IBM i Meets IoT

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Agenda Key:

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About Michael Dawson
IBM Community Lead for Node.js

- Active Node.js community member
  - Collaborator
  - Node.js Technical Steering Committee TSC Chair
  - Community Committee member
  - Working group(s) member/leadership

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- GitHub: @mhdawson
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About **Jesse**

- Business Architect of Open Source on i
  - Leader of development teams
  - Owns IBM i OSS strategy

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Agenda

- Intro to IoT and MQTT
- Using MQTT with Node.js and IBM i
- Lets Look at some devices
- Anatomy of a simple MQTT Light and Temperature Sensor
- Consuming MQTT data on IBM i
- Leveraging the Cloud

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IoT Introduction

- Internet of Things (IoT)
  - network of physically connected devices (things)
  - devices provide data
  - devices can be controlled
  - https://en.wikipedia.org/wiki/Internet_of_Things

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MQTT Introduction

- MQTT (MQ Telemetry Transport)
  - lightweight publish/subscribe
  - small footprint
  - low bandwidth (minimum size is 2 bytes)
  - From http://mqtt.org/

> "MQTT is a machine-to-machine (M2M)/"Internet of Things" connectivity protocol"

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MQTT - History

- Invented in 1999
  - Andy Standford-Clark(IBM)
  - Arlen Nipper (Eurotech)

- IBM and Eurotech Donated MQTT to Eclipse Paho project in 2013 - https://www.eclipse.org/paho/
  - open-source client implementations

- Mosquitto broker also moved into the Eclipse foundation in 2013 - https://projects.eclipse.org/projects/technology.mosquitto
  - open-source broker

- Version 3.11 is an OASIS standard
- ISO standard as of 2016 (IOS/IC 20922)

- Version v5.0 official as OASIS standard as of April 2019

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MQTT – Key terminology

- Client
  - Publishers and subscribers
  - Paho
  - mqtt.js
- Broker
  - Mosquitto
  - ActiveMQ
  - Mosca (Node.js)
- Topic
  - Shared id to subscribe or publish on
- Message
  - Free form text
- QoS
  - Quality of Service (0-2)

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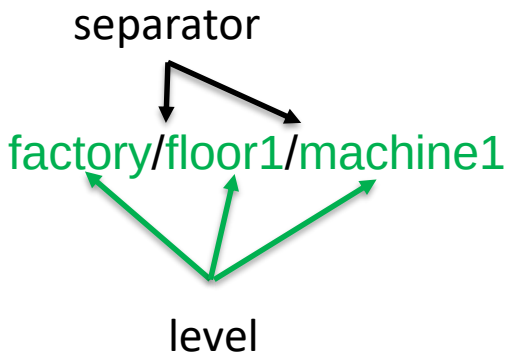
MQTT Topics

- **Topics** are one or more **levels** separated by the topic level **separator**



- **Restrictions**
  - Must be at least one character
  - Case sensitive

- **Wildcards**

+ Matches one level

factory/+/machine1 factory/floor1/machine1 (yes) factory/floor1/room1/machine1 (no)

matches multiple levels

only allowed at end

factory/# factory/floor1/machine1 (yes) factory/floor1/room1/machine1 (yes)

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MQTT QoS

- 3 Levels
  - 0 – At most once
  - 1 – At least once
  - 2 – Exactly once
- Downgrade of QoS
  - Uses QoS of receiver, so downgrade may occur if sending used higher level
- More overhead for each level
- 0 is generally the default

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Why IoT with IBM i?

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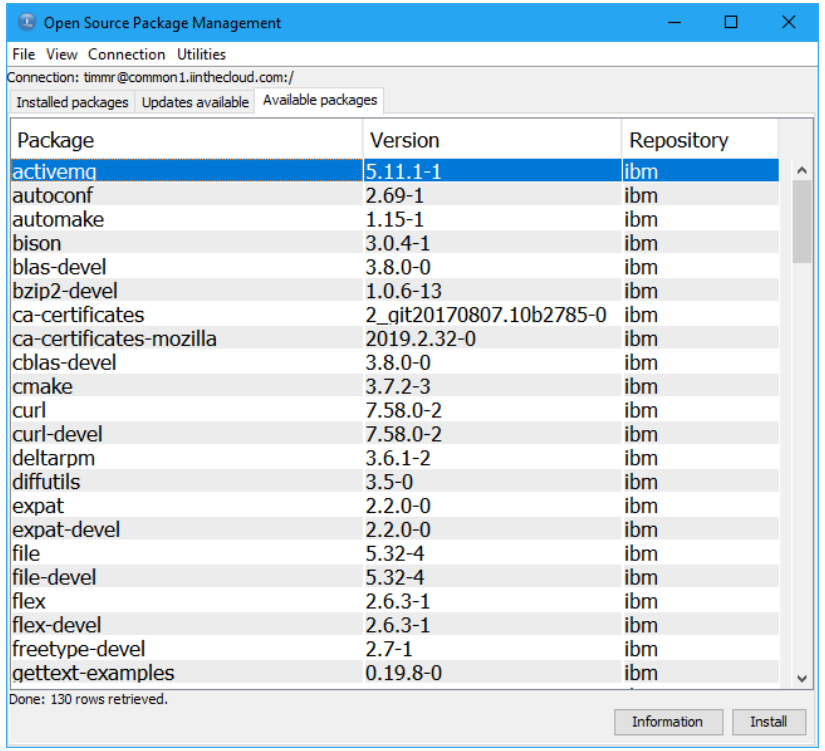
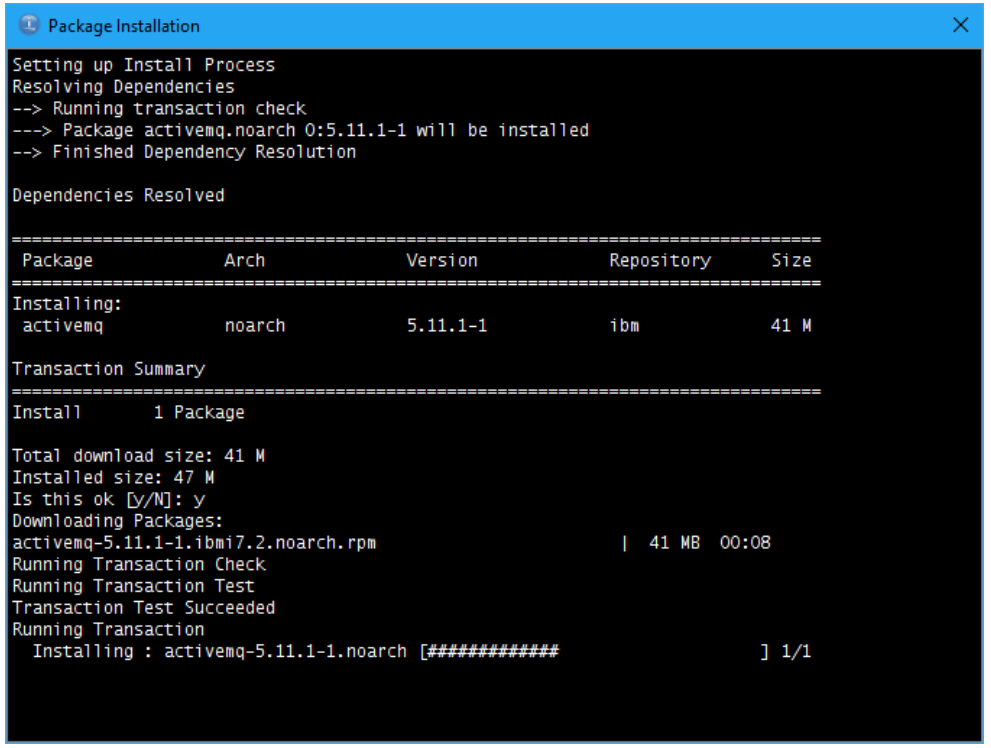
Using MQTT with IBM i

- ActiveMQ Install





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Using MQTT with IBM i

- Start ActiveMQ

```
activemq start
```

- Configure
  - http://activemq.apache.org/mqtt.html
  - Default config in - /QOpenSys/pkgs/lib/activemq/conf/

- Support
  - http://ibm.biz/ibmi-oss-support

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MQTT install

npm install mqtt

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Simple Client (client-local.js)

```
const fs = require('fs');
const path = require('path');
const mqtt = require('mqtt');

// setup mqtt
let  mqttOptions;
mqttOptions = {
                key: fs.readFileSync(path.join(__dirname, 'mqttclient', '/client.key')),
                cert: fs.readFileSync(path.join(__dirname, 'mqttclient', '/client.cert')),
                ca: fs.readFileSync(path.join(__dirname, 'mqttclient', '/ca.cert')),
                clientId: 'simple-client',
                checkServerIdentity: function() { return undefined },
                rejectUnauthorized: false,
                username: '',
                password: ''
}

const mqttClient = mqtt.connect('mqtts:common1.iinthecloud.com:8883', mqttOptions);
mqttClient.on('connect', () => {
  console.log('connected');
  mqttClient.subscribe('onibmi/topic');
  mqttClient.on('message', (topic, message) => {
    console.log('message received topic (' + topic + ') message (' + message.toString() + ')');
  });
});
```


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Simple Publisher (publisher-local.js)

```
const fs = require('fs');
const path = require('path');
const mqtt = require('mqtt');

// setup mqtt
let  mqttOptions;
mqttOptions = {
                key: fs.readFileSync(path.join(__dirname, 'mqttclient', '/client.key')),
                cert: fs.readFileSync(path.join(__dirname, 'mqttclient', '/client.cert')),
                ca: fs.readFileSync(path.join(__dirname, 'mqttclient', '/ca.cert')),
                clientId: 'simple publish',
                checkServerIdentity: function() { return undefined },
                rejectUnauthorized: false,
                username: '',
                password: ''
}

const mqttClient = mqtt.connect('mqtts:common1.iinthecloud.com:8883', mqttOptions);
mqttClient.on('connect', () => {
  console.log('connected');
  setInterval(() => {
    console.log('publishing');
    mqttClient.publish('onibmi/topic', 'hello world');
  }, 10000 );
});
```


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Demo

```
driveway@Common1:~/michael/mqttsamples$ node
publish-local.js
connected
publishing
publishing
publishing
publishing
publishing
publishing
publishing
publishing
```

```
driveway@Common1:~/michael/mqttsamples$ node client-local.js
connected
message received topic (onibmi/topic) message (hello world)
message received topic (onibmi/topic) message (hello world)
message received topic (onibmi/topic) message (hello world)
message received topic (onibmi/topic) message (hello world)
message received topic (onibmi/topic) message (hello world)
```


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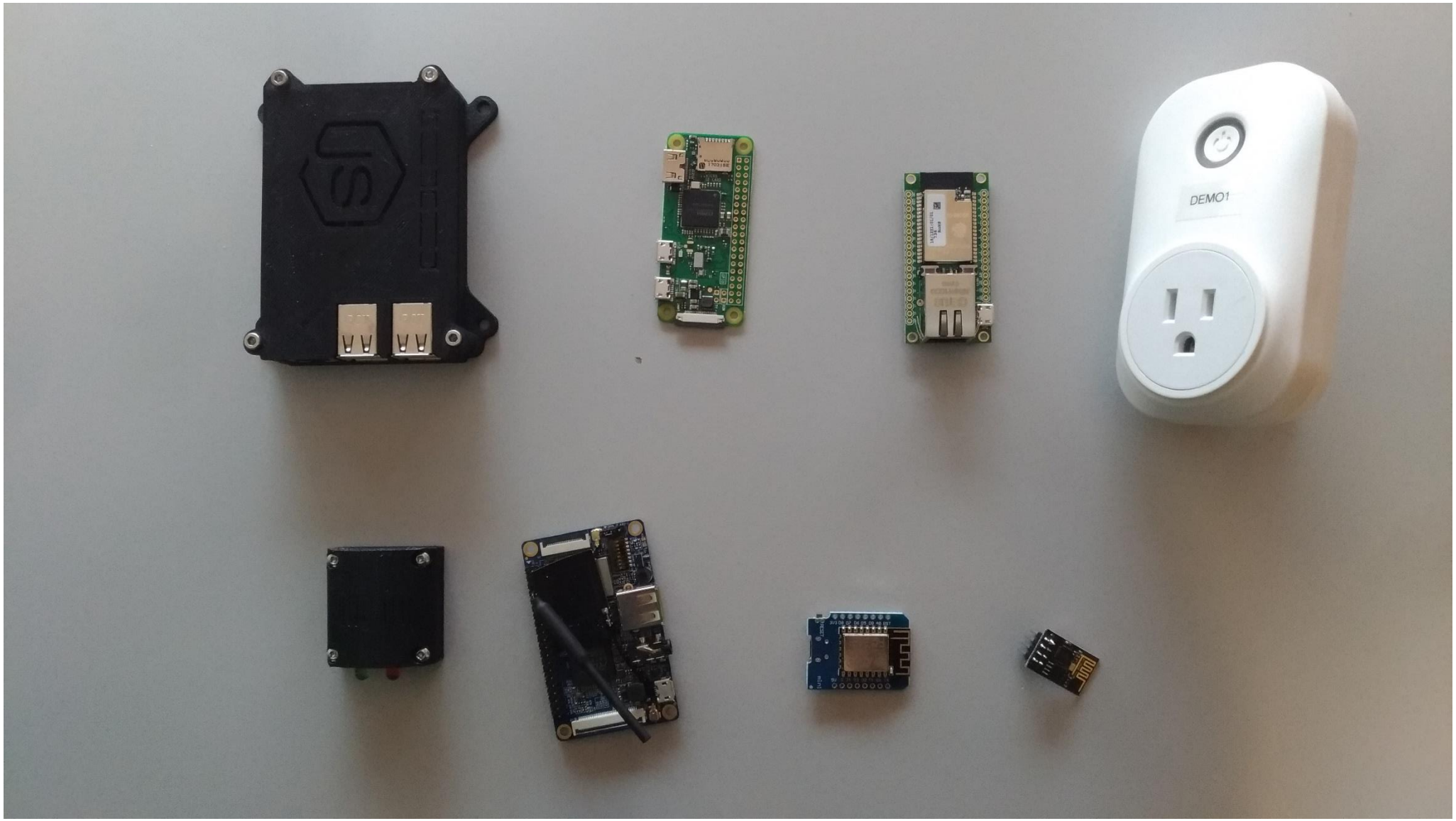
Lets look at some Devices



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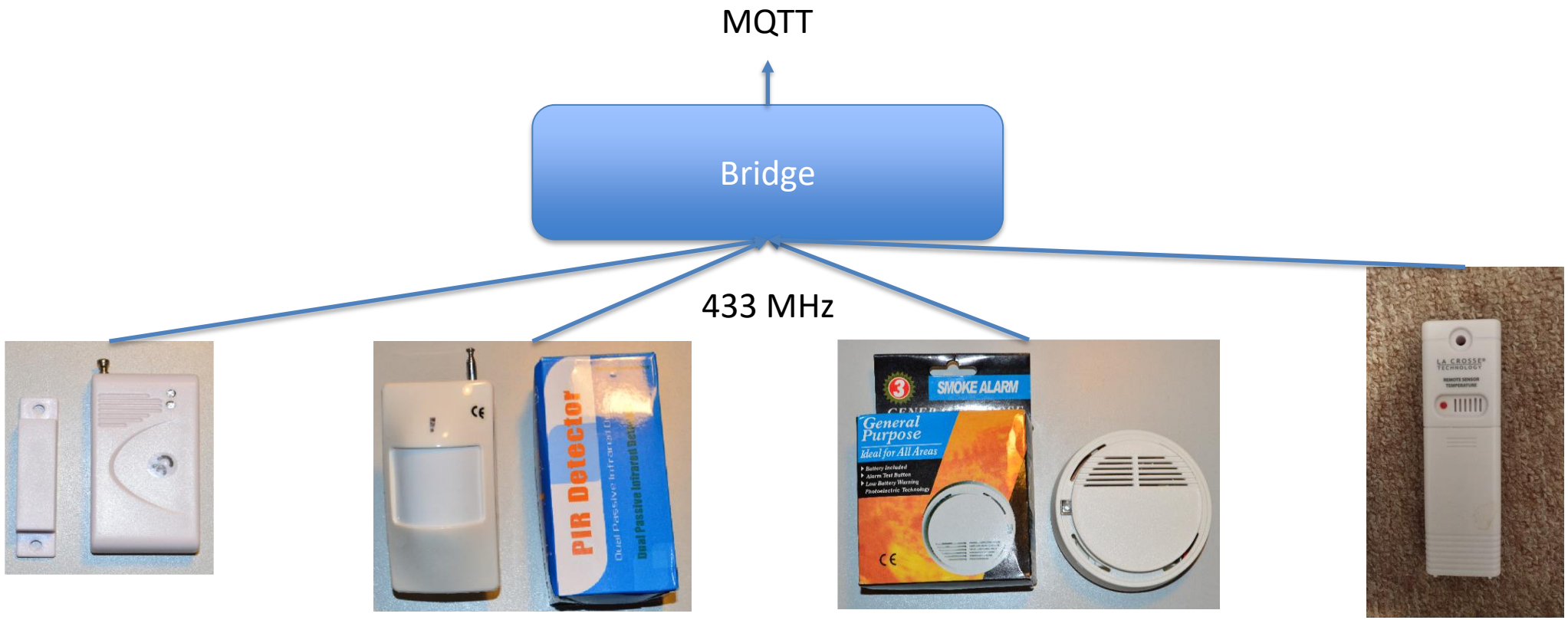
Other/Existing Devices

- Common approach is gateway or bridge

- As an example 433MHz to MQTT bridge
  https://github.com/mhdawson/arduino-esp8266/tree/master/Mqtt433Bridge



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Anatomy of a Simple Device

- Maybe your business grows plants?
- **Temperature** and **Light** intensity through the day might be interesting?

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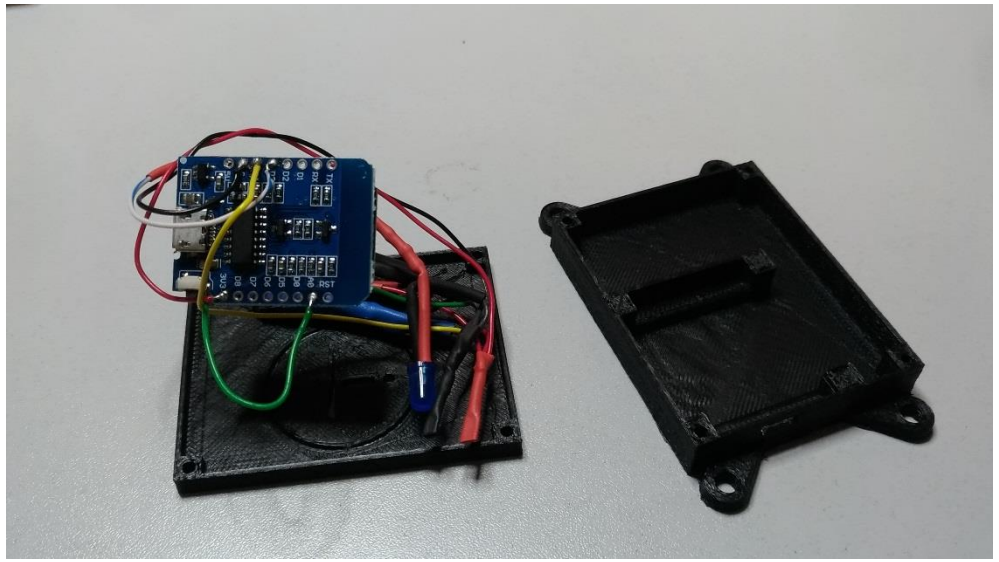
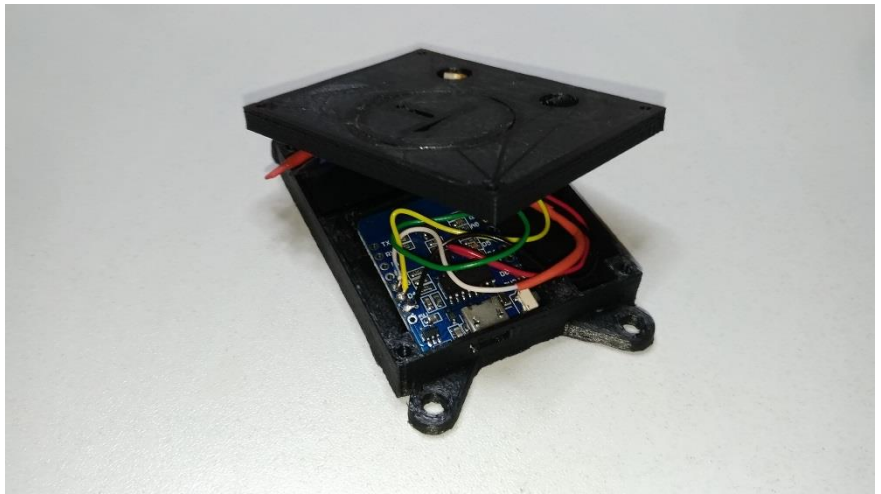
Anatomy of a Simple Device – Temp and Light Sensor





https://github.com/mhdawson/arduino-esp8266/tree/master/TempAndLightSensor

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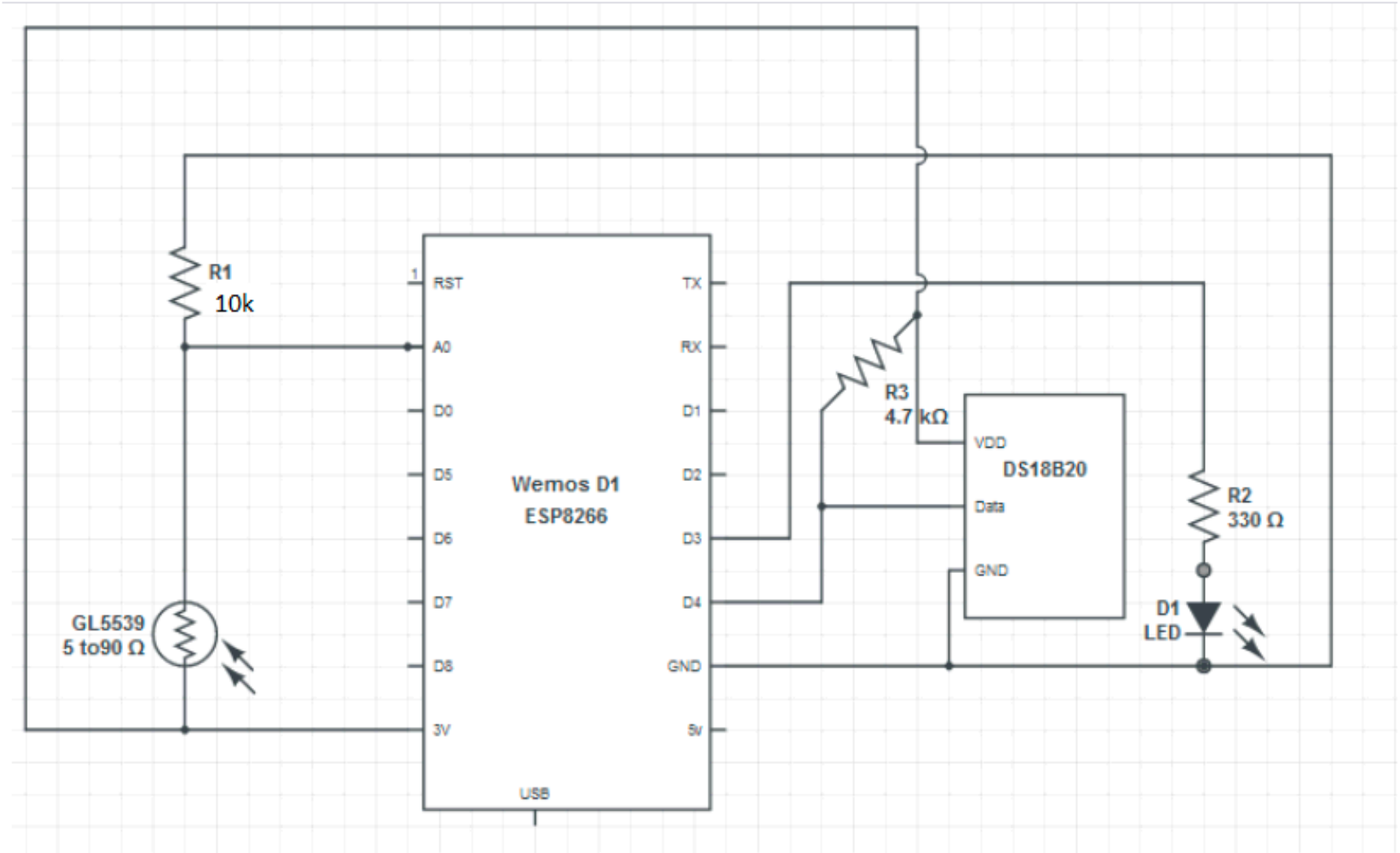
Anatomy of a Simple Device



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Anatomy of a Simple Device

```
#ifndef __SENSOR_CONFIG_H__
#define __SENSOR_CONFIG_H__
#define LIGHT_TOPIC "factory/1/light"
#define TEMP_TOPIC  "factory/1/temp"
#define LED_TOPIC   "factory/1/led"
#endif
```

```
// wireless setup
#ifndef __WIRELESS_H__
#define __WIRELESS_H__
const char *ssid =  "XXXXXXXXXX";   // cannot be longer than 32 characters!
const char *pass =  "XXXXXXXXX";   //
const char* mqttServerString = "XX.XX.XX.XX";
const uint16_t mqttServerPort = 8883;

#define USE_CERTS
unsigned char client_cert[] PROGMEM = {
  0x30, 0x82, 0x03, 0x92, 0x30, 0x82, 0x02, 0x7a, 0x02, 0x09, 0x00, 0xcb,
.............
};
unsigned int client_cert_len = YYYY;


unsigned char client_key[] PROGMEM = {
  0x30, 0x82, 0x04, 0xa5, 0x02, 0x01, 0x00, 0x02, 0x82, 0x01, 0x01, 0x00,
 .......
};
unsigned int client_key_len = ZZZZ;
#endif
```


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Anatomy of a Simple Device

```
#include <Arduino.h>
#include <ESP8266WiFi.h>
#include <WiFiClientSecure.h>
#include <PubSubClient.h>
#include <OneWire.h>
#include <DallasTemperature.h>

// device specifics
#include "WirelessConfig.h"
#include "SensorConfig.h"

#define TRANSMIT_INTERVAL_SECONDS 60
#define MILLIS_IN_SECOND 1000
#define LOOP_DELAY 100

#define LED_PIN D3
#define LED_BLINK_TIME_SECONDS 2

#define MAX_MESSAGE_SIZE 100

#define LIGHT_PIN A0

#define DS18B20_PIN D4  // don't use D0 or D2 as can interfere with boot
OneWire ds(DS18B20_PIN);
DallasTemperature tempSensors(&ds);
```


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Anatomy of a Simple Device

```
31  bool ledOn = true;
32  void toggleLED() {
33    if (ledOn) {
34      ledOn = false;
35      digitalWrite(LED_PIN, LOW);
36    } else {
37      ledOn  = true;
38      digitalWrite(LED_PIN, HIGH);
39    }
40  }
41
42  void callback(char* topic, uint8_t* message, unsigned int length) {
43    if (strncmp((const char*)message,"on", strlen("on")) == 0) {
44      digitalWrite(LED_PIN, HIGH);
45      ledOn = true;
46    } else {
47      digitalWrite(LED_PIN, LOW);
48      ledOn = false;
49    }
50  };
```


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Anatomy of a Simple Device

```
52  ESP8266WiFiGenericClass wifi;
53
54  #ifdef USE_CERTS
55  // if certs are used the following must be defined in WirelessConfig.h
56  //    unsigned char client_cert[] PROGMEM = {bytes in DER format};
57  //    unsigned int client_cert_len = 918;
58  //    unsigned char client_key[] PROGMEM = {bytes in DER format};
59  //    unsigned int client_key_len = 1193;
60  //
61  //    conversion can be done using
62  //    openssl x509 -in cert -out client.cert -outform DER
63  //    openssl rsa -in key -out client.key -outform DER
64  //    and then using xxd to generate the required array and lengths
65  //    see https://nofurtherquestions.wordpress.com/2016/03/14/making-an-esp8266-web-accessible/
66  //    for more detailed info
67  WiFiClientSecure wclient;
68  #else
69  WiFiClient wclient;
70  #endif
71
72  PubSubClient client(mqttServerString, mqttServerPort, callback, wclient);
73
74  int counter = 0;
75  char macAddress[] = "00:00:00:00:00:00";
```

Runs when MQTT message received

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Anatomy of a Simple Device

```
77  void setup() {
78    delay(1000);
79
80    // Setup console
81    Serial.begin(115200);
82    delay(10);
83    Serial.println();
84    Serial.println("Started");
85
86    pinMode(LED_PIN, OUTPUT);
87    digitalWrite(LED_PIN, HIGH);
88
89  #ifdef USE_CERTS
90    wclient.setCertificate_P(client_cert, client_cert_len);
91    wclient.setPrivateKey_P(client_key, client_key_len);
92  #endif
93
94    // turn of the Access Point as we are not using it
95    wifi.mode(WIFI_STA);
96    WiFi.begin(ssid, pass);
97
98    // first reading always seems to be wrong, read it early and
99    // throw it away
100   tempSensors.requestTemperatures();
101
102    // get the mac address to be used as a unique id for connecting to the mqtt server
103   byte macRaw[6];
104   WiFi.macAddress(macRaw);
105   sprintf(macAddress,
106           "%02.2X:%02.2X:%02.2X:%02.2X:%02.2X:%02.2X",
107           macRaw[0],
108           macRaw[1],
109           macRaw[2],
110           macRaw[3],
111           macRaw[4],
112           macRaw[5]);
113 }
```


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Anatomy of a Simple Device

```
115  void loop() {
116    client.loop();
117    delay(LOOP_DELAY);
118
119    // make sure we are good for wifi
120    if (WiFi.status() != WL_CONNECTED) {
121      Serial.print("Connecting to ");
122      Serial.println(ssid);
123      WiFi.reconnect();
124
125      if (WiFi.waitForConnectResult() != WL_CONNECTED) {
126        Serial.println("Failed to reconnect WIFI");
127        Serial.println(WiFi.waitForConnectResult());
128        delay(1000);
129        return;
130      }
131    }
132
133
134    if (!client.connected()) {
135      if (client.connect(macAddress)) {
136        Serial.println("mqtt connected:");
137        Serial.println(macAddress);
138        Serial.println("\n");
139        client.subscribe(LED_TOPIC);
140      }
141    }
```

Make sure ID is Unique !

Subscribe to topics of interest

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Anatomy of a Simple Device

```
143     counter++;
144     if (counter == (TRANSMIT_INTERVAL_SECONDS * (MILLIS_IN_SECOND/LOOP_DELAY))) {
145       Serial.println("Sending");
146
147       // don't send out temperature too often as we'll get
148       // incorrect values if we sample too often
149       char tempMessage[MAX_MESSAGE_SIZE];
150       char floatBuffer[10];
151       tempSensors.requestTemperatures();
152       float currentTemp = tempSensors.getTempCByIndex(0);
153       snprintf(tempMessage, MAX_MESSAGE_SIZE, "0, 0 - temp: %s",
154                dtostrf(currentTemp, 4, 2, floatBuffer));
155       client.publish(TEMP_TOPIC, tempMessage);
156
157       char lightMessage[MAX_MESSAGE_SIZE];
158       int lightValue = analogRead(LIGHT_PIN);
159       snprintf(lightMessage, MAX_MESSAGE_SIZE, "0, 0 - light: %d", lightValue);
160       client.publish(LIGHT_TOPIC, lightMessage);
161
162       toggleLED();
163       counter = 0;
164     } else if (counter == (LED_BLINK_TIME_SECONDS * (MILLIS_IN_SECOND/LOOP_DELAY))) {
165       toggleLED();
166     }
167   }
```

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Anatomy of Simple Device

- Don’t like C++? Can use JavaScript as well
  - https://github.com/mhdawson/espruino-stuff/blob/master/SmartPlug.js

```
client.on('publish', function(message) {
  console.log(message);
  if (message.topic === (devicePrefix + '/power')) {
    if (message.message === 'on') {
      powerState = 1;
    } else if (message.message === 'off') {
      powerState = 0;
    }
    digitalWrite(powerPin, powerState);
    console.log('Power state:' + powerState);
  } else if (message.topic === (devicePrefix + '/led')) {
    clearLedFlashTimer();
    if (message.message === 'on') {
      ledState = 1;
    } else if (message.message === 'off') {
      ledState = 0;
    } else if (message.message.substr(0, 'flash'.length) === 'flash') {
      try {
        timeout = message.message.split(':')[1];
        startFlashTimer(timeout);
      } catch (err) {
        console.log(err);
      }
    }
    digitalWrite(ledPin, (ledState + 1) % 2);
    console.log('Led state:' + ledState);
  } else if (message.topic === (devicePrefix + '/query_state')) {
    client.publish(devicePrefix + '/state/power', powerState);
    client.publish(devicePrefix + '/state/led', ledState);
  }
});
```

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Consuming Sensor Data on IBM i (client-sensor.js)

```
const fs = require('fs');
const path = require('path');
const mqtt = require('mqtt');

// setup mqtt
let  mqttOptions;
mqttOptions = {
                key: fs.readFileSync(path.join(__dirname, 'mqttclient', '/client.key')),
                cert: fs.readFileSync(path.join(__dirname, 'mqttclient', '/client.cert')),
                ca: fs.readFileSync(path.join(__dirname, 'mqttclient', '/ca.cert')),
                clientId: 'simple-client',
                checkServerIdentity: function() { return undefined },
                rejectUnauthorized: false,
                username: '',
                password: ''
}

const mqttClient = mqtt.connect('mqtts:common1.iinthecloud.com:8883', mqttOptions);
  mqttClient.on('connect', () => {
    console.log('connected');
    mqttClient.subscribe('factory/1/light');
    mqttClient.subscribe('factory/1/temp');
    mqttClient.on('message', (topic, message) => {
      console.log('message received topic (' + topic + ') message (' + message.toString() + ')');
    });
});
```


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Controlling Sensor on IBMi (control.js)

```
const fs = require('fs');
const path = require('path');
const mqtt = require('mqtt');


// setup mqtt
let  mqttOptions;
mqttOptions = {
                key: fs.readFileSync(path.join(__dirname, 'mqttclient', '/client.key')),
                cert: fs.readFileSync(path.join(__dirname, 'mqttclient', '/client.cert')),
                ca: fs.readFileSync(path.join(__dirname, 'mqttclient', '/ca.cert')),
                clientId: 'control client',
                checkServerIdentity: function() { return undefined },
                rejectUnauthorized: false,
                username: '',
                password: ''
}

const mqttClient = mqtt.connect('mqtts:common1.iinthecloud.com:8883', mqttOptions);
mqttClient.on('connect', () => {
  console.log('connected');
  mqttClient.publish('factory/1/led', process.argv[2], () => {
    setTimeout( () => {
      process.exit(0);
    }, 2000);
  });
});
```


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Consuming Sensor Data on IBM i – Store to DB

```
const { DBPool } = require('idb-pconnector');
const pool = new DBPool();

async function setupDb() {
  try {
    await pool.prepareExecute('CREATE SCHEMA JESSEGIOT');
  }catch(err) {
    if(err.stack.includes('SQLSTATE=42710')) {
        console.log('schema already exists');
    } else {
      console.log('error: '+err.stack);
    }
  }
  try {
    await pool.prepareExecute(`CREATE OR REPLACE TABLE JESSEGIOT.IOT_RECORDS (
                                    DEVICE VARCHAR(80) ALLOCATE (10) CCSID 1208 NOT NORMALIZED NOT NULL NOT HIDDEN,
                                    SENSORVALUE DECIMAL(7, 2) NOT NULL NOT HIDDEN,
                                    SENSORTIME TIMESTAMP(6) GENERATED ALWAYS FOR EACH ROW ON UPDATE AS ROW CHANGE TIMESTAMP
                                    NOT NULL NOT HIDDEN
                                )
                                NOT VOLATILE UNIT ANY KEEP IN MEMORY NO`);
  }catch(err) {
      console.log('error: '+err.stack);
  }
  console.log('Database setup complete!');
}
```


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Consuming Sensor Data on IBM i – Store to DB

```
const mqttClient = mqtt.connect('mqtts:common1.iinthecloud.com:8883', mqttOptions); mqttClient.on('connect', () => {
    console.log('connected');
    mqttClient.subscribe('factory/1/light');
    mqttClient.subscribe('factory/1/temp');
    mqttClient.on('message', (topic, message) => {
      let value = message.toString().replace(/.*:/g,'').replace(/[^0-9.]+/g,'');
      pool.prepareExecute('insert into JESSEGIOT.IOT_RECORDS(device, sensorvalue) values(?, ?)', [topic, value]);
      console.log('message received topic (' + topic + ') message (' + message.toString() + ')');
    });
});
```


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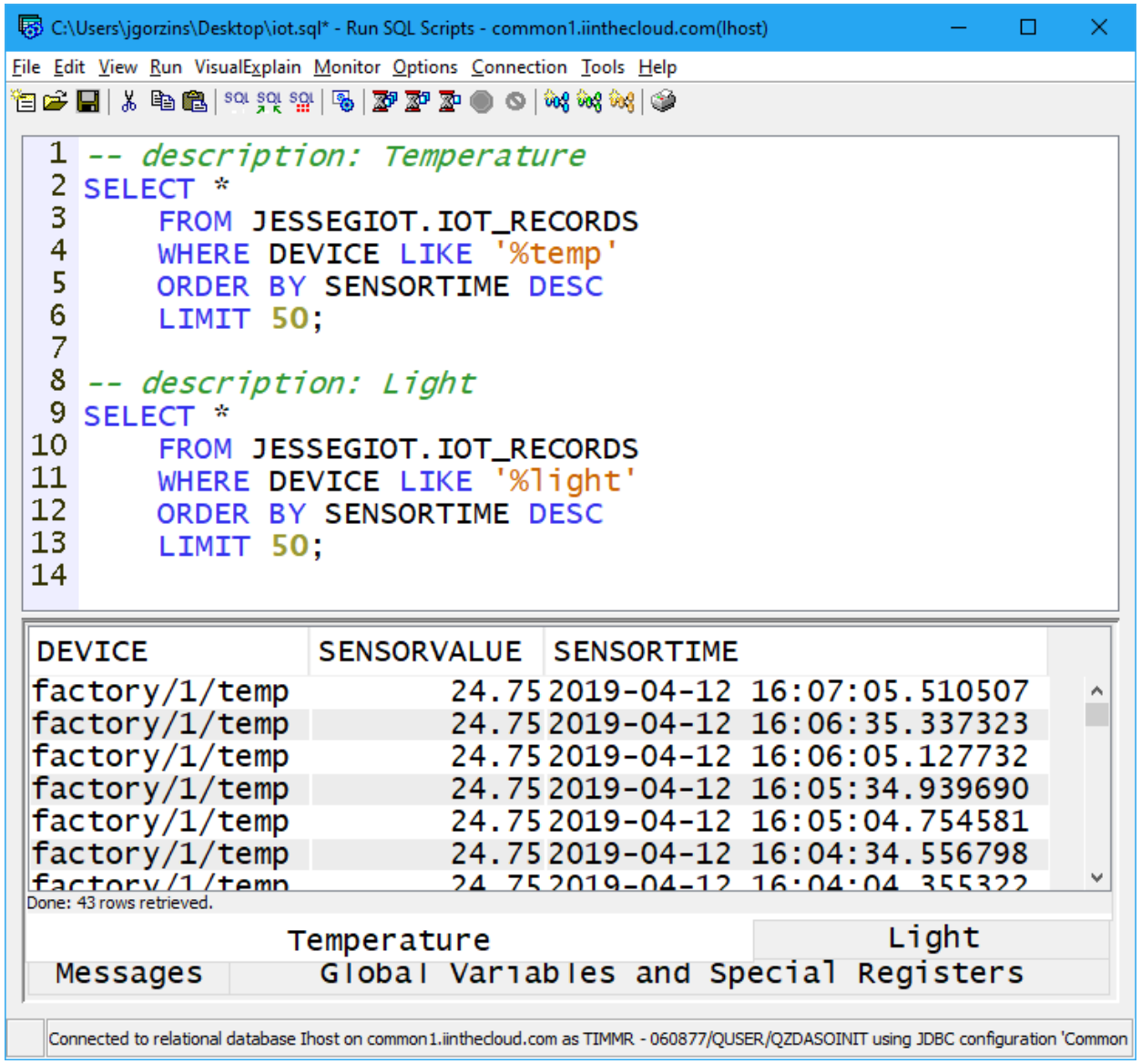
Controlling Sensor on IBM i (control.js)



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Demo

- Live Device data flow

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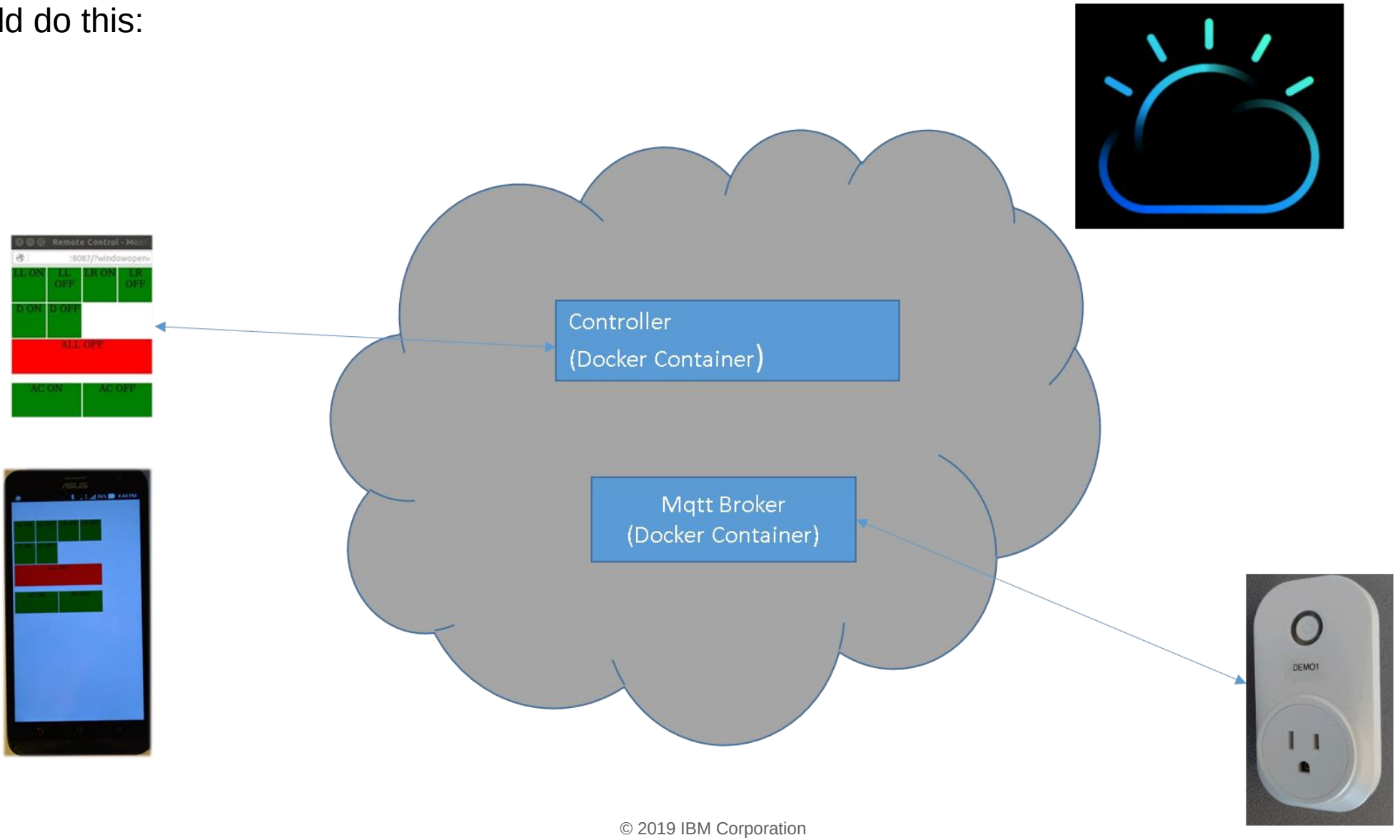
Leveraging the Cloud

- Could do this:



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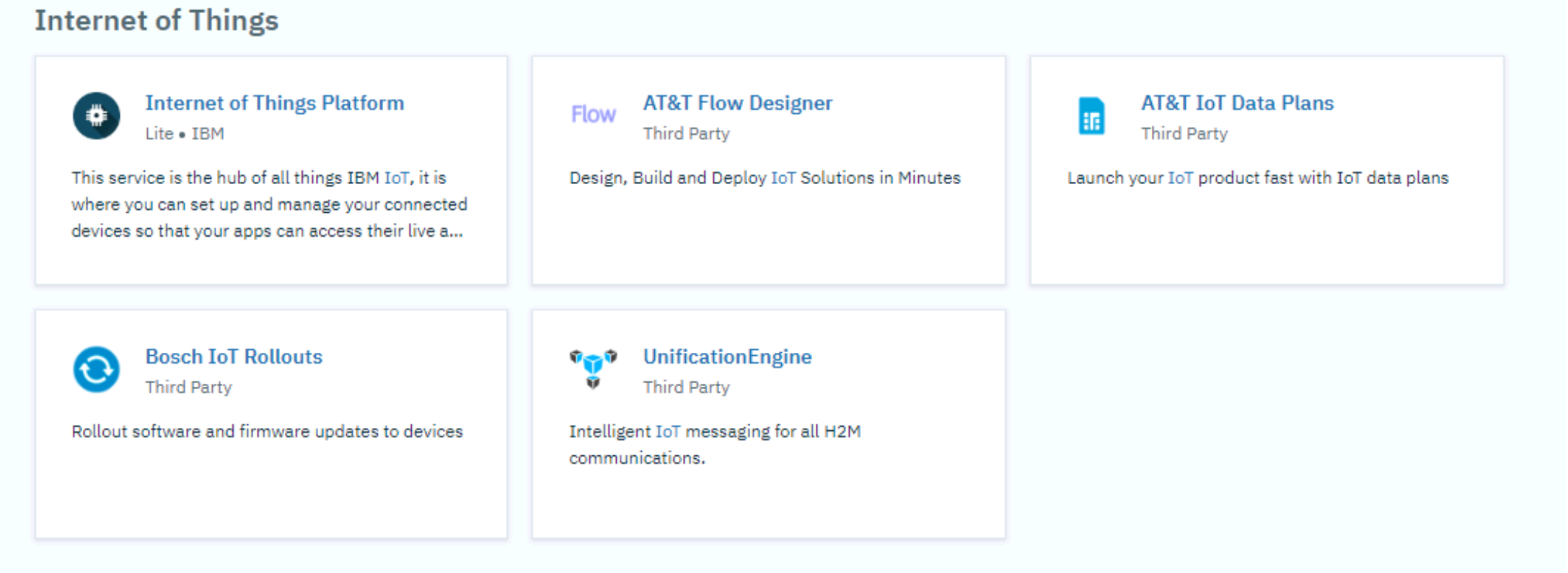
Leveraging the Cloud – Even Better

- Cloud Based Service
  - Don’t worry about infrastructure
  - Get started fast
  - Easy visualization



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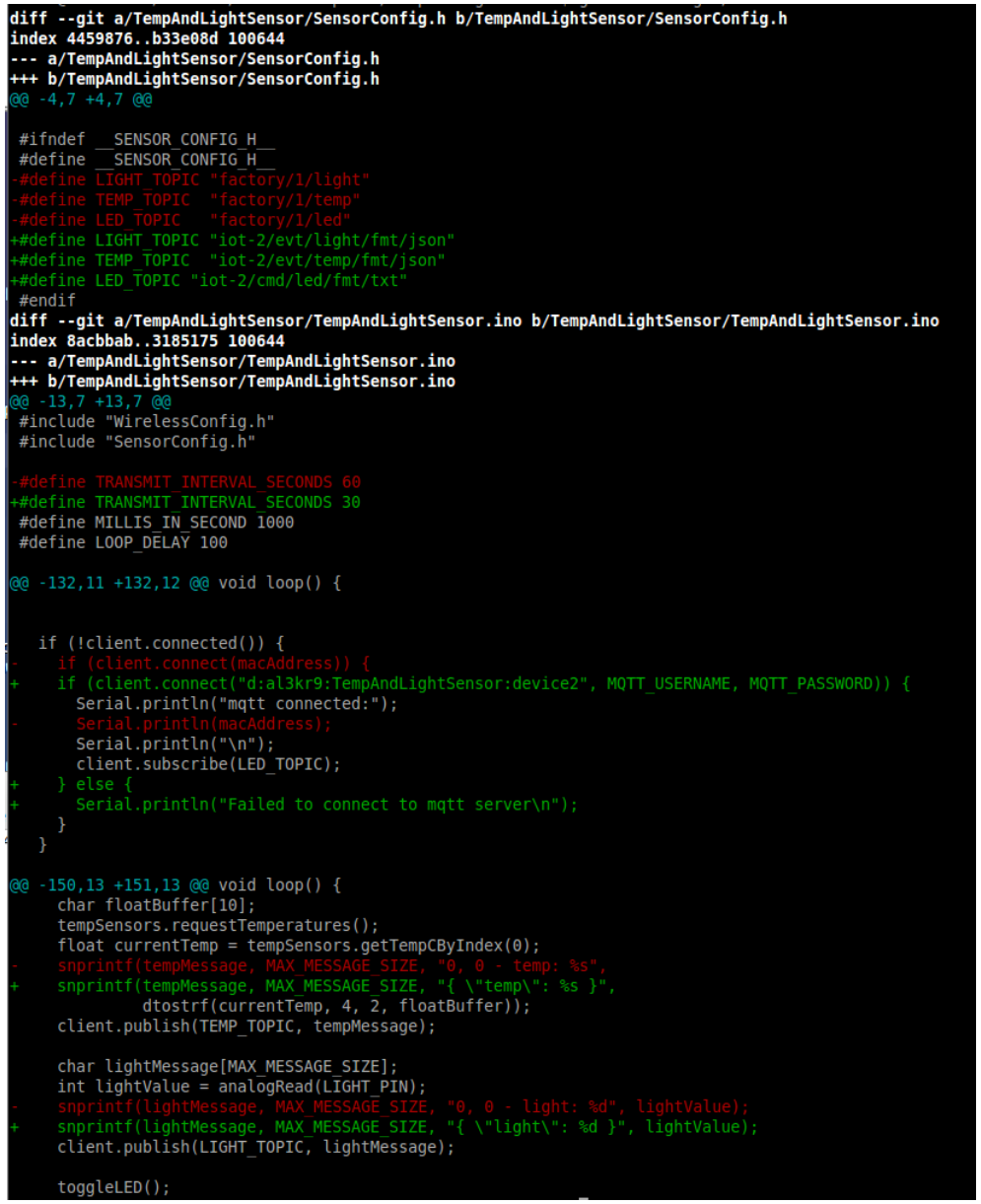
Leveraging the Cloud



```
diff --git a/TempAndLightSensor/SensorConfig.h b/TempAndLightSensor/SensorConfig.h
index 4459876..b33e08d 100644
--- a/TempAndLightSensor/SensorConfig.h
+++ b/TempAndLightSensor/SensorConfig.h
@@ -4,7 +4,7 @@

 #ifndef __SENSOR_CONFIG_H__
 #define __SENSOR_CONFIG_H__
-#define LIGHT_TOPIC "factory/1/light"
-#define TEMP_TOPIC  "factory/1/temp"
-#define LED_TOPIC   "factory/1/led"
+#define LIGHT_TOPIC "iot-2/evt/light/fmt/json"
+#define TEMP_TOPIC  "iot-2/evt/temp/fmt/json"
+#define LED_TOPIC "iot-2/cmd/led/fmt/txt"
 #endif
diff --git a/TempAndLightSensor/TempAndLightSensor.ino b/TempAndLightSensor/TempAndLightSensor.ino
index 8acbbab..3185175 100644
--- a/TempAndLightSensor/TempAndLightSensor.ino
+++ b/TempAndLightSensor/TempAndLightSensor.ino
@@ -13,7 +13,7 @@
 #include "WirelessConfig.h"
 #include "SensorConfig.h"

-#define TRANSMIT_INTERVAL_SECONDS 60
+#define TRANSMIT_INTERVAL_SECONDS 30
 #define MILLIS_IN_SECOND 1000
 #define LOOP_DELAY 100

@@ -132,11 +132,12 @@ void loop() {


   if (!client.connected()) {
-    if (client.connect(macAddress)) {
+    if (client.connect("d:al3kr9:TempAndLightSensor:device2", MQTT_USERNAME, MQTT_PASSWORD)) {
       Serial.println("mqtt connected:");
-      Serial.println(macAddress);
       Serial.println("\n");
       client.subscribe(LED_TOPIC);
+    } else {
+      Serial.println("Failed to connect to mqtt server\n");
     }
   }

@@ -150,13 +151,13 @@ void loop() {
     char floatBuffer[10];
     tempSensors.requestTemperatures();
     float currentTemp = tempSensors.getTempCByIndex(0);
-    snprintf(tempMessage, MAX_MESSAGE_SIZE, "0, 0 - temp: %s",
+    snprintf(tempMessage, MAX_MESSAGE_SIZE, "{ \"temp\": %s }",
             dtostrf(currentTemp, 4, 2, floatBuffer));
     client.publish(TEMP_TOPIC, tempMessage);

     char lightMessage[MAX_MESSAGE_SIZE];
     int lightValue = analogRead(LIGHT_PIN);
-    snprintf(lightMessage, MAX_MESSAGE_SIZE, "0, 0 - light: %d", lightValue);
+    snprintf(lightMessage, MAX_MESSAGE_SIZE, "{ \"light\": %d }", lightValue);
     client.publish(LIGHT_TOPIC, lightMessage);

     toggleLED();
```

https://cloud.ibm.com/docs/services/IoT/reference/security?topic=iot-platform-connect_devices_apps_gw#connect_devices_apps_gw

```
-#define LIGHT_TOPIC "factory/1/light"
-#define TEMP_TOPIC  "factory/1/temp"
-#define LED_TOPIC   "factory/1/led"
+#define LIGHT_TOPIC "iot-2/evt/light/fmt/json"
+#define TEMP_TOPIC  "iot-2/evt/temp/fmt/json"
+#define LED_TOPIC "iot-2/cmd/led/fmt/txt"
```

```
-    snprintf(lightMessage, MAX_MESSAGE_SIZE, "0, 0 - light: %d", lightValue);
+    snprintf(lightMessage, MAX_MESSAGE_SIZE, "{ \"light\": %d }", lightValue);
```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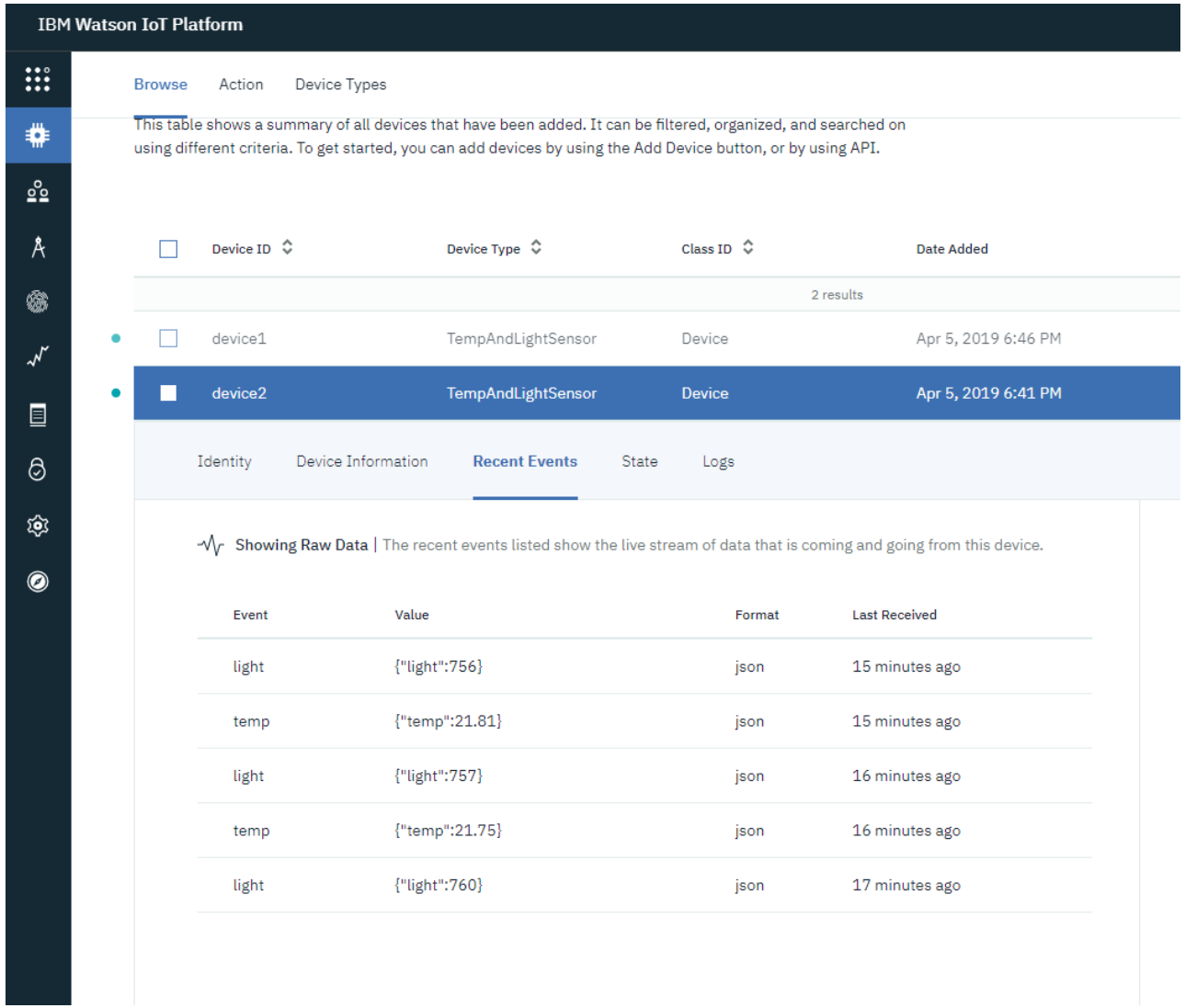
Leveraging the Cloud



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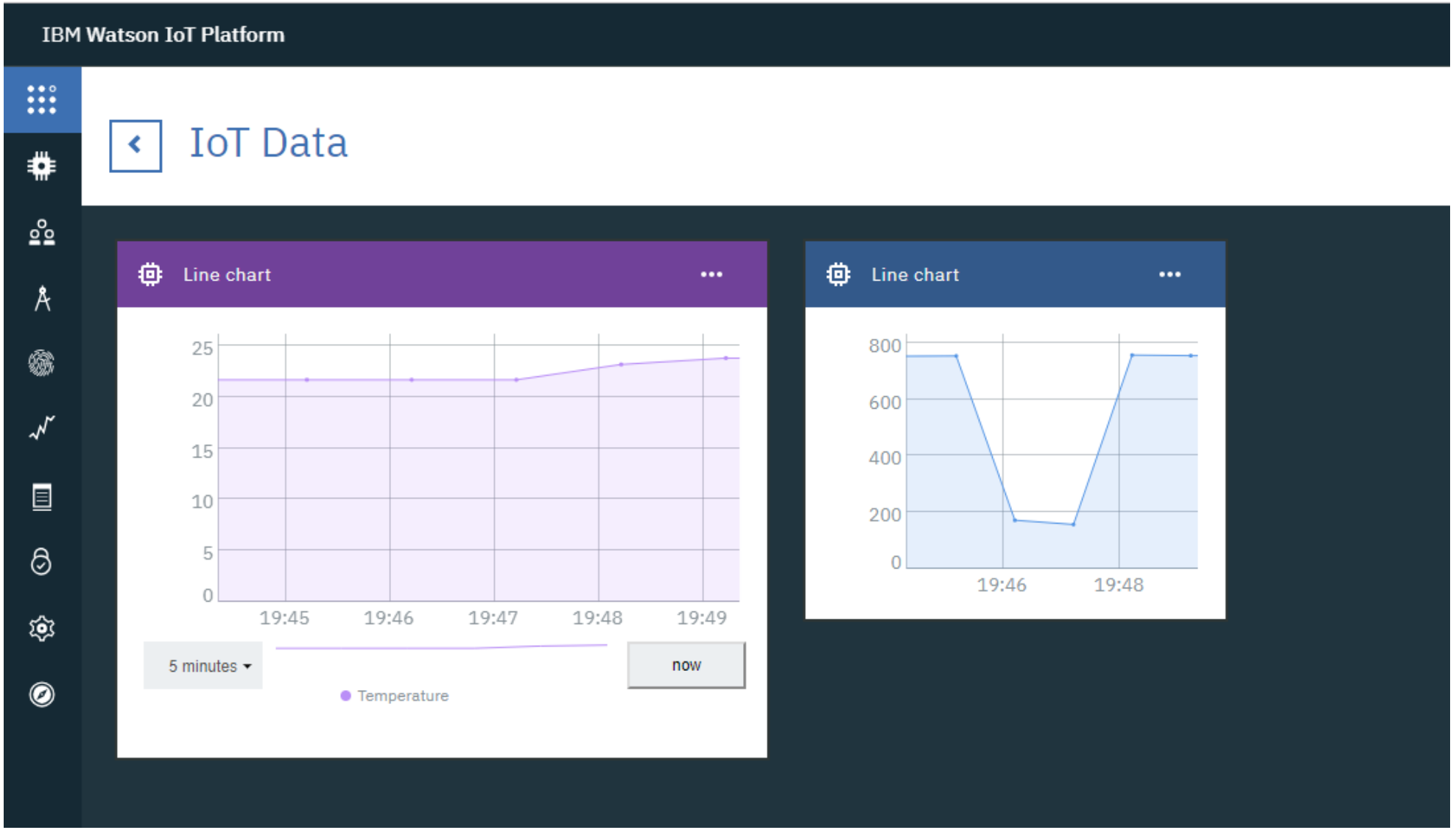
Leveraging the Cloud



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Consuming Data on IBMi (client-ibmcloud.js)

```
const fs = require('fs');
const path = require('path');
const mqtt = require('mqtt');


// setup mqtt
let  mqttOptions;
mqttOptions = {
                key: fs.readFileSync(path.join(__dirname, 'mqttclient', '/client.key')),
                cert: fs.readFileSync(path.join(__dirname, 'mqttclient', '/client.cert')),
                ca: fs.readFileSync(path.join(__dirname, 'mqttclient', '/ca.cert')),
                clientId: 'A:XXXXXX:XXXXXXXXXX',
                checkServerIdentity: function() { return undefined },
                rejectUnauthorized: false,
                username: 'a-XXXXXX-XXXXXXXXXX',
                password: 'XXXXXXXXXXXXXXXXX'
}

const mqttClient = mqtt.connect('mqtts:XXXXXX.messaging.internetofthings.ibmcloud.com:8883', mqttOptions);
mqttClient.on('connect', () => {
  console.log('connected');
  mqttClient.subscribe('iot-2/type/+/id/+/evt/+/fmt/+');
  mqttClient.on('message', (topic, message) => {
    console.log('message received topic (' + topic + ') message (' + message.toString() + ')');
  });
});
```


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Summary

- Intro to IoT and MQTT
- Using MQTT with Node.js and IBM i
- Lets Look at some devices
- Anatomy of a simple MQTT Light and Temperature Sensor
- Consuming MQTT data on IBMi
- Leveraging the Cloud

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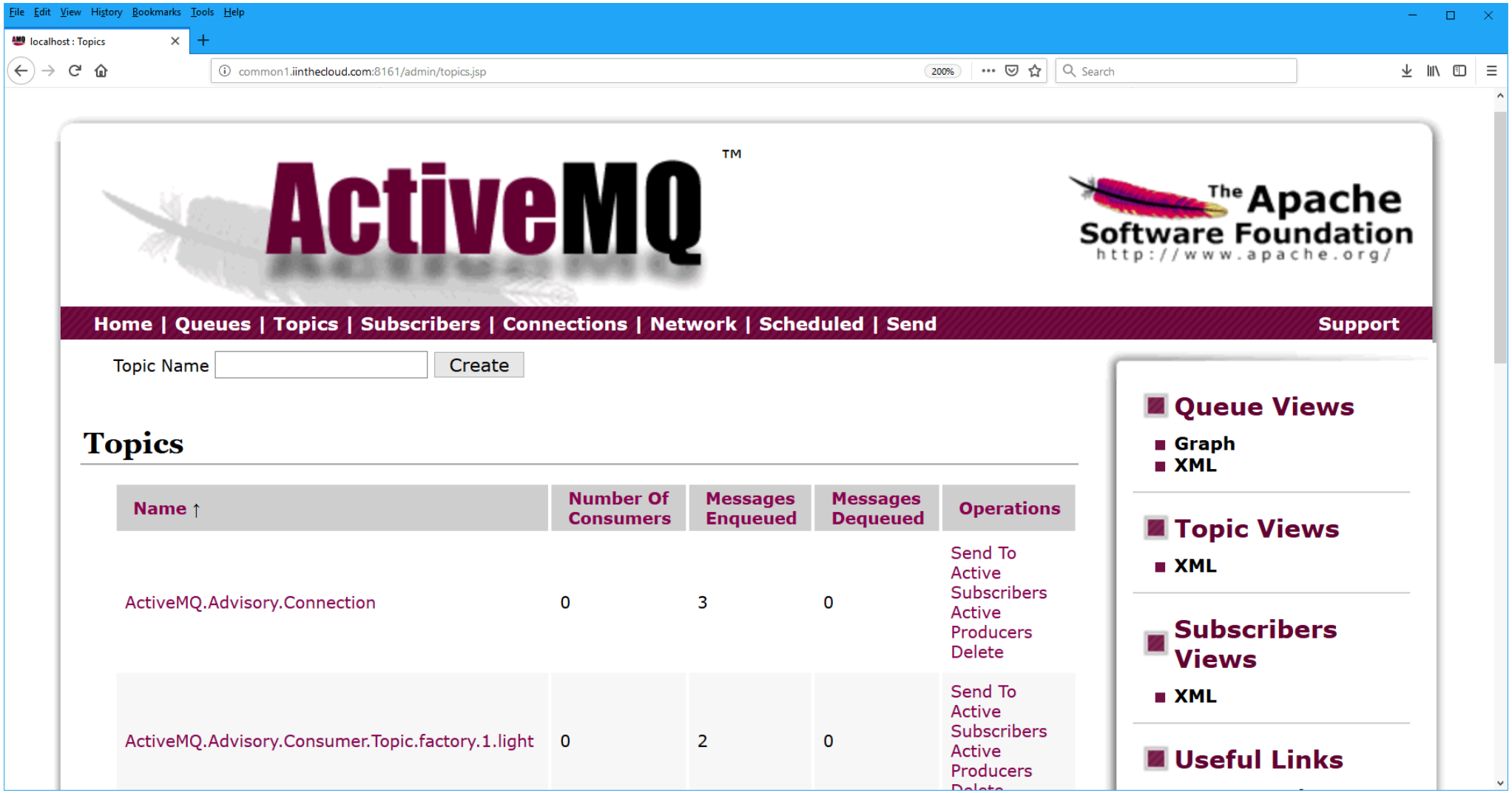

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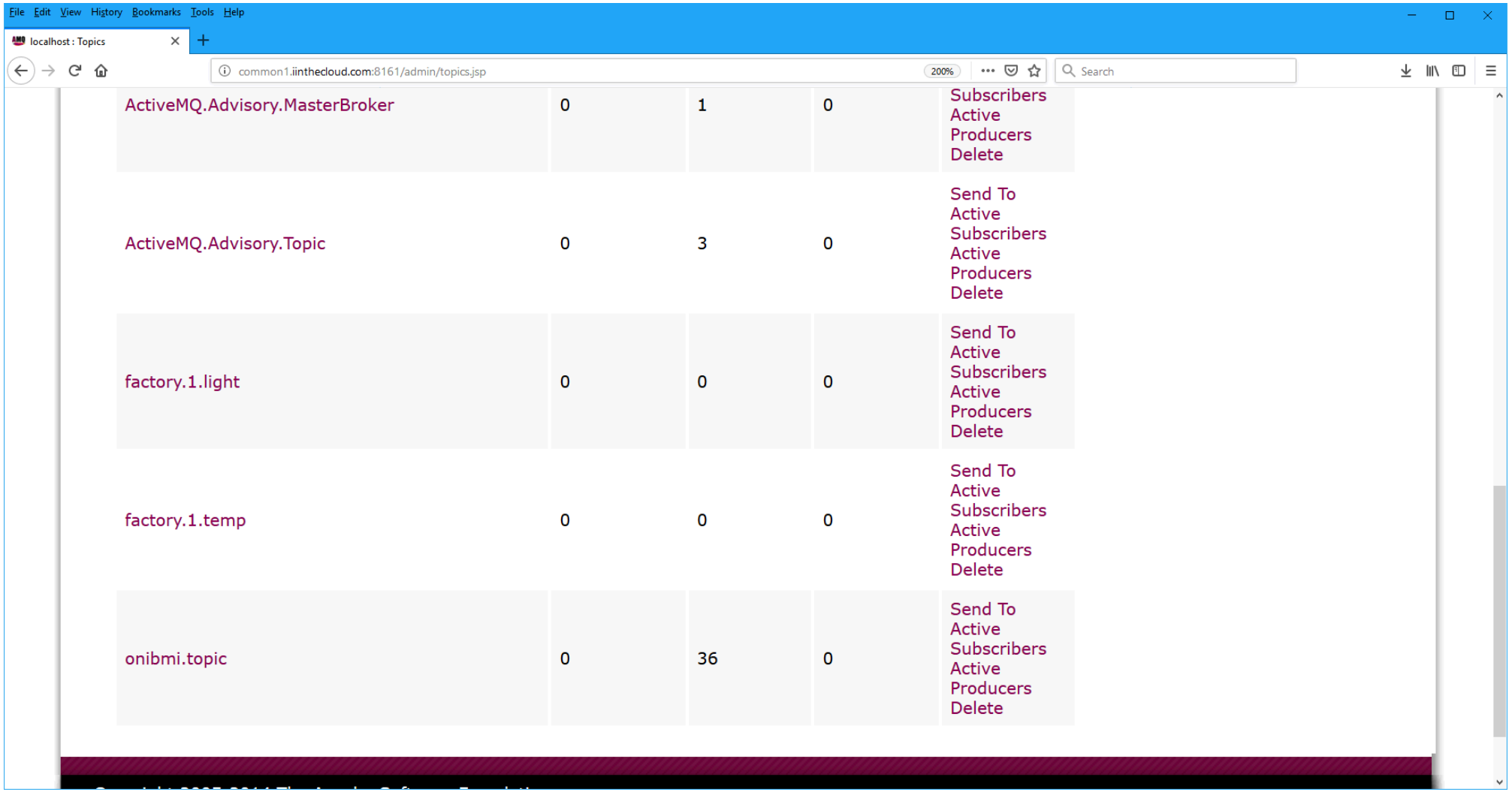

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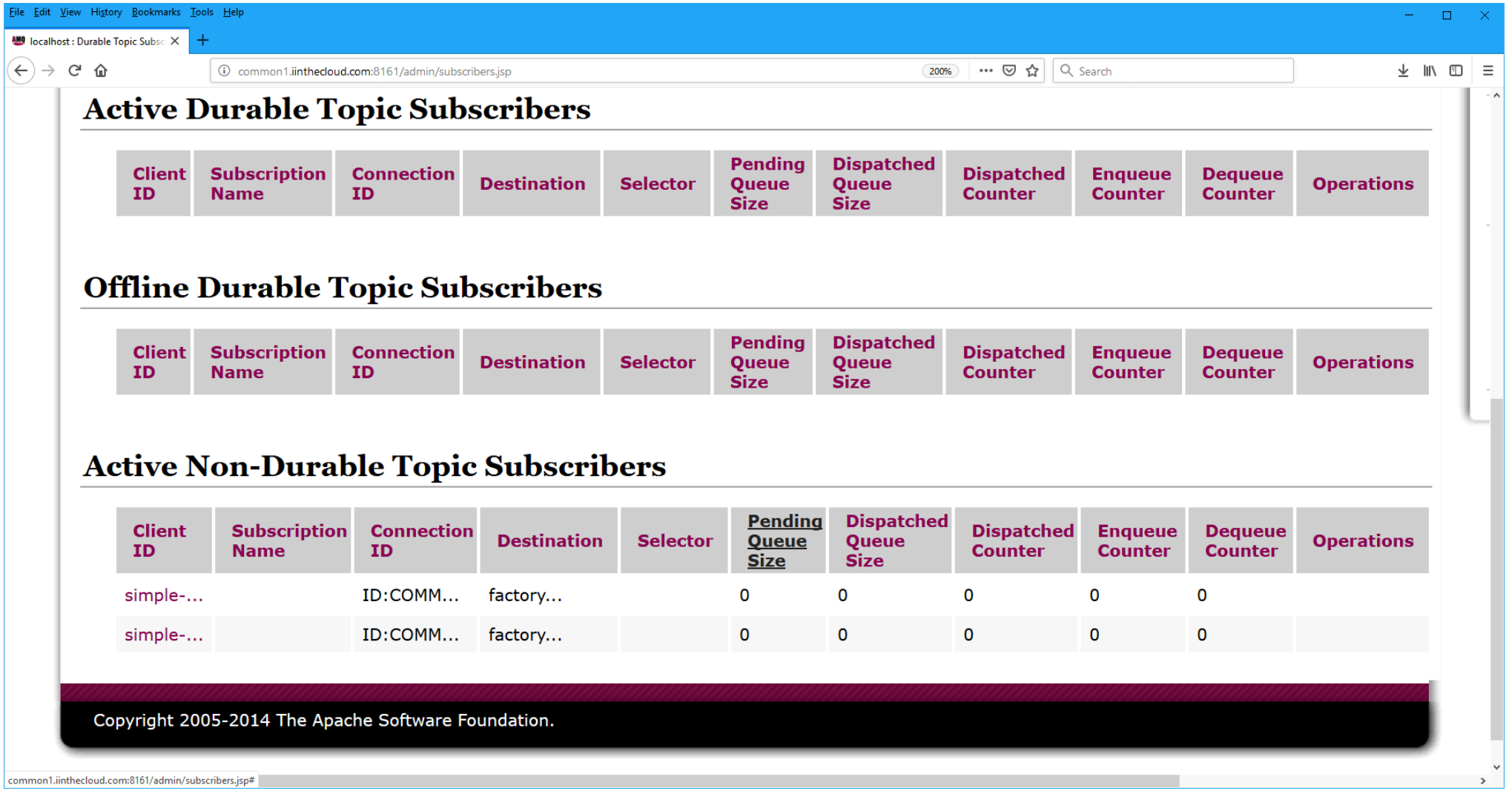

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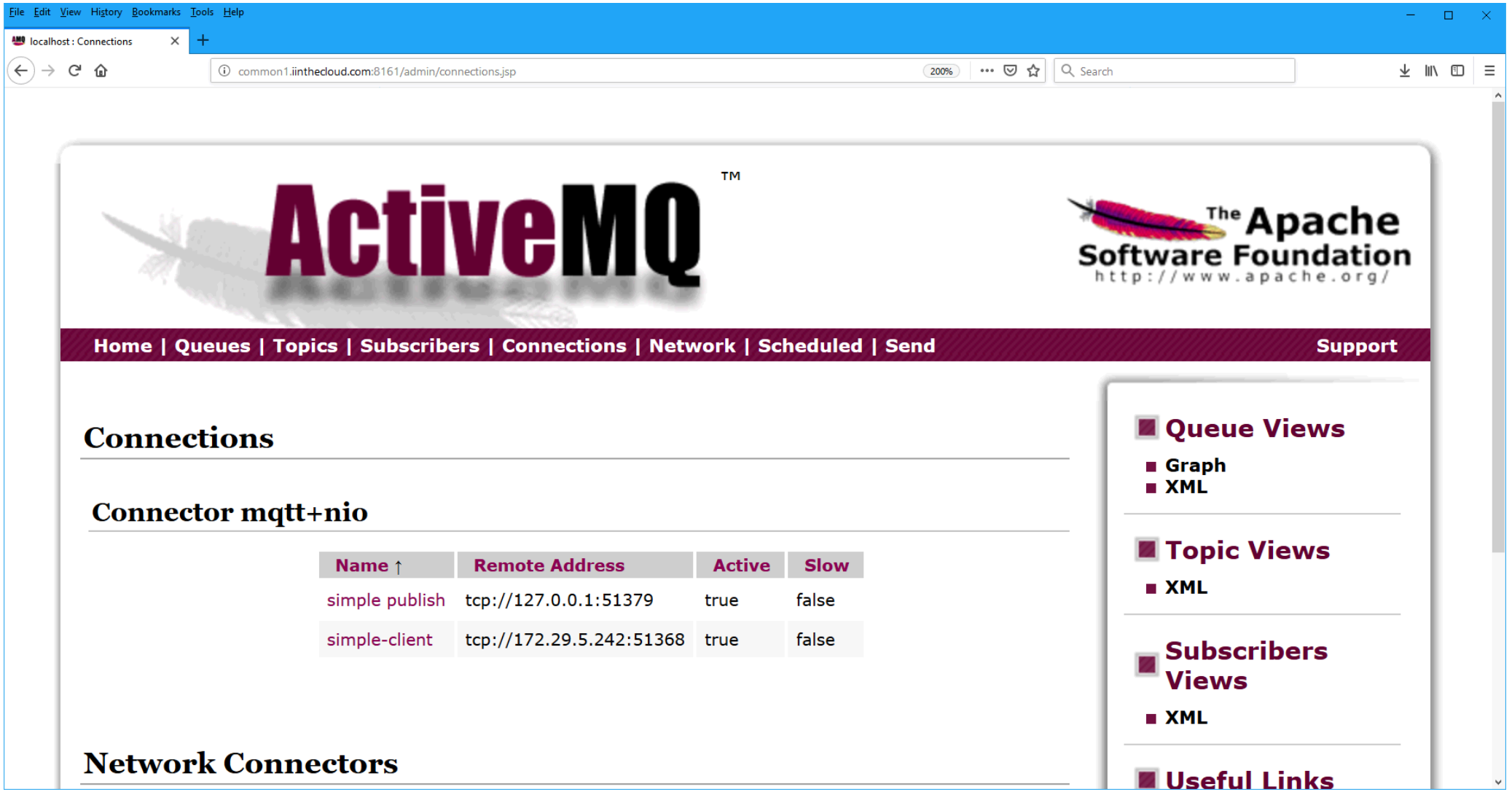

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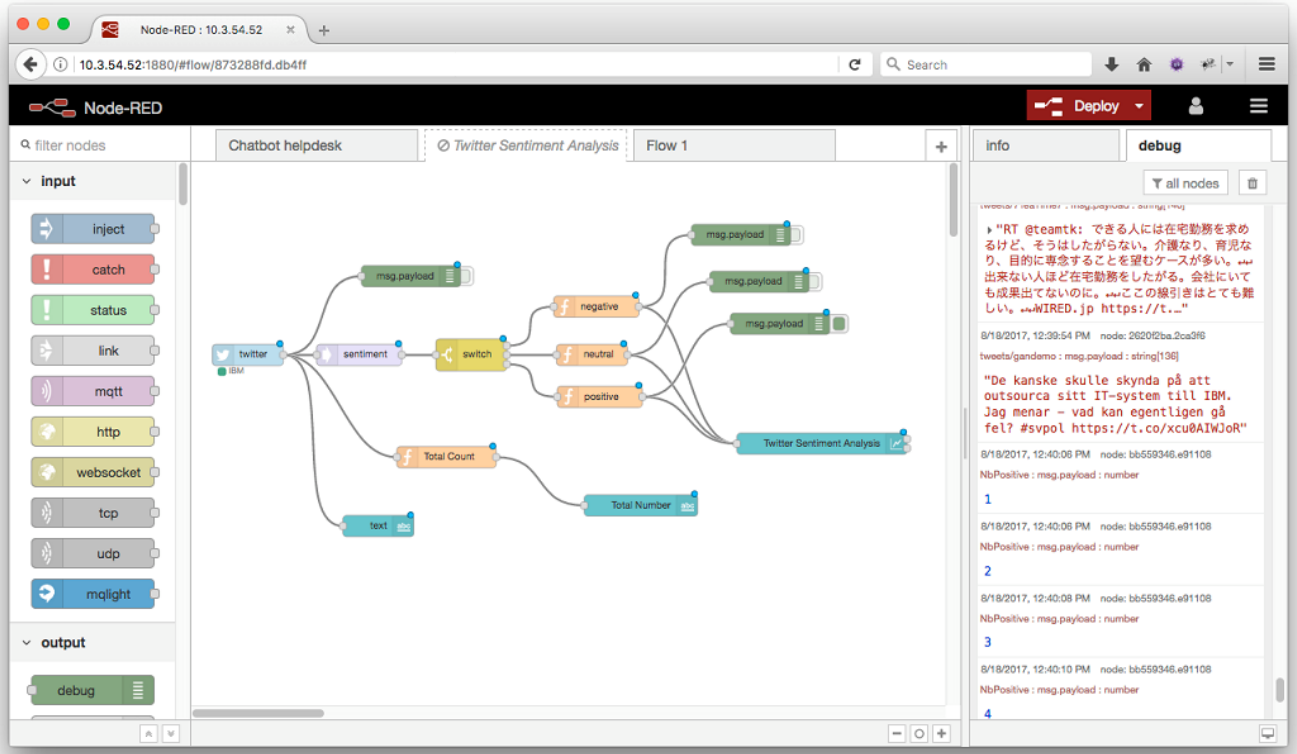
Node-RED

- Created by IBM
- Low-code graphical way to write flow-based programs
- https://developer.ibm.com/tutorials/i-running-node-red/
- Nodes can be any building block that can receive and send messages. Examples include:
  - Db2 for i queries
  - IoT devices
  - Web pages
  - Web APIs
  - Cloud services
  - Dashboards



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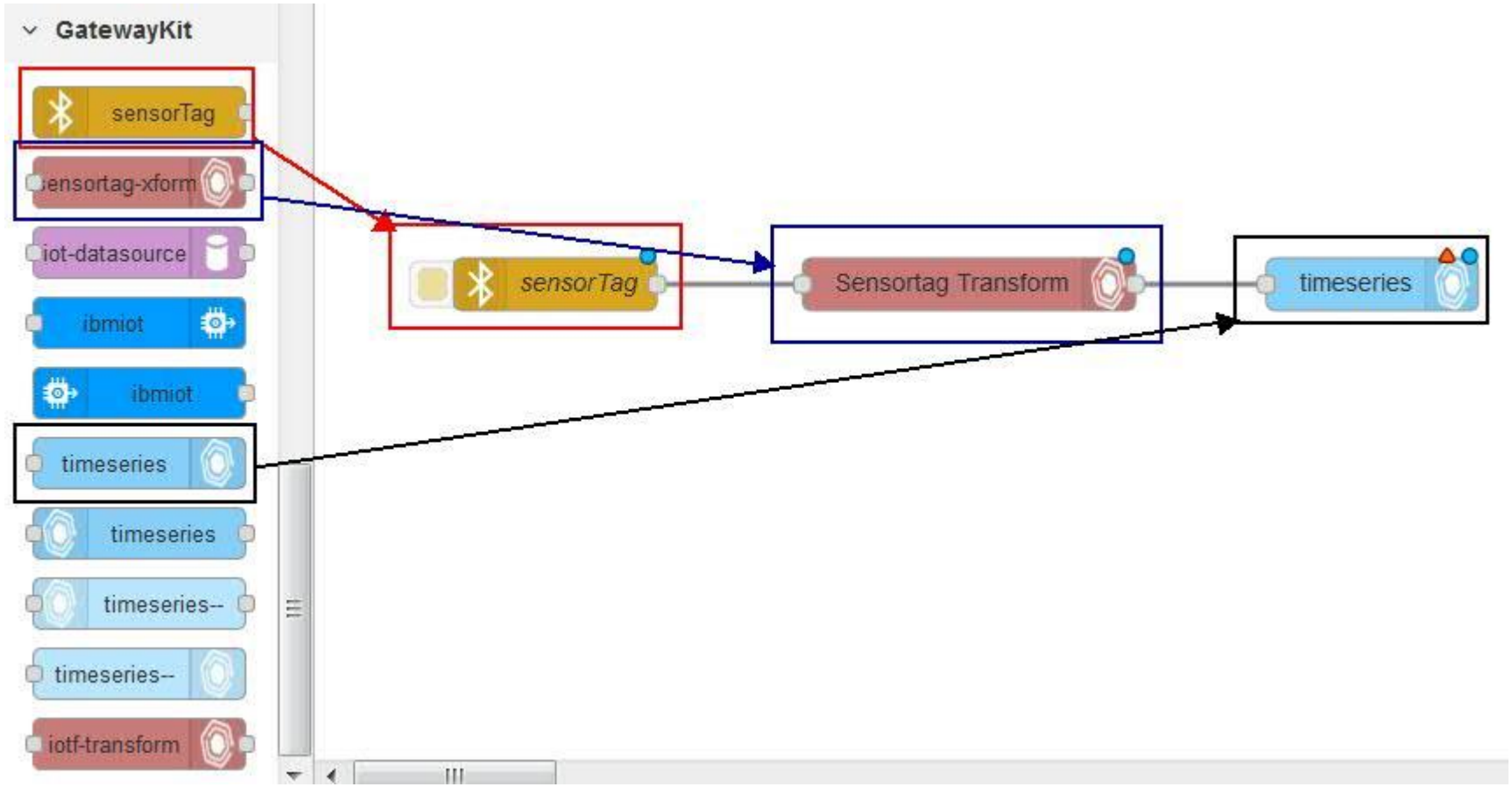
Node-RED for IoT

- https://www.ibm.com/developerworks/community/blogs/cee6c09c-a315-4b04-ad14-57d6a60fa8bb/entry/Creating_A_Node_red_Flow_for_IoT?lang=en



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Q&A

The END!

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