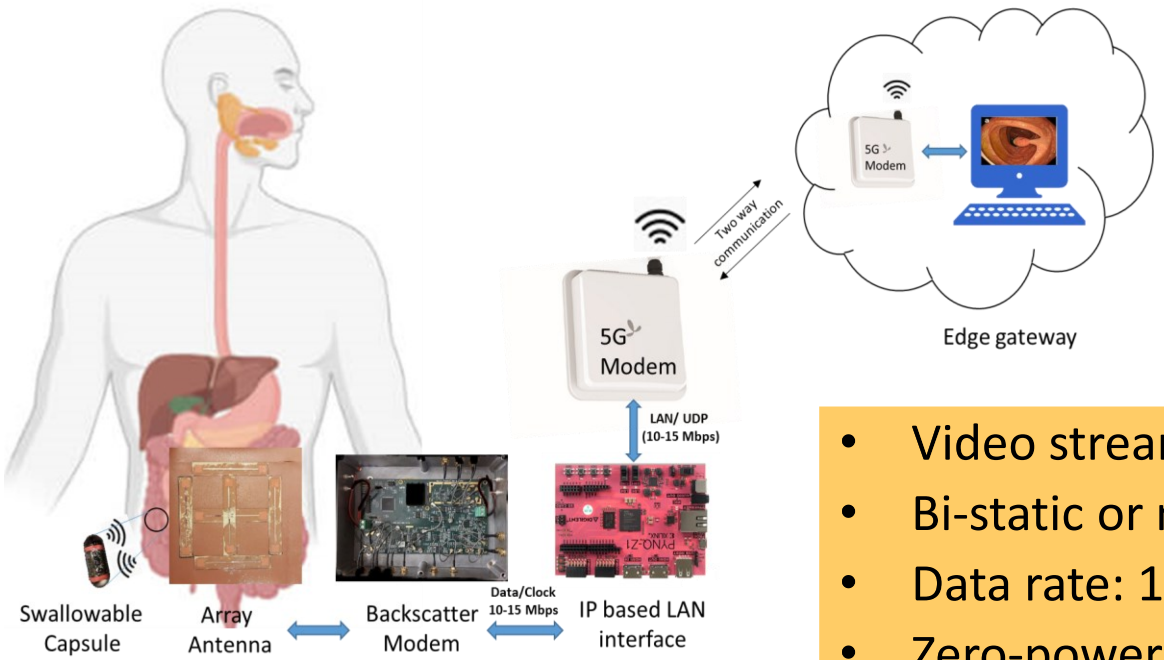
Pilot for Battery less Wireless Capsule Endoscopy



- Video streaming
- Bi-static or multi-static reader
- Data rate: 10-30 Mbps
- Zero-power for comm.
- Network connection
- Streaming to 5G system
- Video processing in the edge
- Feedback loop to WCE

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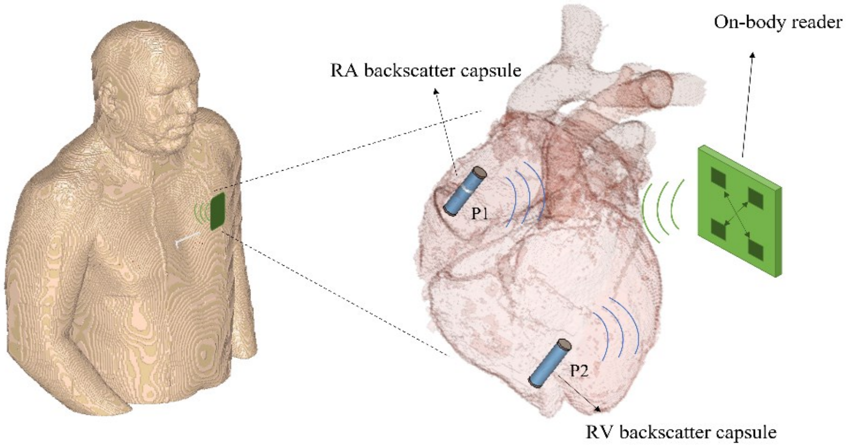
Pilot for multi-chamber Leadless Cardiac Pacemaker module

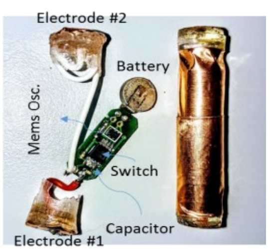
S1: Backscatter communication for pacemaker

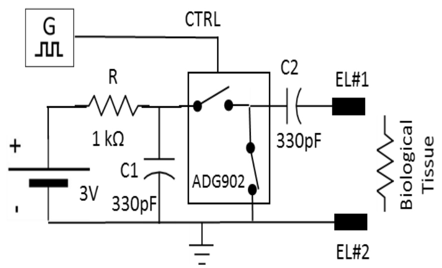
- Low data rate RF backscatter
- Subcarrier applied in the pacemaker
- Use of subcutanous reader for WPT and low rate (100 kbps) communication.

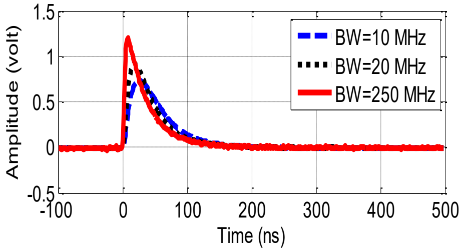


S2: Conductive Impulse communication

- Implant to Implant
- Implant to subcutaneous can
- Ultra-low power (pico-watt/ bit)
- Battery powered or can be charged with RF signal







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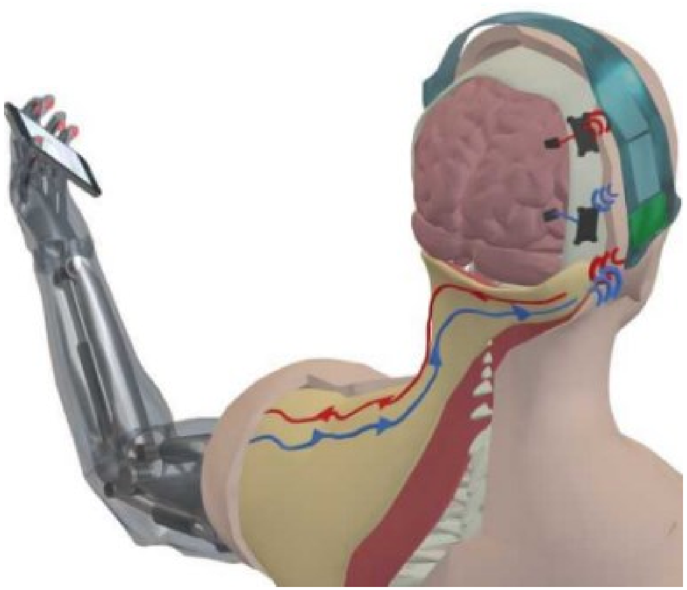
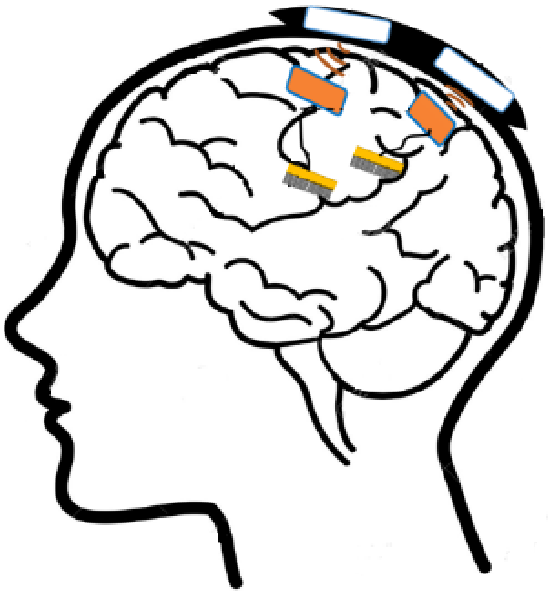
NTNU Role in B-CRATOS

- Wireless charging of the Brain implant
- Wireless data telemetry and tele-command
- High data rate implant data readout





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Brain Readout and Stimulation Overview

Wireless Powering Unit

- Wireless charging and safety
- Supply power for readout and stimulation system provided by BRME
- Supply power to the sensory system and MCU

Wireless Communication Unit

- Support Telemetry and Telecommand
  - Provide data security
- Support communication payload:
  - Data rate 32-64 Mbps
  - Data security
  - Radiation safety
  - Reliability for 24/7 (min 6 month)

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Conclusion

- Ultra low power implant communication payload is essential for IOI medical devices
- Battery free communication removes the system complexity of tiny IMD
- Wireless network capacity can be deployed to empower the tiny implants
- Online detection and treatment becomes feasible
- Better Healthcare and sustainable health systems can be deployed with IOIMD

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Institute for Electronic Systems (IES) at NTNU leads B-CRATOS WP2: Communication system and wireless powering of BMI

https://www.b-cratos.eu/

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