

OpenPowerQuality: An Open Source Framework for Power Quality Collection, Analysis, Visualization, and Privacy

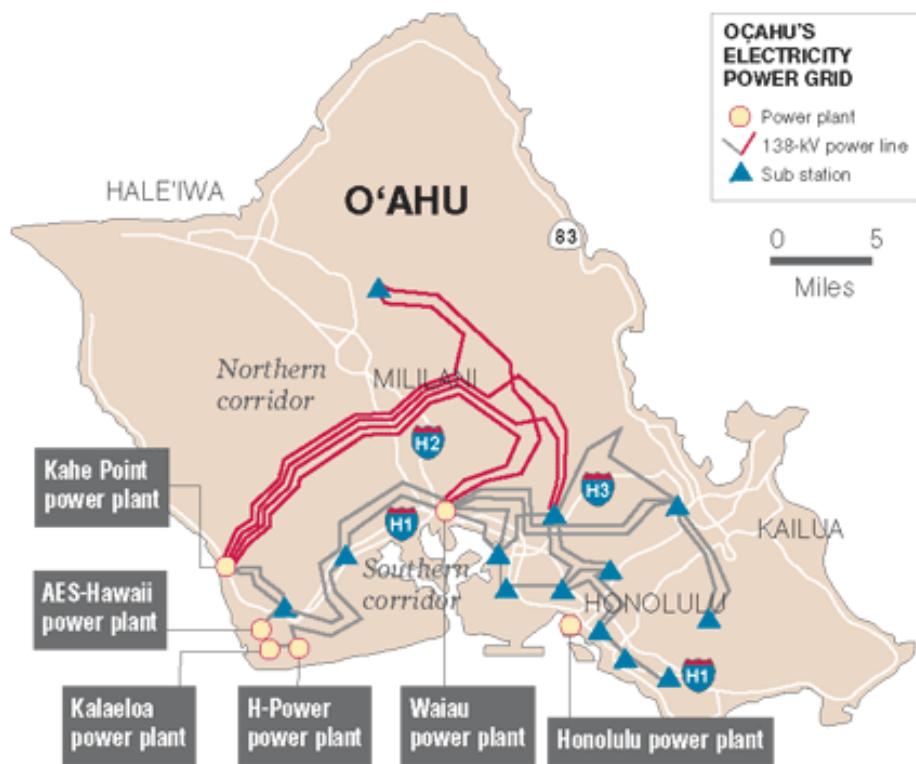
A. Christe, S. Negrashov, P. Johnson
University of Hawaii at Manoa

IEEE ISGT 2016
Minneapolis, Minnesota

Today's Talk

- Hawaii's Unique PQ Situation
- Brief overview of Open Power Quality
- Pilot Study Results
- Privacy Concerns
- OPQHub
- Conclusions and Future Work

PQ Research in the Pacific?



Hawaii's Unique PQ Situation

PRESS RELEASE: GOVERNOR IGE SIGNS BILL SETTING 100 PERCENT RENEWABLE ENERGY GOAL IN POWER SECTOR

Posted on Jun 8, 2015 in [Latest News](#), [Newsroom](#), [Press Releases](#)

Hawaii's Growing Solar Energy Incentive Program Derailed by State-Imposed Limits

Friday, July 15, 2016

Navy, electric company teaming to build Hawaiian solar farm

Aug. 10, 2016

Rejected Hawaii Utility Merger Scraps Aging Power Plant Upgrades

Gridlocked by the power grid: Why Hawaii's solar energy industry is at a crossroads

April 11, 2015 at 11:23 AM EDT

MORE VIDEO

Smart sharing: Sun-saturated Hawaii debates first TOU community solar proposal

Crediting community solar users depending on time of day could open new markets for storage and help optimize the grid, PUC staff says

By [Herman K. Trabish](#) | August 11, 2016  print



Utility vs. Homeowners Over Solar Power
By Erik Braund and Eugene Yi

Solar Power Battle Puts Hawaii at Forefront of Worldwide Changes

By DIANE CARDWELL APRIL 18, 2015



Hawaii's Unique PQ Situation

State tallies counties' progress toward grid's solar power limit

By Kathryn Mykleseth

Posted on June 1, 2016 12:05 am

The Interconnection Nightmare in Hawaii and Why It Matters to the US Residential PV Industry

Solar Customers Get Burned In Hawaii

© 10/15/2013 01:27 pm ET

How Much Solar Can HECO and Oahu's Grid Really Handle?

A Solar Boom So Successful, It's Been Halted

Photovoltaics proved so successful in Hawaii that the local utility, HECO, has instituted policies to block further expansion

Want Solar Panels? You May Have to Pay HECO Thousands in Studies

Hurdles remain for residents wanting solar panels despite recent PUC ruling.

Is HECO the Dark Side of Solar?

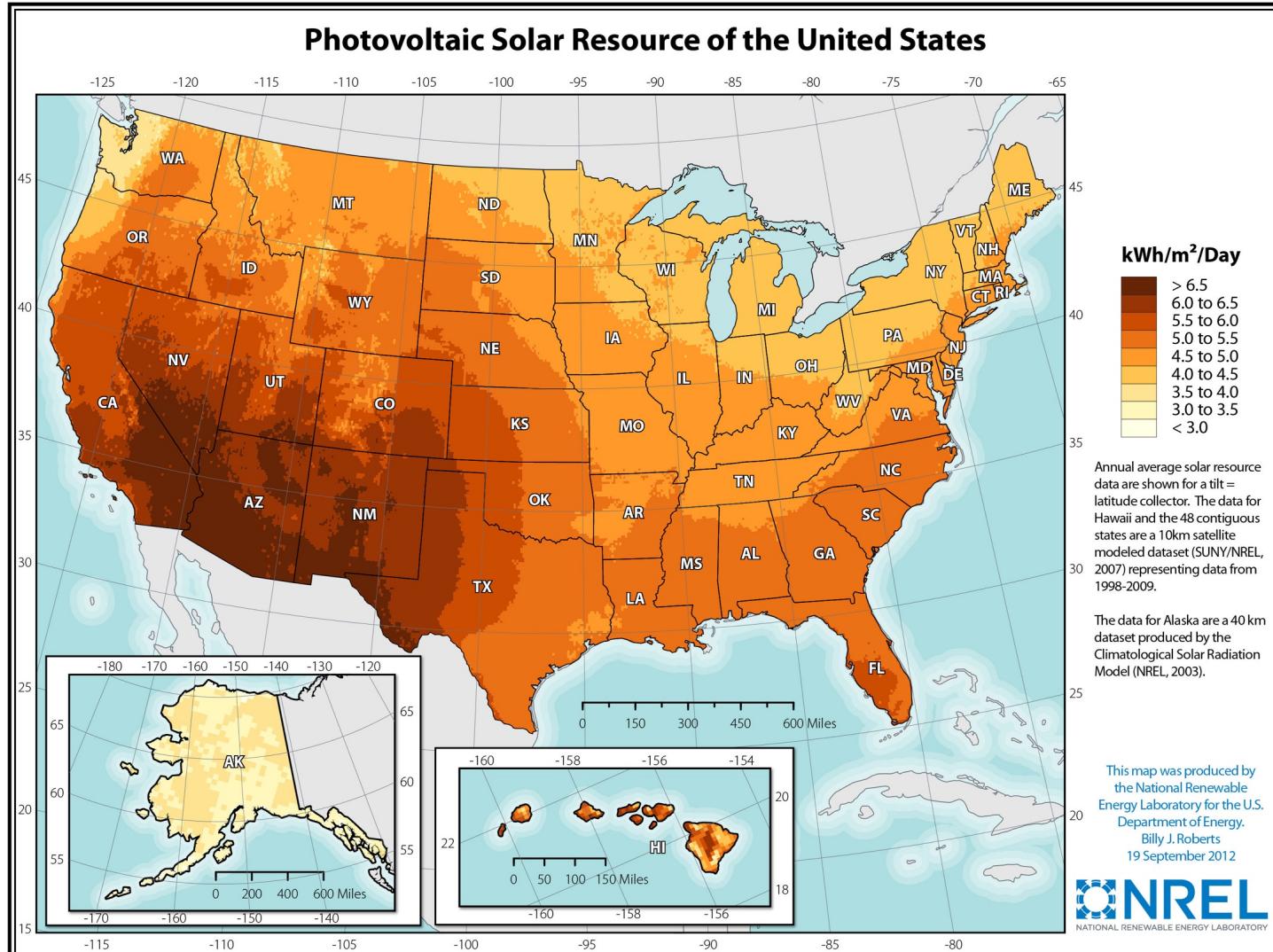
By Henry Curtis

Hawaiian Electric Raises Small-Solar Threshold to 100%

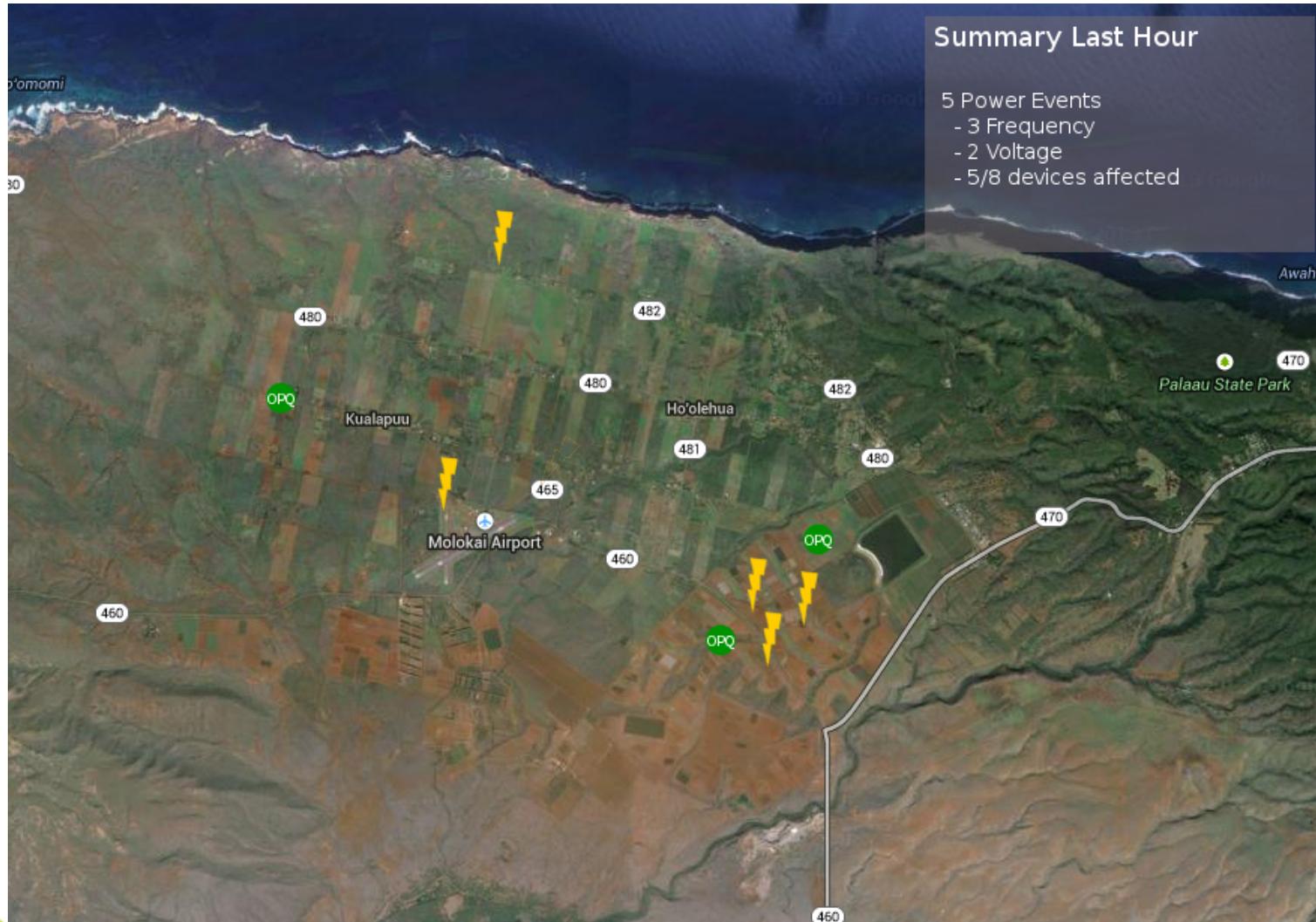
HECO faces big challenges after solar PV explosion

January 27, 2015

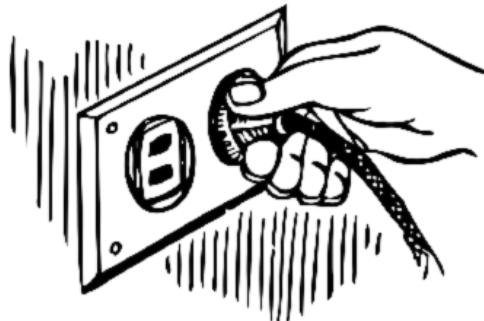
Hawaii's Unique PQ Situation



OPQ: Let's Crowdsource PQ Data!



OPQ Hardware



PQ data collected
directly from wall
outlet

Data is transferred
over WiFi

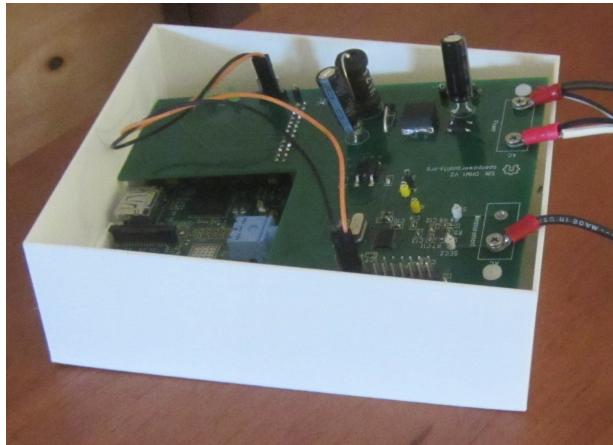
To the consumers
local router

Open Source Hardware

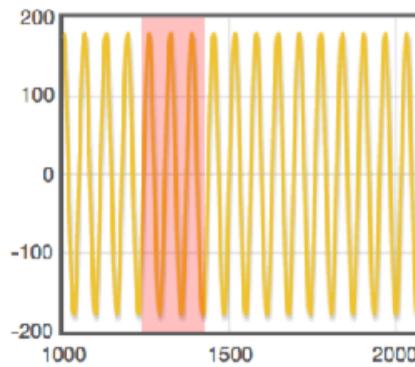
12v Transformer

24Bit 4KSps ADC

Linux SBC



OPQ: A High Level Perspective



Data is collected on
our server

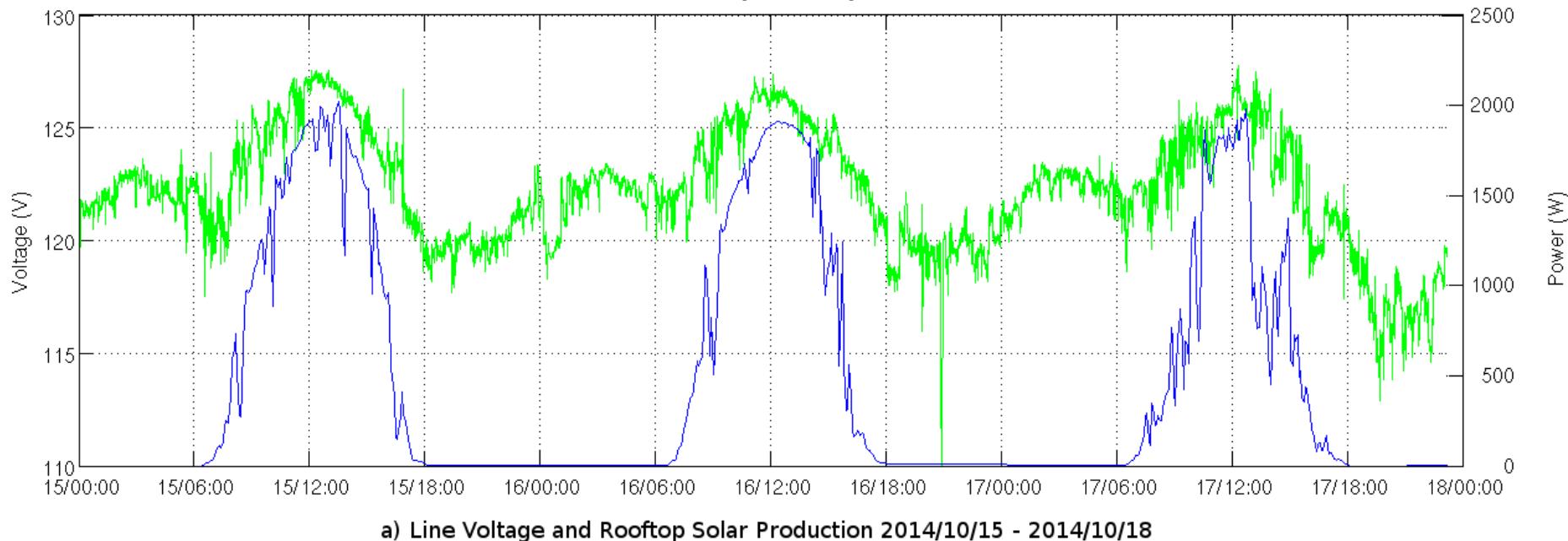
Where it is
analyzed, stored, &
displayed

And users are alerted
w/ preconfigured
triggers

OPQ: A High Level Overview

- OPQBox1
 - Voltage Sags / Swells
 - Frequency Fluctuations
- OPQBox2
 - Harmonic Distortion
 - Transients

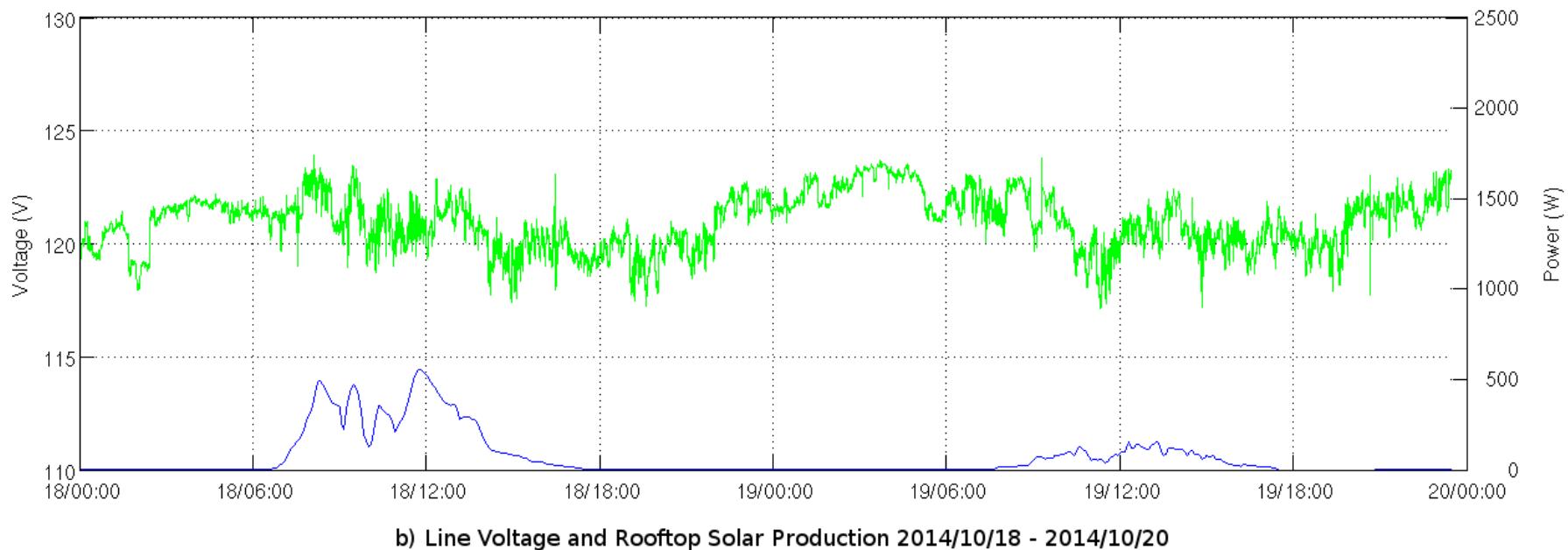
OPQ: Daily Trends



— RMS LN Voltage(V)

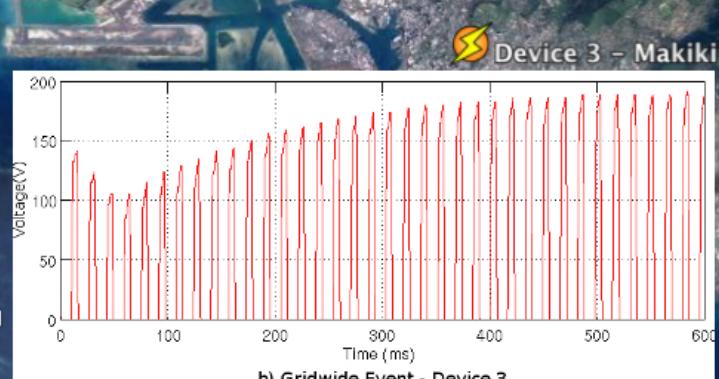
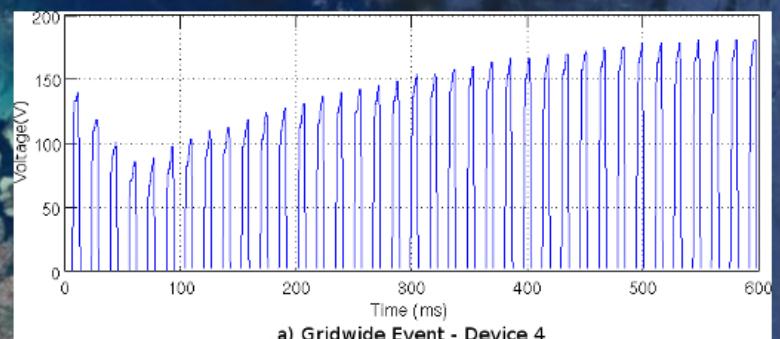
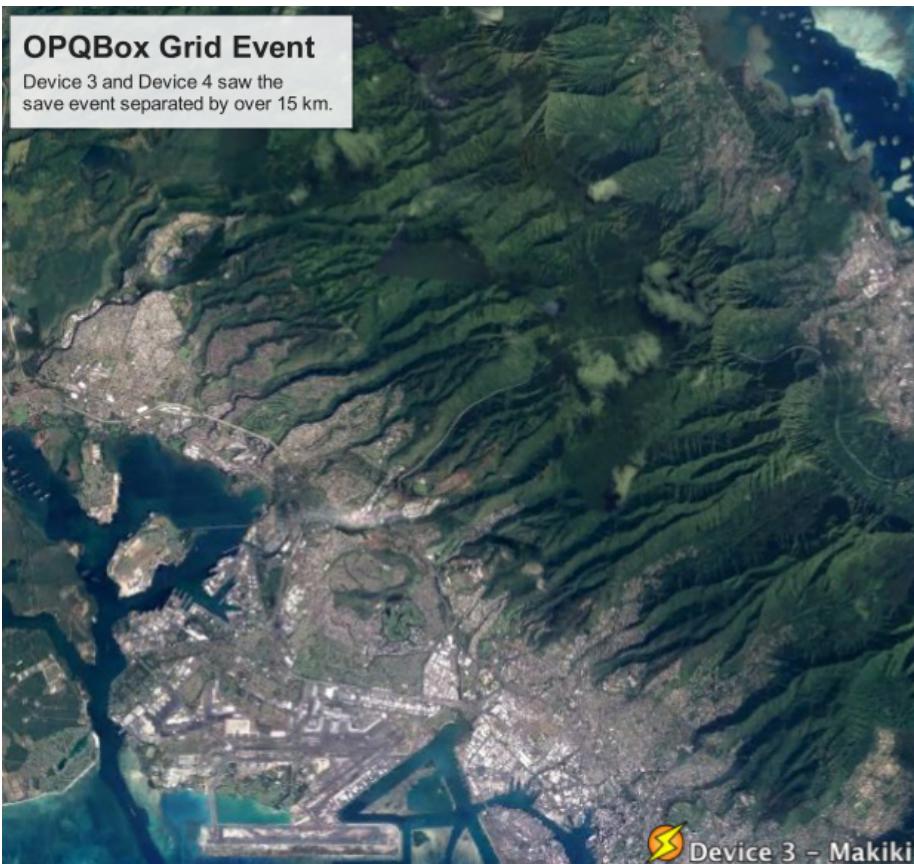
— Solar Power Produced (W)

OPQ: Daily Trends



OPQBox Grid Event

Device 3 and Device 4 saw the event separated by over 15 km.



Google earth

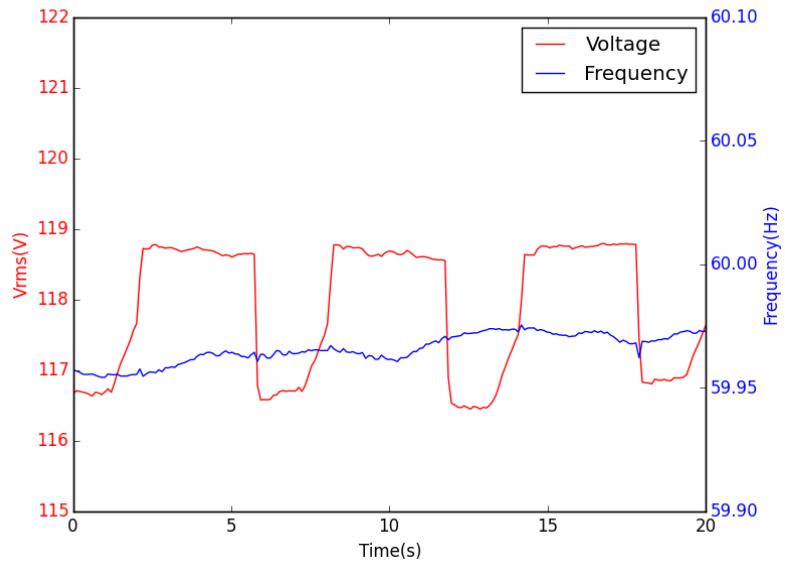
Data SOEST/UHM

Data USGS

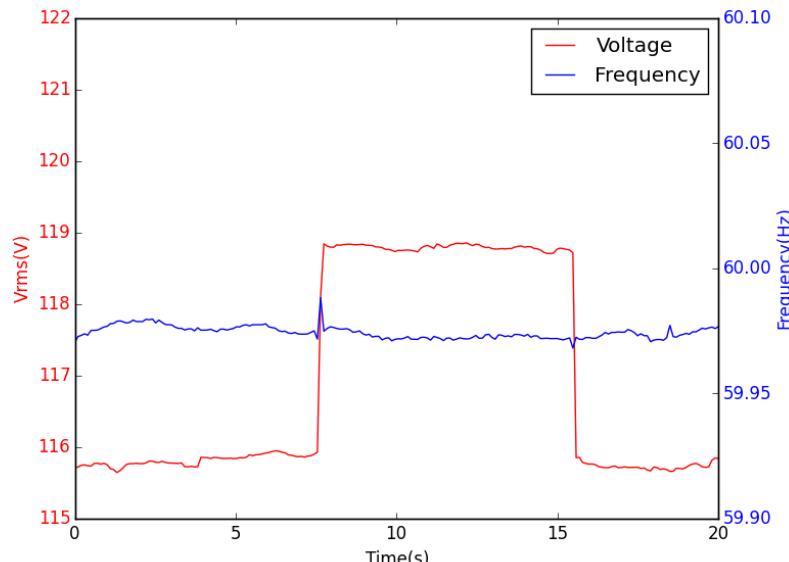


6 mi

OPQ: Local event signatures

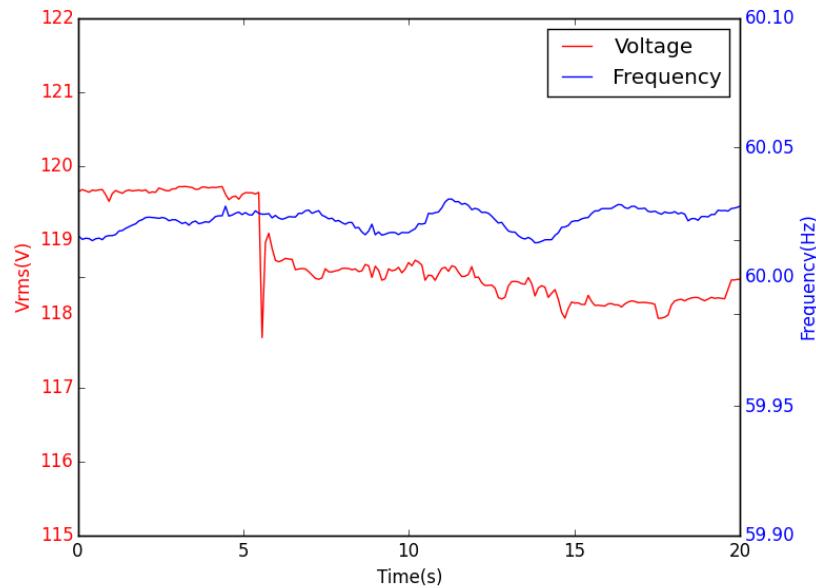


Inductive Hotplate

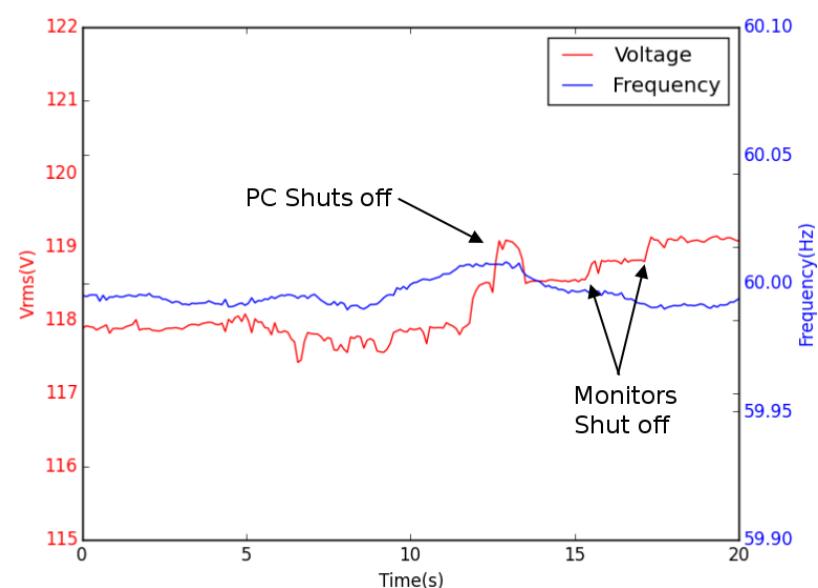


Toaster Oven

OPQ: Local event signatures

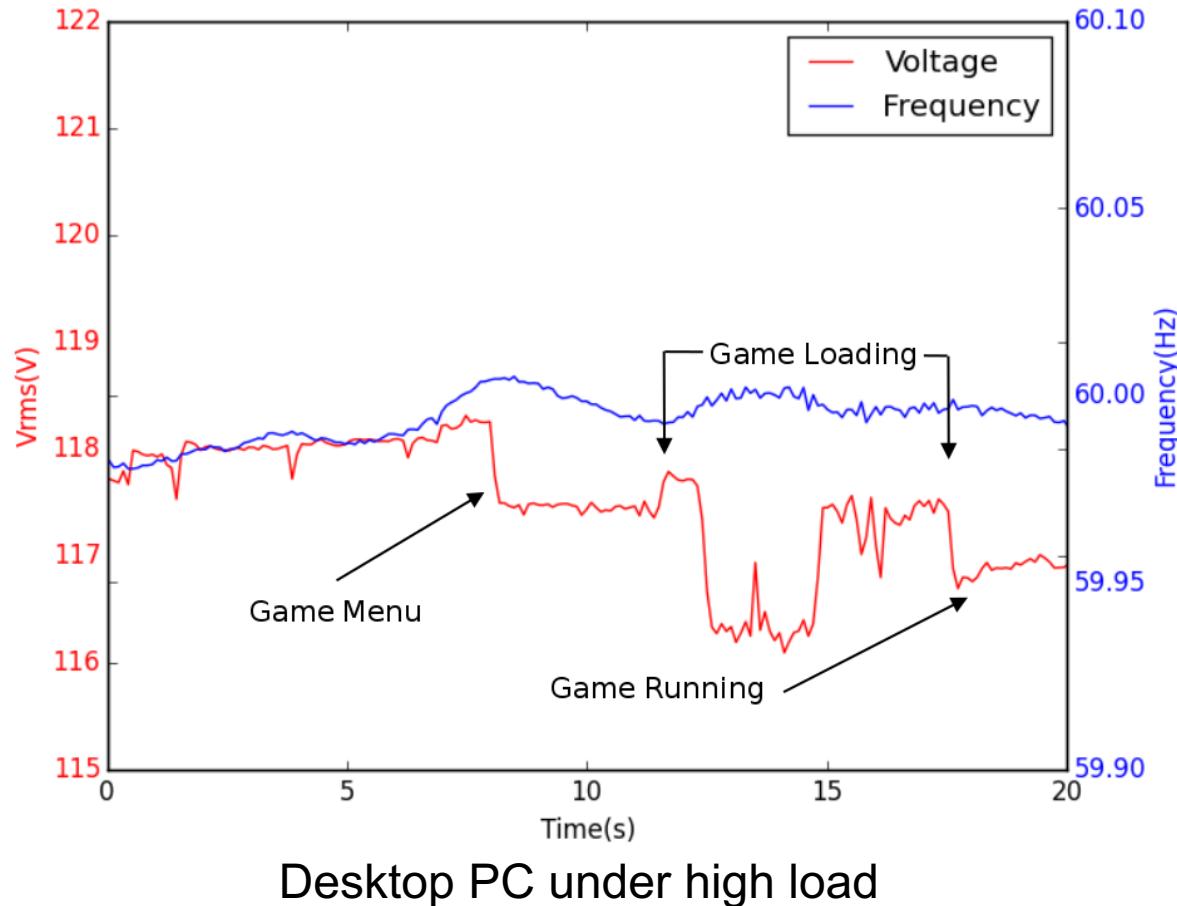


Desktop PC Power
on



Desktop PC Power
off

OPQ: Local event signatures



Privacy by Design

- ... one of main areas of focus when implementing smart grids – NIST
- ... privacy can be compromised even with perfect security – White House Paper on Big Data
- ... Our own lab experience shows how easily information can be leaked

OPQHub

- Software Platform that Provides
 - Acquisition
 - Aggregation
 - Simple classification
 - Querying
 - Alerts
 - Privacy by Design

A Filter

Freq. (Hz) 59.50 61.50

Voltage (V) 100.0 140.0

Duration (sec) 1 256

ITIC Severe Moderate OK

Time Interval 07/31/2014 5:21:1 02/08/2016 11:31

Quick View Today's Data Week's Data Month's Data

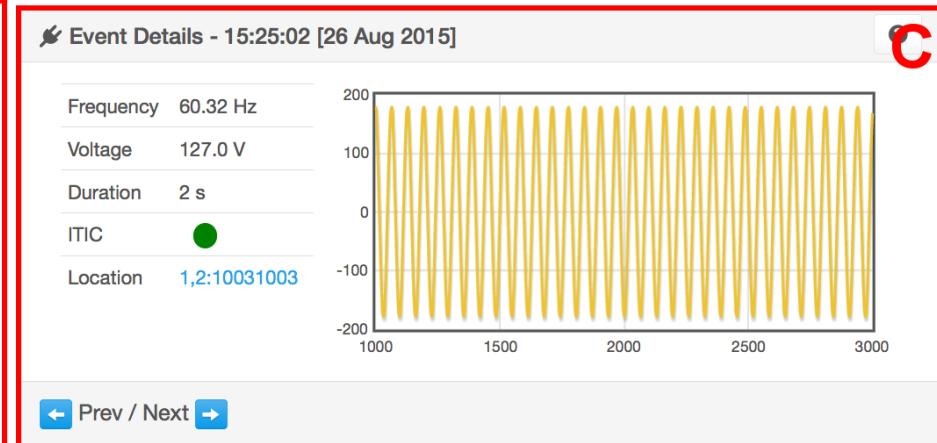
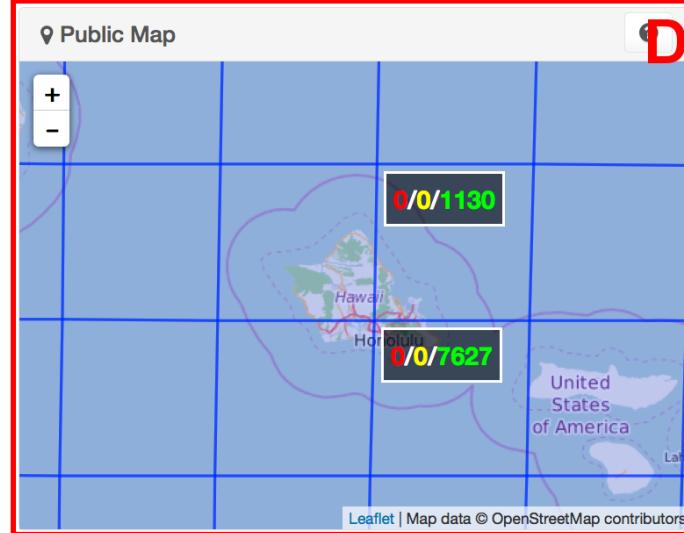
Update

B Events

Total Events 8757 Frequency Events 12 Voltage Events 8745

Timestamp	Type	Duration	Value	ITIC
15:25:02 [26 Aug 2015]	Voltage Event	2 s	127.0 V	●
03:43:38 [13 Aug 2015]	Frequency Event	1 s	61.00 Hz	●
05:44:28 [12 Jun 2015]	Frequency Event	1 s	60.60 Hz	●
16:35:52 [08 May 2015]	Frequency Event	1 s	60.74 Hz	●
23:04:15 [12 Apr 2015]	Voltage Event	1 s	107.1 V	●
15:09:49 [28 Feb 2015]	Frequency Event	1 s	60.68 Hz	●

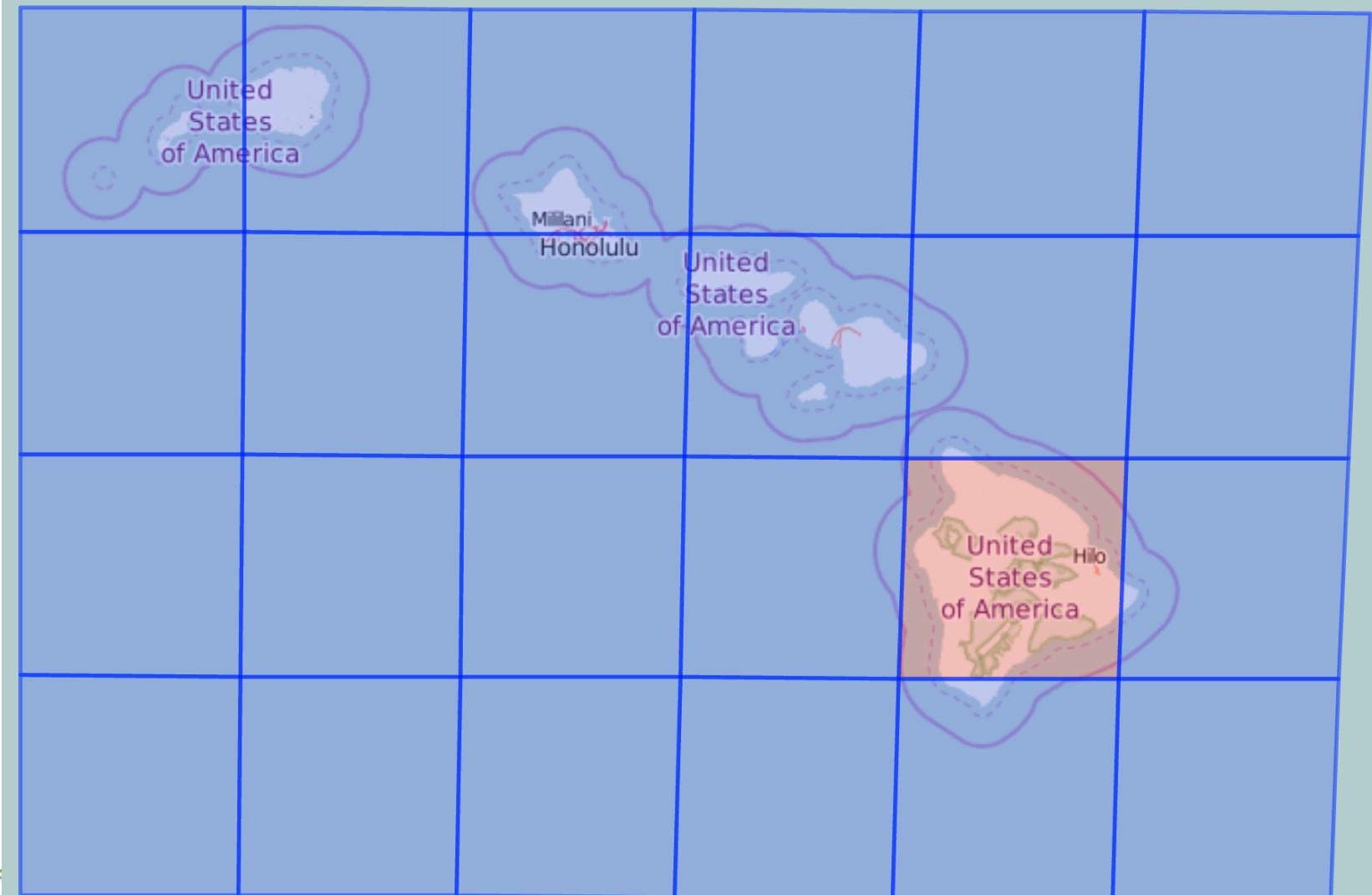
1 / 88



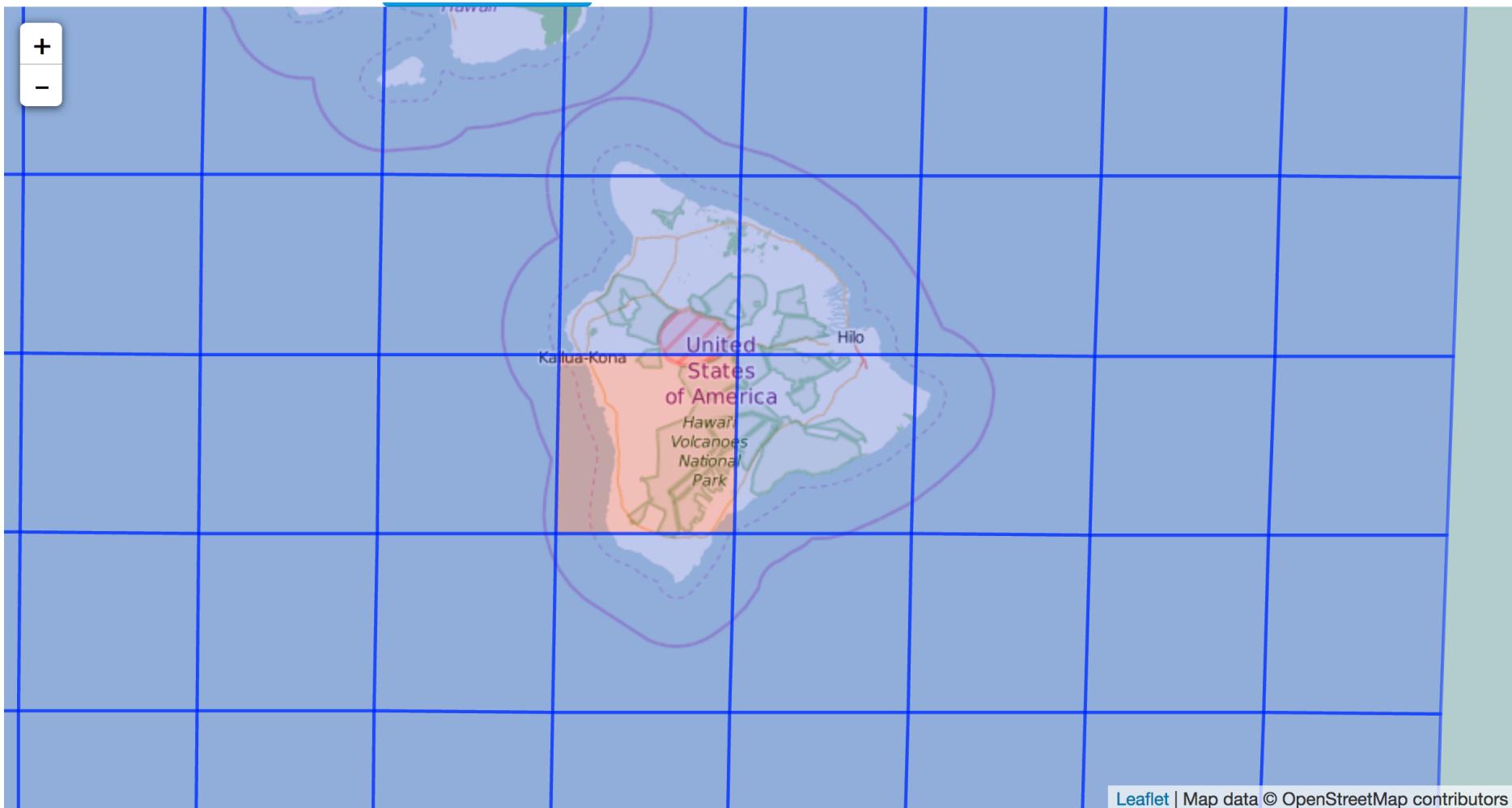
OPQ: Privacy by Design

- Users in control of their data
 - Data can be anonymized
 - Location based on geographic quad-tree
 - Map partitioned by square areas as follows:
 - 128, 64, 32, 16, 8, 4, 2, 1, 0.5, 0.25, 0.125 (km)

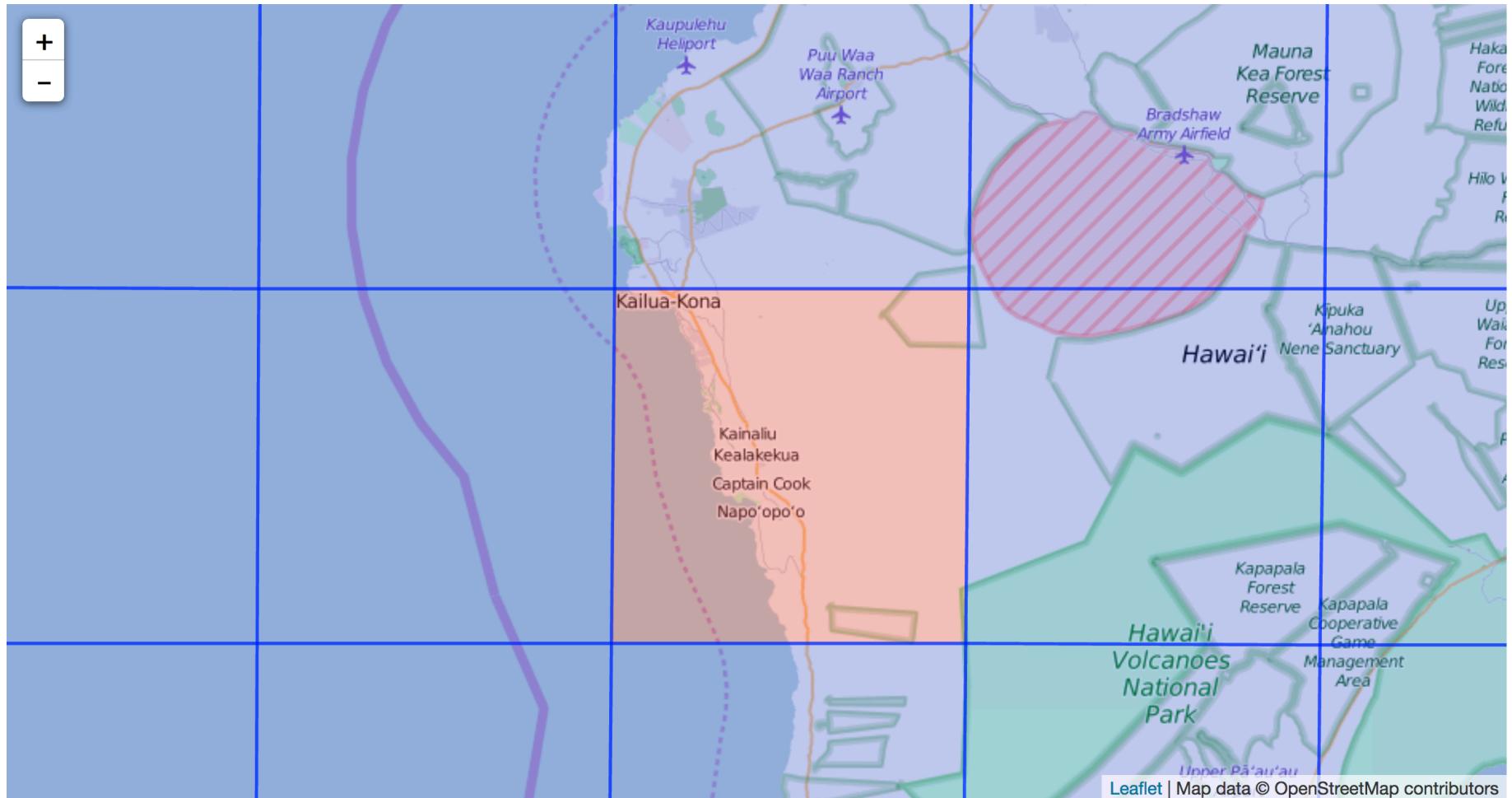
OPQ: Quad-Tree Based Locations – 128 km



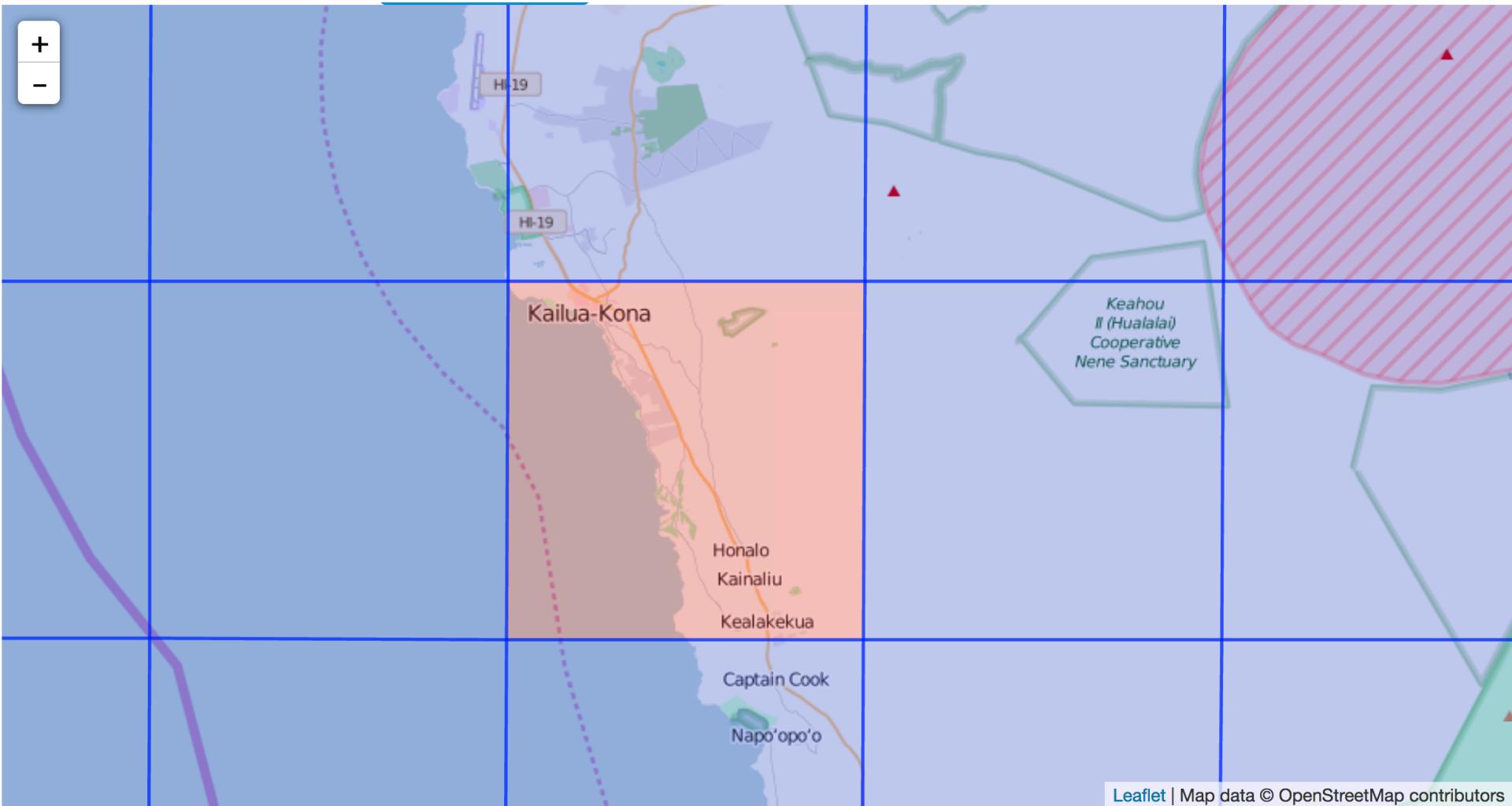
OPQ: Quad-Tree Based Locations – 64 km



OPQ: Quad-Tree Based Locations – 32 km

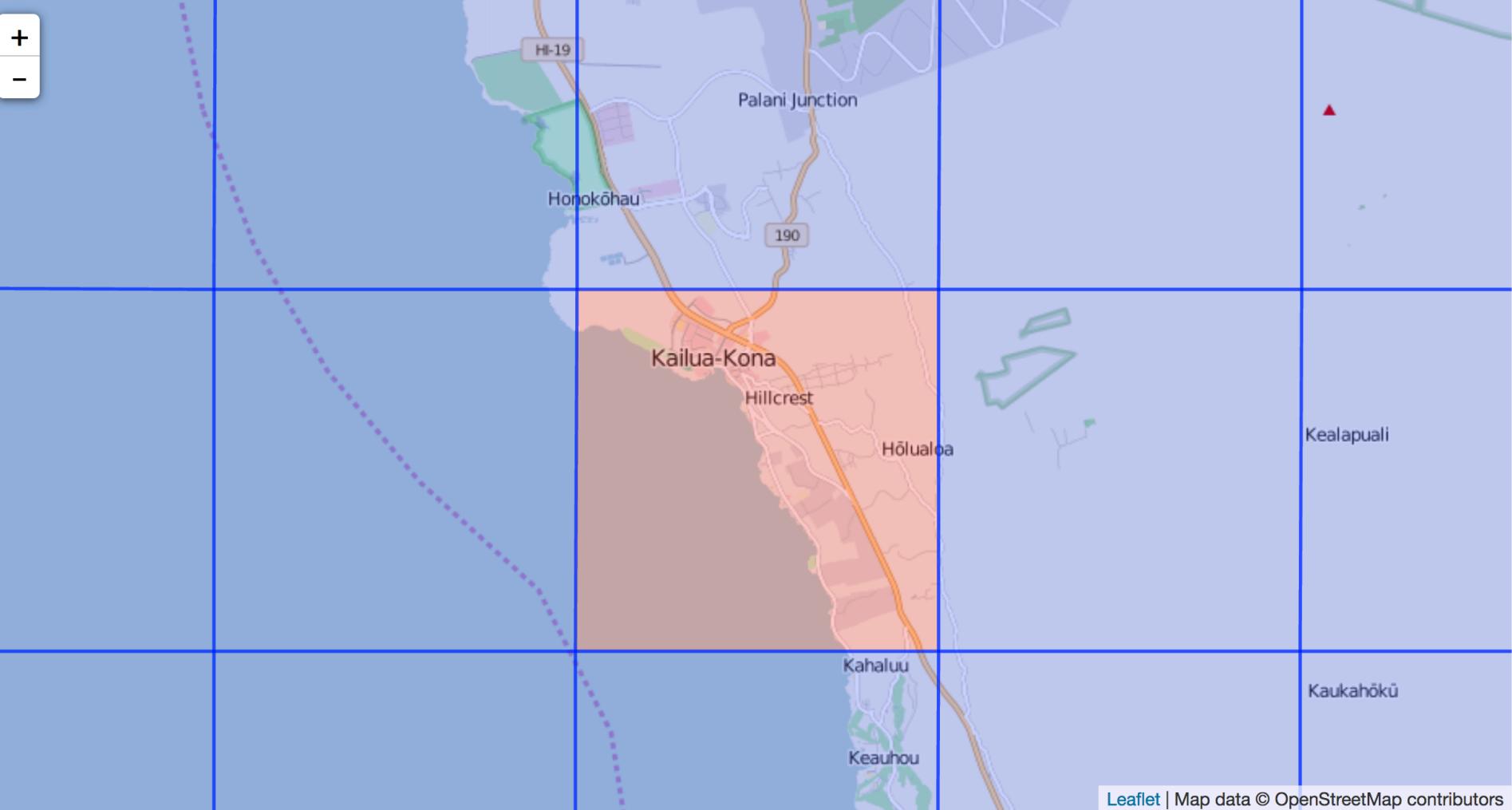


OPQ: Quad-Tree Based Locations – 16 km

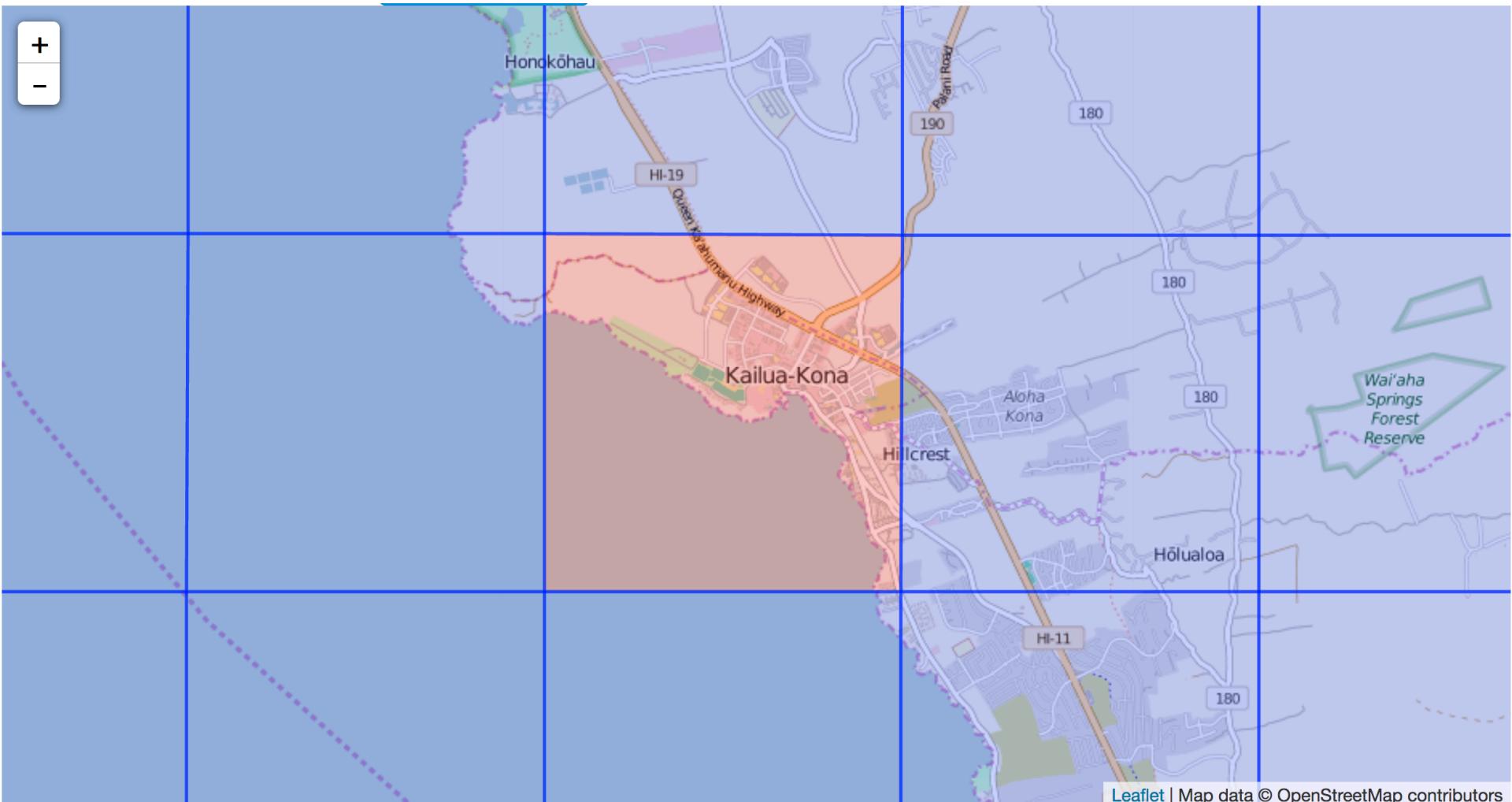


Leaflet | Map data © OpenStreetMap contributors

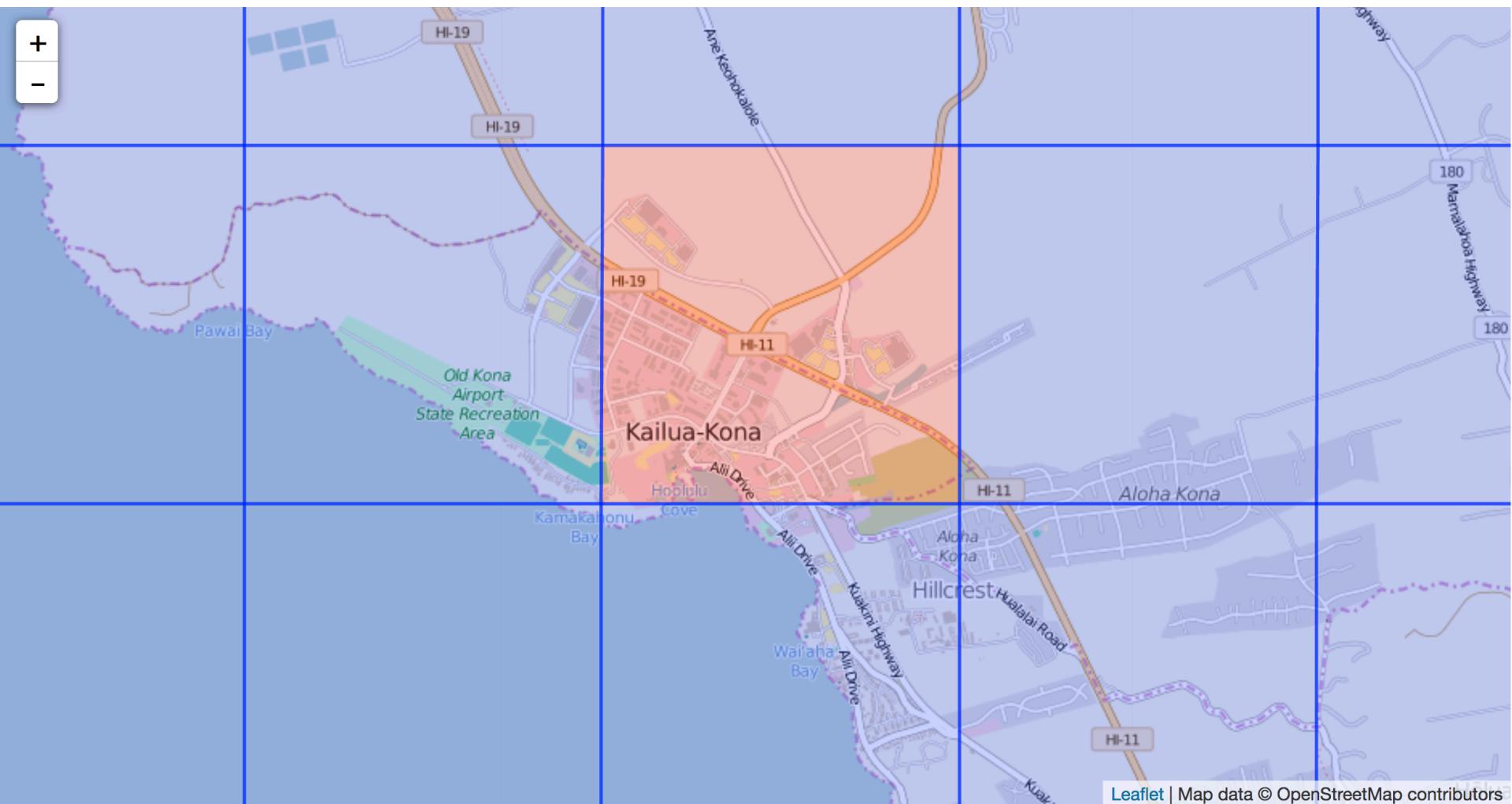
OPQ: Quad-Tree Based Locations – 8 km



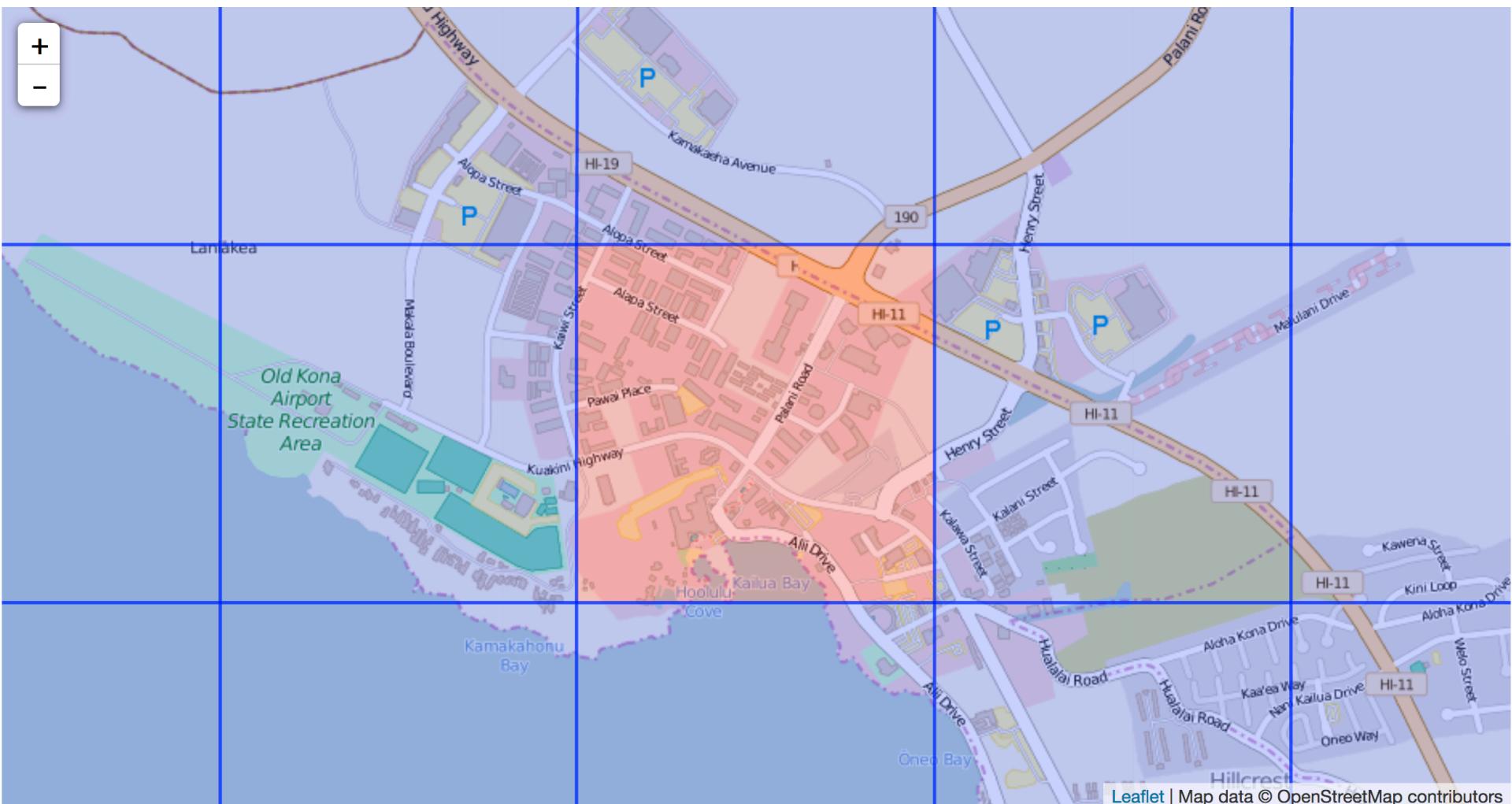
OPQ: Quad-Tree Based Locations – 4 km



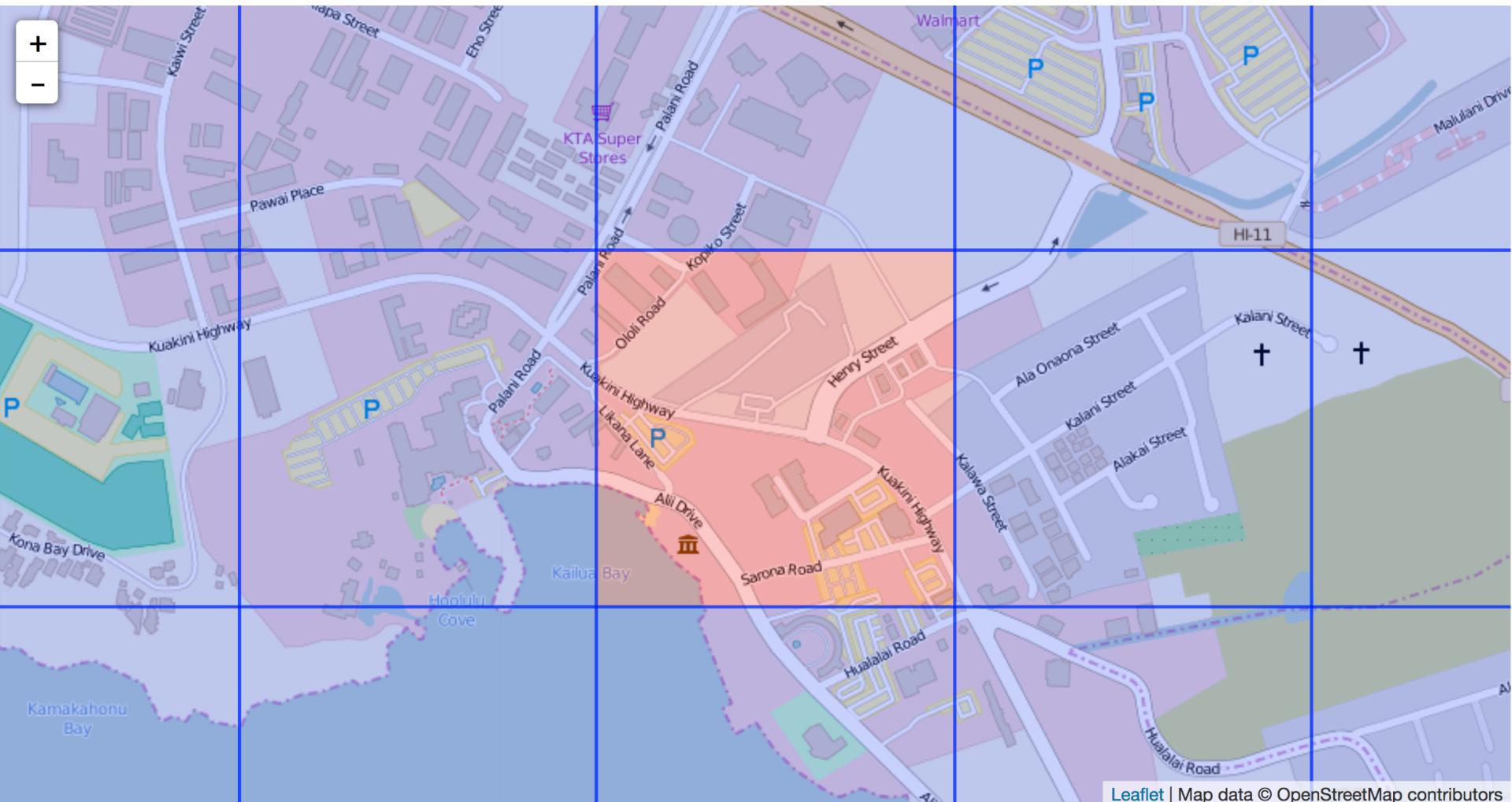
OPQ: Quad-Tree Based Locations – 2 km



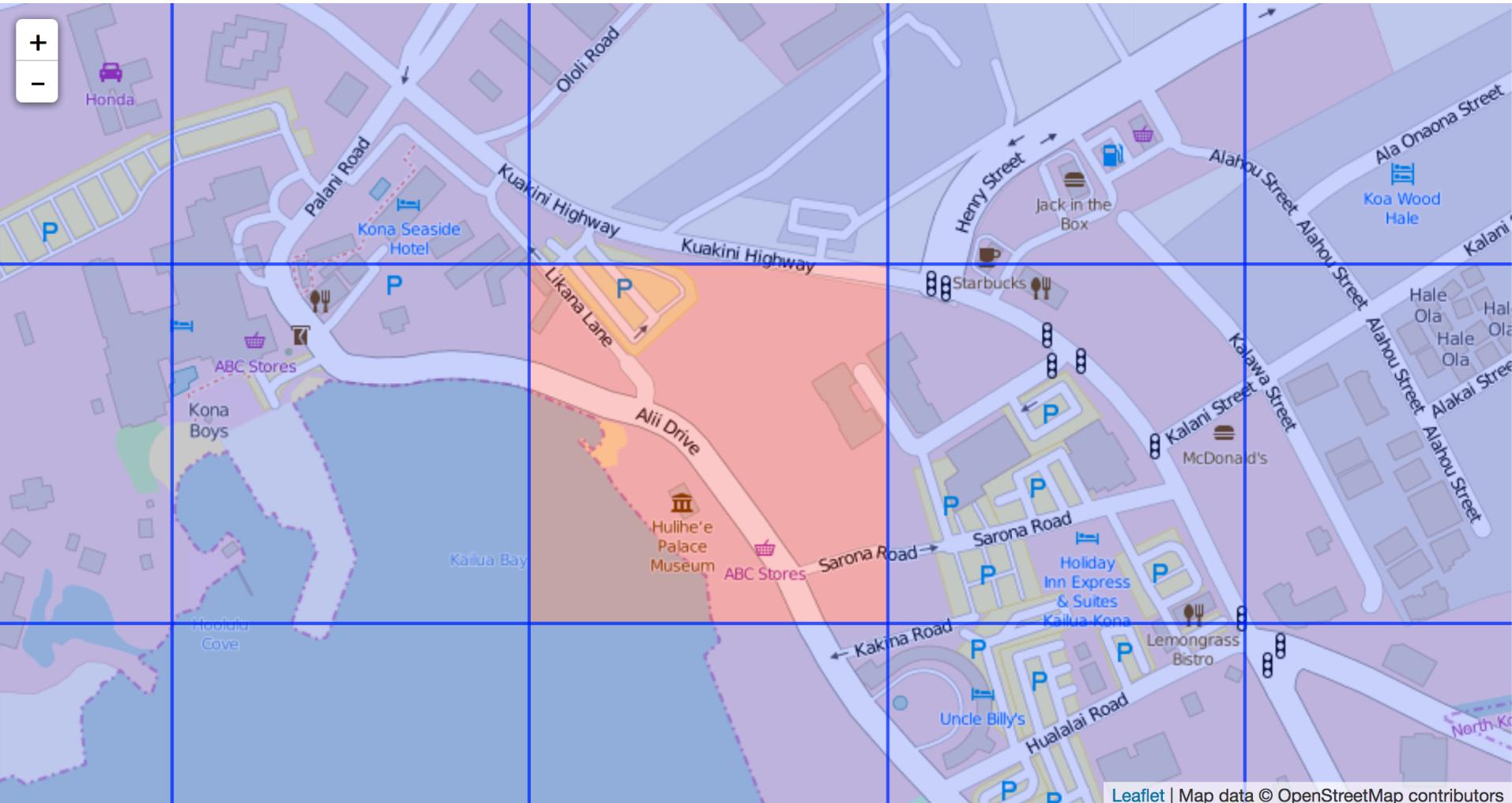
OPQ: Quad-Tree Based Locations – 1 km



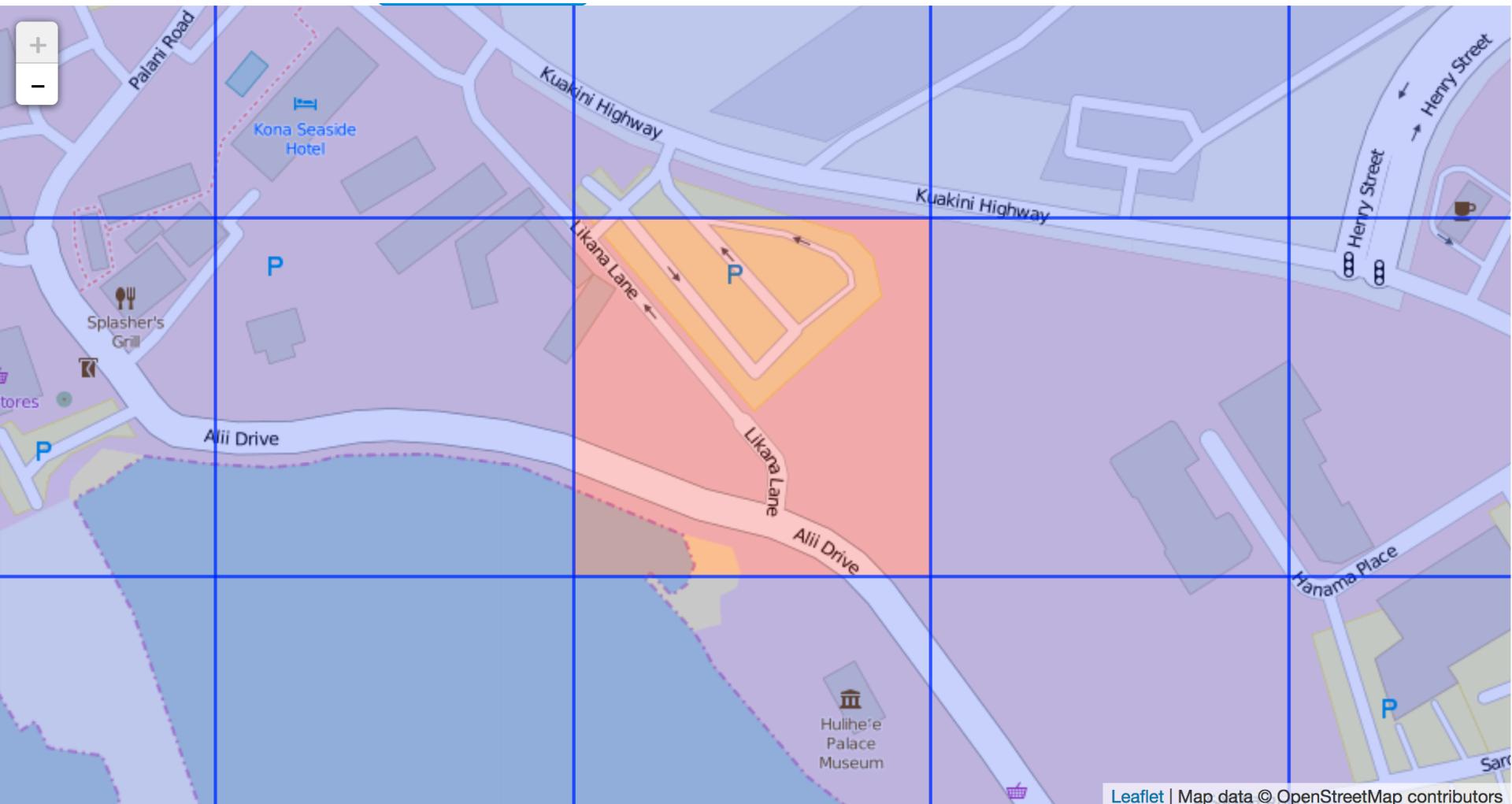
OPQ: Quad-Tree Based Locations – 0.5 km



OPQ: Quad-Tree Based Locations – 0.25 km



OPQ: Quad-Tree Based Locations – 0.125 km



Leaflet | Map data © OpenStreetMap contributors

Future Work

- Privacy study
- Signal classification
- PQ communities
- Limited bandwidth data acquisition

Future Work

Collaboration With You?

We Welcome Contributions

- Find us at
 - <http://openpowerquality.org>
 - <http://github.com/openpowerquality>
- Contact us at
 - anthony@openpowerquality.org
 - sergey@openpowerquality.org

Acknowledgements

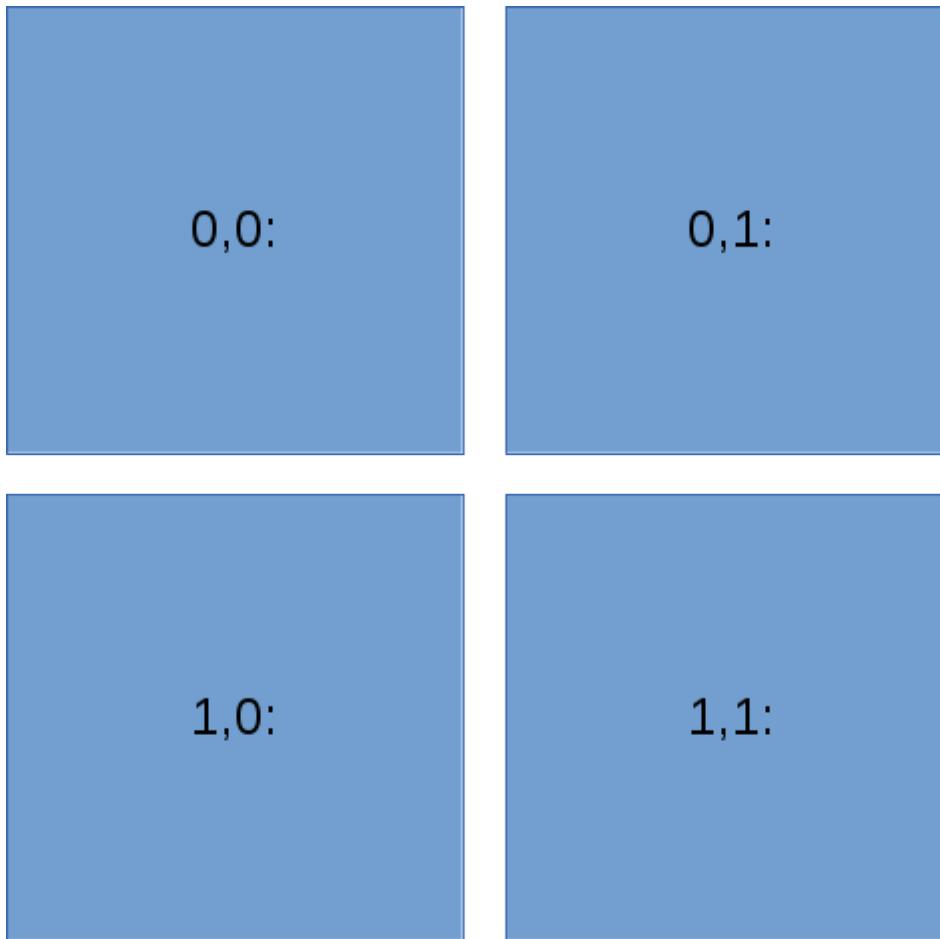
- CSDL at UH Manoa
 - D. Badke, G. Liu, J. Ugalino, R. Pagaduan, D. Aghalarpour
- Other contributions
 - Electric Power Research Institute
 - Hawaiian Electric Company
 - Power Standards Lab

Mahalo!

Questions?

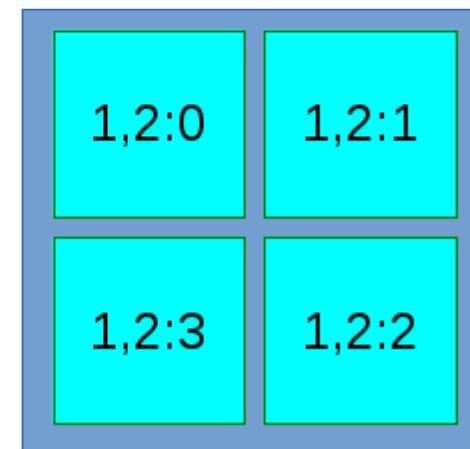
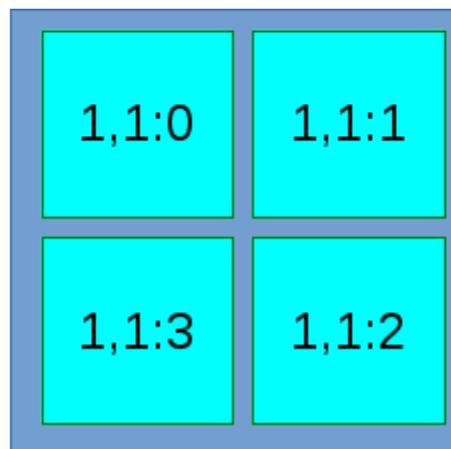
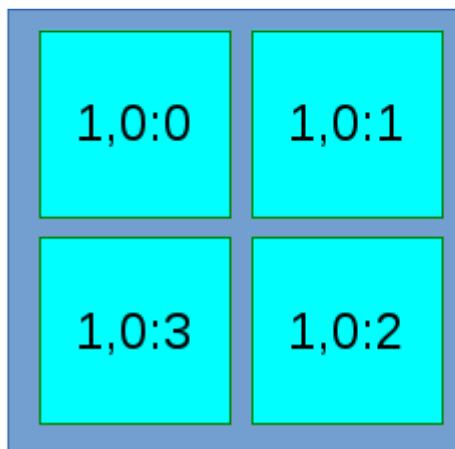
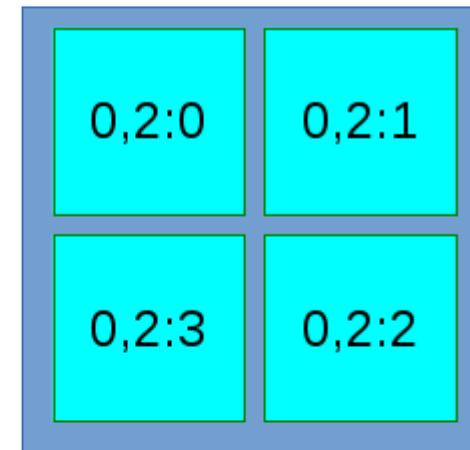
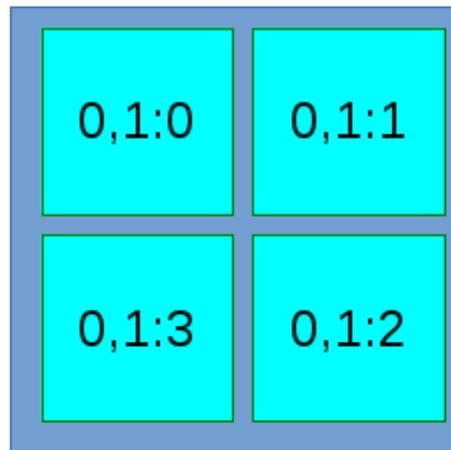
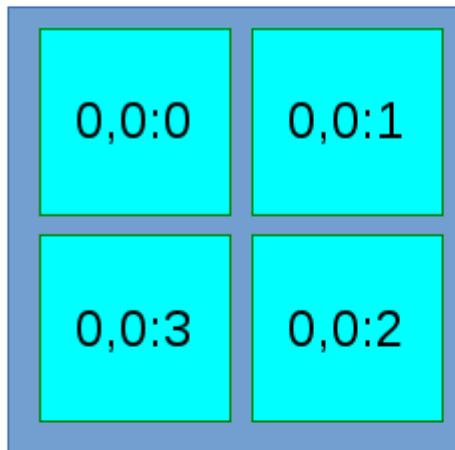
OPQ: Privacy by Design

- Quad-Tree Based Locations



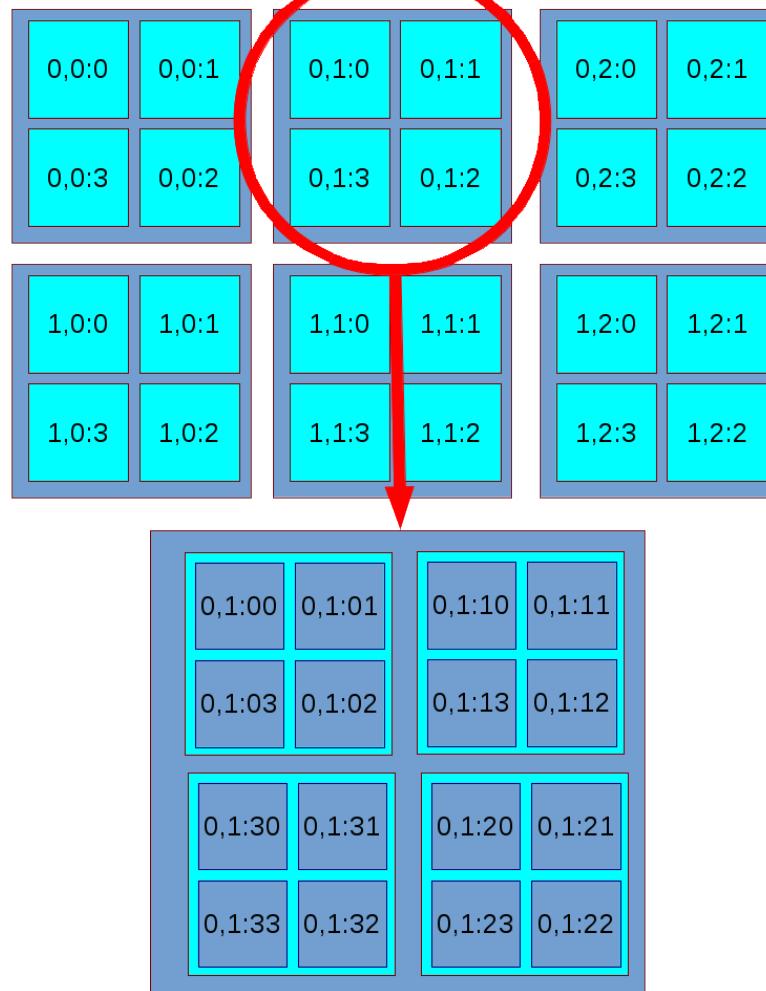
OPQ: Privacy by Design

- Quad-Tree Based Locations



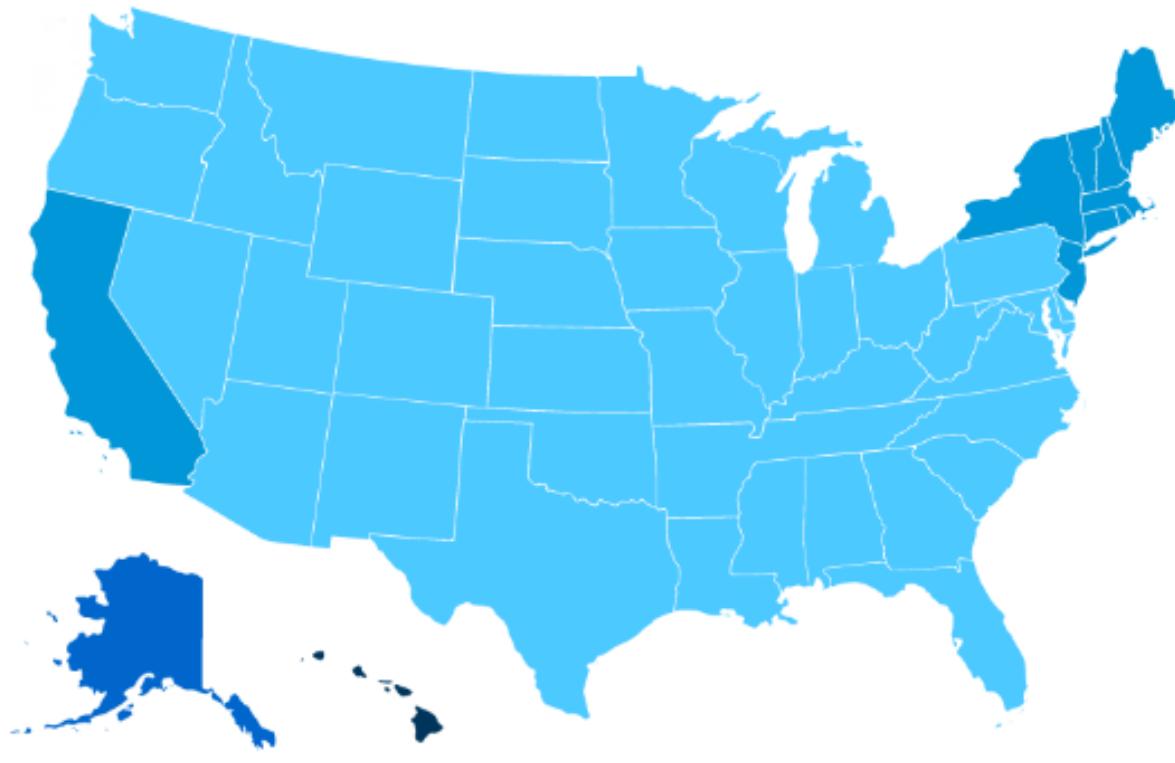
OPQ: Privacy by Design

- Quad-Tree Based Locations



Hawaii's Unique PQ Situation

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



6.90 to 11.42

11.43 to 15.93

15.94 to 20.45

20.46 to 24.97

24.98 to 29.48

29.49 to 34.00

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

-