OPQ Version 2: An Architecture for Distributed, Real-Time, High Performance Power Data Acquisition, Analysis, and Visualization

A. Christe, S. Negrashov, P. Johnson,
D. Aghalarpour, D. Badke, D. Nakahodo

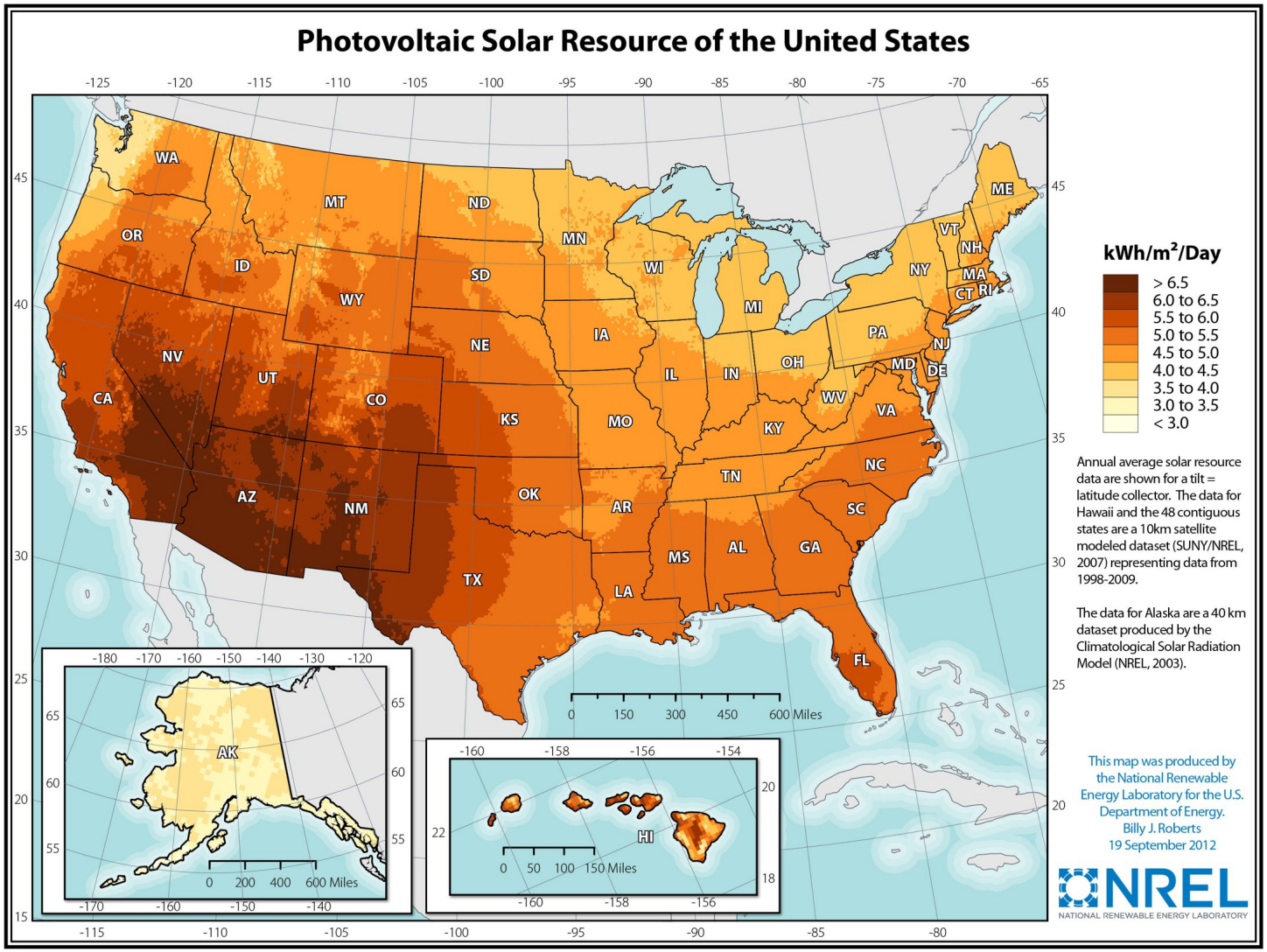
University of Hawaii at Manoa

IEEE Cyber 2017
Waikiki, Hawaii

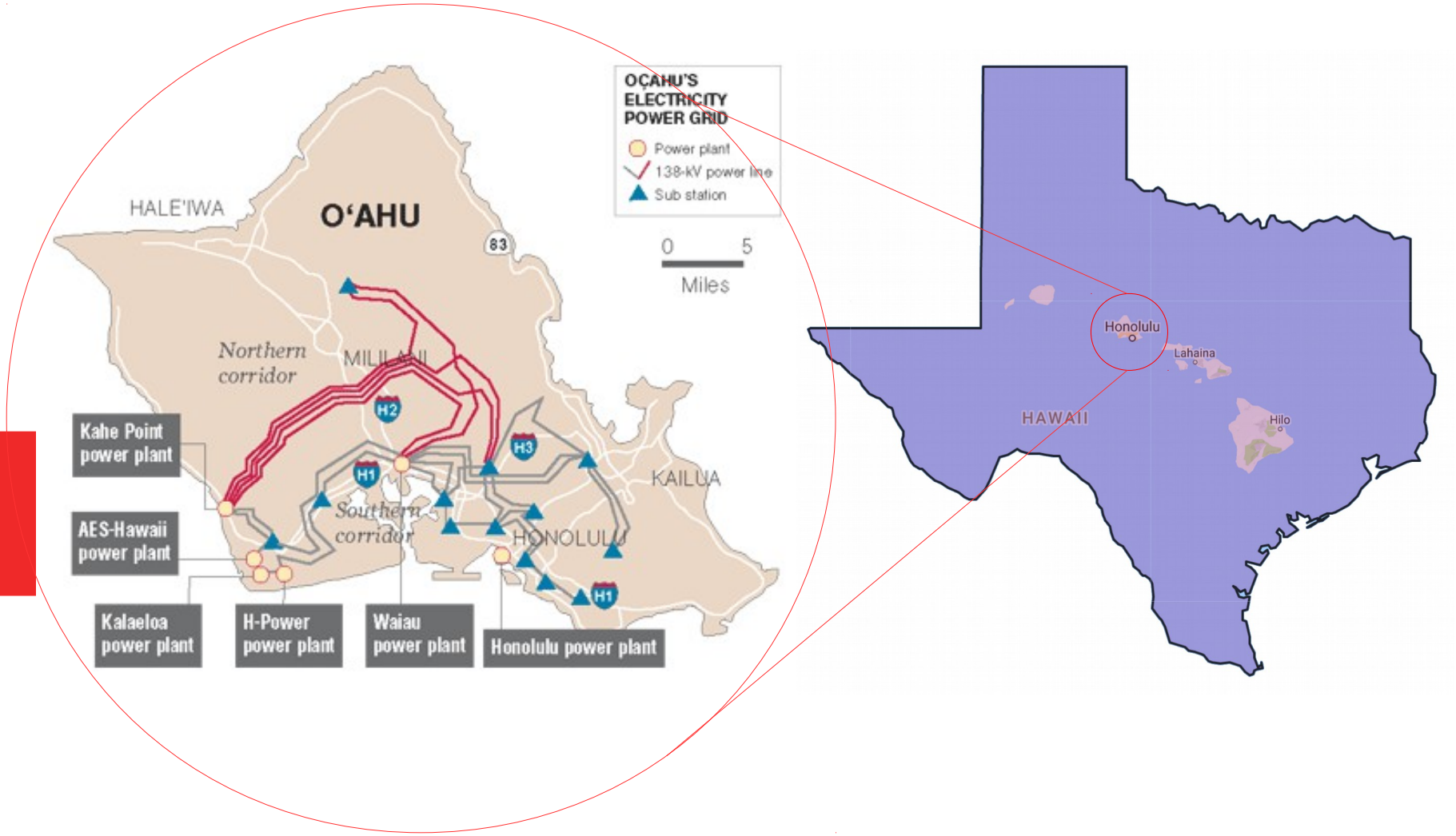
Today’s Talk

- Hawaii’s unique PQ situation
- Brief overview of Open Power Quality
- Power quality event acquisition
- System architecture
- Conclusions and future work

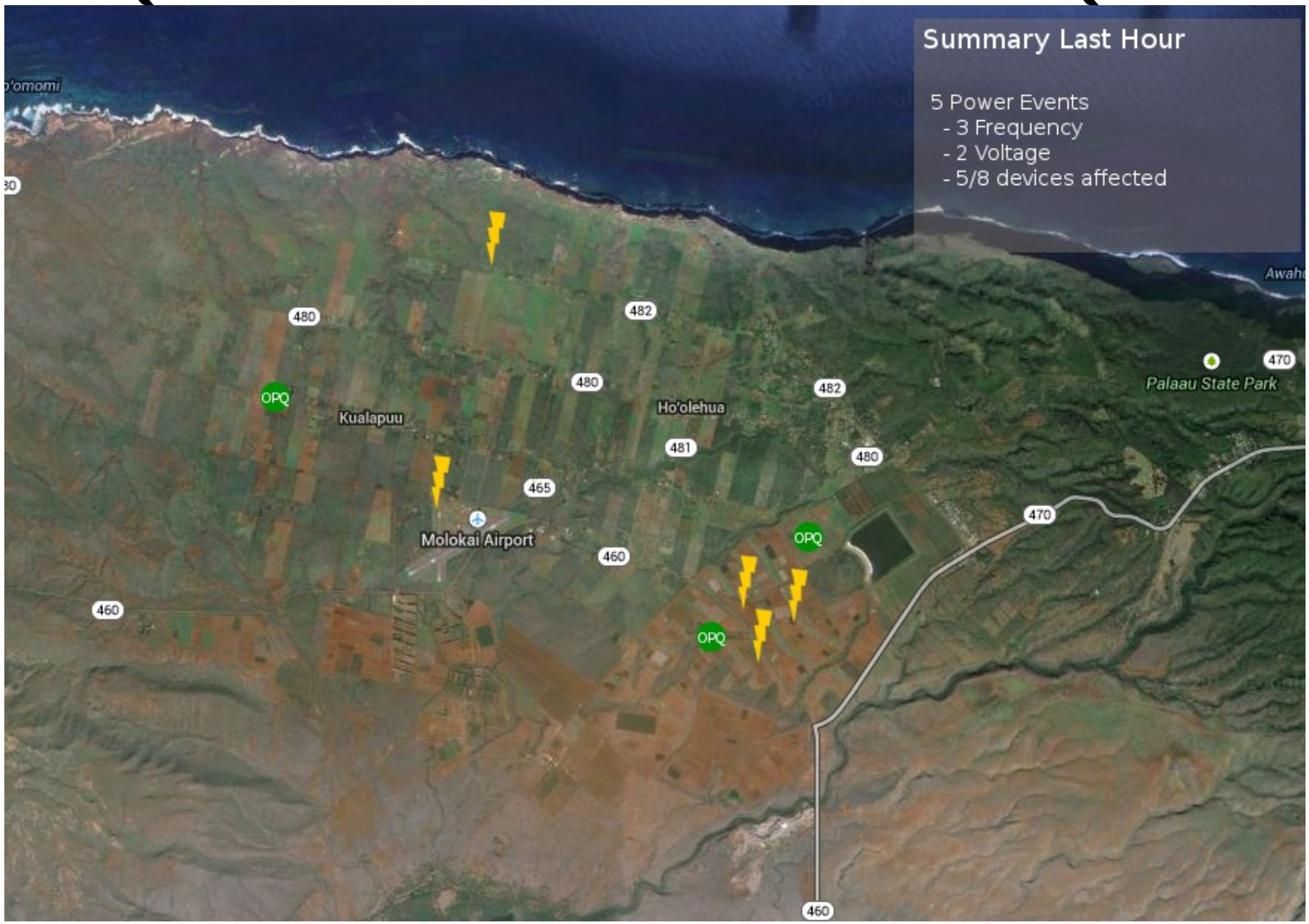
Hawaii's Unique PQ Situation

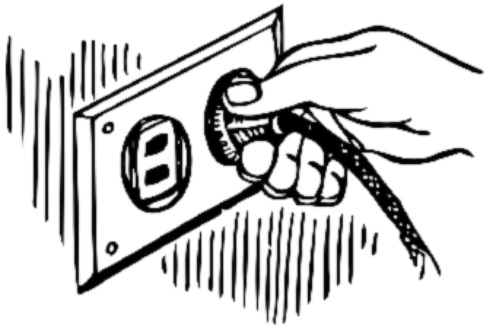


PQ Research in the Pacific?



OPQ: Let's Crowdsource PQ Data!





PQ data collected directly from wall outlet

Data is transferred over WiFi

To the consumers local router

OPQMakai

Reduced feature sets collected

Raw data req. from devices of interest

OPQMauka

Raw data recv. local/global event analysis

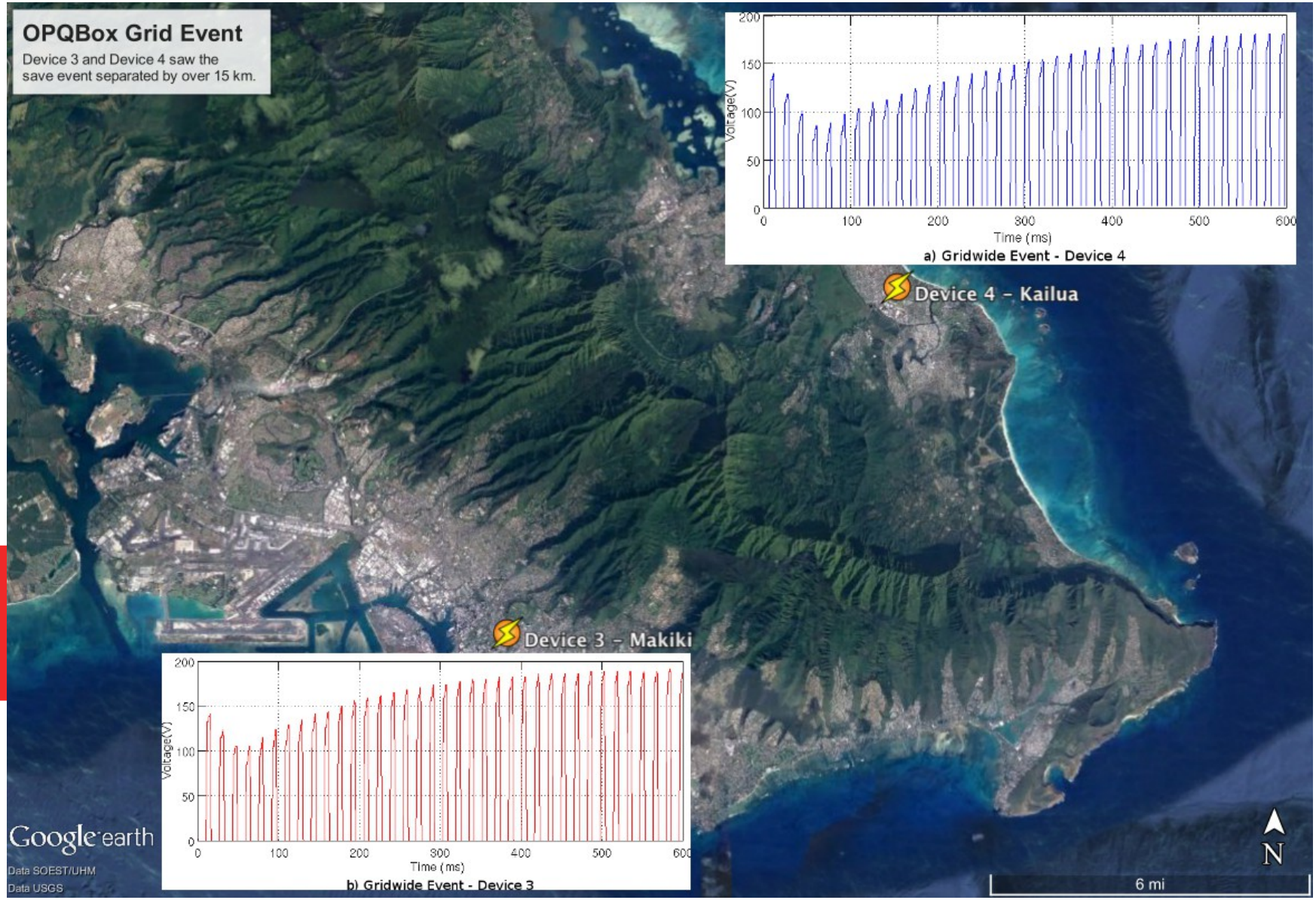
Store high-level products in DB

OPQView

Display high-level products

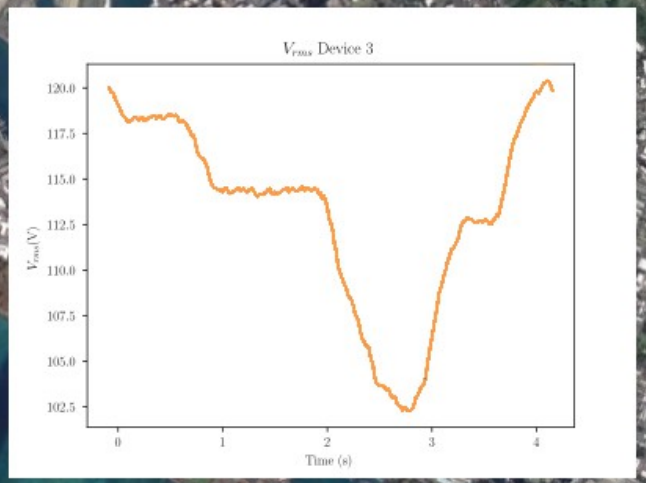
OPQ: A High Level Overview

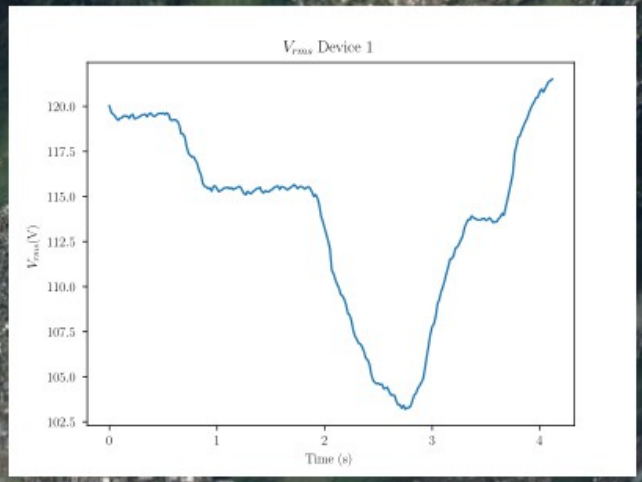
- Inexpensive, high performance PQ meter
  - -High resolution/Sampling rate
  - -$50/Box ~100 devices
- Utilizes cloud/local analysis
  - -Low Bandwidth requirement
- Flexible acquisition and analysis architecture
  - -Pluggable distributed analytics and event detection


OPQBox Grid Event
Device 3 and Device 4 saw the save event separated by over 15 km.
Device 4 – Kailua
Device 3 – Makiki
Voltage(V)
Time (ms)
a) Gridwide Event - Device 4
b) Gridwide Event - Device 3
Google earth
Data SOEST/UHM
Data USGS
N
6 mi

OPQBox Grid Event #2

Devices 1 and 3 saw the same voltage event 5 miles apart.



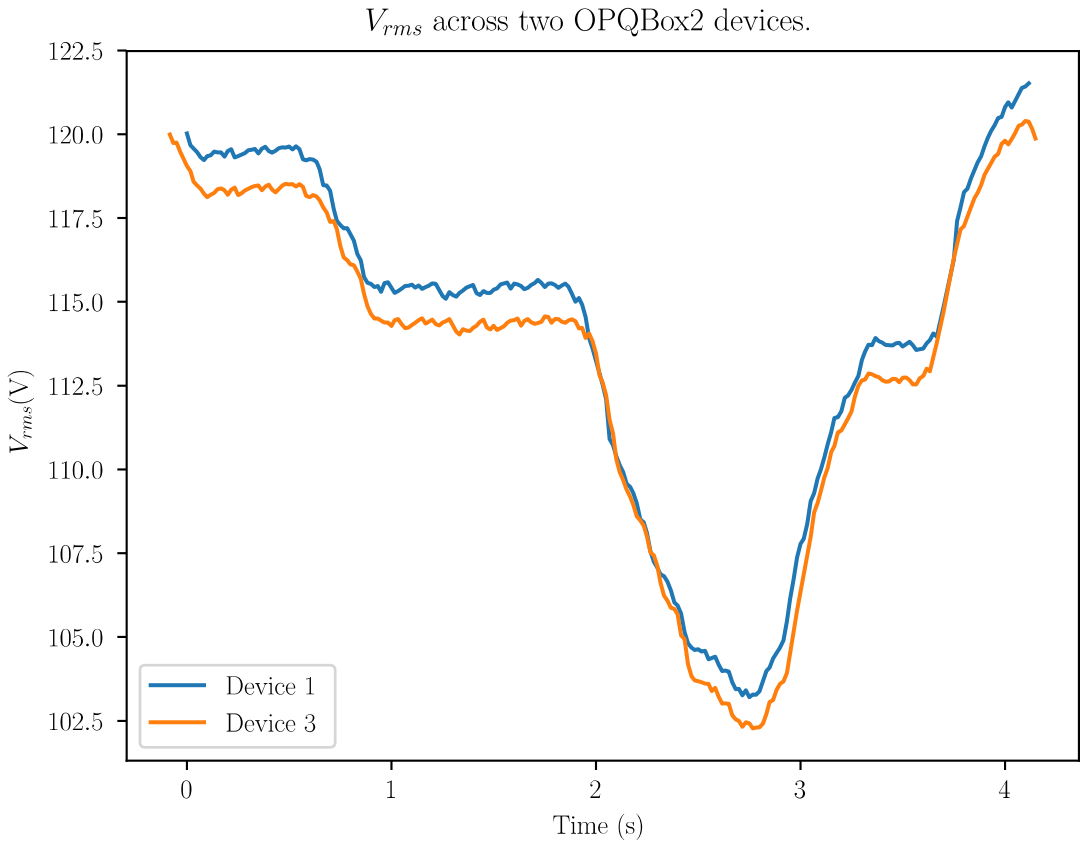


Google earth

N

5000 ft

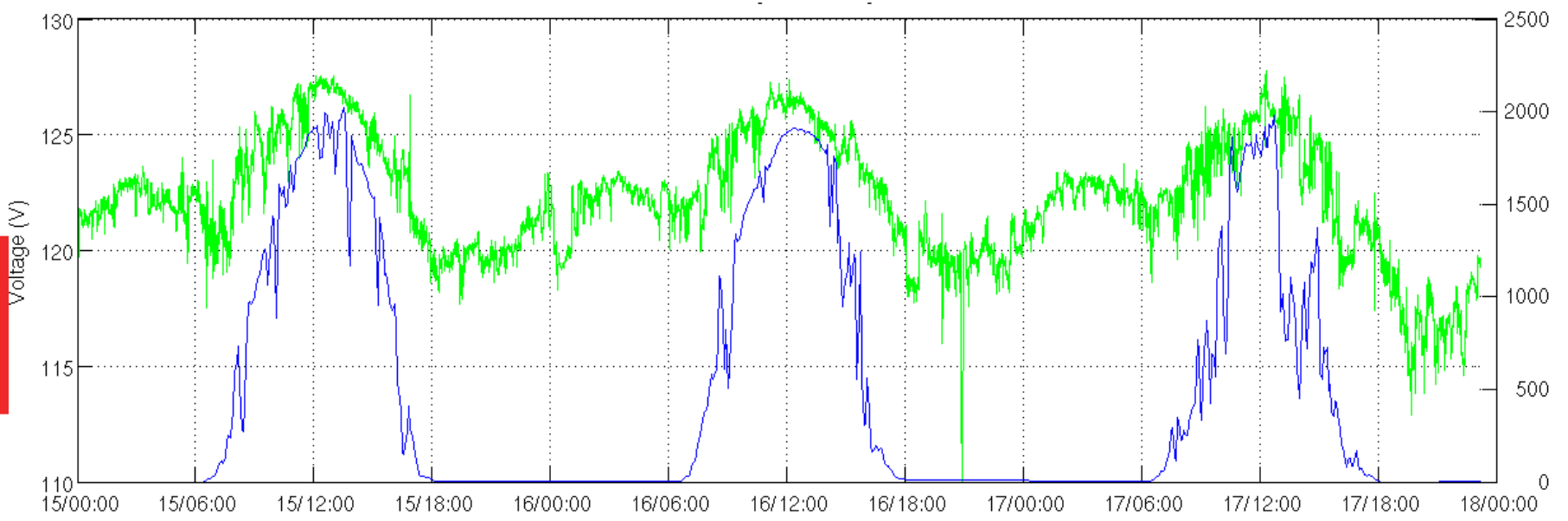
Second Global Event



V_{rms}(V)

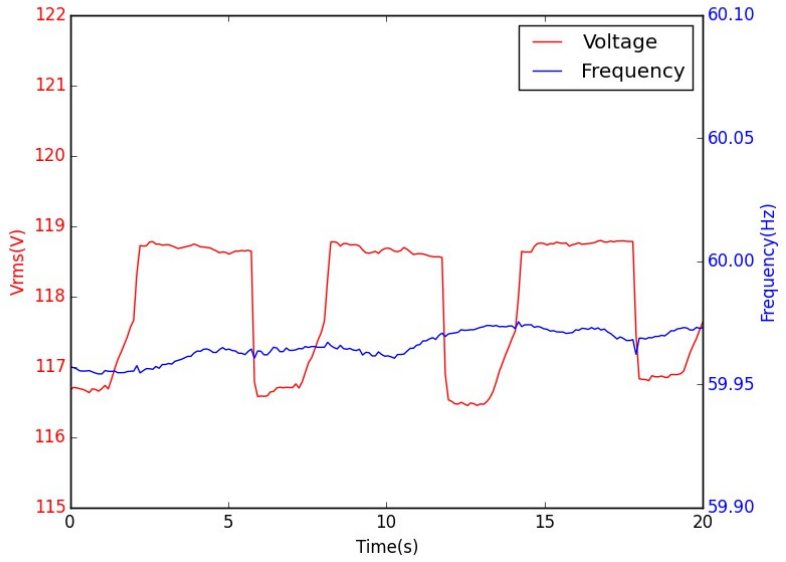
PQ Disturbances occur on both sides of the power meter

- Consumer Power generation:

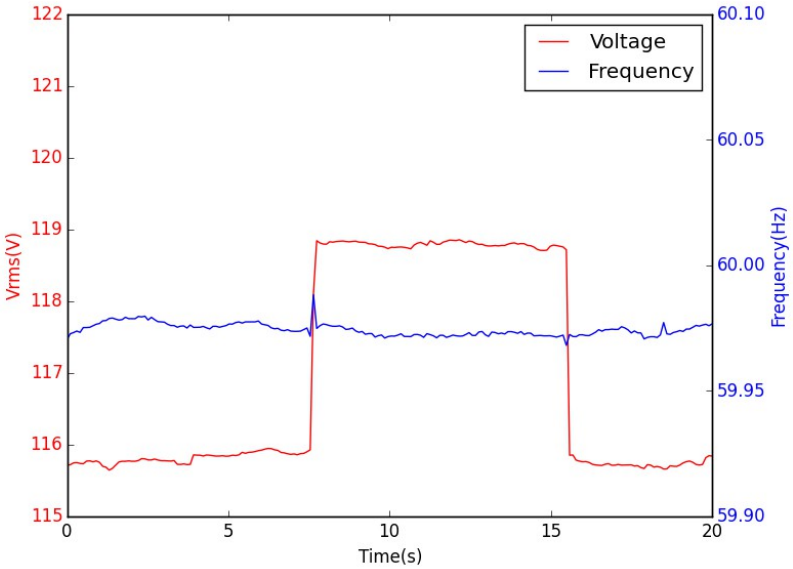


a) Line Voltage and Rooftop Solar Production 2014/10/15 - 2014/10/18

PQ Disturbances occur on both sides of the power meter

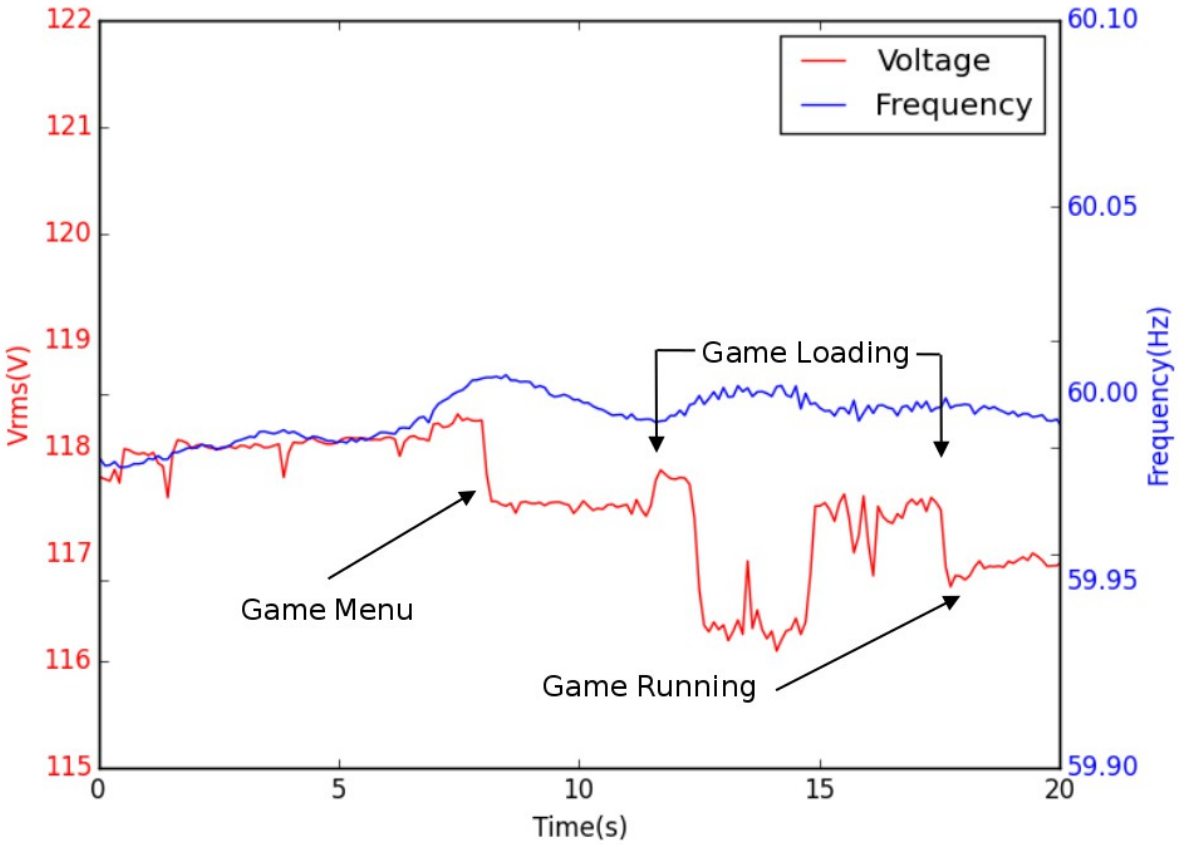


Inductive Hotplate



Toaster Oven

PQ Sensitivity



Desktop PC under high load

Event Detection

Local Event Detection is impractical:

- High rate of False positives
- Missed sub-threshold data
- Privacy concerns

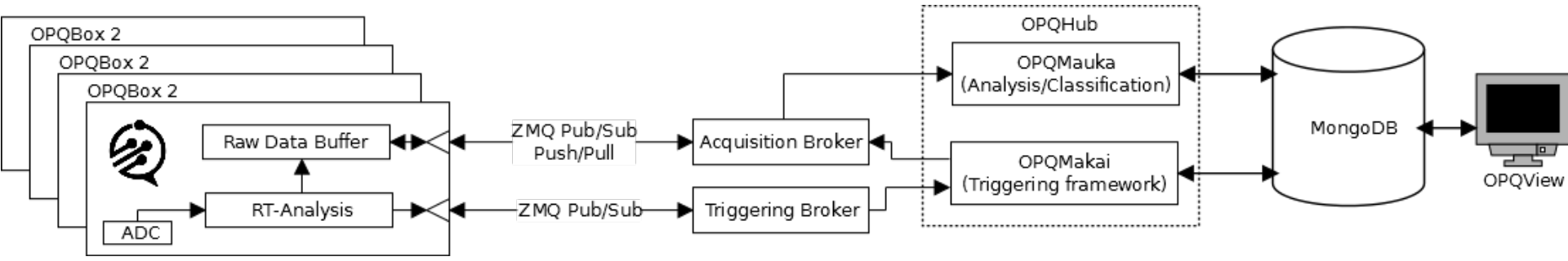
Centralized Event Detection is too expensive:

- High bandwidth/Computational cost
- Even more privacy concerns

We need a hybrid approach

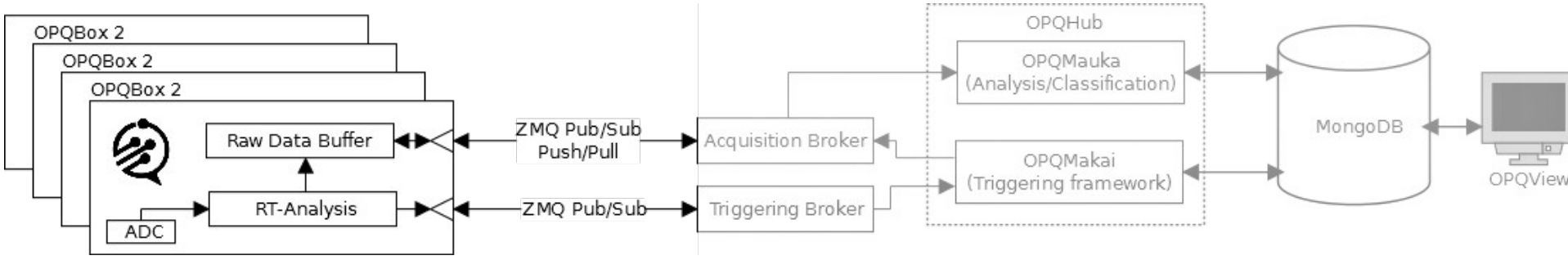
System Architecture

- OPQBox2 processes and stores [how long is the buffer?] data locally
- Data features are sent to the cloud
- High fidelity data is requested based on data features
- OPQMakai is an acquisition and triggering backend
- OPQMauka is an analysis middleware component
- OPQView is the event display frontend



OPQBox2

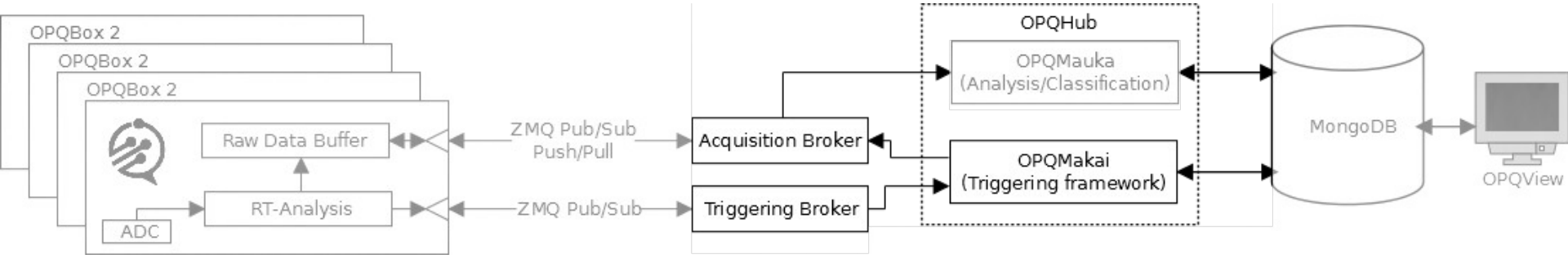
- 16Ks/s 16Bit sampling
- Electrically isolated from the mains
- STM32 DSP:
  - Sampling control
- Raspberry Pi Zero W:
  - NTP synchronization
  - Local feature extraction
  - 30 minute buffer for raw waveforms
  - 802.11 WiFi
- Optional features
  - Battery backup
  - GPS synchronization



OPQMakai

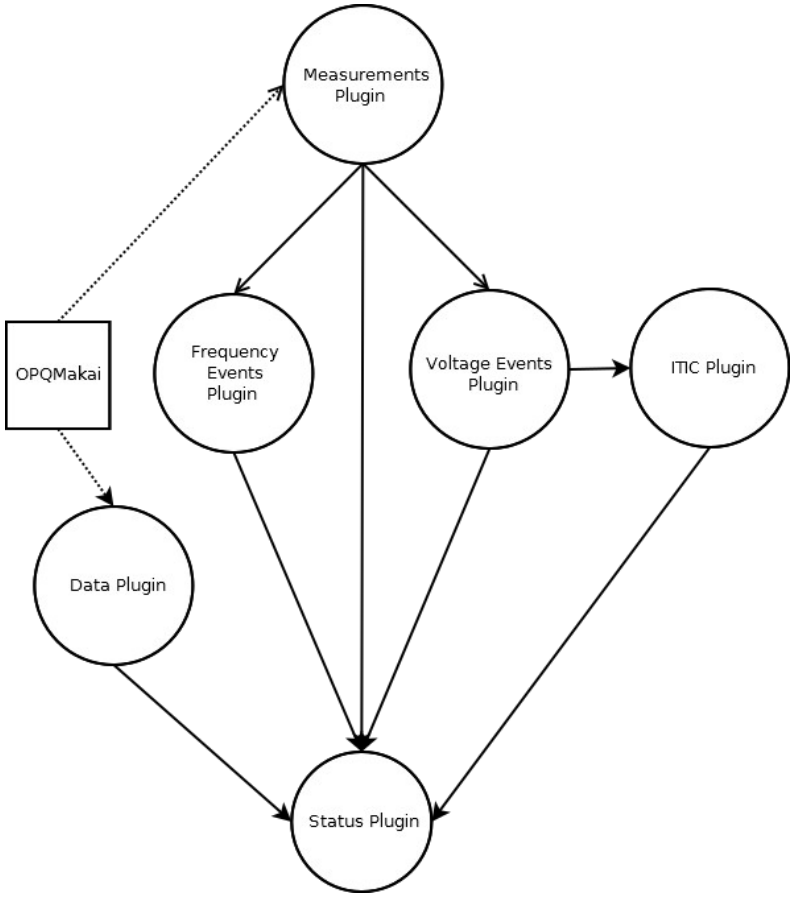
Communication with OPQBox2s:

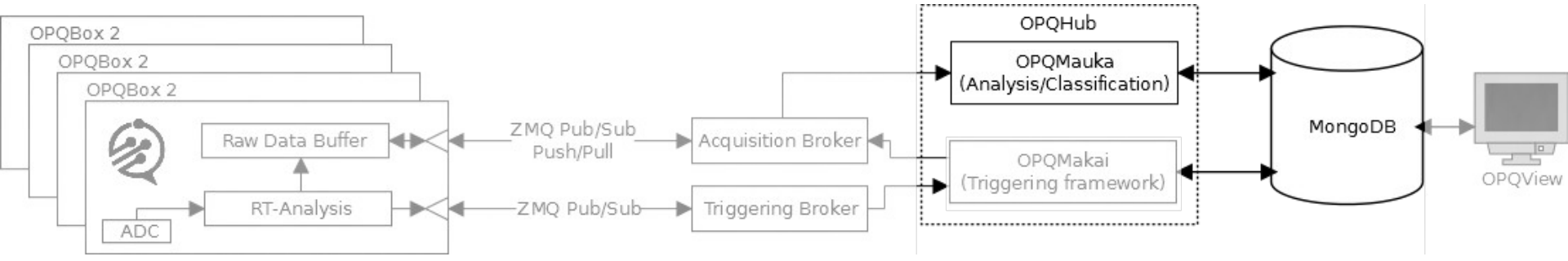
- Encrypted
- Brokered
- Scalable [appears to be]
- Asynchronous



OPQMauka

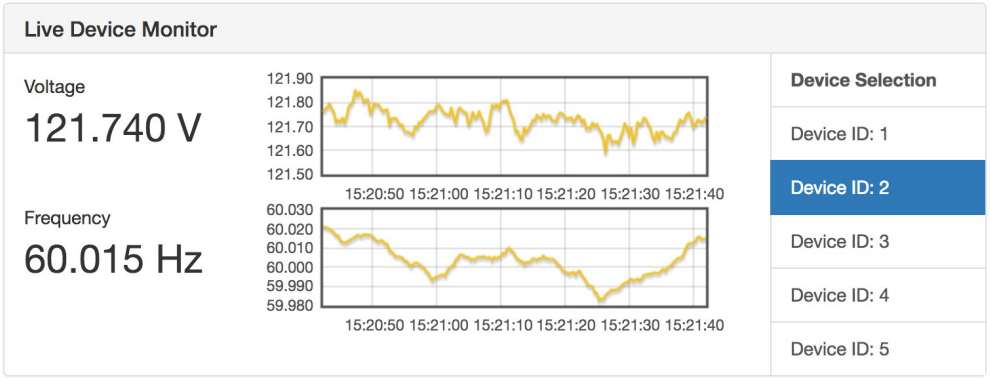
- Distributed plugin based analysis middleware
  - Acts on data from OPQMakai
  - I.P.C. via ZeroMQ
  - Plugins form D.A.G.
  - Publish/subscribe
  - Basic classification
  - Store products for OPQView

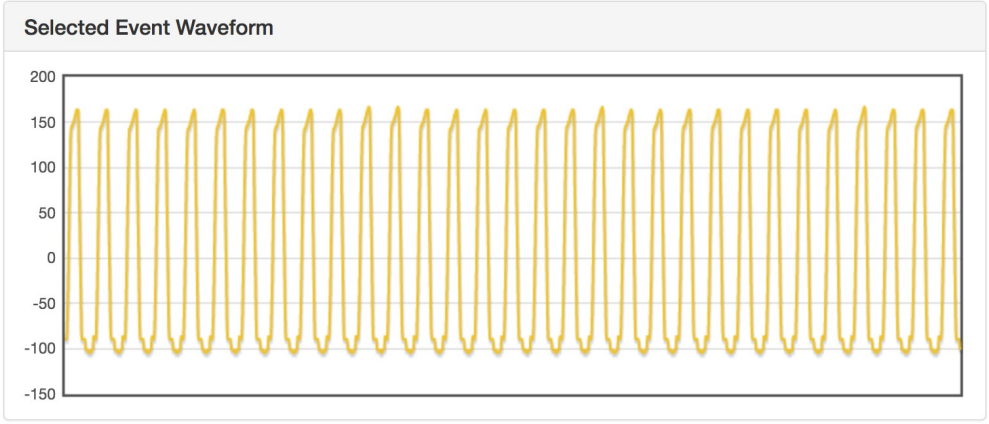


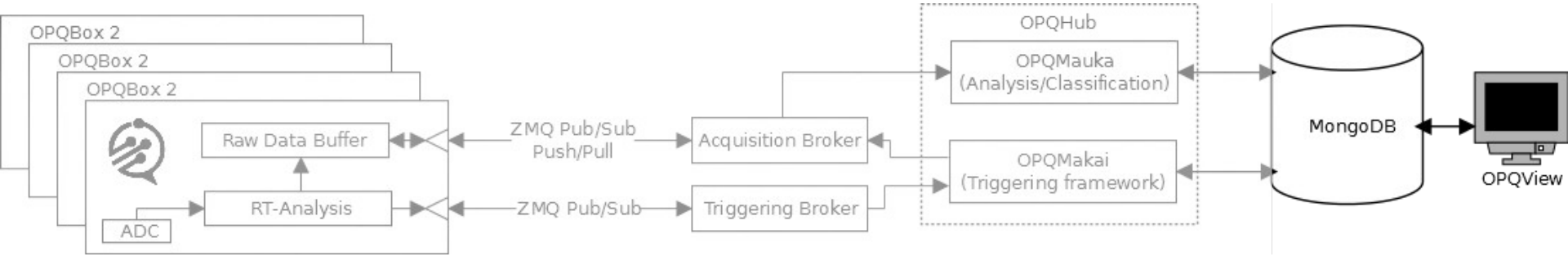


OPQView

- Web based PQ
  - Reporting
  - Analytics
  - Trends
  - Status of network







Future Work

- Privacy study
- Signal classification
- PQ communities
- Higher level feature extraction on OPQBox2
- Kickstarter campaign (Fall 2017)

Future Work

Collaboration With You?

We Welcome Contributions

- Find us at
  - http://openpowerquality.org
  - http://github.com/openpowerquality
- Contact us at
  - achriste@hawaii.edu
  - sin8@hawaii.edu
  - johnson@hawaii.edu

Acknowledgements

- Electric Power Research Institute
- Hawaiian Electric Company
- Power Standards Lab

Mahalo!

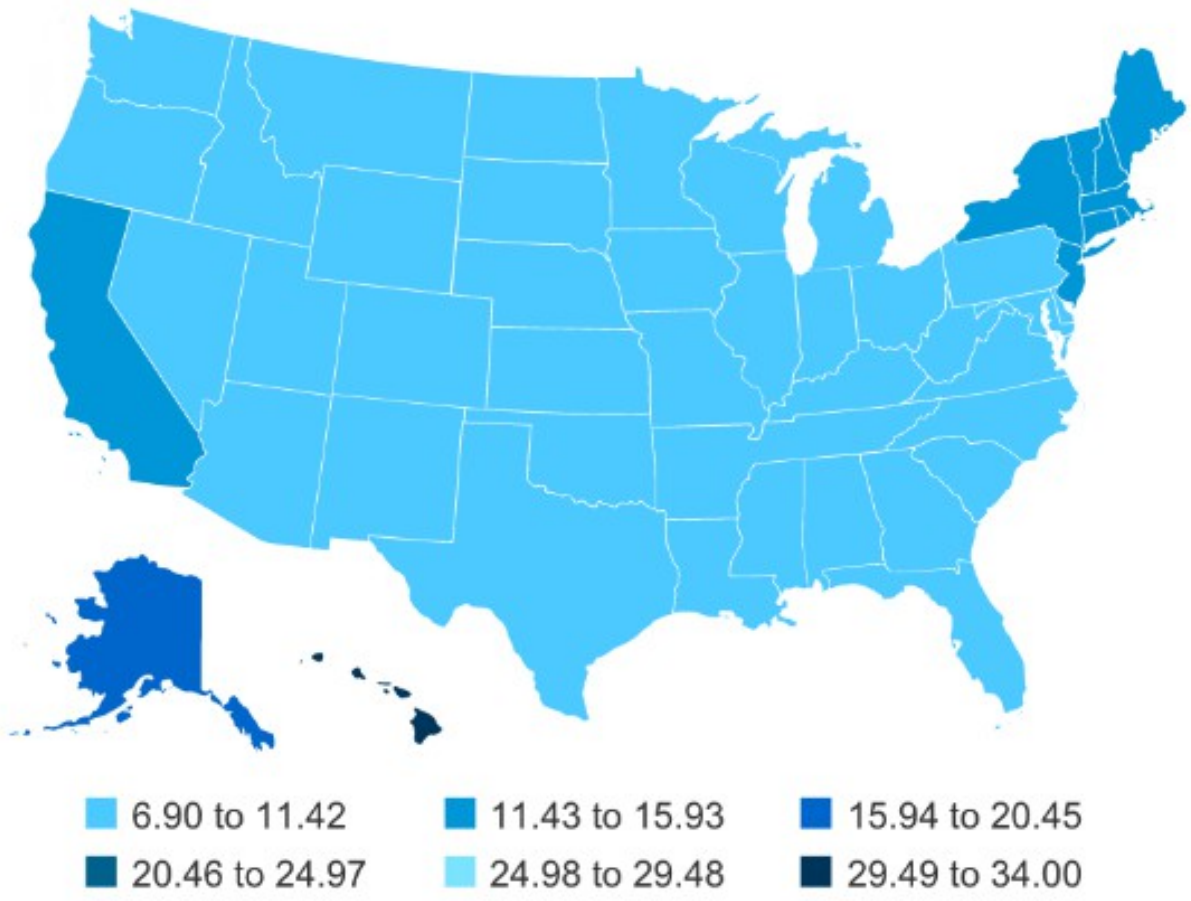
Questions?

Future Work – Privacy Study

- Identify sensitive PQ data
- Ensure sensitive PQ data is not leaked
- Do users feel that their privacy is respected?
- Do privacy controls affect overall DQ?

Hawaii's Unique PQ Situation

Average state electricity price in cents per kilowatt-hour
(Source: U.S. Energy Information Administration. Data for 2013)



Future Work – Privacy Study

- Identify sensitive PQ data
- Ensure sensitive PQ data is not leaked
- Do users feel that their privacy is respected?
- Do privacy controls affect overall DQ?

Future Work – Signal Classification

- Better classification of PQ events
- Local Events vs. Grid Wide Events
- Creation of a training set of events for supervised learning

Future Work – PQ Communities

- Examine the electrical distance between devices
- Group devices into communities based on electrical distance
- Group devices into communities based on PQ

Future Work
Grid Based Time Synchronization

- Replace GPS and NTP synchronization with grid based synchronization

Future Work
Limited Bandwidth Data Acquisition

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