Bluetooth Low Energy (BLE) RF Dataset for Machine Learning in WBANs

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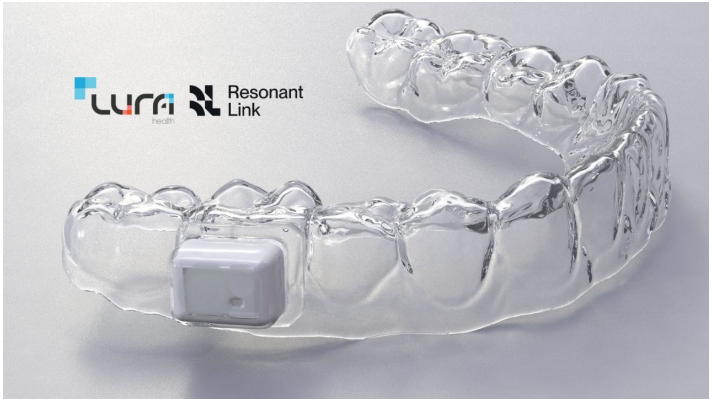
Introduction to Wireless Body Area Network (WBAN)

BLE is widely used in healthcare devices.

- Smart watch
- Insulin delivery pumps
- Glucose monitoring system
- Blood oxygen sensor
- Blood pressure sensor
- ECG sensor
- …



Picture from: www.resonant-link.com

BLE Authentication

BLE uses 3 schemes to avoid Man-In-The-Middle attacks while authentication:

- Numeric comparison
- Passkey entry
- Out-of-Bound (such as NFC)

The above methods verify the exchanged key.

Is it Practical?

Data entry or display functionality!

- No space for a display or a button
- Extremely small energy capacity

Making the **secure pairing** using the BLE standard **extremely difficult** .

Picture of a glucose monitoring sensor

Physical Layer signal's ~~Fingerprint~~

Extracting unique **hardware** and **channel characteristics**.

In WBAN, **body** affects the RF signal.

No public dataset for on-body recording

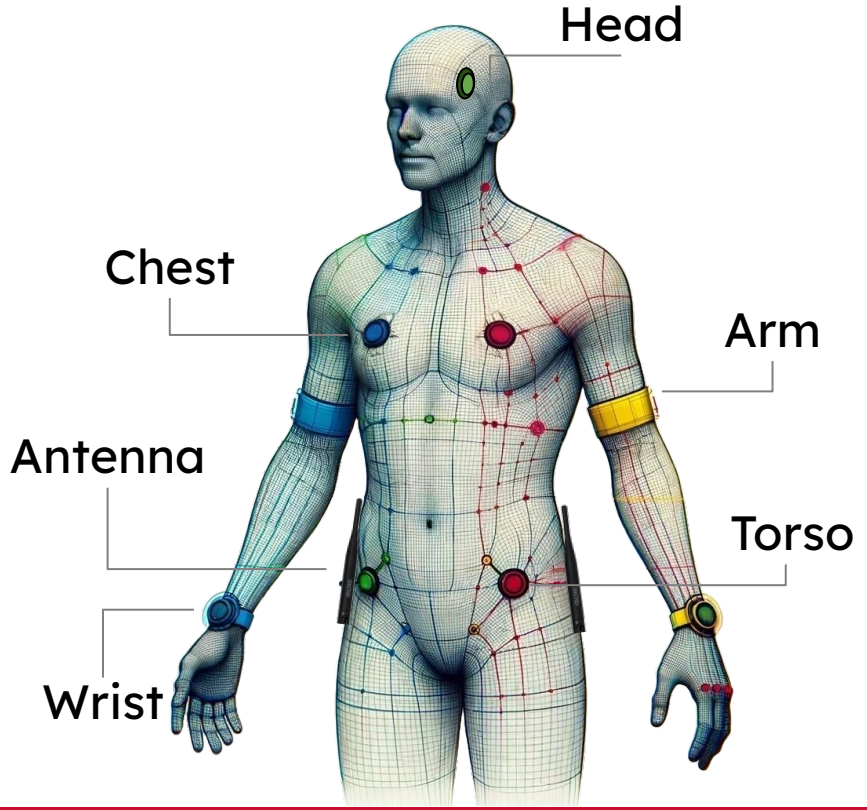
Introducing BLE-WBAN

- **On** and **off body** recordings
- **Two** different USRP X310 **SDRs** for recordings
- Recording inside **anechoic chamber**

- **Entire BLE spectrum** with high sampling rate of **100 MSps**

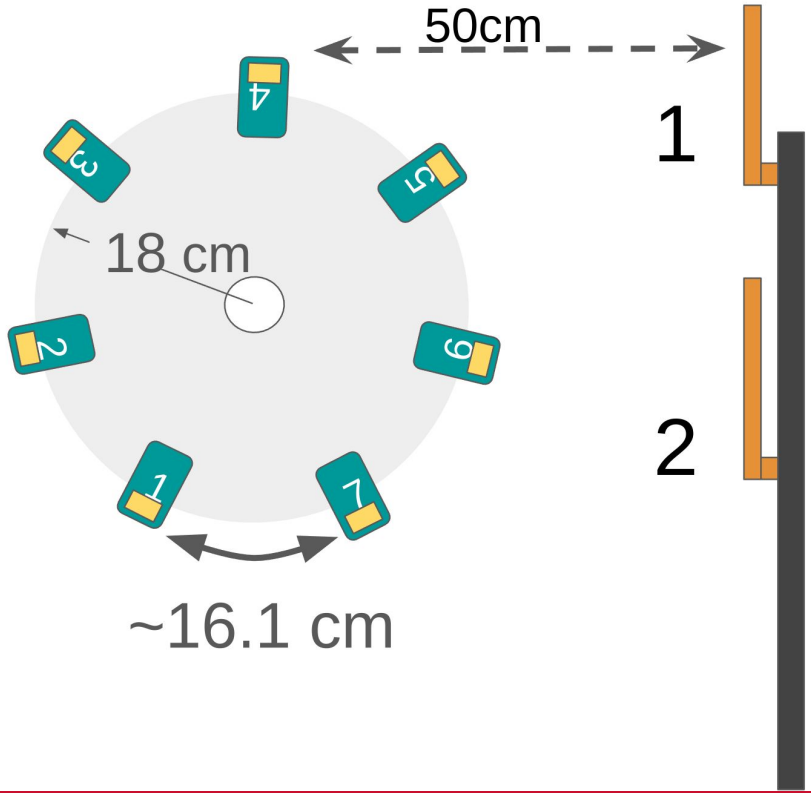
BLE-WBAN (on-body)

- **12** BLE devices on the body
- **Two** receiving **antennas** on the left and right side of the hip
- Body at **rest** and body in **motion recordings**

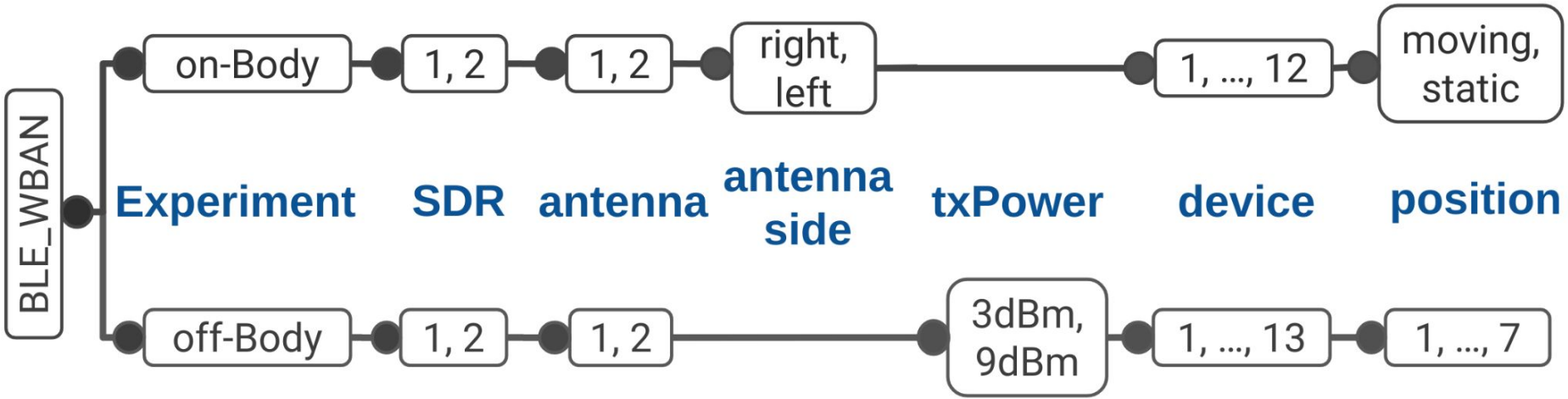


BLE-WBAN (off-body)

- 13 BLE **devices** on
- 7 different **positions**
- 2 different **TX power** levels
- 2 receiving **antenna**

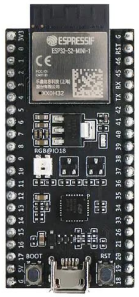


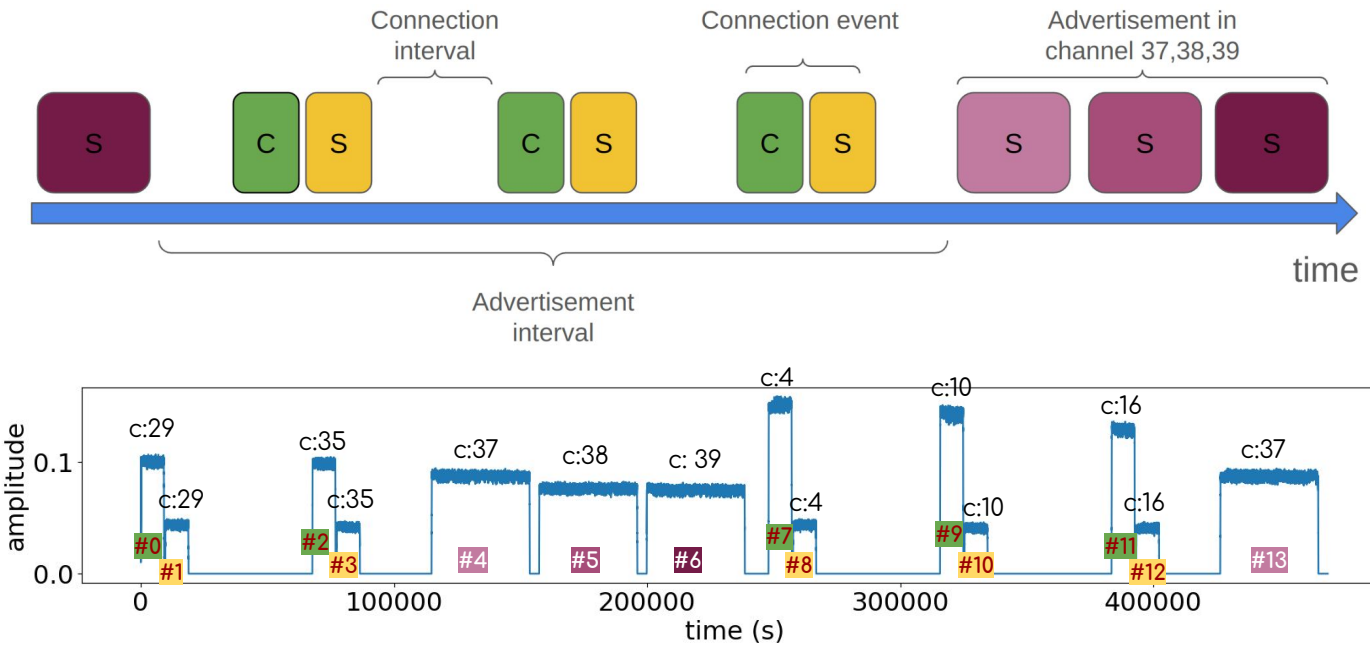
Compact tree representation



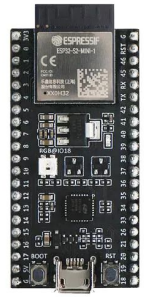
Traffic generation

Server

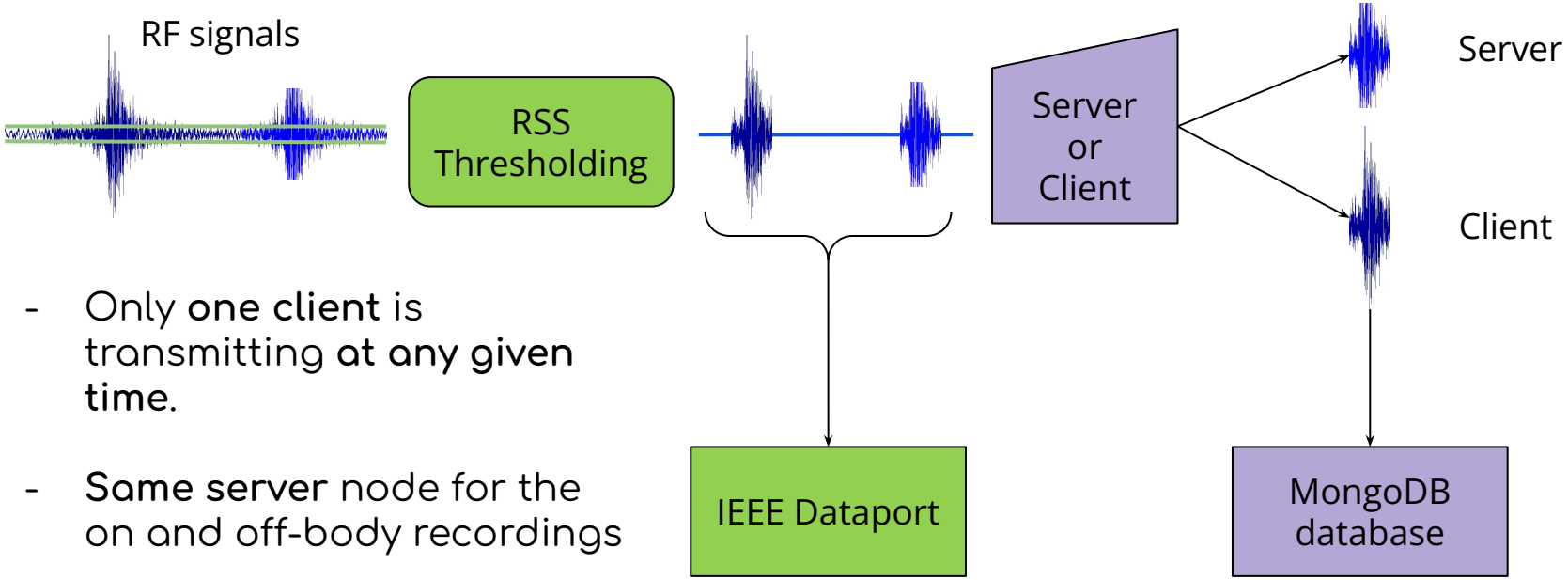




Client



Data acquisition procedure



- Only **one client** is transmitting **at any given time**.
- **Same server** node for the on and off-body recordings

Dataset summary

	on-body	off-body
↔ size	10GB	40GB
Number of recordings	12,000	80,000
 Number of nodes	12	13
 Number of receiver	2 SDR x 2 Channel	2 SDR x 2 Channel

MongoDB database: example query

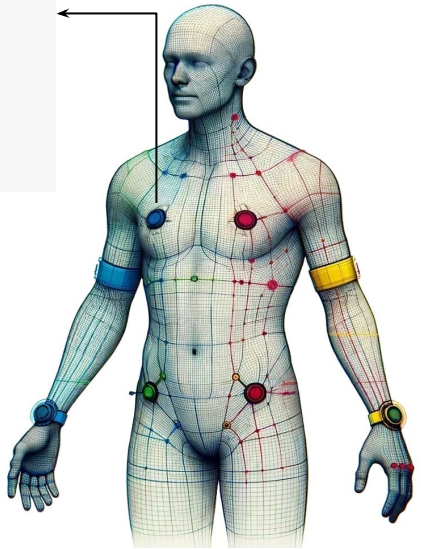
```
client = pymongo.MongoClient("mongodb://test:12345678910111213@S
BLE_WBAN = client["BLE"]
```

```
filter = {'placement':'chest','side':'right', 'pos':'static'}
query = list(BLE_WBAN.onBody.find(filter))
df = pd.DataFrame(query)
df.describe()
```

This will return 518 recordings.

	frameDecode	bitLen	max_gradient_unwrapped_phase	I	Q
0xaa9206f2f4a9100ab525		[54, 99, 159, 103, 98, 100, 99, 99	[0.0008993643194350476, -0.01209078298054167, ...	[-0.013367107138037682, -0.0036317026242613792...	[-0.0002136295661330223, -0.010345774702727795...

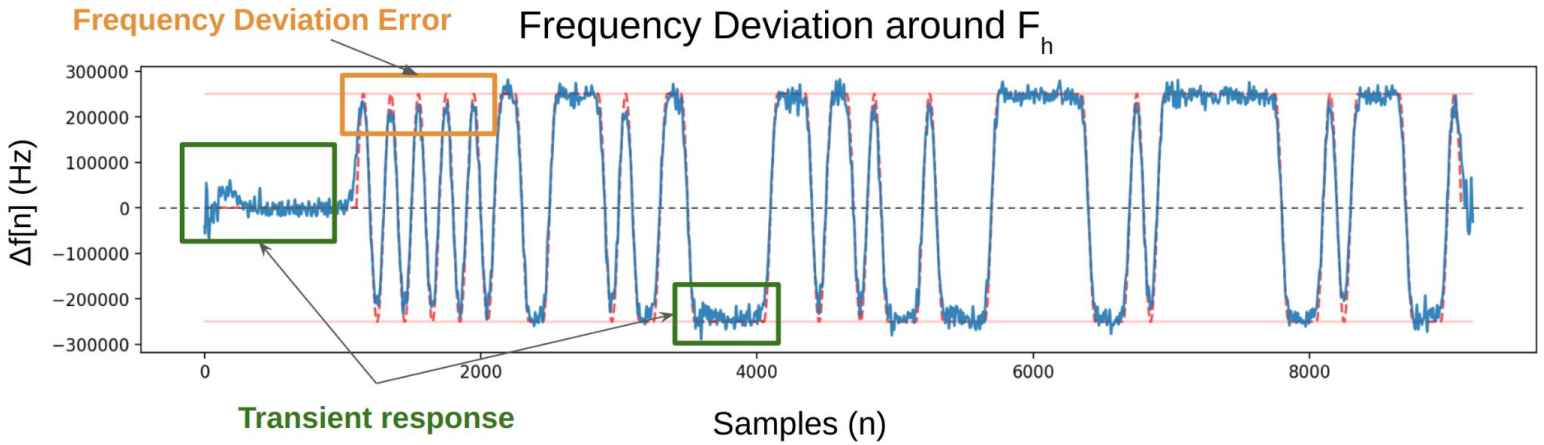
Google colab live example!



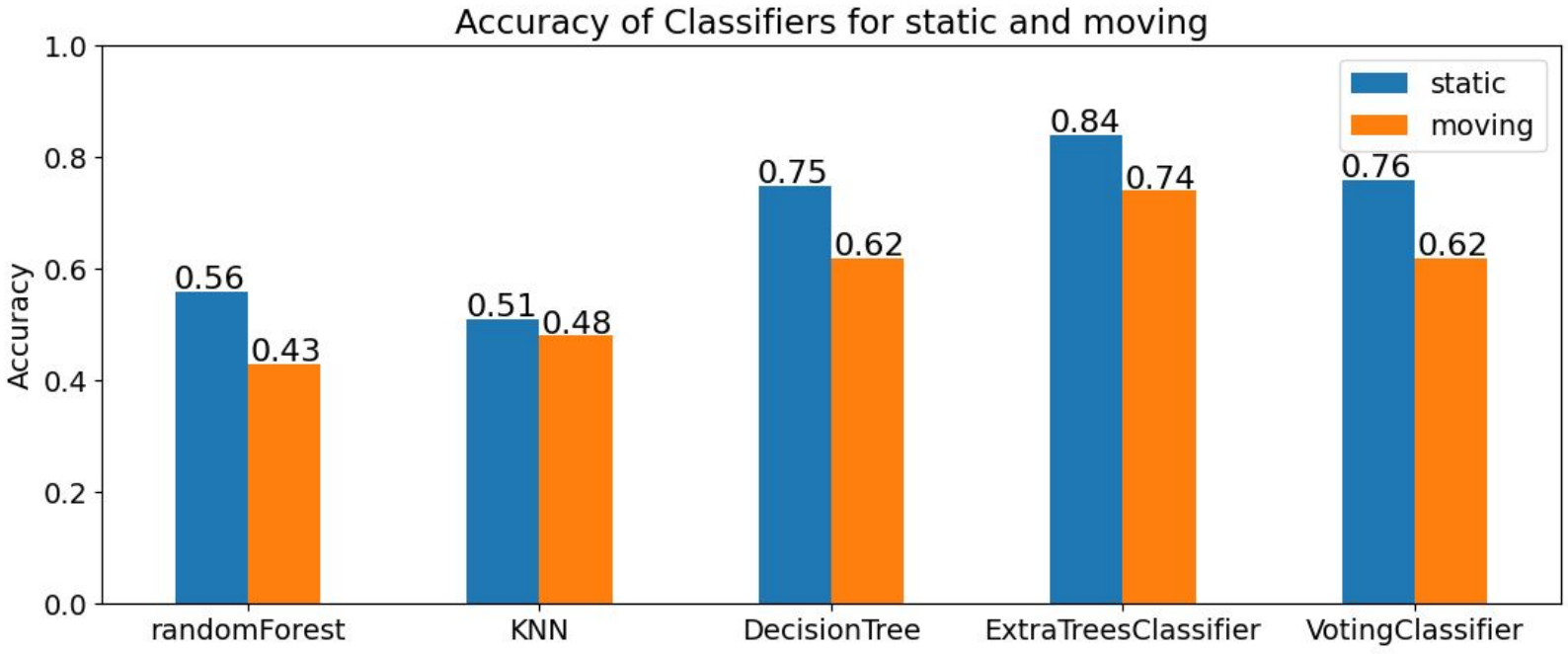
Dataset Features and Analysis cont'd

Feature set used for analysis and Machine Learning

Frame Channel	Frame length	RSSI	Bit length	Max freq. dev.



Results: on-Body node classification



Use Cases and Future Directions

Application:

- Authentication,
- ranging/localization,
- PHY layer security enhancements.

Future Directions:

- Expanding dataset applications
- improving data collection methodologies
- integrating more complex ML models.

Summary

- State the **necessity of the Physical Layer Security** in WBAN
- Introduced the **BLE-WBAN** dataset
- Provided **Python package** to interface with the dataset
- Demonstrates the potentials of the BLE-WBAN dataset for **on-Body classification**

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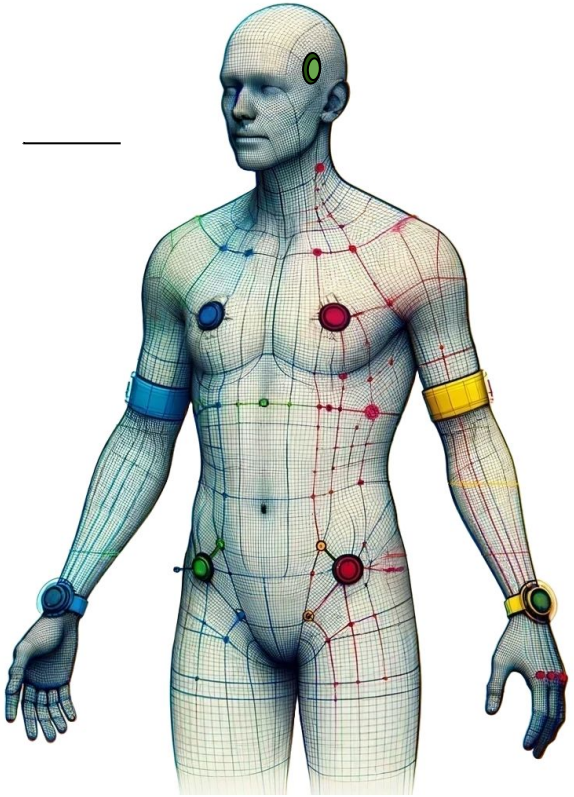
Thank you

Further questions?



Dataset Features and Analysis

Every recording has the following meta-data

`file`	Raw file name	`SDR`	Receiver number	`frameTime`	Number of samples
`frame_nr`	Frame number in the raw file	`Antenna_side` \ `txPower`	Left or Right \ 3dbm or 9dbm	`frameChnl`	0 to 36 BLE channel
`date`	Recording date	`antenna`	1 or 2	`rssi`	Received signal strength
`test`	On or Off Body	`pos`	Static or Moving body \ 1 … 7	`Frame Decode`	Bits of the frame
`Fs`	Sampling rate	`dvc`	Node(or tx) number	`bitLen`	length of the freq deviation
`Fc`	Recording Center freq.	`placement`	Position on the body	`max_freq_dev`	Max and min freq. deviation
`gain`	Receiver's gain	`side`	Left or Right	`I`	In-phase samples
Yellow is off-body and green is on-body specific parameter.				`Q`	Quadrature samples