Putting MQTT in your toolkit

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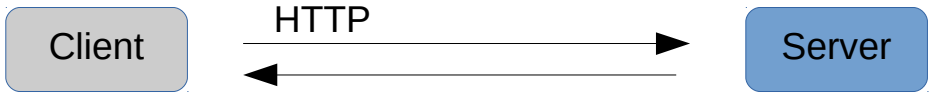
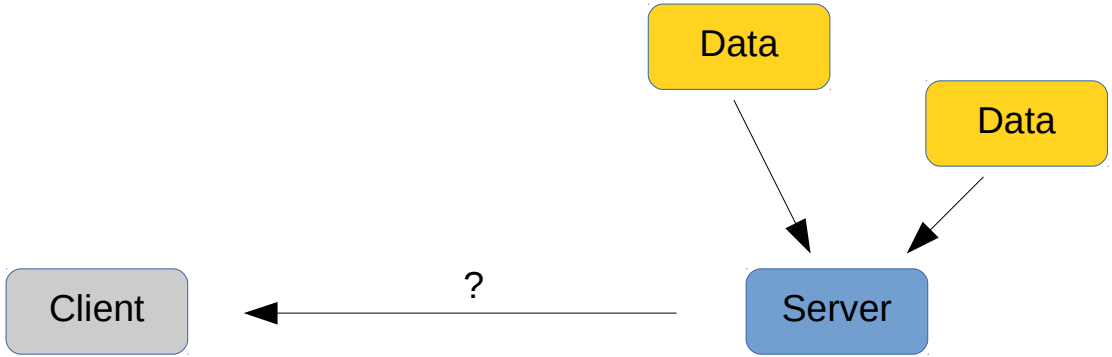
July 19th 2018

IBM

Interaction Patterns

Client driven queries





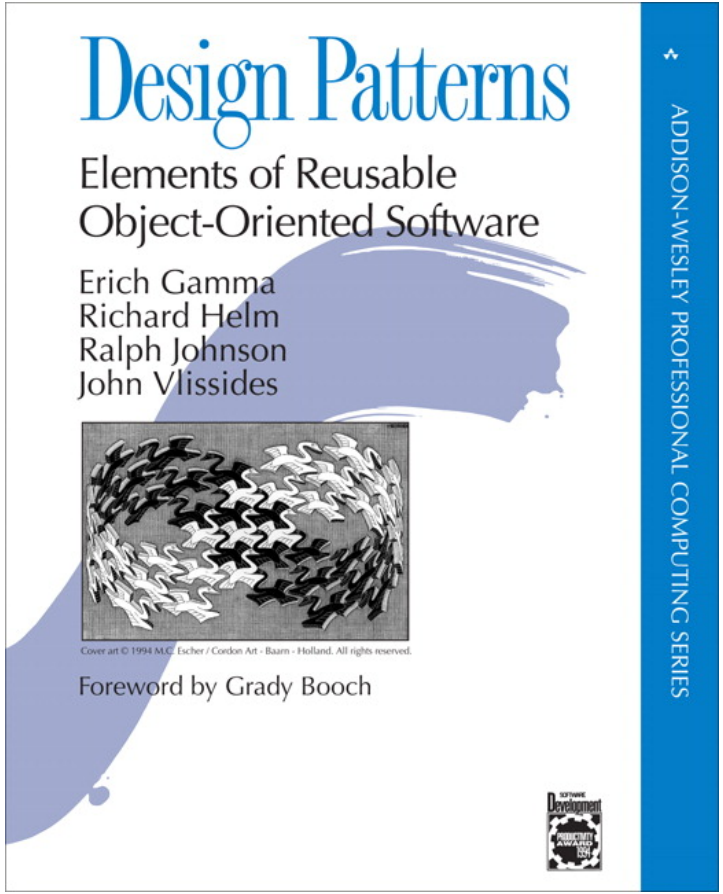
Server driven data distribution

Real Time Event Strategies

- Client Polling
  - Easy to implement
  - Really inefficient - 99+% noop
- HTTP Long Poll
  - Keep HTTP socket open, block on requests
  - Heavy server resource usage
- Websockets
  - Connected sockets in web browser
- Webhooks
  - Register callback URL
  - Need highly available "catcher" service
  - Only available for service owners
- MQTT / AMQP
  - Optimized pub/sub systems
  - Web client support requires bridging

Publish / Subscribe Design Pattern

- Common message bus
  - Everyone can publish to it
  - Messages directed to topics
  - Consumers subscribe to specific topics (possibly by wildcard)
- Good for many to many interactions

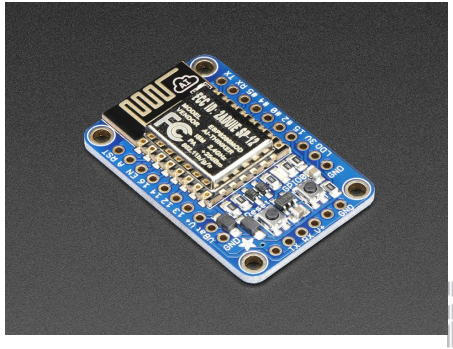


What is MQTT?

- MQTT is an open standard
  - Created in 1999 by IBM & Cirrus Link, OASIS standard since 2013
- MQTT is designed for “small footprint” and “limited network bandwidth”
- MQTT is the backbone of all major Public Cloud IoT services
  - Google IoT Core - https://cloud.google.com/iot-core/
  - IBM Watson IoT - https://www.ibm.com/internet-of-things/
  - Amazon IoT - https://aws.amazon.com/iot-platform
  - Microsoft Azure IoT - https://azure.microsoft.com/en-us/services/iot-hub/
- MQTT has many open source implementations
  - Mosquitto very popular broker
  - Clients bindings: A couple dozen languages
  - Even an Arduino library – PubSubClient

ESP8266

- Arduino with built in Wifi
- $9.95 at Adafruit



MQTT Message Format

QoS	Retain	Topic	Payload
0,1,2	0,1	220 characters	Any content, up to 2 GB

- QoS - 0 best effort, 1 deliver at least once, 2 deliver exactly once
- Retain - content will be stored on the server, replayed on connect, defaults to not stored
- Topic - name for message, / are special
- Payload - anything, 2 GB payload limit

Note: no metadata on packets (like time sent), must put it in payload manually

What makes a good Topic Structure?

- Root with App Name
  - Assume multi tenancy
- Find any natural hierarchy of data
- Optimize for subscriber efficiency
  - Often need to rethink topic structure once you see usage patterns
- There is no formal schema system
  - topic structure encoded into applications

Example:

{app name}/{location}/{device type}/{sensor type}

Allows the following subscriptions:

mysensors/portland/# - see everything in Portland

mysensors/+/weather/+ - see all weather sensors

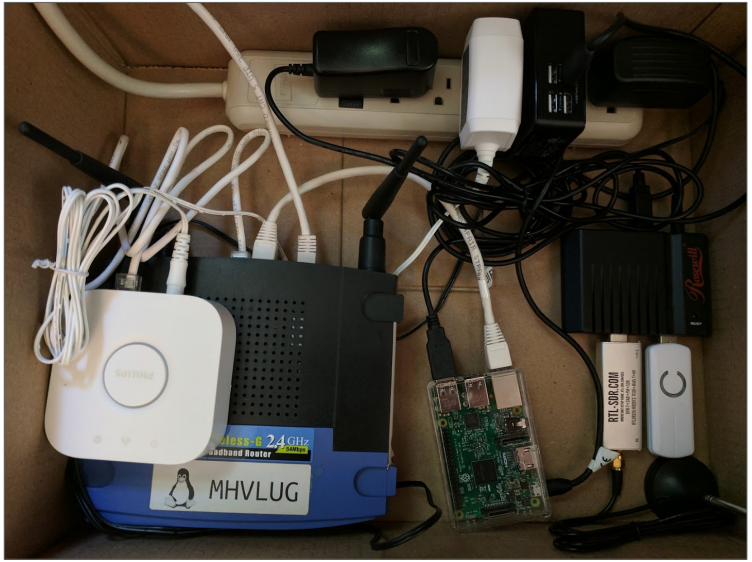
MQTT Wills

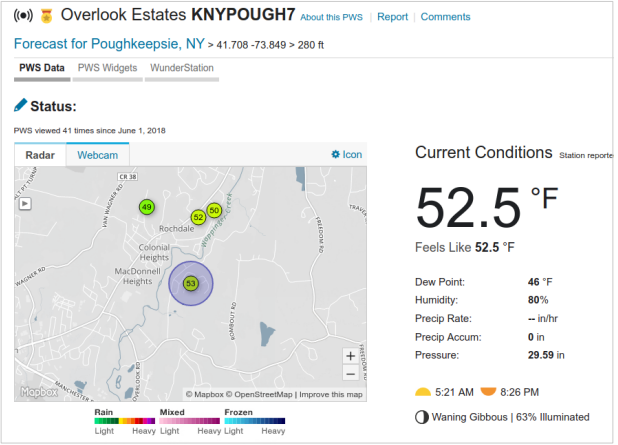
- Event based system - messages only sent when event happens
- If nothing is sent, is the client healthy with no new data, or did it disappear?
- Clients ca set a "Will" on client connect
  - a message stored in the server that will be sent if the socket connection to the client breaks
  - building block for fault tolerance

Example Applications

My Home Weather Station

- Bill of Materials
  - 10+ Oregon Scientific Weather Sensors
  - Raspberry Pi 3 – needs specific placement to see all sensors
  - RTL-SDR Dongle to decode 433Mhz signal out of air
- Long term (10 year) background hacking project
- Reports to Weather Underground via PWS API
- Collects temperature from nearly every room in the house
  - Extremely useful for tuning Forced Air HVAC system





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In early 2017, discovered Home Assistant

Home Assistant

- Overview
- Logbook
- History
- Log out

Developer tools

Home

DEFAULT_VIEW | TEMPS | AUDIO | AUTOMATION | CAR_AND_FURNACE

outside

Barometer	1002.0 mbar
Outside	64.4 °F
Porch MS6 - Temp	55.70 °F
Porch MS6 - Humid	90 %
Porch 2 - Temp	57.50 °F
Rain Since Midnight	0.0 in
Subaru	54.1 °F
Wind Speed	0.0 mph
Wind Gust	0.0 mph
Wind Direction	270.0 °

upstairs temps

Arwen Room	68.4 °F
Bed Room	69.4 °F
Office	69.6 °F
Office MS6 - Temp	71.60 °F

appliances

Freezer	-6.3 °F
Refrigerator	36.7 °F

downstairs temps

Living Room - Temp	67.70 °F
Living Room - Humid	64 %
Family Room - Temp	65.70 °F
Hallway - Temp	67.70 °F
Basement	65.8 °F
Bomb Shelter	64.2 °F

How to integrate my weather station to this?

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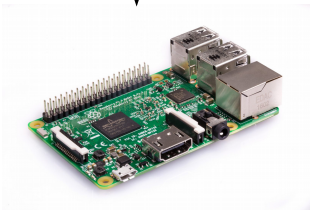
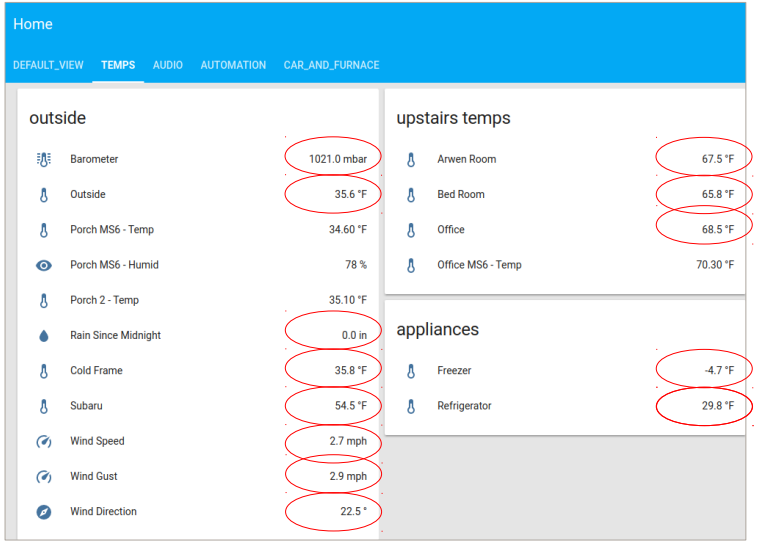
433 Mhz over the air

0x0850022a9603814179
0x0d54012a96038141600304060079





mqtt:
  broker: 10.42.0.3

sensor 1:
  platform: arwn

mosquitto

```
arwn/temperature/Freezer {"bat": "LOW", "sensor_id": "6a:03", "humid": 53.0, "temp": -10.8, "dewpoint": -23.2, "units": "F", "timestamp": 1527695510}
arwn/temperature/Arwen Room {"bat": "OK", "sensor_id": "ce:08", "humid": 54.0, "temp": 72.7, "dewpoint": 55.1, "units": "F", "timestamp": 1527695511}
arwn/wind {"bat": "OK", "sensor_id": "33:00", "timestamp": 1527695512, "units": "mph", "gust": 0.9, "speed": 2.5, "direction": 315.0}
```

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Rain Gauge - Retain Topics

arwn/totals/rain	{"timestamp": 1528084804, "total": 70.78} ← retained topic
arwn/rain	{"timestamp": 1528084868, "total": 70.78}
arwn/rain/today	{"timestamp": 1528084868, "since_midnight": 0.00}
arwn/rain	{"timestamp": 1528091737, "total": 70.818}
arwn/rain/today	{"timestamp": 1528091737, "since_midnight": 0.04}
arwn/rain	{"timestamp": 1528092583, "total": 70.944}
arwn/rain/today	{"timestamp": 1528092583, "since_midnight": 0.16}
arwn/rain	{"timestamp": 1528107858, "total": 71.358}
arwn/rain/today	{"timestamp": 1528107858, "since_midnight": 0.58}

...

arwn/rain	{"timestamp": 1528171098, "total": 71.358}
arwn/rain/today	{"timestamp": 1528171098, "since_midnight": 0.58}

... rollover event

arwn/rain	{"timestamp": 1528171218, "total": 71.358}
arwn/totals/rain	{"timestamp": 1528171218, "total": 71.358} ← retained topic
arwn/rain/today	{"timestamp": 1528171218, "since_midnight": 0.0}

- Self emptying bucket
  - 3 increments added based on time between bucket dumps
- Reports Rain Total
  - (10ths of mm accumulator)
- Wunderground API
  - rainin - [rain inches over the past hour)] -- the accumulated rainfall in the past 60 min
  - dailyrainin - [rain inches so far today in local time]

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When Should I Charge My Car?

- Supports Time of Departure Charging
  - Be fully charged by a set time every day
- Time of Use metering at our home
  - Peak is 2 - 7pm Weekdays
  - Peak power costs 120%, off peak costs 89%
- What's the difference in power off peak?
  - What is generating the power?
  - What's the carbon intensity at different times?
- Can we make data available in real time?
  - Others might want to do things with this data

Market Data
Market & Operational Data
Pricing Data
Power Grid Data
Load Data
Reports & Information
Postings by Date
Zone Maps
Charts & Graphs
Market Access Login
Custom Reports
TCC
ICAP
Distributed Energy Resource (DER)
Ancillary Services
Interregional Data
System Conditions
Services
Budget and Finance [+]
Customer Registration
Market Training [+]
Market Monitoring [+]
Reliability Compliance
Support
Customer Support
Documents
Tariffs
Manuals & Guides
Publications & Presentations
Technical Bulletins
Legal & Regulatory
Studies & Reports

Data Graphs and Fuel Mix Chart

Pricing Data | Power Grid Data | Load Data | Reports & Info | Postings by Date | Maps | Charts & Graphs | Market Access Login

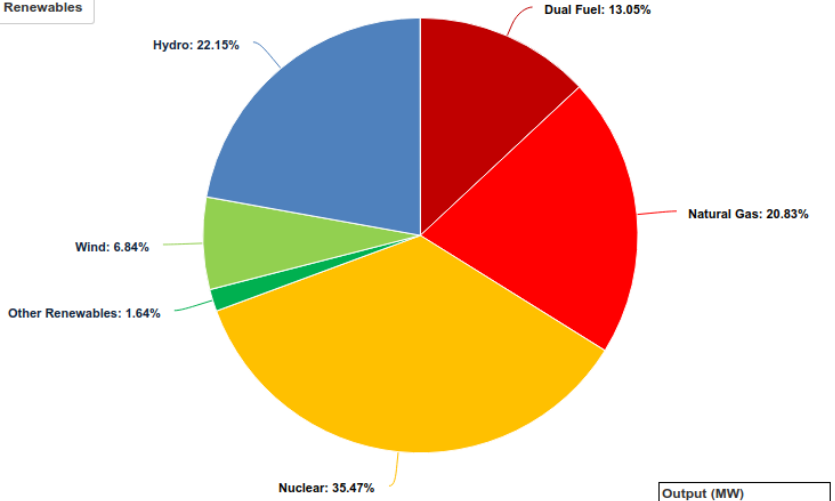
Load | Load vs. LBMP | Flow | Daily Fuel | Current Fuel

Auto Refresh: On
Updated: 14:11

All Fuels
Renewables

Real-Time Fuel Mix as of 02/12/2018 2:00pm EST

Energy generated within New York State



Output (MW)	
Total	15,270
Renewables	4,679

Current CSV
Historical CSV

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NEW YORK INDEPENDENT SYSTEM OPERATOR
Building The Energy Markets Of Tomorrow...Today

OASIS (Open Access Same-Time Information System)

Generator P-4B

Ancillary Service Prices
- Real-Time Market P-6B
- Day-Ahead Market P-5

- NYISO Reference Bus LBMP P-28
- NYISO Price Correction Logs P-29

External RTO CTS Prices
- RTC vs. External RTO CTS Prices P-42

Power Grid Data

Outages
- Real-Time Scheduled Outages P-54A
- Real-Time Actual Outages P-54B
- Day-Ahead Scheduled Outages P-54C
- Outage Schedules P-14
- Outage Schedules CSV P-14B
- Generation Maintenance Report P-15

Constraints
- Day-Ahead Limiting Constraints P-511A
- Limiting Constraints P-33

Interface Flows
- Internal & External Interface Limits & Flows P-32
- Lake Erie Circulation - Day-Ahead P-53B
- Lake Erie Circulation - Real-Time P-34A

PARs
- PAR Schedules P-53A
- PAR Flows P-34

ATC/TTC
- ATC/TTC P-8
- Long Term ATC/TTC P-8A
- Transfer Limitations

Load Data

Load Forecast/Commitment
- ISO Load Forecast P-7
- Zonal Bid Load P-59
- Weather Forecast P-7A

Actual Load
- Real-Time Actual Load P-58B
- Integrated Real-Time Actual Load P-58C

Reports & Information
- Day-Ahead Market Daily Energy Report P-30
- NYISO Capacity Report P-60
- Balancing Market Advisory Summary P-31
- Real-Time Events P-35
- Real-Time Fuel Mix P-63
- NYISO Operational Announcements P-25
- Dispatcher Notices

- NYISO Generation Economic Dispatch Analysis P-61

- Generator Names P-19
- Load Names P-20
- Transmission Owner Information P-16
- Subzones by Transmission Owner P-23

- DOE EIA 930 - Same-Day Hourly Demand Posting P-930A
- DOE EIA 930 - Daily Posting P-930B

Real-Time Fuel Mix

CSV Files	Last Updated
02-12-2018	02/12/18 14:10 EST
02-11-2018	02/12/18 00:05 EST
02-10-2018	02/11/18 00:05 EST
02-09-2018	02/10/18 00:05 EST
02-08-2018	02/09/18 00:05 EST
02-07-2018	02/08/18 00:05 EST
02-06-2018	02/07/18 00:05 EST
02-05-2018	02/06/18 00:05 EST
02-04-2018	02/05/18 00:05 EST
02-03-2018	02/04/18 00:05 EST

Archived Files (zip format)

CSV Files	Last Updated
02-2018	02/12/18 14:10 EST
01-2018	02/01/18 00:05 EST
12-2017	01/01/18 00:05 EST
11-2017	12/01/17 00:05 EST
10-2017	11/01/17 00:05 EDT
09-2017	10/01/17 00:05 EDT
08-2017	09/01/17 00:05 EDT
07-2017	08/01/17 00:05 EDT
06-2017	07/01/17 00:05 EDT
05-2017	06/01/17 00:05 EDT
04-2017	05/01/17 00:05 EDT
03-2017	04/01/17 00:05 EDT
02-2017	03/15/17 11:23 EDT
01-2017	03/15/17 11:05 EDT
12-2016	03/15/17 11:24 EDT
11-2016	03/15/17 10:36 EDT
10-2016	11/01/16 00:05 EDT
09-2016	10/01/16 00:05 EDT
08-2016	09/01/16 00:05 EDT
07-2016	08/01/16 00:05 EDT
06-2016	07/01/16 00:05 EDT
05-2016	06/01/16 00:05 EDT
04-2016	05/01/16 00:05 EDT
03-2016	04/01/16 00:05 EDT
02-2016	03/01/16 00:05 EST
01-2016	02/01/16 00:05 EST
12-2015	01/01/16 00:05 EST

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ny-power microservices architecture

NY ISO CSVs

Time Stamp	TZ	Fuel	Gen MW
05/09/2018 00:05:00	EDT	Dual Fuel	1400
05/09/2018 00:05:00	EDT	Natural Gas	2144
05/09/2018 00:05:00	EDT	Nuclear	4114

ny-power-pump

MQTT publish

ny-power/status/fuel-mix/updated {"ts": "05/09/2018 00:05:00"}
ny-power/upstream/fuel-mix/Nuclear {"units": "MW", "value": 4114, "ts": "05/09/2018 00:05:00"}
ny-power/upstream/fuel-mix/Dual Fuel {"units": "MW", "value": 1400, "ts": "05/09/2018 00:05:00"}
ny-power/upstream/fuel-mix/Natural Gas {"units": "MW", "value": 2144, "ts": "05/09/2018 00:05:00"}

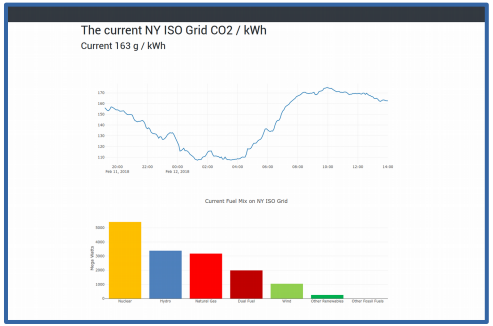
mosquitto

ny-power-influx

ny-power-archive

http://ny-power.org

ny-power-web



ny-power/archive/co2/24h {"units": "g / kWh", "values": [162.698, 163.928, 161.587 ...], "ts": [...]

ny-power/computed/co2 {"units": "g / kWh", "value": 135.088, "ts": "05/09/2018 00:05:00"}

ny-power-mqtt (access with "mosquitto_sub -h 169.60.78.157 -t ny-power/# -v")

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ny-power topics

{app name}/{source}/{details}/{more details}

Allows the following subscriptions:

ny-power/upstream/fuel-mix/{fuel type}
ny-power/computed/co2
ny-power/archive/co2/24h

```
var client = new Paho.MQTT.Client("mqtt.ny-power.org", Number("80"), "client-" + Math.random());

// set callback handlers
client.onMessageArrived = onMessageArrived;

// connect the client
client.reconnect = true;
client.connect({onSuccess: onConnect});

// called when the client connects
function onConnect() {
    // Once a connection has been made, make a subscription and send a message.
    console.log("onConnect");
    client.subscribe("ny-power/computed/co2");
    client.subscribe("ny-power/archive/co2/24h");
    client.subscribe("ny-power/application/webui");
    client.subscribe("ny-power/upstream/fuel-mix/#");
}

// called when a message arrives
function onMessageArrived(message) {
    console.log("onMessageArrived:"+message.destinationName + message.payloadString);
    if (message.destinationName == "ny-power/computed/co2") {
        var data = JSON.parse(message.payloadString);
        $("#co2-per-kwh").html(Math.round(data.value));
        $("#co2-units").html(data.units);
        $("#co2-updated").html(data.ts);
    }
    if (message.destinationName.startsWith("ny-power/upstream/fuel-mix")) {
        fuel_mix_graph(message);
    }
    if (message.destinationName == "ny-power/archive/co2/24h") {
        var data = JSON.parse(message.payloadString);
        var plot = [
```

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http://ny-power.org

CO2 calculated from 2016 totals (MW & Emissions Per fuel source)

Provided as MQTT stream

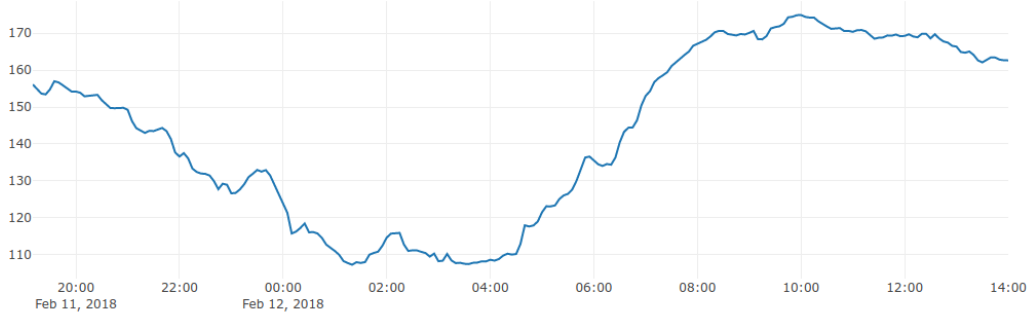
Answer: complete charging by 5am before load / NG starts ramping up

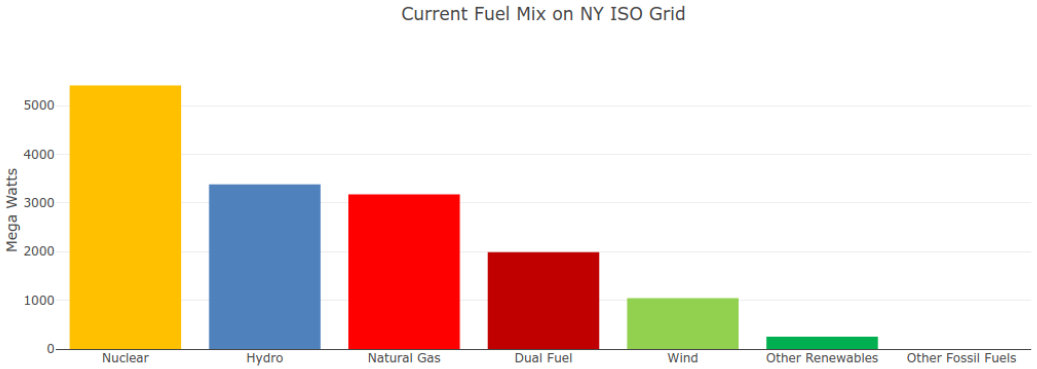
http://github.com/IBM/ny-power

- Helm Kube application
- Core logic in python
- 5 pods

The current NY ISO Grid CO2 / kWh

Current 163 g / kWh





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Put MQTT in your toolkit

- In a world awash in data, efficient event streams are critical
- Open event streams can be a public good
- MQTT dominates IoT, but also useful in other domains
- The Pub / Sub programming makes you think of problems in new ways

Thank You!

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Blog: https://dague.net - software engineering, open source projects, climate & energy

Get the code:

- arwn: https://dague.net/arwn
- ny-power project: https://dague.net/ny-power

CALL FOR CODE

COMMIT TO THE CAUSE. PUSH FOR CHANGE.

callforcode.org

Call for Code inspires developers to solve **pressing global problems** with **sustainable software solutions**, delivering on their vast potential to do good.
Bringing together NGOs, academic institutions, enterprises, and startup developers to compete build effective **disaster mitigation solutions**, with a focus on health and well-being.
The American Red Cross, and the **United Nations Human Rights Office** combine for the ***Call for Code Award*** *to* elevate the profile of developers.

Award winners will receive **long-term support** through the **Linux Foundation**, **financial prizes**, the **opportunity to present their solution to leading VCs**, and will deploy their solution through **IBM's Corporate Service Corps**.
Developers will jump-start their project with dedicated **IBM Code Patterns**, combined with **optional enterprise technology** to build projects over the course of three months.
Judged by the world's most **renowned technologists**, the **grand prize** will be presented in **October** at an Award Event.