REFERENCE ARCHITECTURE

Monitoring a City's CO2 emissions by using Intel & AWS secure IoT solutions

Intel® IoT Gateway
Amazon IoT Service
Internet of Things

By 2020, more than 20 billion compute and internet enabled devices will be connected to the cloud and each other[1] in what is commonly called the Internet of Things (IoT). Communication protocols, Device SDKs and secure connectivity are all key requirements to use the power of cloud resources and realize the power of IoT. A key objective for IoT solutions is to enable greater insight from data provided by connected devices, have devices making better and smarter decisions for the users and create new business models all together.

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The Industry Challenge

Industrial devices and other systems are not always designed with interconnectivity and the ability to share data in mind. That leaves a lot of useful data locked away in a massive array of equipment, like HVAC units, vending machines, fleet management, and much more. The ability to process that data and gain useful information from it exists today with Big Data clusters and other types of computing. The data was not initially intended for analytics and remains inaccessible in many cases. Thus, there is a definite need to address interoperability of legacy systems in order to avoid the incredibly large cost of replacing all existing infrastructure with Internet enabled components.

Solutions from Intel and Amazon Web Services

Intel Gateway Solutions for IoT (Figure 1) offer companies a key building block to enable the connectivity of legacy industrial devices and next generation intelligent infrastructure to the IoT. It integrates technologies and protocols for networking, embedded control, enterprise-grade security, and easy manageability on which application specific software can run. Intel Gateway Solutions for IoT enables:

• Connectivity up to the cloud and enterprises.
• Connectivity down to sensors and existing

controllers embedded in the system.

- Pre-process filtering of selected data for delivery.
- Local decision making, enabling easy connectivity to legacy systems.
- A hardware root of trust, data encryption, attestation, and software lockdown for security.
- Local computing for in-device analytics.

Amazon Web Services (AWS)

AWS is a leading provider of cloud computing infrastructure and services. AWS IoT is a managed cloud platform that lets connected devices easily and securely interact with cloud applications and other devices.

AWS IoT (Figure 2) can support billions of devices, and trillions of messages, and can process and route those messages to AWS endpoints and to other devices reliably and securely. With Amazon IoT your applications can keep track of and communicate with all your devices, all the time, even when they aren't connected.

AWS IoT makes it easy to use services like AWS Lambda, Amazon Kinesis, Amazon S3, Amazon Machine Learning, and Amazon DynamoDB to build IoT applications that gather, process, analyze and act on data generated by connected devices, without having to manage any infrastructure.

Congestion Charge Use Case Demo Scenario

In order to demonstrate a complete end to end solution using industry building blocks from both Intel and AWS we have created a proof of concept to show how some Smart City applications can be architected and developed in the cloud.

Overcrowding, traffic congestion and air pollution are an increasing problem as populations grow and more vehicles pass through our streets. This poses a pressing challenge to city leaders and affects the quality of life for residents and commuters alike.

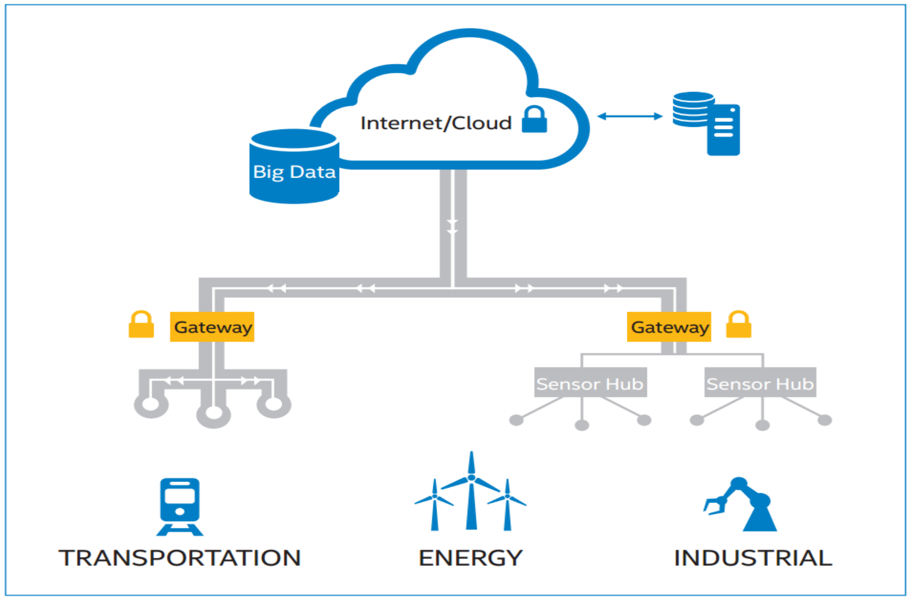

Figure 1
Intel IoT Gateways Addressing Endless Use Cases

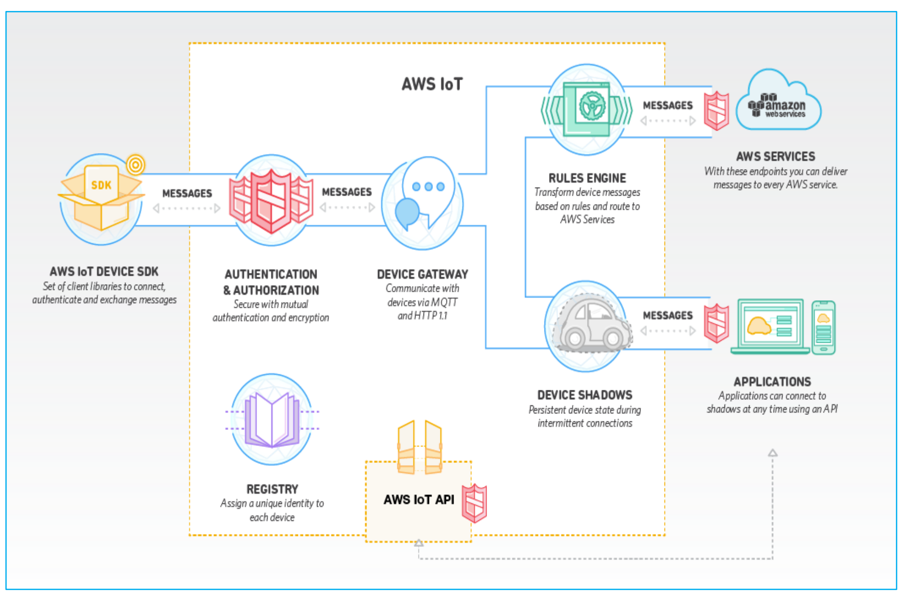

Figure 2
AWS IoT Service

The Internet of Things brings greater connectivity to our cities, and offers the opportunity for government, city bodies and local enterprises to collaborate on projects that can use smart technology and data analytics to help monitor and managecongestion.

Our solution (Figure 3) features an edge to cloud solution utilizing Intel and Amazon Web Services components including gateways, security, management, and analytics.

In a real implementation, CO2 sensors are located in and around the city, these are represented by circles on the City Manager application. Sensor data is read by the Intel Gateway and sent to the AWS IoT service in real time. This data is monitored by the City Manager web service (Figure 4) and triggers predefined actions based on air quality values.

Examples of actions that might be taken as a result of data collected and analysed could be setting a Congestion charge for entering areas of high pollution, offering discounts on a park and ride option, these could then be displayed on electronic road signs located at strategic locations (Figure 4).

Hardware Description

Intel IoT Gateway (DK-100) is an intelligent device connecting the sensor simulator to the Internet. It collects sensor data and sends the data to the cloud using MQTT.

Sensor Simulator A custom hardware unit consisting of 8 potentiometers, when moved voltages are set in this example we are using the values to simulate different levels of CO2 in the air.

Software running on the IoT Gateway

Node.js Agent an MQTT client service that sends sensor data from the gateway to the MQTT broker available in the AWS IoT service using MQTT-S.

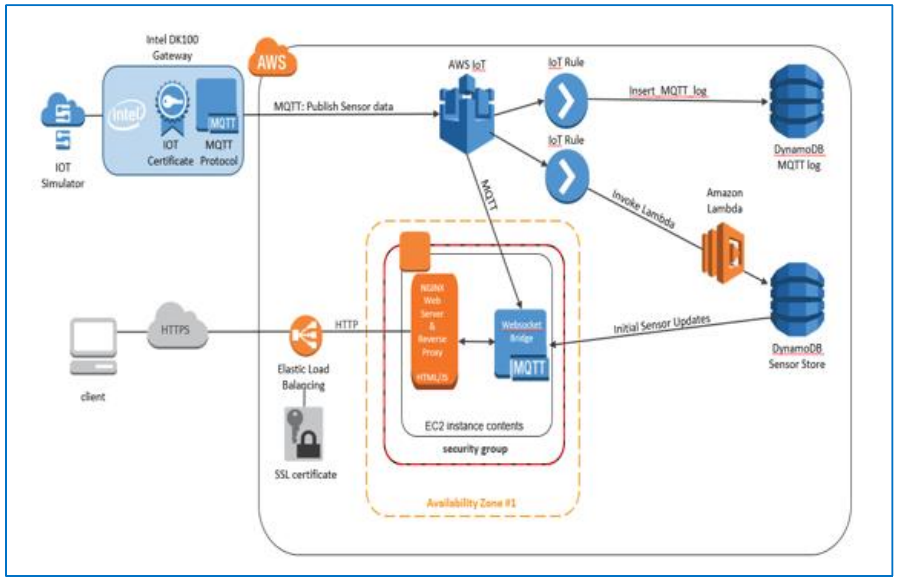

Figure 3
End to end Solution

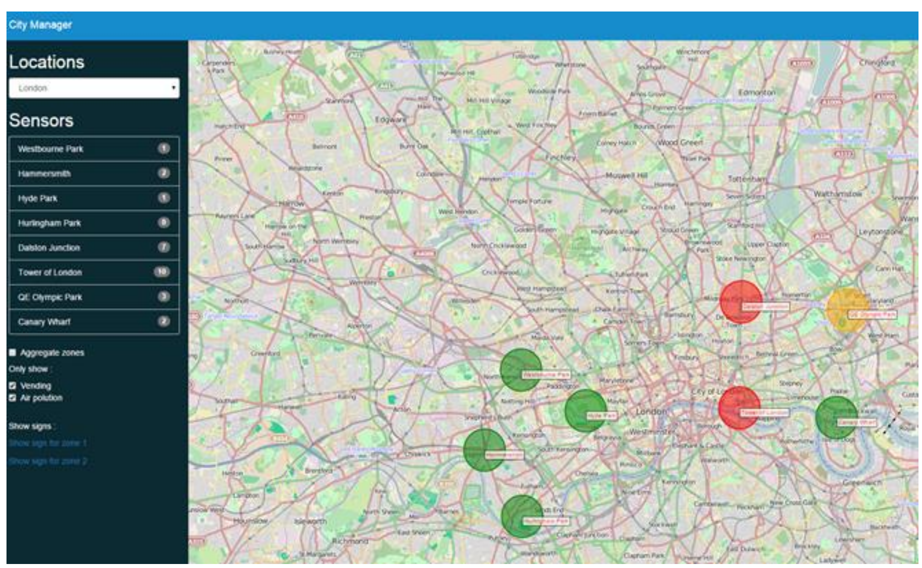

Figure 4 Client Displays

City Manager with Sensor locations & values and Smart Road Signs

Wind River® Intelligent Device Platform, is the Gateway's operating system with device security, smart connectivity, and rich network options.

McAfee® Embedded Control is used to monitor and protect data security by dynamically managing whitelists.

AWS IoT Service

Authentication & Authorization is performed using AWS IoT issued certificates. The process of creating and registering a certificate with AWS IoT is called provisioning. Restricted authorization is achieved using an AWS IoT policy (Appendix A) attached to the certificate which then allows the Intel Gateway to only publish to specified topics.

Device Gateway Provides a secure mechanism for "things" and IoT applications to publish and receive messages between each other and supports both MQTT and HTTP protocols. We use the secure MQTT protocol MQTT-S to communicate with the Intel Gateway Node.js agent to obtain sensor data.

Rules Engine Provides message processing and integration with other AWS services and is used to send sensor data to Amazon DynamoDB tables. (Appendix B). The table "MQTT log" stores all historical sensor data including a timestamp. This data could be used for analytics, the other table "Sensor Store" is updated with the last known sensor value using an AWS Lambda function (Appendix B) and used to initialize sensor values.

Software running on AWS EC2

City Manager is a web service running in an Amazon EC2 instance that communicates with the AWS IoT Device Gateway's MQTT broker.

On the client side a secure bidirectional data stream is established via websocket between the web service and the client's browser. Using an AWS Elastic Load Balancer when the client first logs in client side scripting uses Google Maps API's to identify and display the sensor locations using data from the Amazon DynamoDB table "Sensor Store". This data is used to set the initial sensor values via a websocket connector.

Real time sensor data is then published by the broker to the web service via the websocket connector.

Summary

This proof of concept demonstrates how an intelligent system gathers, analyses and acts on data from CO2 or other sensors placed around city streets. Connected via an Intel® Gateway to Amazon Web Services, this can be used to change driving behaviours thereby offering the potential to improve traffic flows, reduce pollution and congestion that would improve the environment for citizens.

Often, the power of IoT is in the simplicity of the solution and engaging the community to support, contribute and scale the syatem. A City Hall can look into various scenarios, e.g. sensors are installed on public transportation vehicles (allowing a limited number of devices to cover a wider city area), or subsidized devices distributed to people interested to participate in such a program (devices are connected and managed at people's houses) and agree to share the collected data.

The key aspect here is the power of open sourcing the data to the wider development community to create innovative solutions and products for the public services (traffic routing, speed management) or consumers (life style apps).

Technologies Used

- Intel® IoT Gateway , Security, local analytics and cloud connectivity
- AWS IoT service
- Amazon DynamoDB
- AWS Lambda
- Amazon EC2

Potential Use Cases

- Automatic congestion charge control and park and Ride discount
- Traffic routing
- Traffic speed control
- Building data monitoring
- Lifestyle apps e.g. Health, Retail

For more information visit
www.intel.com/iot
www.aws.amazon.com/iot

Appendix A

AWS IoT Certificate Policy


```
{
 "Version": "2012-10-17",
 "Statement": [
  {
   "Effect": "Allow",
   "Action": [
    "iot:Publish"
        ],
        "Resource": [
         "arn:aws:iot:us-east-1:awsaccountn#:topic//device/amazon_loft/sensors/input_0",
         "arn:aws:iot:us-east-1:awsaccountn#:topic//device/amazon_loft/sensors/input_1",
         "arn:aws:iot:us-east-1:awsaccountn#:topic//device/amazon_loft/sensors/input_2",
         "arn:aws:iot:us-east-1:awsaccountn#:topic//device/amazon_loft/sensors/input_3",
         "arn:aws:iot:us-east-1:awsaccountn#:topic//device/amazon_loft/sensors/input_4",
         "arn:aws:iot:us-east-1:awsaccountn#:topic//device/amazon_loft/sensors/input_5",
         "arn:aws:iot:us-east-1:awsaccountn#:topic//device/amazon_loft/sensors/input_6",
         "arn:aws:iot:us-east-1:awsaccountn#:topic//device/amazon_loft/sensors/input_7",
         "arn:aws:iot:us-east-1:awsaccountn#:topic/$aws/things/amazon_loft/shadow/update"
        ]
   },
   {
        "Effect": "Allow",
        "Action": [
         "iot:Connect"
        ],
        "Resource": [
         "*"
        ]
    }
 ]
```

Appendix B

AWS IoT Rules

Invoke Lambda Function IoT Rule

```
{
    "sql": "SELECT *,topic() AS topic FROM '/device/+/sensors/#'",
    "ruleDisabled": false,
    "actions": [
      {
        "lambda": {}
      }
    ],
}
```

Lambda Function Code

```
console.log('Loading function');
var AWS = require('aws-sdk');
var dynamodbDoc = new AWS.DynamoDB.DocumentClient();
exports.handler = function(event, context) {
  console.log('Received event:', JSON.stringify(event, null, 2));
  if (event.topic) {
    var splittopic = event.topic.split('/');
    if (splittopic.length !== 5) {
      context.fail("Error: unexpected topic length");
    }
    var devicename = splittopic[2];
    var sensorname = splittopic[4];
    var value = {
      value: event.value,
      lat: event.lat,
      lng: event.lng
    }
    var params = {
      TableName: 'SensorStore',
      Item:{
        "devicename": devicename,
        "sensorname": sensorname,
        "fulltopic": event.topic,
        "sensorvalue": JSON.stringify(value),
        "lastupdated": Date.now()
      }
    }
    dynamodbDoc.put(params, function (err, data) {
      if (err) {
        context.fail(JSON.stringify(err), null, 2);
      } else {
        context.succeed('Item inserted! ');
      }
    });
  } else {
    context.fail('unexpected event')
  }
    //context.succeed('Success!');  // Echo back the first key value
```

```
    // context.fail('Something went wrong');
};
```

<u>DynamoDB Table Insert Sensor values Rule</u>


```
{
  "sql": "SELECT * FROM '/device/+/sensors/#'",
  "ruleDisabled": false,
  "actions": [
    {
      "dynamoDB": {
        "hashKeyField": "topic",
        "roleArn": "arn:aws:iam::awsaccountn#:role/my-iot-role",
        "tableName": "mqtt_log",
        "hashKeyValue": "${topic()}",
        "rangeKeyValue": "${timestamp()}",
        "rangeKeyField": "timestamp"
      }
    }
  ],
}
```

1 http://www.morganstanley.com/articles/internet-of-things-opportunities-for-investors