Raproto: An Open Source Platform for Rapid Prototyping of Wearable Medical Devices

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Introduction

- It is common to expend a significant amount of time and effort to develop data collection systems
- These systems tend to be customized and highly specific to the task at hand and are not general enough to support other tasks

Challenges

We want to make a rapid prototyping platform that is:

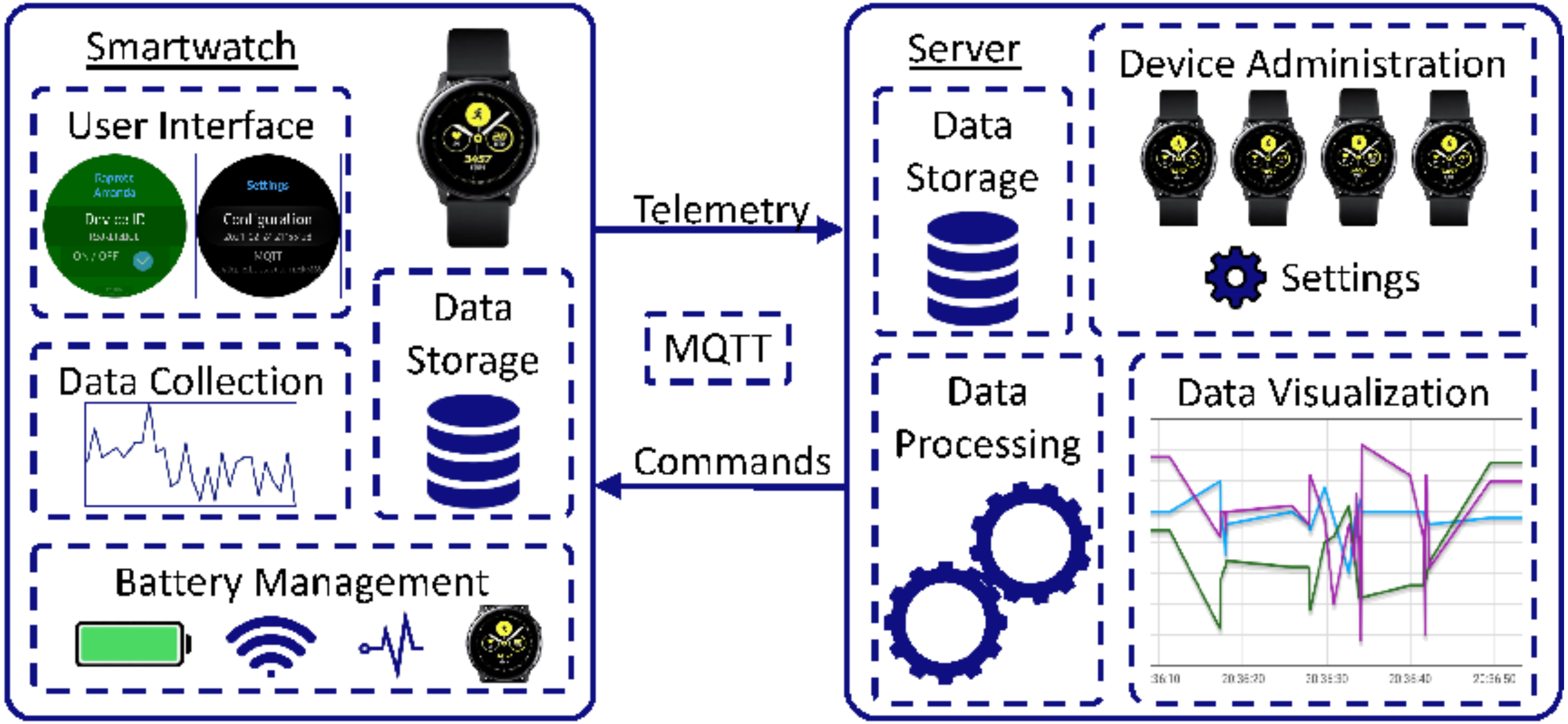
- Open-source
- Easy-to-use by non-coders
- Customizable sensors
- Customizable data collection rates
- Provides visualization of data
- Works with off-the-shelf smartwatches

Raproto

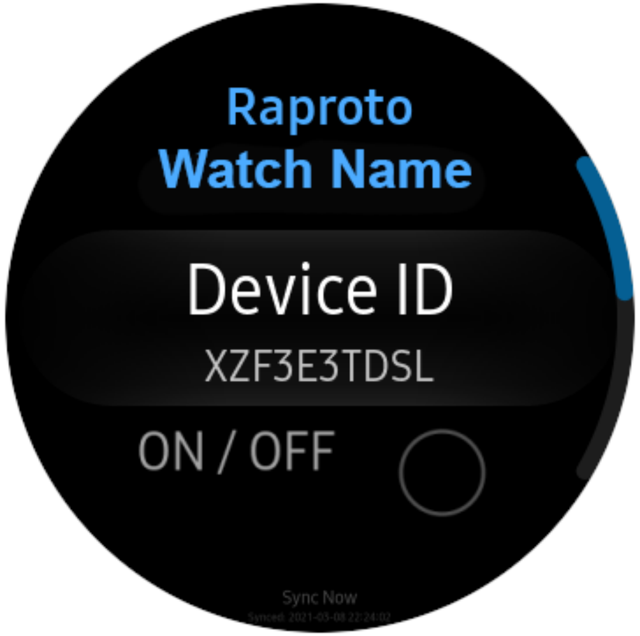
Outline

1. Introduction
2. Raproto Platform
3. Evaluation
4. Extensibility
5. Conclusion

Raproto Platform



Smartwatch Application: UI



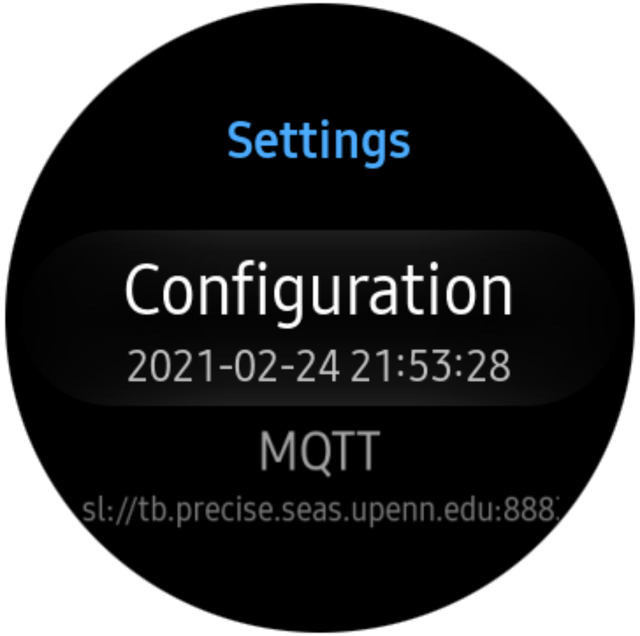
Raproto
Watch Name

Device ID
XZF3E3TDSL

ON / OFF ○

Sync Now
Synced: 2021-03-08 22:24:02

Main Screen

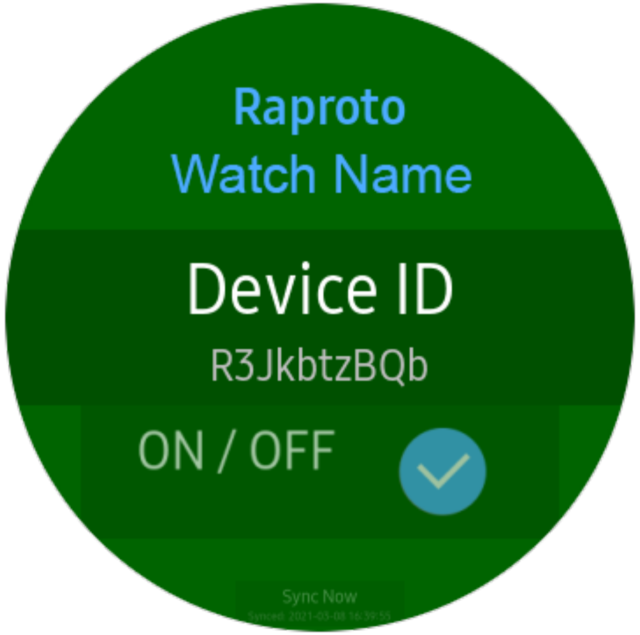


Settings

Configuration
2021-02-24 21:53:28

MQTT
sl://tb.precise.seas.upenn.edu:888

Configuration



Raproto
Watch Name

Device ID
R3JkbtzBQb

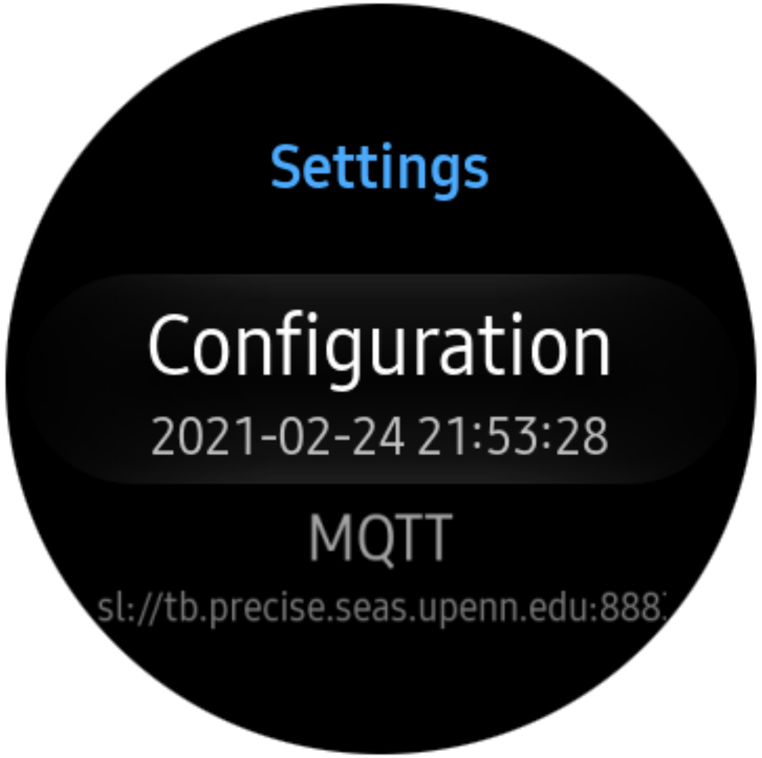
ON / OFF ✓

Sync Now
Synced: 2021-03-08 16:39:55

Data Collection

Smartwatch Application: Watch Configuration

- Settings for each watch are configured on the remote server
  - Sensor Selection
  - Sampling Rates
  - Wi-Fi Usage
  - Transmission Rates
- To receive these settings, a configuration button must be pressed in the smartwatch



Settings

Configuration

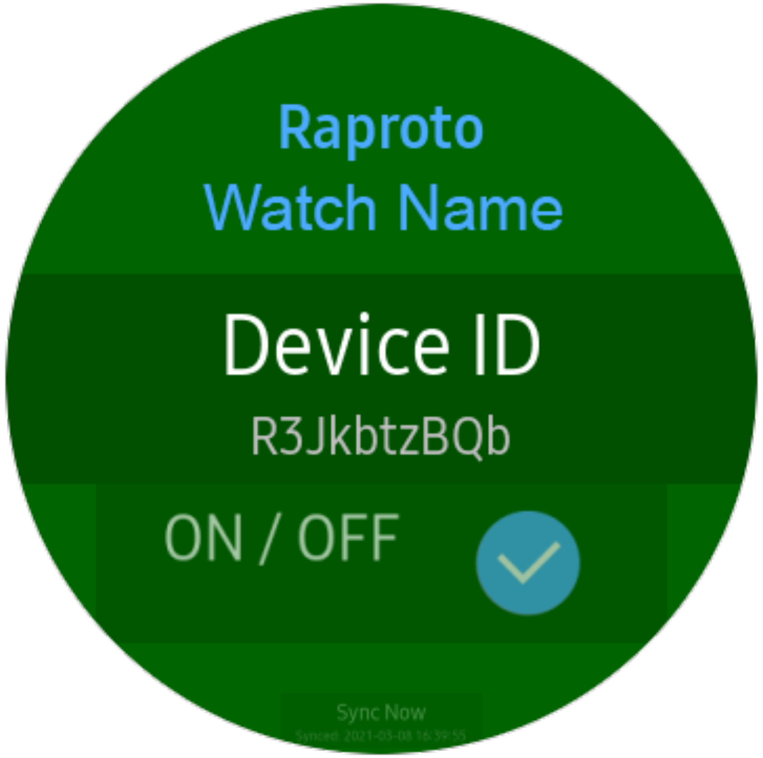
2021-02-24 21:53:28

MQTT

sl://tb.precise.seas.upenn.edu:888

Smartwatch Application: Data Collection

- Supported Sensors:
  - Accelerometer
  - Gyroscope
  - Gravity sensor
  - Heart rate monitor
  - PPG
  - Battery level
- Sensor data is stored in JSON format



Device ID

R3JkbtzBQb

ON / OFF ✓

Synced: 2021-03-08 16:39:55

Smartwatch Application: Data Storage

- Sensor data is not always immediately transmitted to the remote server
- 40 megabytes of buffer storage
- Data is packaged in 10 KB messages
- Once a wireless connection is established, data is sent out

Smartwatch Application: Battery Management

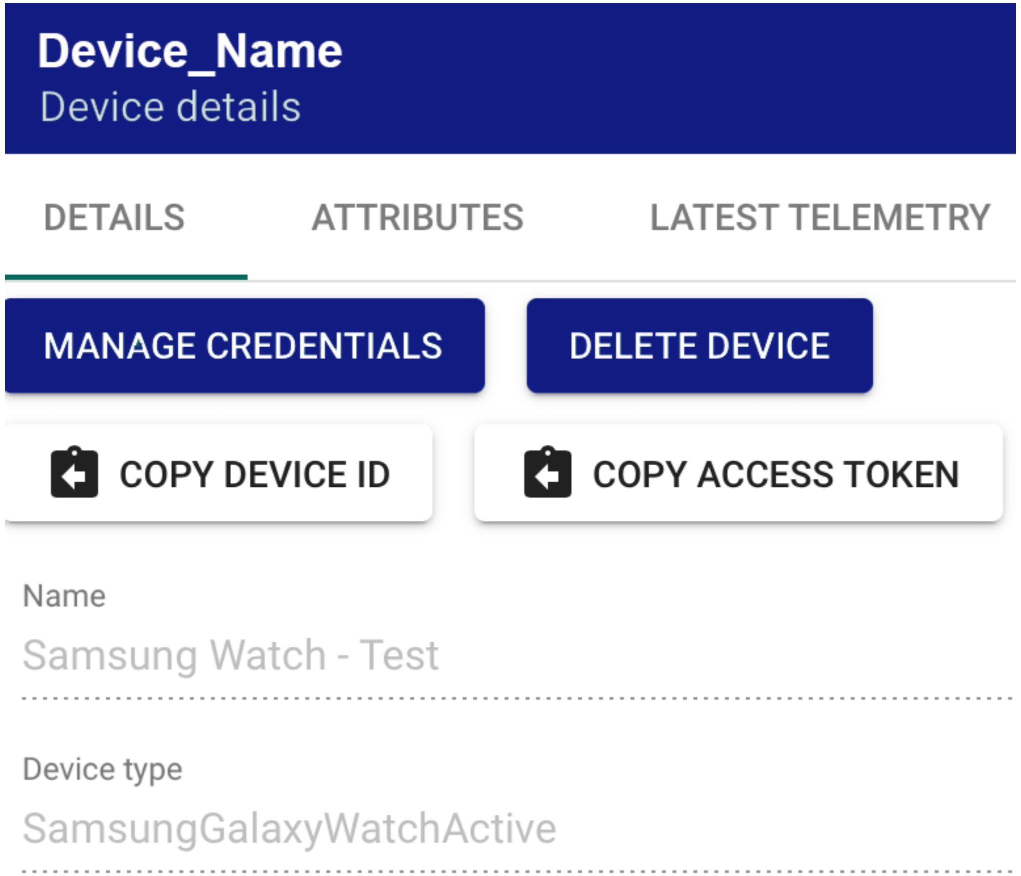
The largest drains on the battery life:

- Display
    - One-time configuration
    - Less than 5 minutes
- Wi-Fi Radio Settings
    - Configure time spent between data transmission events
- Volume of Sensor Data
    - Select sensors
    - Configure data sampling rates

Communication Protocol

- MQTT is a publish/subscribe messaging protocol
  - Telemetry: Smartwatches to the Server
  - Commands: Server to the Smartwatches
- MQTT supports three levels of quality of service
  - Level 0: telemetry is sent without acknowledgment that the server has received it.
  - Level 1: guarantees that the server receives the telemetry by sending an acknowledgment back. If the acknowledgment is lost, then telemetry is resent until it receives an acknowledgment.
  - Level 2: guarantees the telemetry will be received exactly one time by completing a "handshake" to confirm that the telemetry has been sent and that the acknowledgment has been received.

Remote Server: Device Administration



Device_Name
Device details

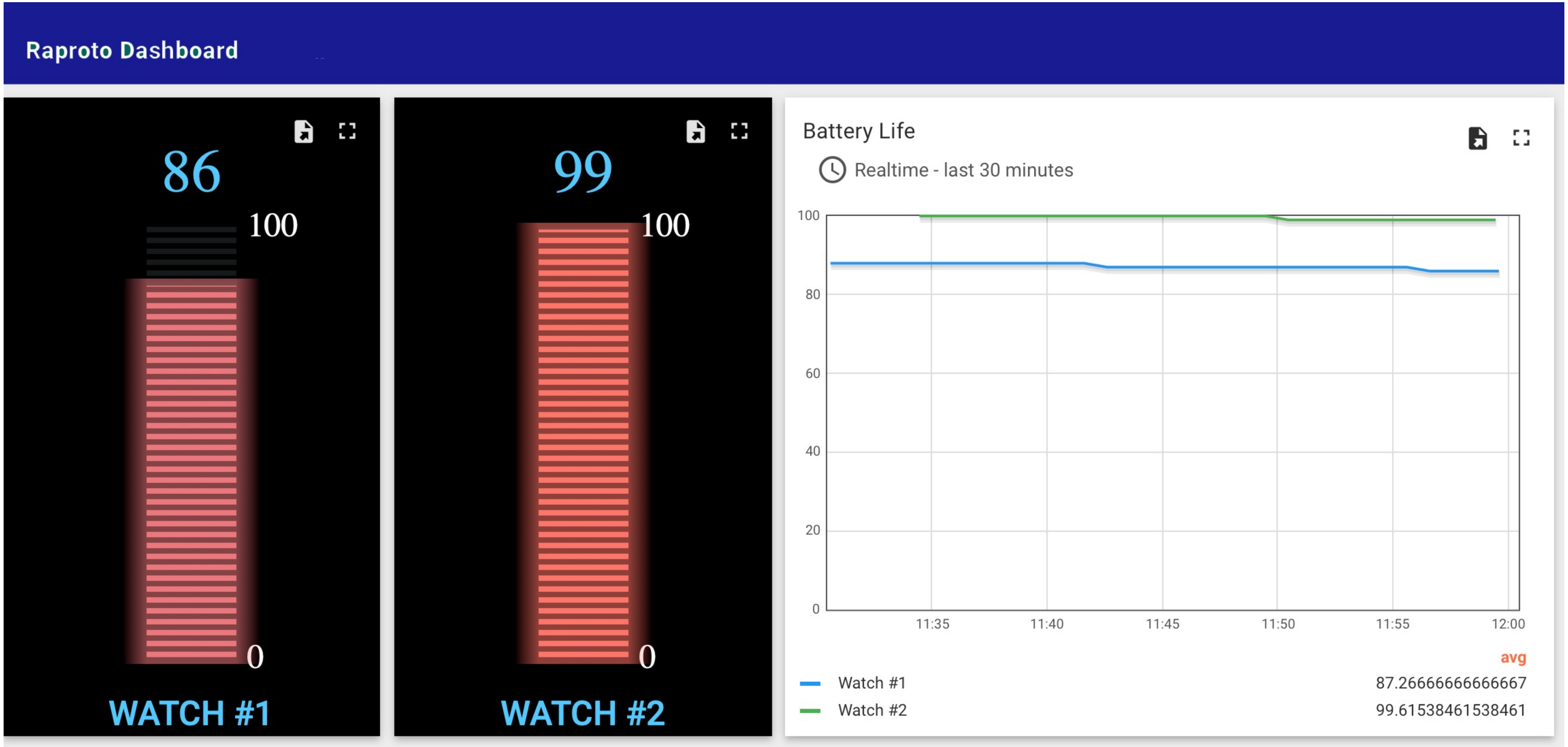
Name
Samsung Watch - Test

Device type
SamsungGalaxyWatchActive

Remote Server: Data Storage

- TimescaleDB
  - Open-Source
  - Optimized for time-series data
  - Fast storage of new entries
  - Quick processing of complex analysis
- SQL queries are used to access the data
- Not directly accessible for end-users

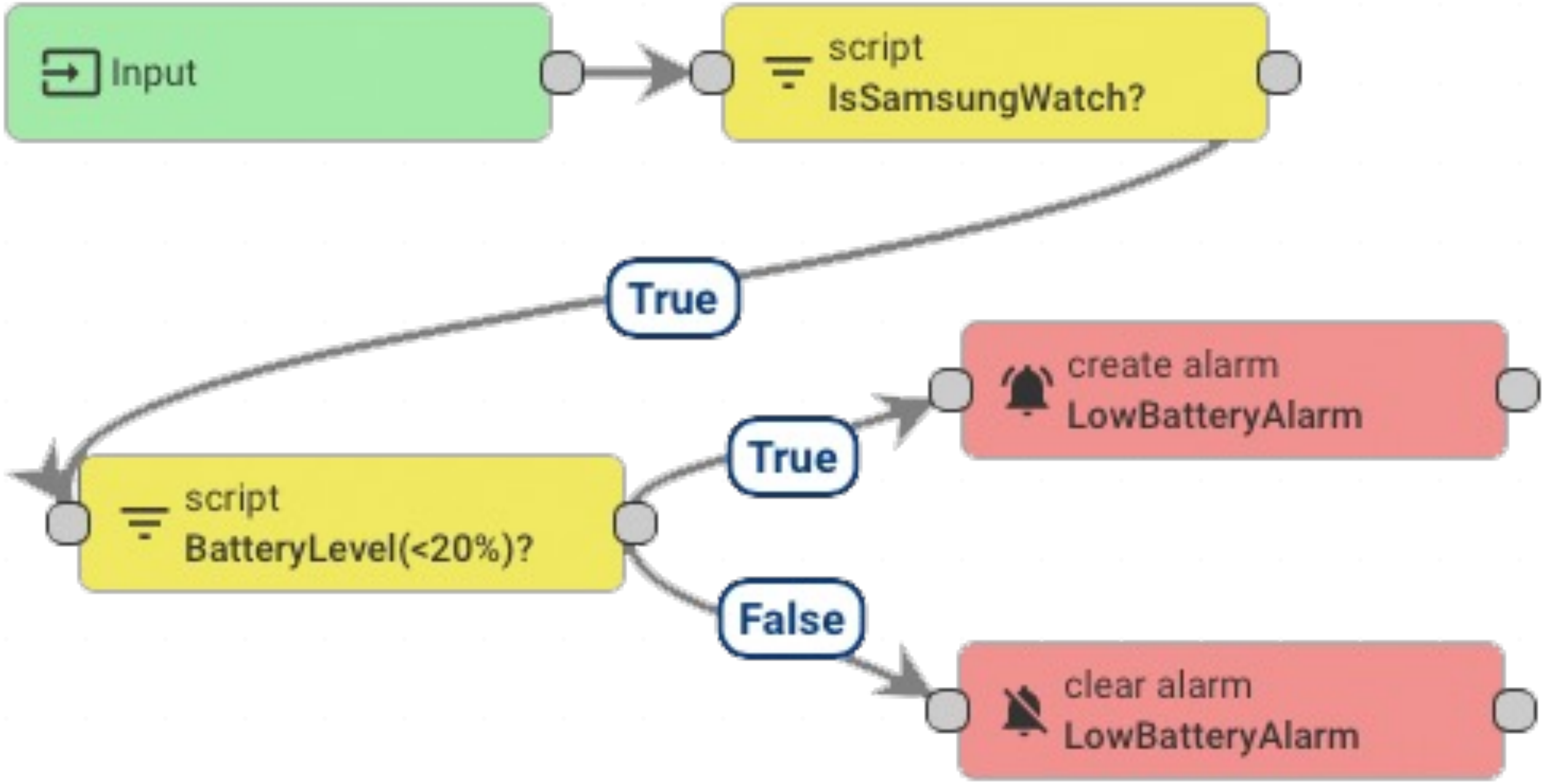
Remote Server: Data Visualization



Raproto Dashboard

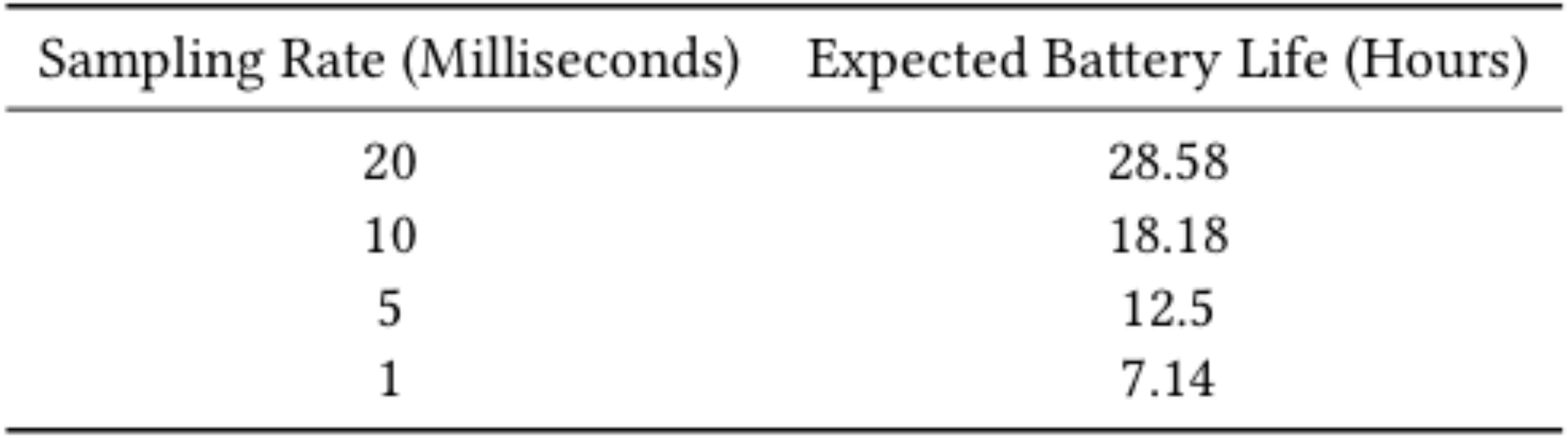
	avg
Watch #1	87.26666666666667
Watch #2	99.61538461538461

Remote Server: Data Processing



Evaluation – Battery Life

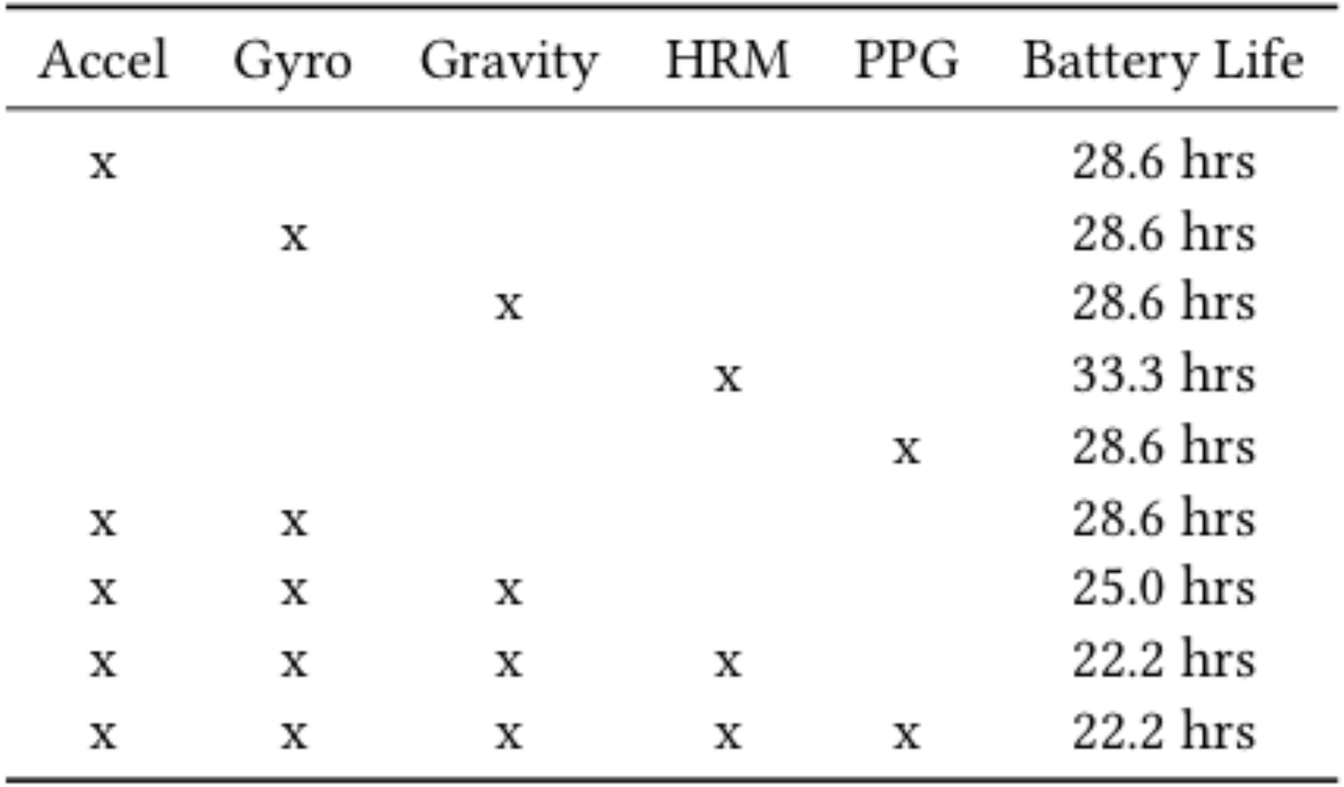
Expected Battery Life with Accelerometers at Various Sampling Rates



Sampling Rate (Milliseconds)	Expected Battery Life (Hours)
20	28.58
10	18.18
5	12.5
1	7.14

Evaluation – Battery Life

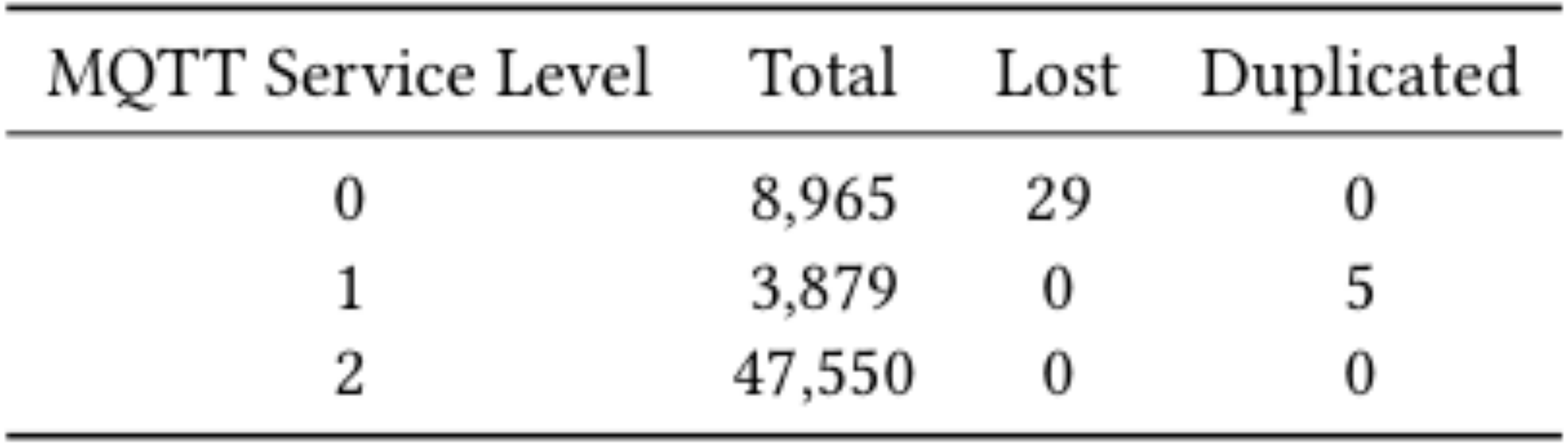
Sensor Combinations Expected Battery Life



Accel	Gyro	Gravity	HRM	PPG	Battery Life
x					28.6 hrs
	x				28.6 hrs
		x			28.6 hrs
			x		33.3 hrs
				x	28.6 hrs
x	x				28.6 hrs
x	x	x			25.0 hrs
x	x	x	x		22.2 hrs
x	x	x	x	x	22.2 hrs

Evaluation – Data Loss

Data Loss and Duplication



MQTT Service Level	Total	Lost	Duplicated
0	8,965	29	0
1	3,879	0	5
2	47,550	0	0

Evaluation – Data Latency

- Time in Storage
  - Configurable
  - Changes based on Wi-Fi Availability
- Transit Time
  - Dependent on MQTT Level of Service
  - Less than 1 Second with MQTT LoS-1

Extensibility

Android OS Support

Google Play Galaxy Apps

Application Store Availability

Cellular Enabled Smartwatches

Conclusion

Raproto is an **open-source**, easy-to-use **rapid prototyping platform** that facilitates data collection from sensors on commercially available **off-the-shelf smartwatches**.

This **platform** provides researchers, especially in remote health monitoring and ubiquitous computing, a **quick**, **simple to use**, and **customizable** solution for developing data collection systems.

We **evaluated** our platform and observed that a smartwatch with the Raproto application running lasted for over **24 hours** on a single charge, has almost **no data loss**, and experienced **less that one second of data latency**.

THANK YOU!

PRECISE

PENN RESEARCH IN EMBEDDED COMPUTING AND INTEGRATED SYSTEMS ENGINEERING

http://precise.seas.upenn.edu

https://github.com/weimerj/Raproto-Tizen