Animal Wireless Body Area Networking

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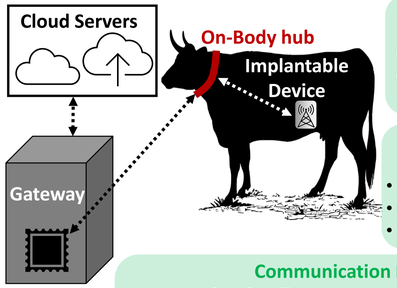
1. Multi-hop Animal Body Area Network



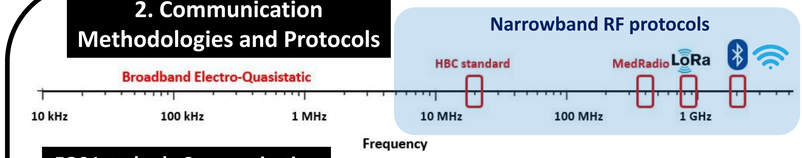
Applications
- Animal health monitoring
- Increased agricultural efficiency
- Resource allocation optimization

Communication Protocol Requirements
- Low power
- Energy efficient
- Data Security

→ Battery life

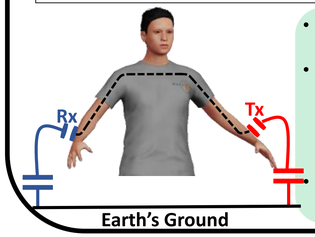
Communication Methodologies
- Narrowband Radio Frequency
  - 400 MHz band – MedRadio
  - 900 MHz band – LoRa
  - 2.4 GHz band – Bluetooth, ZigBee, Wifi
- Broadband Electro-Quasistatic (EQS) Intrabody Communication

2. Communication Methodologies and Protocols



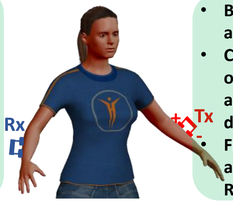
EQS Intrabody Communication

Capacitive Human Body Communication



- Forward path via body
- Return path is formed using floating ground plate and earth's ground
- Can be used for on-body devices

Galvanic Human Body Communication

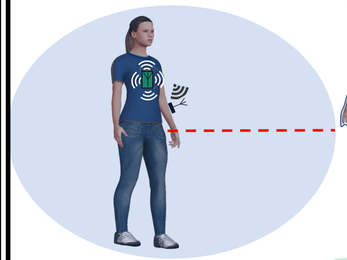


- Both electrodes are on the body
- Can be used for on-body as well as implantable devices
- Fringe fields are captured on Rx

3. Comparison between different protocols

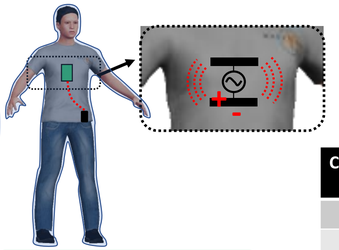
Physical Layer Security

RF WBAN



Signal can be received up to 10m away from the body

Galvanic Intrabody Communication



Signal is confined to few cms away from the body making signal physically secure

Energy Efficiency Study

Communication paradigm	Energy Efficiency numbers
Bluetooth, Wifi	> 1nJ/bit
LoRa	~ 100 µJ/bit
MedRadio	> 100 pJ/bit
EQS Intrabody coupling	< 10pJ/bit

Communication Range

Communication Protocol	Communication Range
Bluetooth	100 m
LoRa	5 km
ZigBee	10 – 100 m
Wi-Fi	50 - 100 m

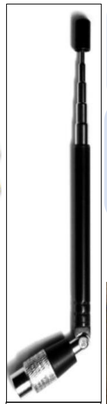
4. Radio Frequency Experiments

Experimental Setup

HackRF One

HackRF One: Software Defined Radio (SDR) is used as a transmitter device
- Device Dimensions: $6 \times 4 \times 1$ inches
- Frequency range covered: 1 MHz to 6 GHz
- Output Power: 1 mW (0dBm) to 30 mW (≈ 15 dBm)

Transmitter antenna and power amplifier setup



ANT700 Antenna
- Length - 9.5 cm to 24.5 cm
- Frequency of operation - 300 MHz to 1100 MHz

Power Amplifier
- Tekbox TBWA2
  - Gain – 40 dB
  - BW – 2Mhz to 6 GHz
  - P1dB – 20 dBm

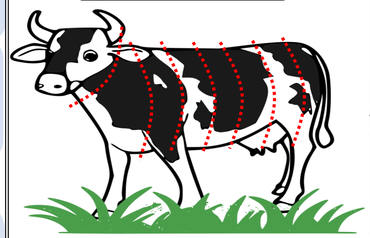
Receiver setup

- Portable Spectrum Analyzer
  - RF Explorer Handheld Spectrum Analyzer
- ANT500 Antenna
  - Length – 20 to 88 cm
  - Operating BW – 75 MHz to 1100 MHz

Experimental Procedure and Results

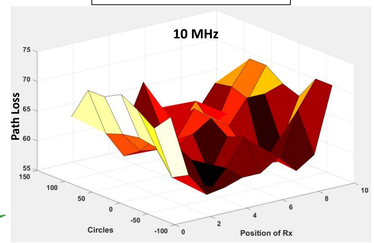
Performing a frequency sweep across various frequency bands and find the channel loss to create a channel model

Receiver Positions



Receiver moved in circles along the body of cow shown in red

Channel Loss Results



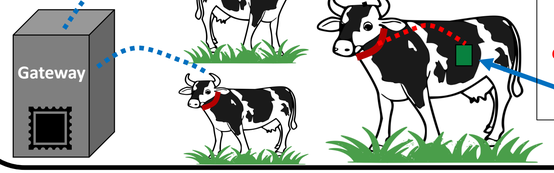
Path loss plots for 10 MHz across all positions on the cow body

Channel Modeling using FEM based simulations to characterize animal body as a communication channel across wide frequency band

5. Collaborative Intelligence

LoRa – Long range communication to gateway

Bluetooth, ZigBee – short range communication within herd



Broadband EQS Galvanic Intrabody communication – In-body to out-of-body communication: Under active research

Collaborative Intelligence among multiple protocols
- Energy consumption minimized
- Higher energy efficiency resulting in increased lifetime of nodes

6. Conclusion and Future Work

- Low power, energy efficient and secure methods of communication are studied for animal WBAN applications.
- Data transmission using RF based approaches performed for various frequency bands
- Preliminary channel modeling using FEM based simulations for basic understanding of channel loss in animal WBAN.

- Further experiments on RF approaches to develop an advanced channel model
- Development of science in the domain of Galvanic Intrabody EQS communication for in-body to out-of-body applications
- Development of galvanic intrabody EQS systems for in-vivo testing
- Study of collaborative intelligence around herd environment

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