

MATLAB EXPO 2017

Developing Analytics and Deploying IoT Systems

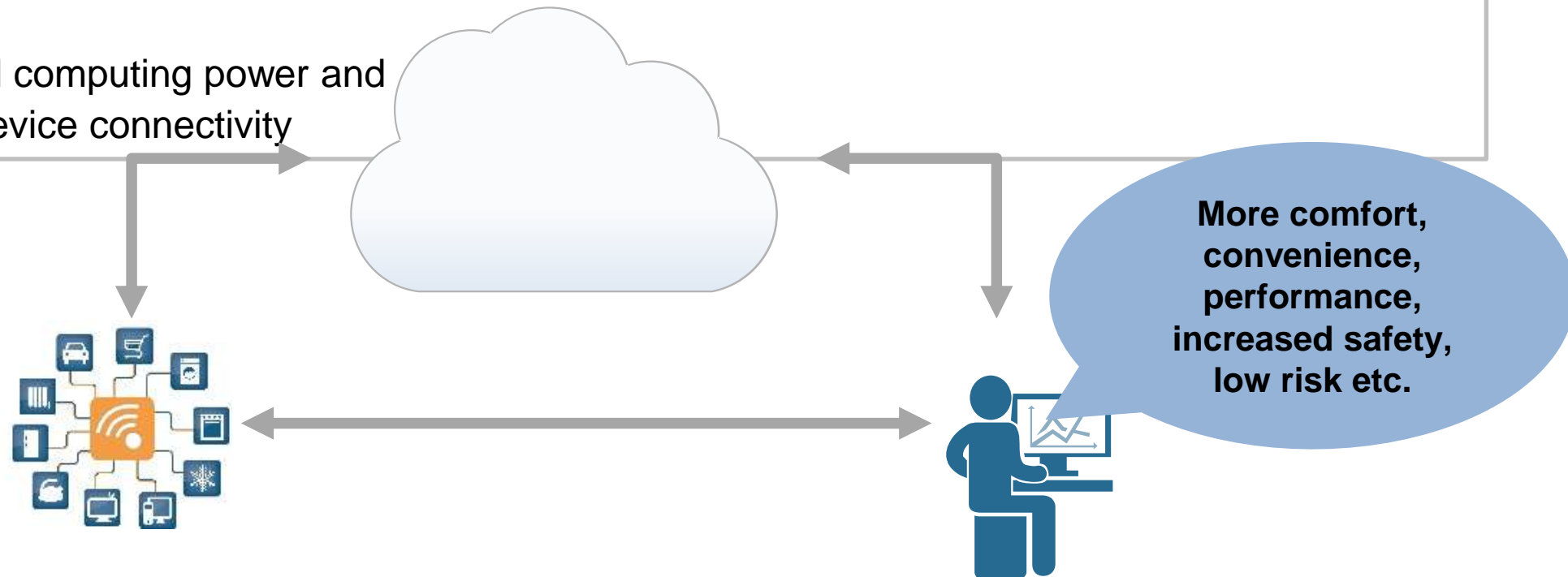
Amit Doshi

Senior Application Engineer, MathWorks India

amit.doshi@mathworks.in

What is Internet of things (IoT)?

- Internet of Things (IoT) is internetworking of a large number of **embedded devices** (“**things**”) which are **connected to the Internet**. These connected devices **communicate with people and other things** and often provide **sensor data to cloud storage and cloud computing resources** where the **data is processed and analyzed to gain important insights**.
- **Why now** –
 - Cheap cloud computing power and
 - Increased device connectivity



'Chips in everything' & the rise of 'Ubiquitous sensing'

Extracting insights from sensor data... a common practice

Deloitte.

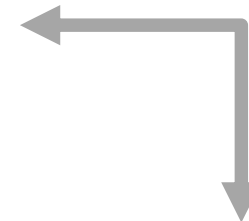
Estimates of the size of the IoT market vary. For instance, **Gartner expects it to include nearly 26 billion devices**, with a "global economic value-add" of **\$1.9 trillion by 2020**.³

Human Applications:

- Medical
- Leisure
- Sports/Fitness
- Military
- Social
- Retail
- Security

HealthLeaders
Tip of the week: Incorporate ADL tracking tools in your everyday care planning

Science & Technology
Analytics: sensor customer behavior analysis



mobihealthnews
NIH's \$10.8M grant for sensor-enabled congestive heart failure, smoking cessation tools

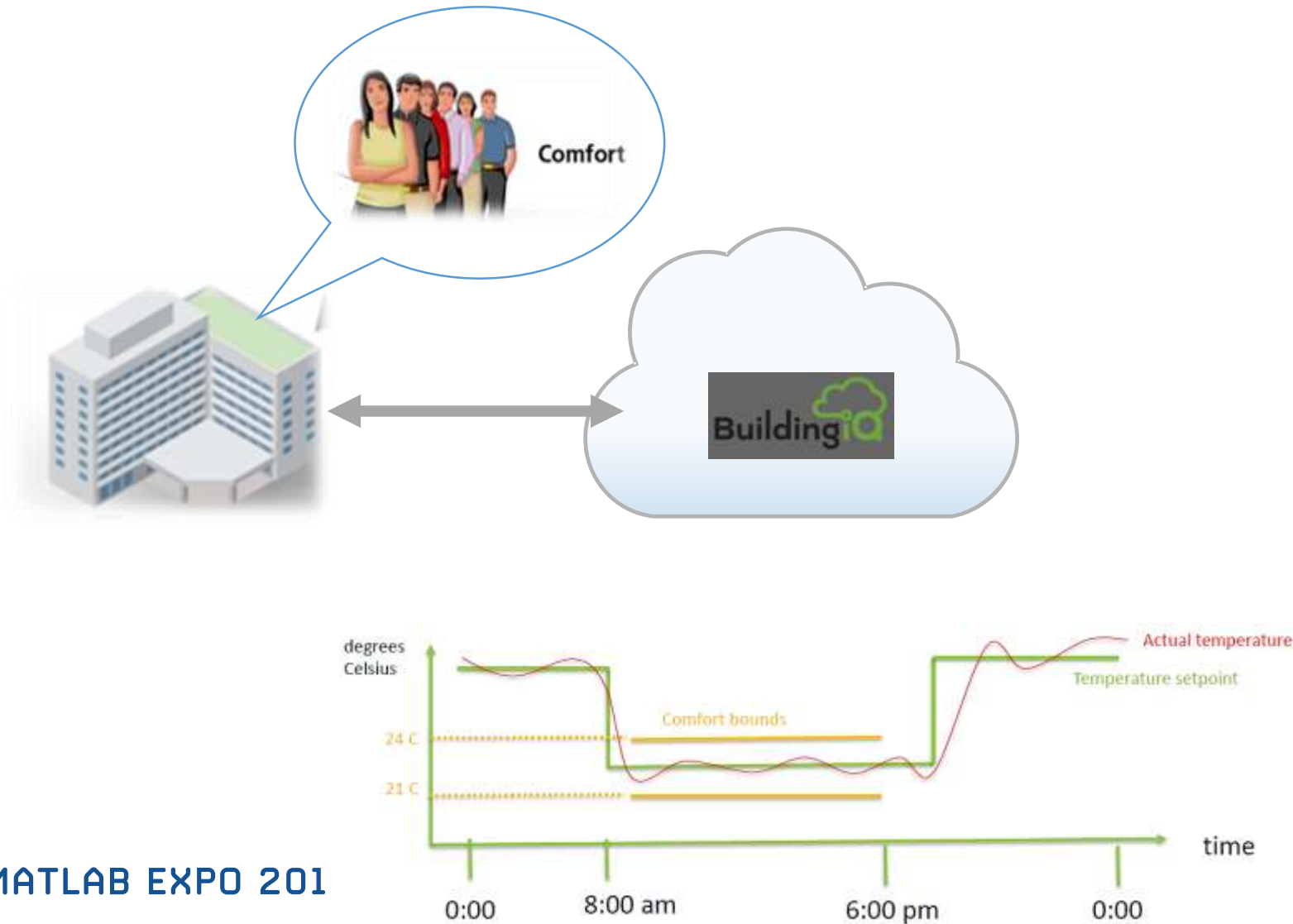
DEFENSESYSTEMS

Army aims to speed up data fusion on the battlefield

By Kevin McCaney | Mar 02, 2015

Example – BuildingIQ

Cloud based adaptive building energy management



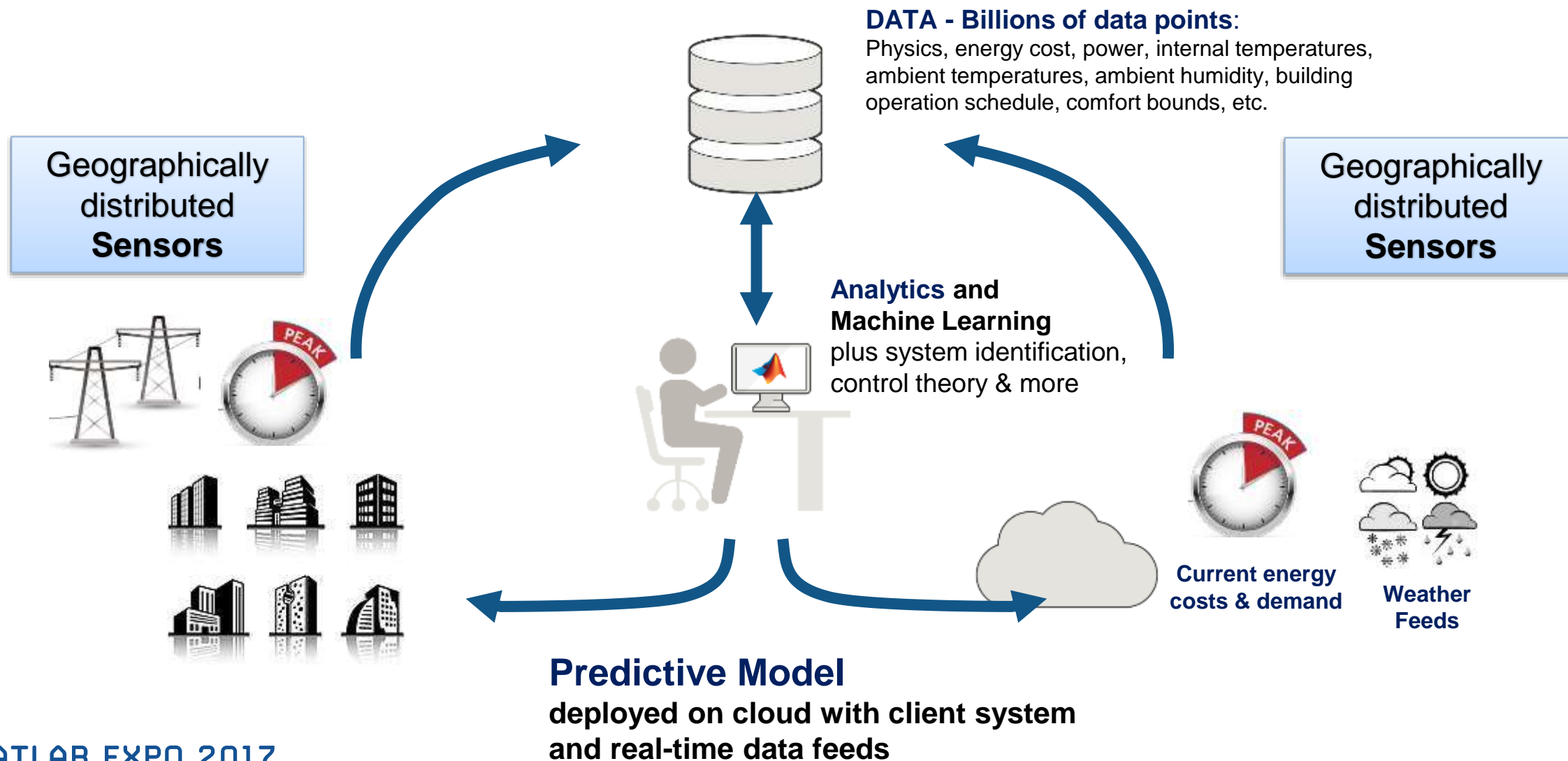
Challenge

Minimize energy costs of large-scale commercial buildings without compromising tenants comfort.

Solution

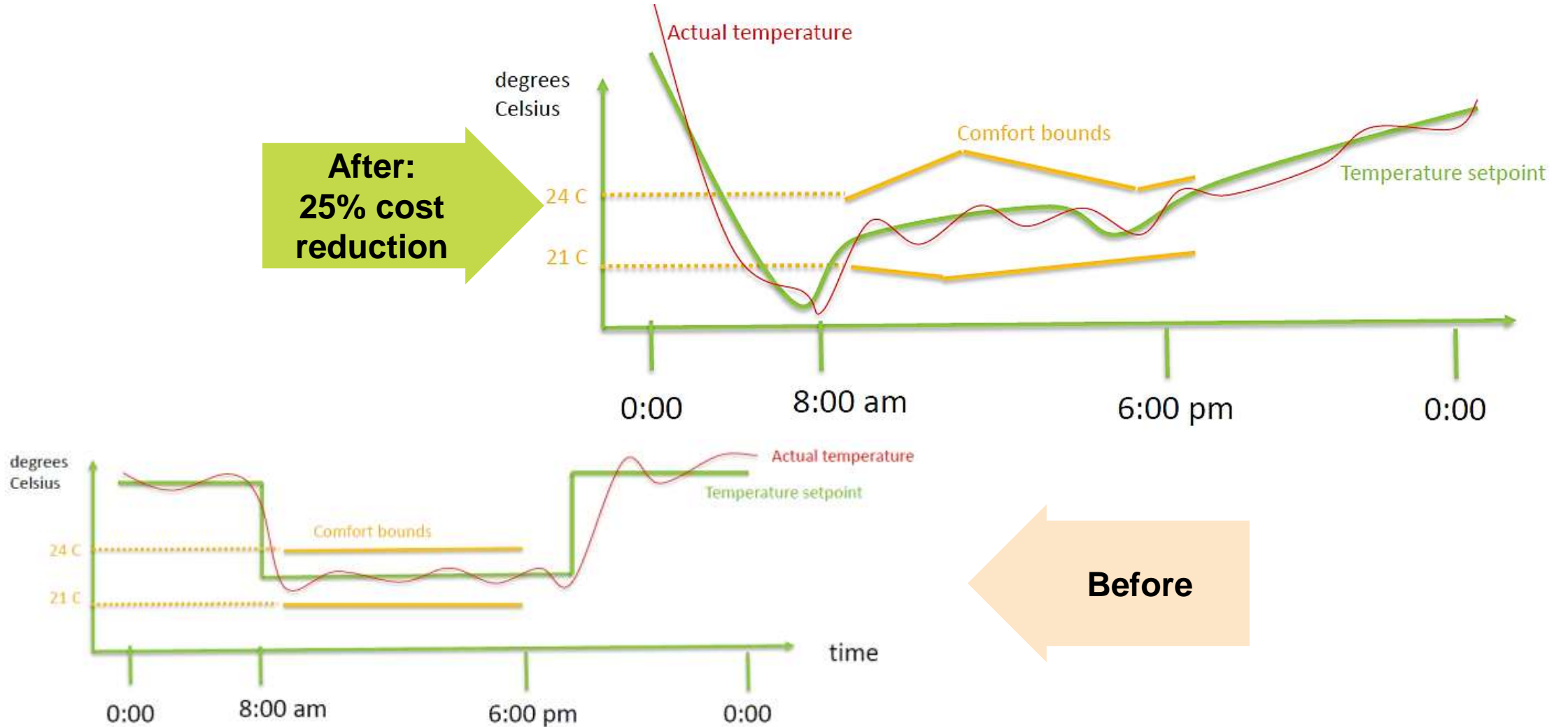
Develop cloud based real-time adaptive system via proactive, predictive optimization algorithm.

Real-time, closed-loop optimization algorithms

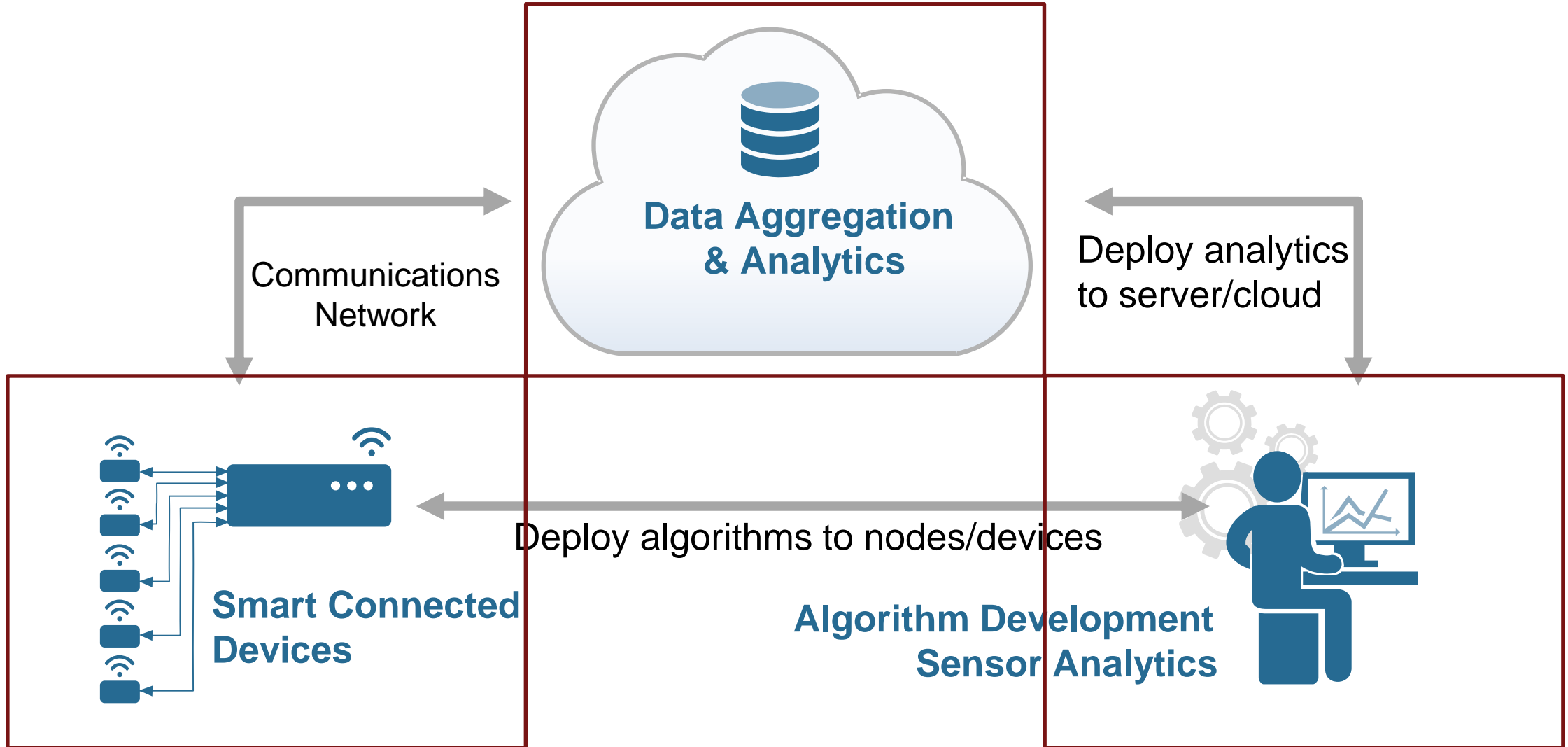


Example – BuildingIQ

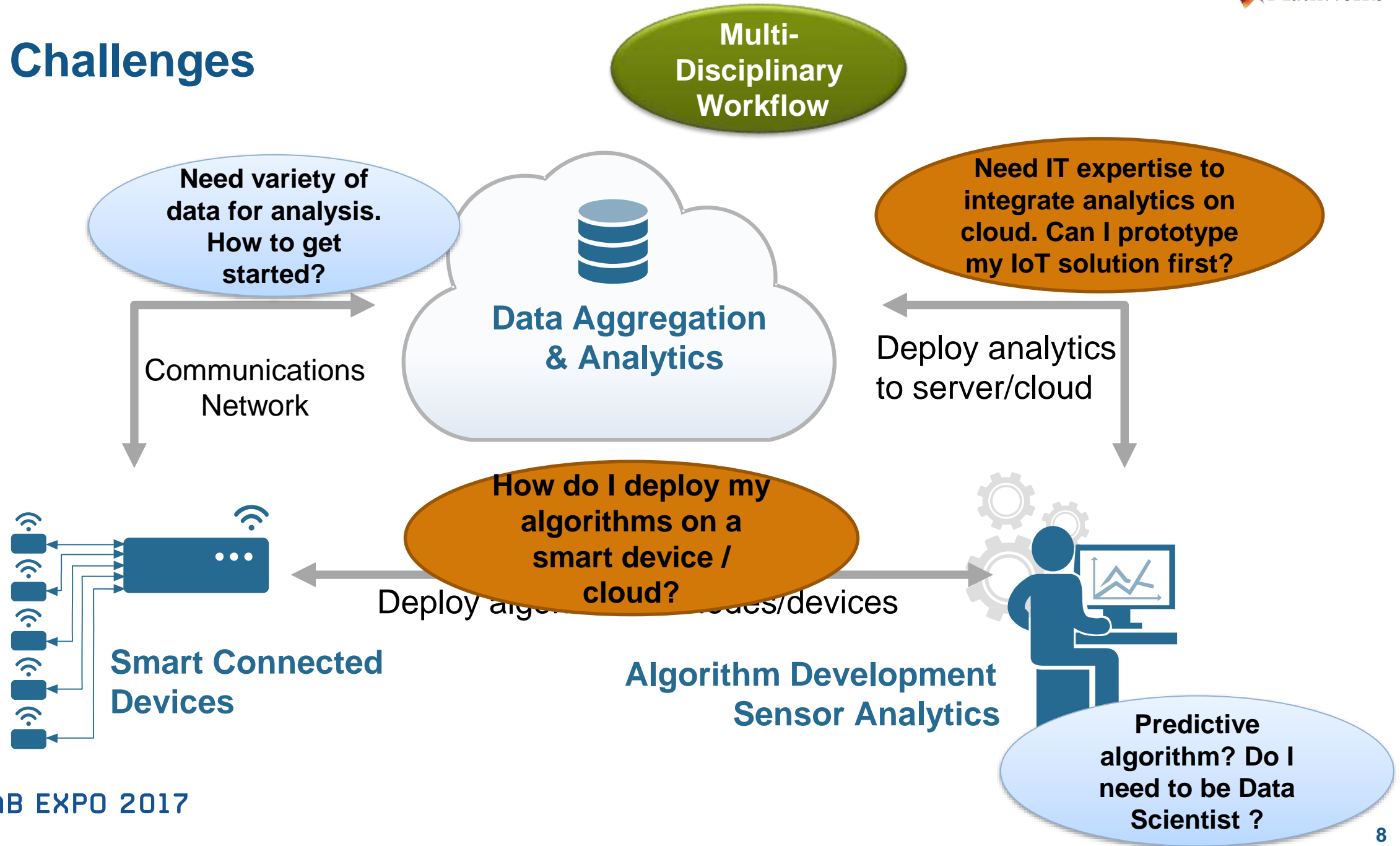
Cloud based adaptive building energy management



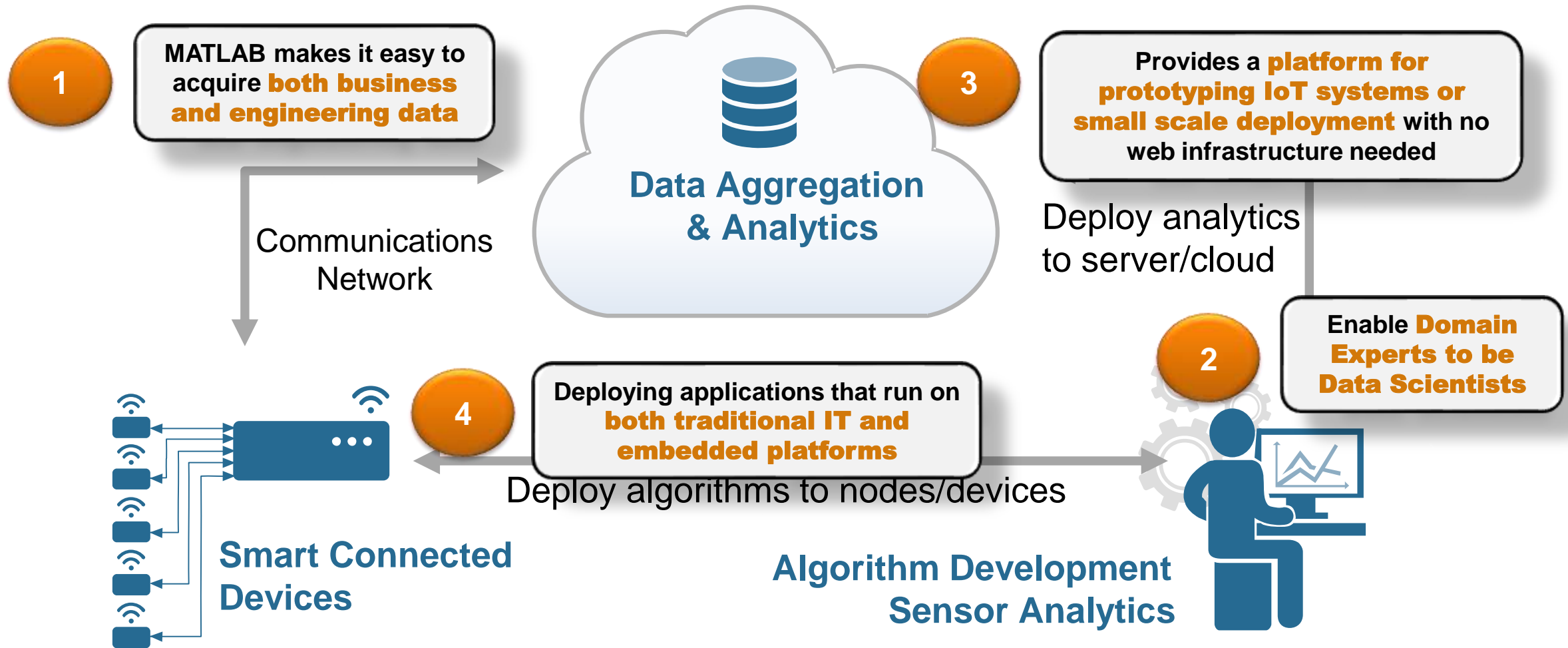
High Level Architectural View of Internet of Things



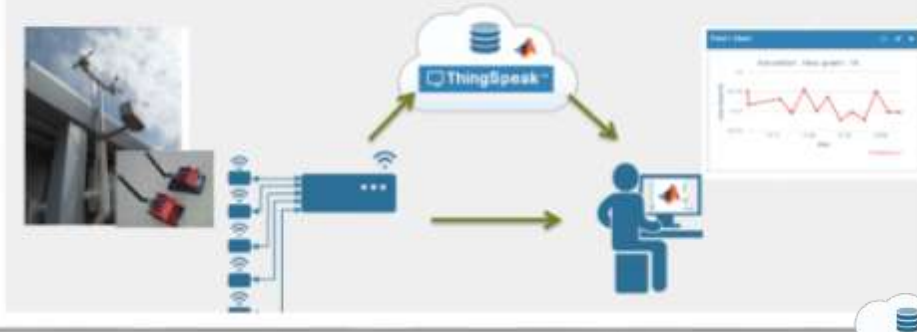
IoT Challenges



How MathWorks Addresses IoT Challenges?



Example 1: Weather monitoring using ThingSpeak and MATLAB



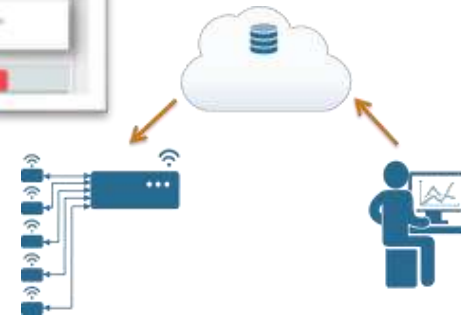
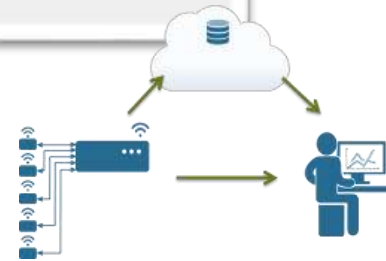
Example 2: Low Tide Prediction Using MATLAB And ThingSpeak

Challenge
Boats get stuck in mud at low tide

Solution
Advance notification of low tide

Even cooler... get notifications on mobile

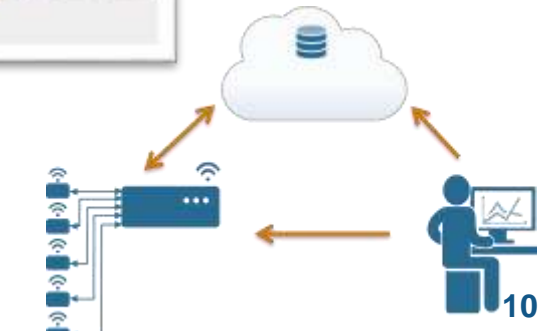
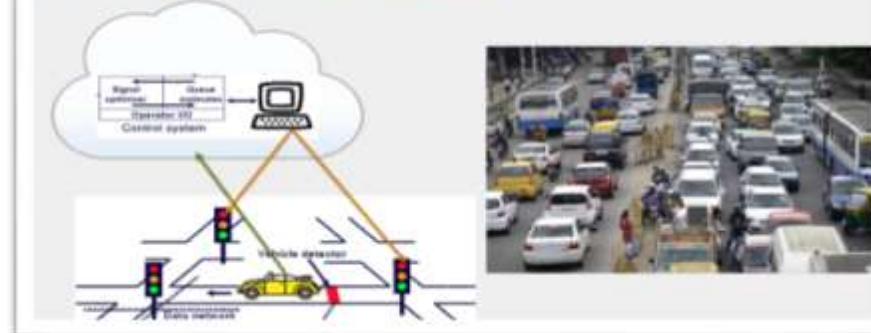
The screenshot shows a mobile notification for 'Low Tide' with a 'Send Message' button. Below it is a graph showing tide levels over time.



Example 3: Human Activity Analysis and Classification

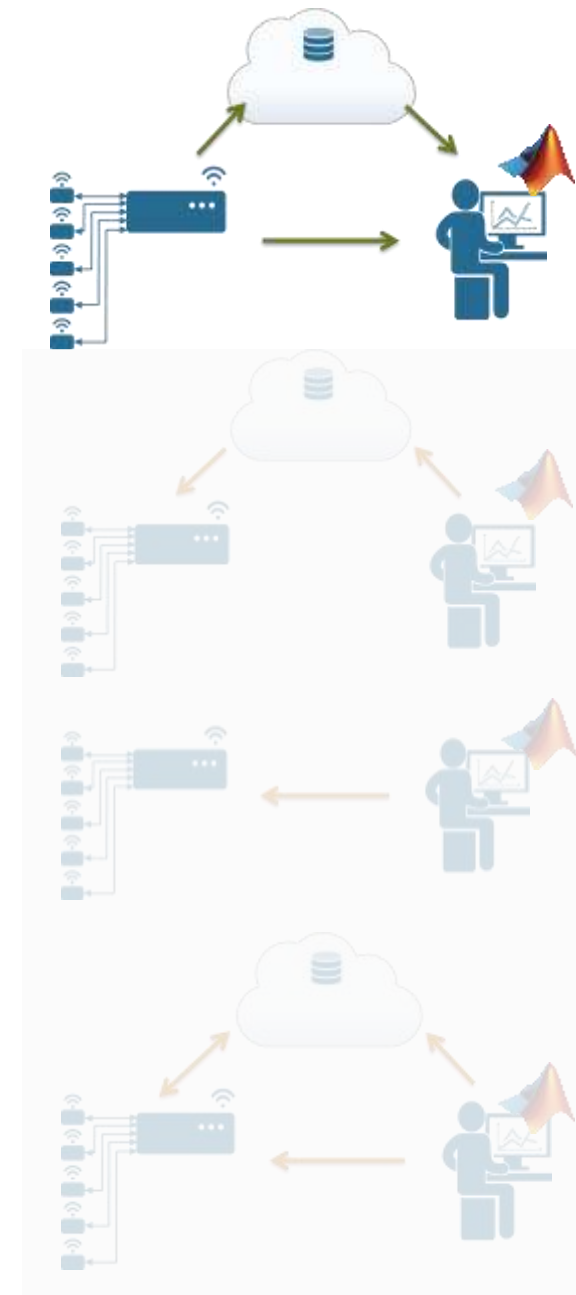


Example 4: Traffic monitoring can be used for smart traffic light management



Examples for Today

- Data acquisition from edge nodes and analysis using MATLAB
 - Measure, explore, discover weather patterns
- Develop analytics using MATLAB and deploy as a web service
 - Forecast wind driven tide levels
- Develop analytics using MATLAB and deploy on a smart device
 - Human Activity Analysis and Classification
- Develop analytics using MATLAB and optimal partition it on an edge device and cloud
 - Smart traffic monitoring using Raspberry Pi webcam



Get Started with IoT by Accessing Sensor Data in MATLAB



- Analog Input



```
[data, time]
= StartForeground(s);
```

- Serial Port



```
s1 = serial('COM1');
l = i2c('aardvark', 0,...
Hex2dec('50')
A = fread (obj);
```

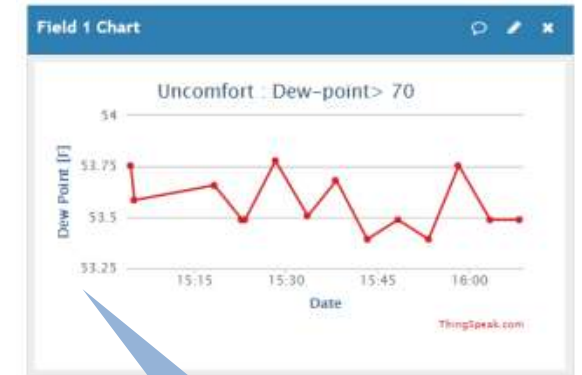
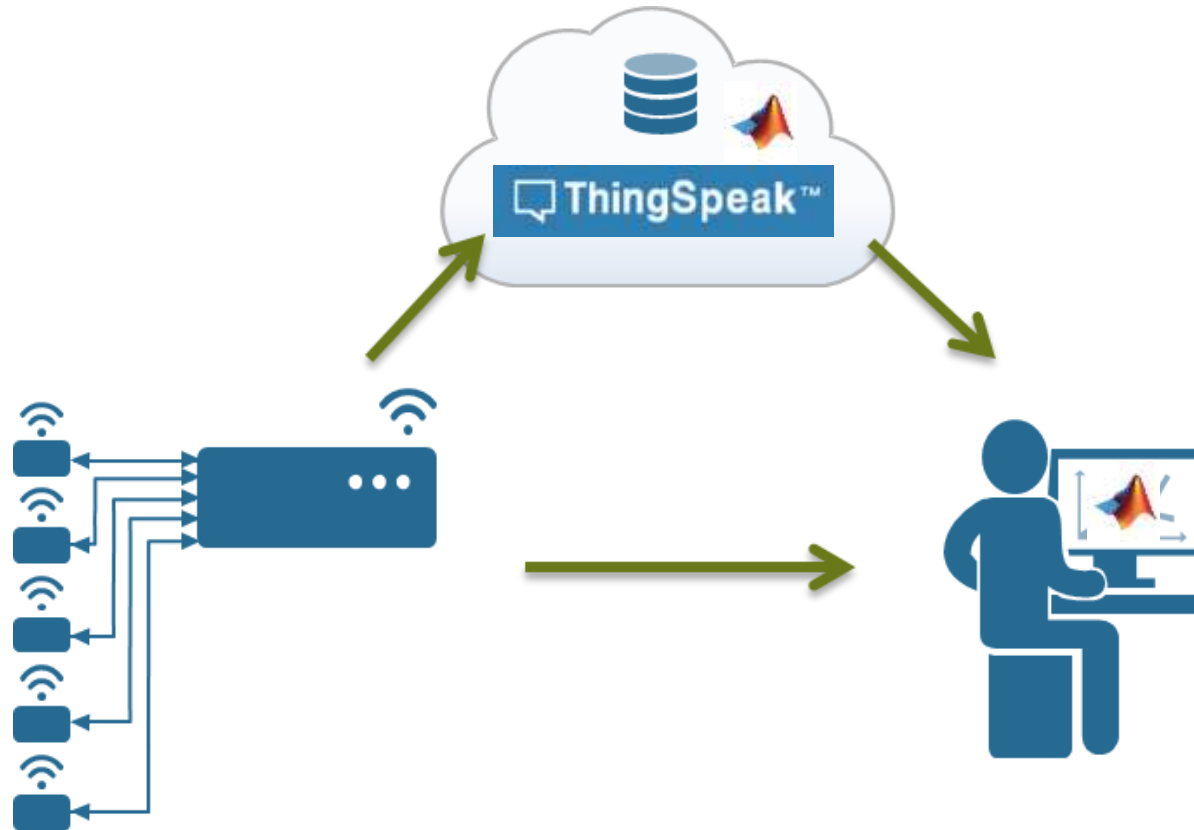
- TCP/IP
- UDP



```
t = tcpip ('localhost', 30000,
'NetworkRole', 'server');
fread (t, 10)
```

Prototyping is an important step in developing IoT system.
You need only a sensor and MATLAB to get started

Example 1: Weather monitoring using ThingSpeak and MATLAB



**“It’s hot out!!
Don’t forget to
carry a bottle of
water”**

What Is ThingSpeak?

Web Site For People



Web Service for Devices

```
{
  - channel: {
    id: 38629,
    name: "Car Counter",
    description: "Counting number of cars passing a reference line in 15 sec interval",
    latitude: "42.28",
    longitude: "-71.35",
    field1: "Number of Westbound Cars",
    field2: "Number of Eastbound Cars",
    created_at: "2015-05-19T20:14:03Z",
    updated_at: "2016-05-19T10:36:35Z",
    last_entry_id: 1477231
  },
  - feeds: [
    - {
      created_at: "2016-05-19T10:36:20Z",
      entry_id: 1477230,
      field1: "18.000000",
      field2: "8.000000"
    },
    - {
      created_at: "2016-05-19T10:36:35Z",
      entry_id: 1477231,
      field1: "18.000000",
      field2: "14.000000"
    }
  ]
}
```

ThingSpeak

- New MathWorks web service hosted on AWS
- Lets you collect, analyze and act on data from “things” such as Arduino[®], Raspberry Pi[™], BeagleBone Black, and other hardware
- Over **130,000** users worldwide
- It has **MATLAB** for IoT Analytics



Example 1: Weather monitoring using ThingSpeak and MATLAB

The screenshot displays the MATLAB R2017a environment. The Editor window shows a script named 'weatherDataDownloadAndAnalysis.m' with the following code:

```

%% Calculate Dew Point
% Now we are ready to answer our second question about how temperature and
% dew point have varied over the past week. The dew point is the
% temperature at which the air (when cooled) would become saturated with
% water vapor. The more humid the air mass, the higher the dew point. Dew
% point is also sometimes a measure of discomfort. When the dew point is
% over 65 degrees, many people start to say the air feels "sticky." Dew
% points over 70 feel uncomfortable to many. A common estimation for dew
% point, tdp, can be found using the equations and constants (see
% <http://en.wikipedia.org/wiki/Dew_point Reference>) shown below:
% 
$$t_{dp} = \frac{c \cdot \gamma}{(b - \gamma)}$$

%
% 
$$\gamma = \ln(\text{humidity}/100) + \frac{b \cdot \text{tempC}}{(c + \text{tempC})}$$

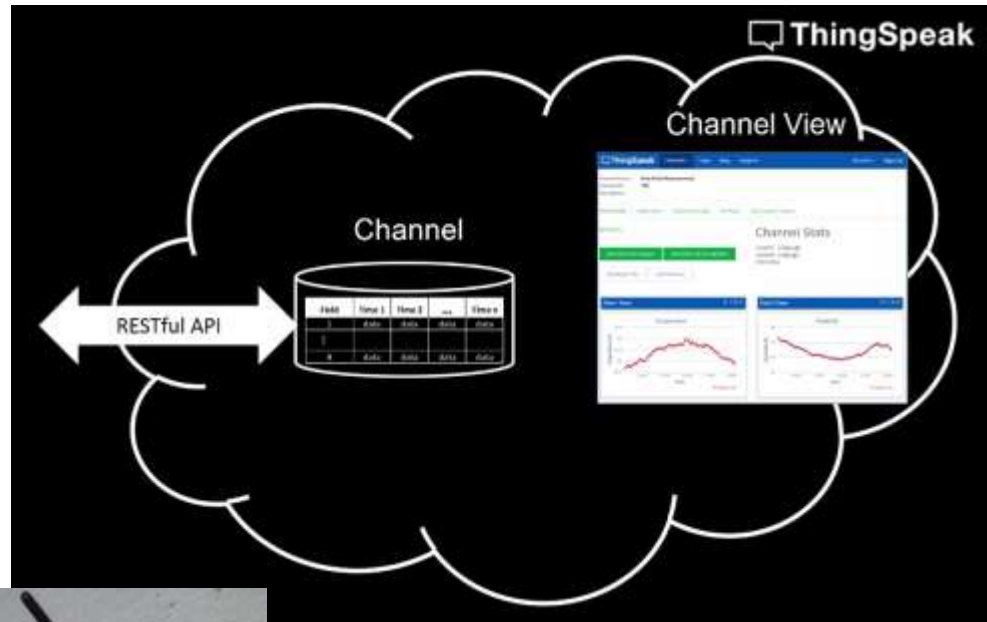

```

The Command Window displays the following data table:

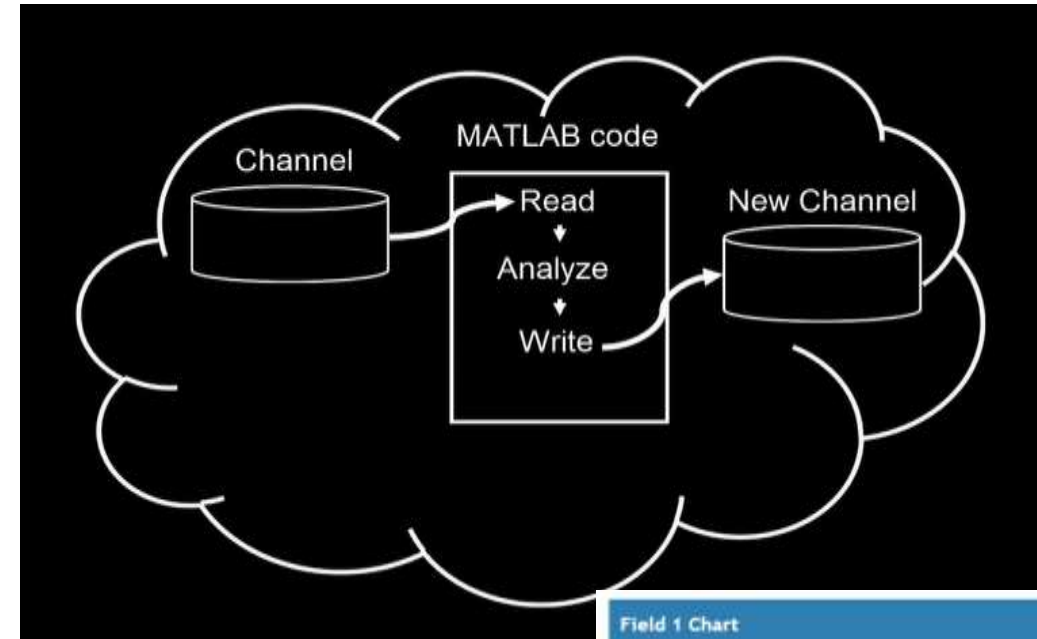
'Wind Direction (North = 0 degrees)'	360	'14-Apr-2017 14:30:53'	192.5	0	'12-Apr-2017 03:37:49'
'Wind Speed (mph)'	21.6	'15-Apr-2017 15:31:24'	5.0151	0	'12-Apr-2017 01:03:45'
'% Humidity'	79	'16-Apr-2017 00:00:32'	43.434	9	'14-Apr-2017 16:42:55'
'Temperature (F)'	91.3	'11-Apr-2017 14:33:24'	63.844	46.2	'15-Apr-2017 05:55:51'
'Rain (Inches/minute)'	0	'10-Apr-2017 12:28:24'	0	0	'10-Apr-2017 12:28:24'
'Pressure ("Hg)'	30.1	'13-Apr-2017 18:30:57'	29.945	29.7	'16-Apr-2017 00:03:34'
'Power Level (V)'	4	'10-Apr-2017 12:28:24'	4	4	'10-Apr-2017 12:28:24'
'Light Intensity'	66	'11-Apr-2017 15:02:07'	43.906	24	'16-Apr-2017 04:03:56'

Example 1: Weather monitoring using ThingSpeak and MATLAB

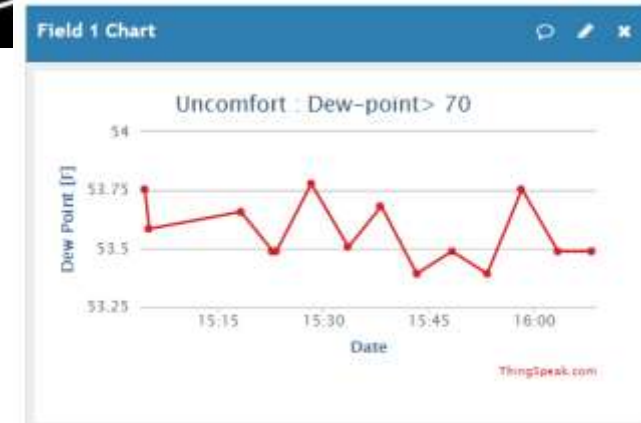
Data Aggregation



Data Analysis

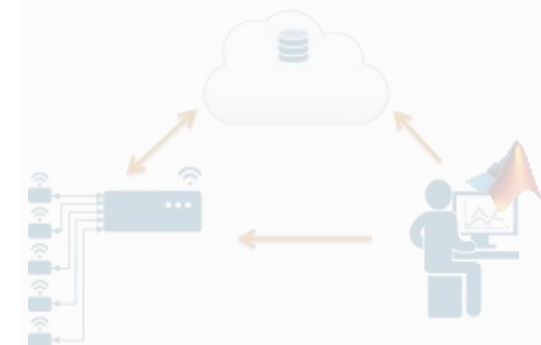
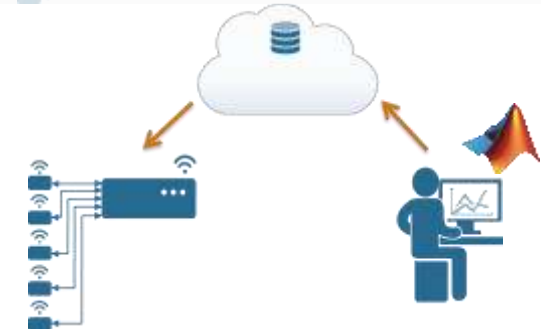
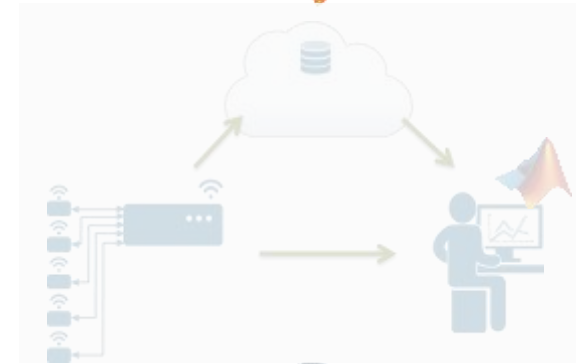


Editing algorithm on cloud is very easy as it's running MATLAB



Examples for Today

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Example 2: Low Tide Prediction Using MATLAB And ThingSpeak

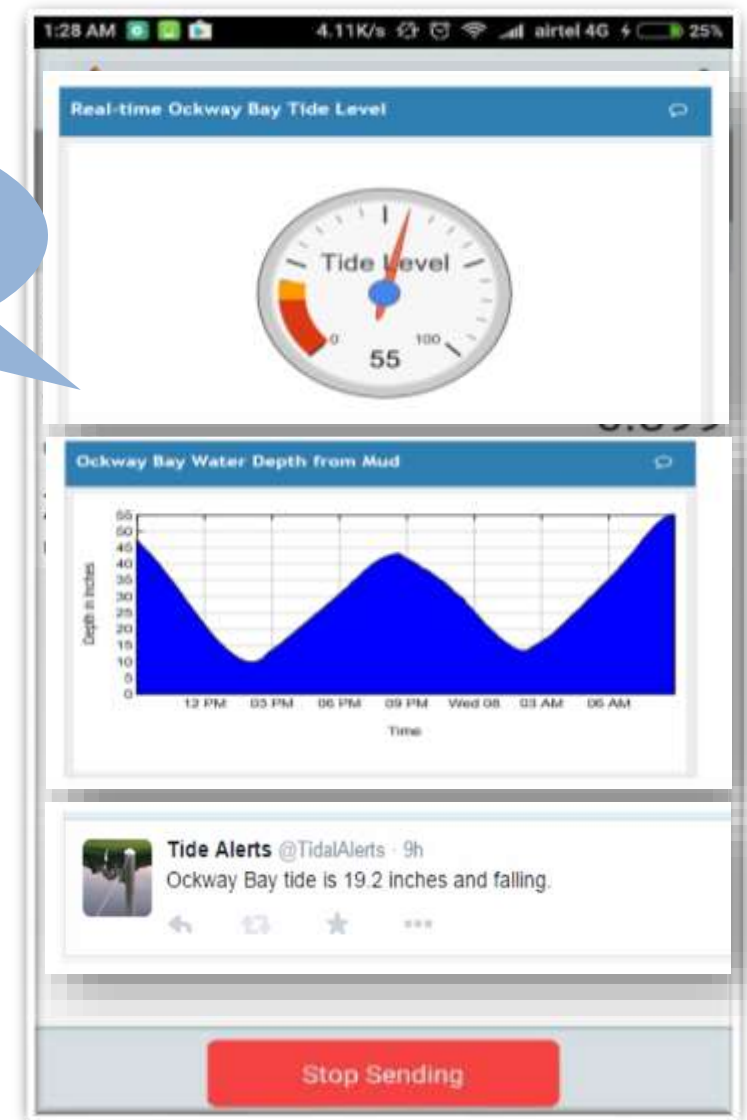
Challenge

Boats get stuck in mud at low tide

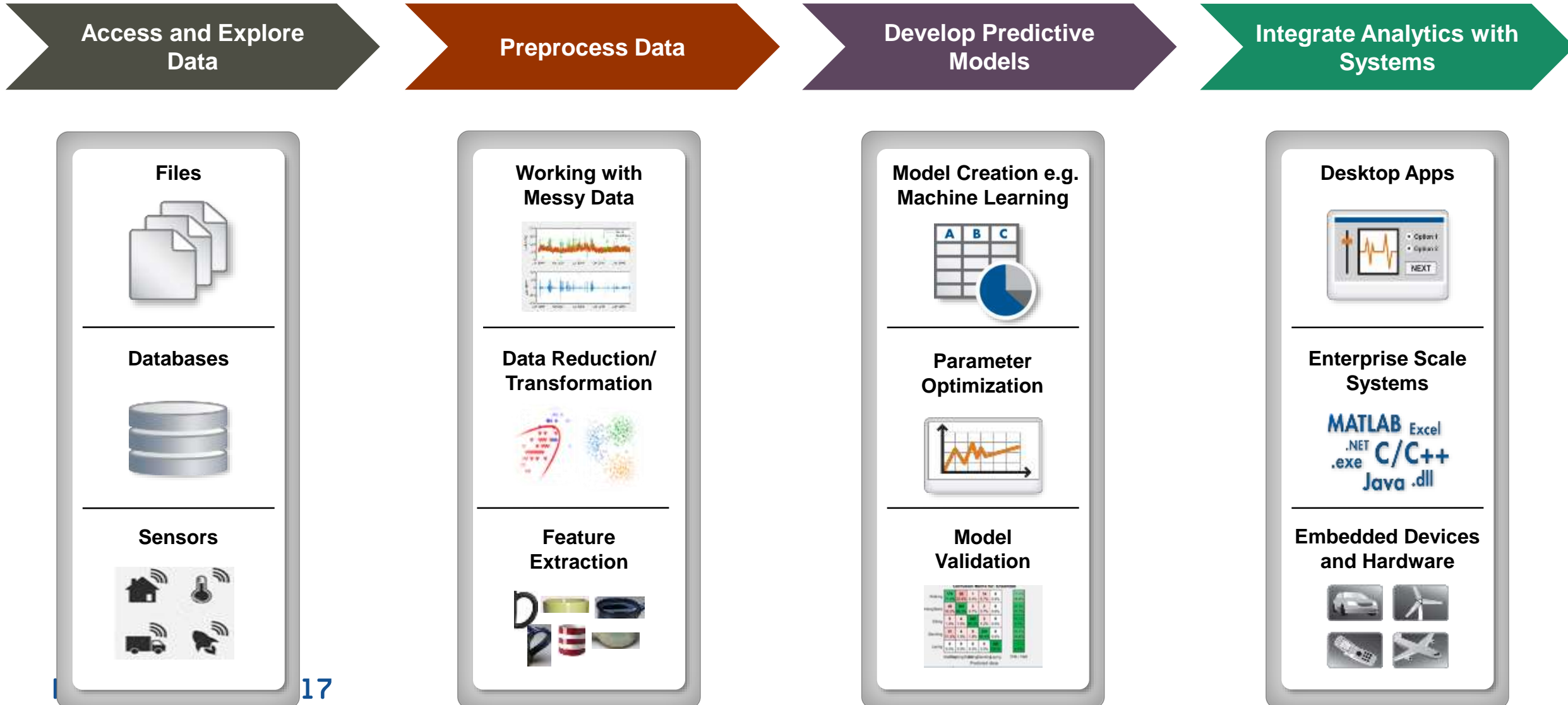
Solution

Advance notification of low tide

Even cooler...to get notifications on mobile



Example 2: Low Tide Prediction - Approach



Example 2: Low Tide Prediction Using MATLAB And ThingSpeak

ThingSpeak™ Channels ▾ Apps Community Support ▾ How to Buy Account ▾

Predicted and Measured Ockway Bay Tide Chart

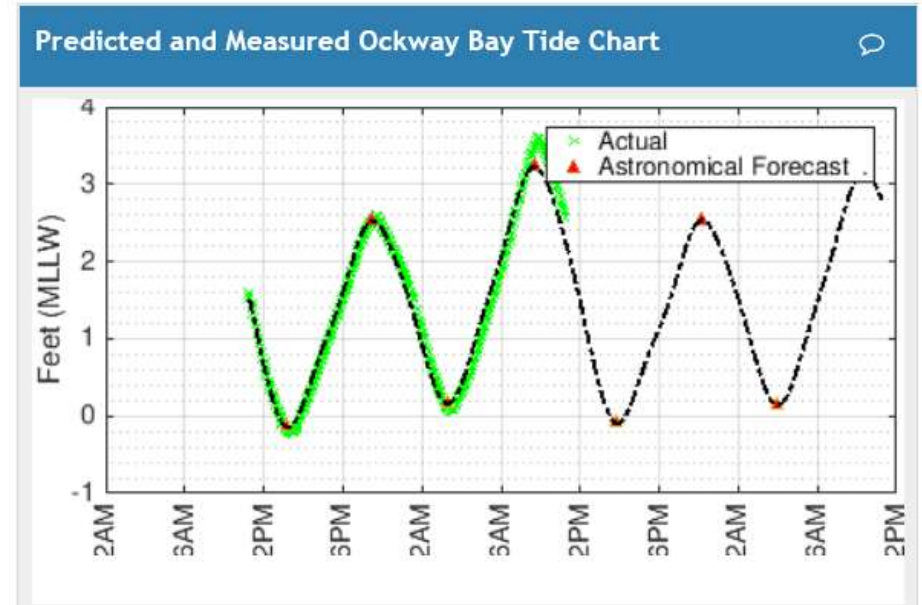
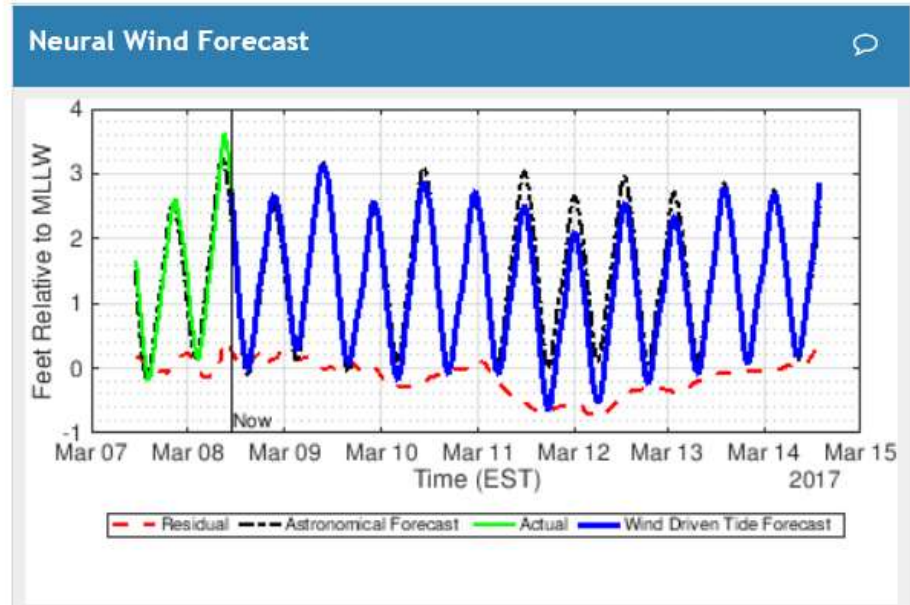
Un-watch Tweet Like 0 Share

Channel ID: 137305
 Author: mawrey
 Access: Public

Tide measurement and forecasting with the effect of wind predicted using neural networks.
 #tide, wind surge, neural network

Data Export More Information MATLAB Analysis MATLAB Visualiz

Historical and Tide



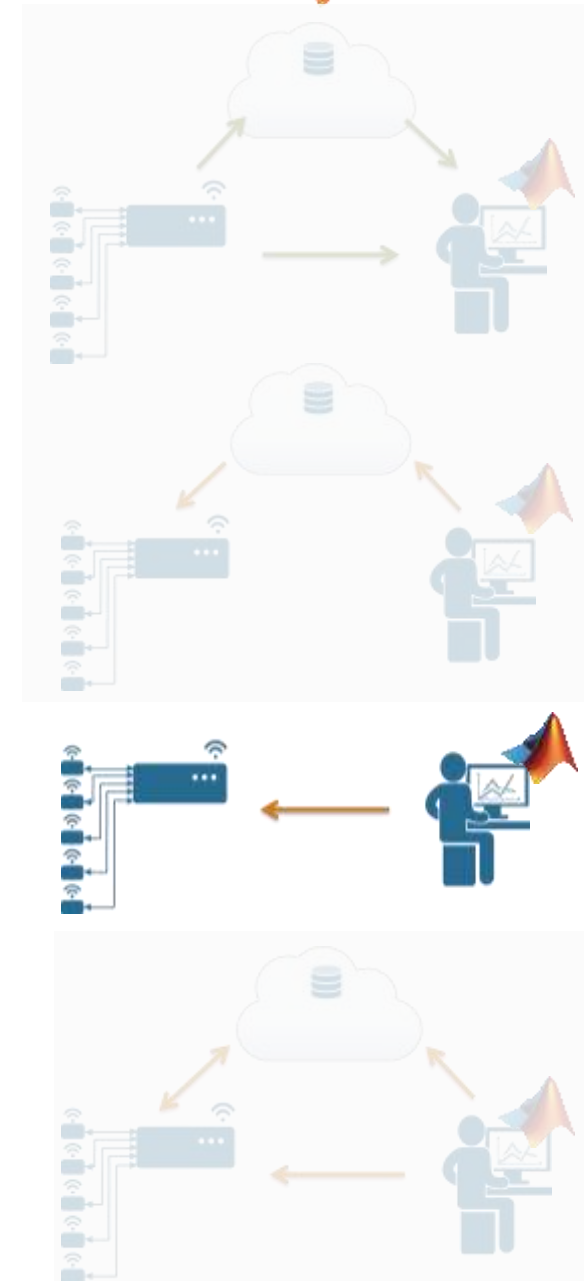
Mar 17 2017

Learn Further: Which Toolboxes Work in ThingSpeak?

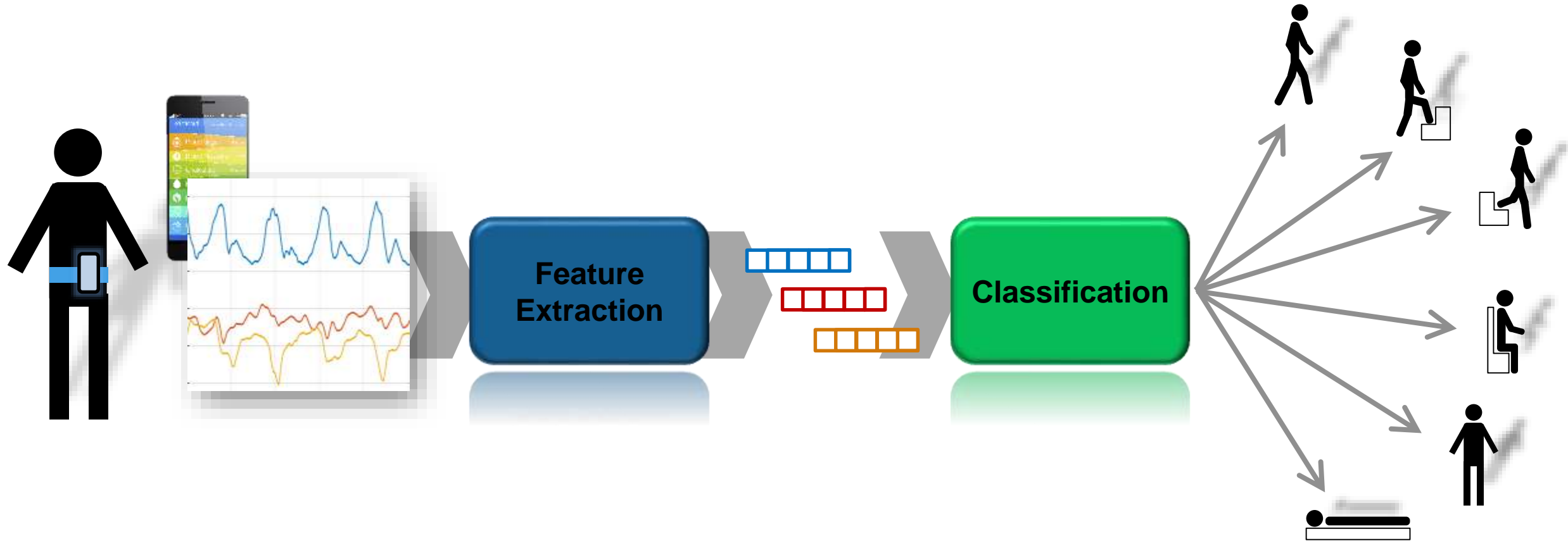
- [Statistics and Machine Learning Toolbox™](#)
- [Curve Fitting Toolbox™](#)
- [Control System Toolbox™](#)
- [Signal Processing Toolbox™](#)
- [Mapping Toolbox™](#)
- [System Identification Toolbox™](#)
- [Neural Network Toolbox™](#)
- [DSP System Toolbox™](#)
- [Datafeed Toolbox™](#)
- [Financial Toolbox™](#)

Examples for Today

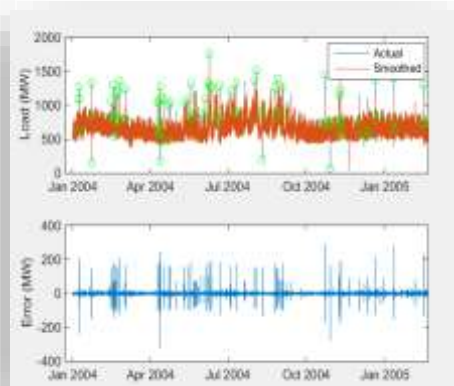
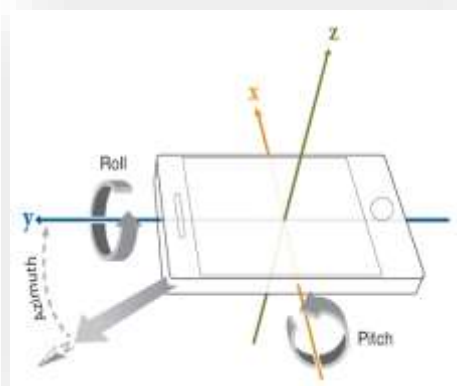
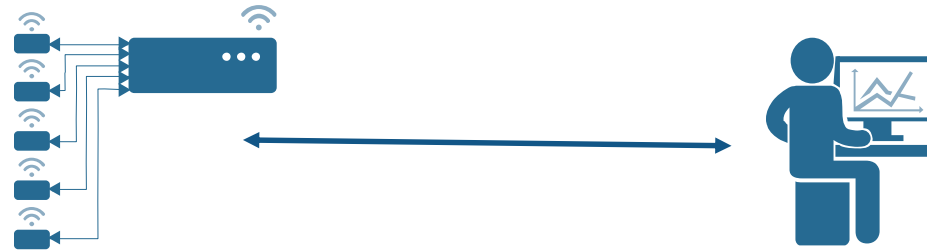
- Data acquisition from edge nodes and analysis using MATLAB
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- **Develop analytics using MATLAB and deploy on a smart device**
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Example 3: Sensor Analytics and Development of Smart Connected Devices



Example 3: Sensor Analytics and Development of Smart Connected Devices - workflow



```

14 % Function Definitions
15
16 % Extract feature vector
17 * Arguments : input
18 * Returns : output
19 * Returns Type : double
20
21 %
22 %
23 %
24
25 Mobile predictActivityFrom
26 double mean(64), count
27
28
29
30 double coef(16);
31 double h_pmf(16);
32 int lastact;
33 double score(8);
34 double temp;
35 int i;
36 int last;
37 double_T weight;
38 featuresFromBuffer(in,
39
40 % Classify with score
41
42 For lastact = 0; lastact < 8; lastact++
43     h_pmf(lastact) = (coef(lastact) + mean(lastact)) / 2;

```

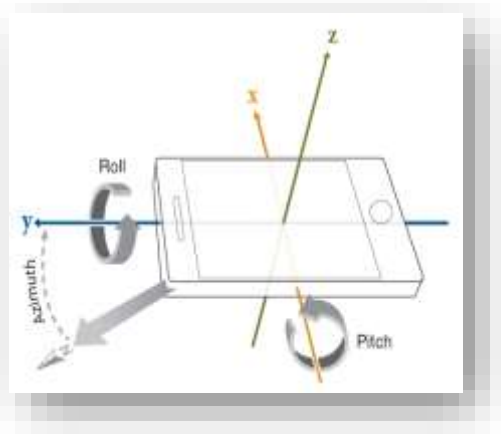
Connect and Acquire

Signal Processing

Machine Learning

Embedded Implementation

Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow



Connect and Acquire

1

1:28 AM 4.11K/s airtel 4G 25%

Sensors

Acceleration

X m/s ²	-0.370
Y m/s ²	-0.899
Z m/s ²	9.864

Stop Sending

MATLAB R2017a

HOME PLOTS APPS SHORTCUTS

C:\AmitDrive\15_EXPOs\2017\IoT

Command Window

```
>> connector on PASSWORD
DNS name: BGL-ADOSHIX.dhcp.mathworks.com
IP address: 192.168.93.1
Use this link to test the MATLAB Connector:
http://BGL-ADOSHIX.dhcp.mathworks.com:31415/
```

MATLAB Support Package for Android Sensors

version 1.4 (15.1 KB) by MathWorks Mobile Sensor Connectivity Team

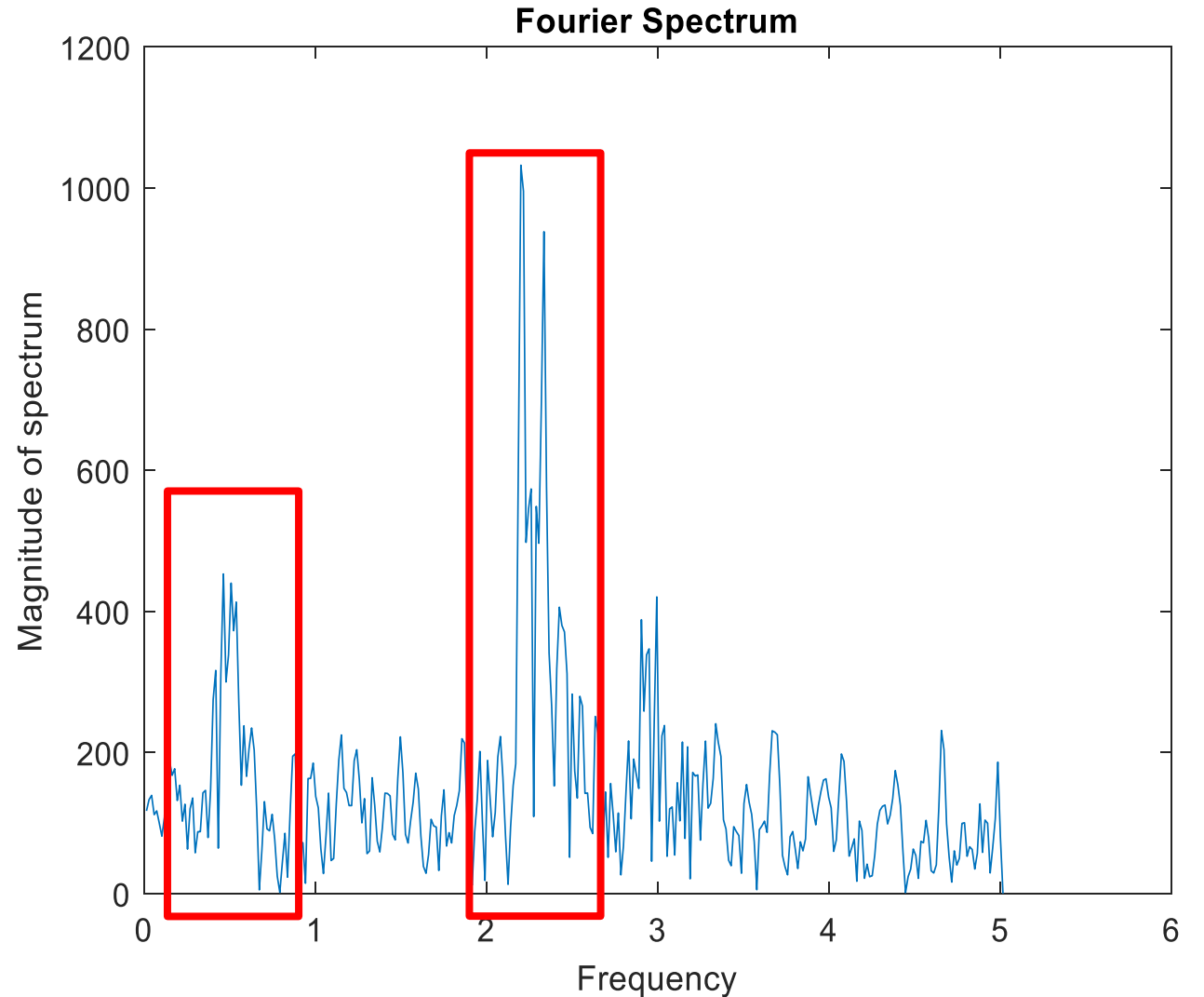
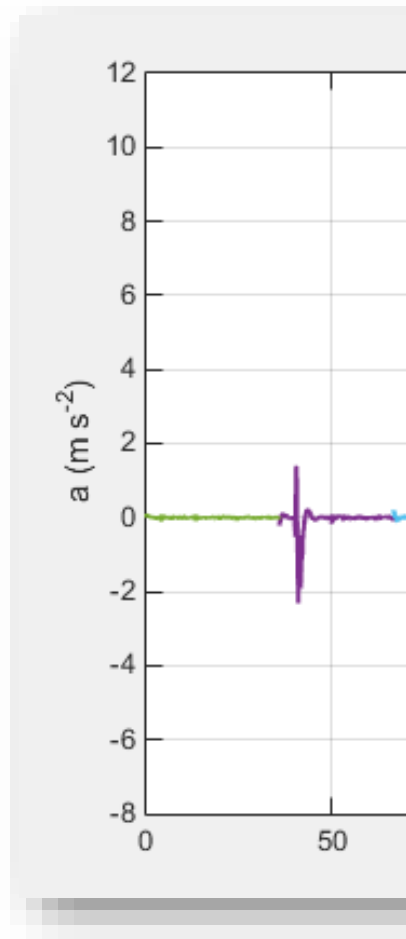
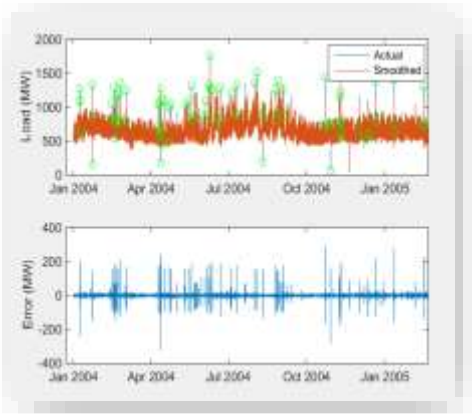
Acquire sensor data from built-in sensors on Android devices.

MATLAB Mobile

Connect to MathWorks Cloud

Run MATLAB commands any time you have internet access.

Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow



Signal Processing and feature extraction

2

Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow



Machine Learning

3

Current Folder

Name	Size	Type
FUNCTION		
plotModelResul...	4 KB	Function
saveSensorData...	4 KB	Function
plotActivityResu...	4 KB	Function
plotRawSensor...	2 KB	Function
downloadSenso...	2 KB	Function
Wpca1.m	1 KB	Function
Wstd.m	1 KB	Function
Wmean.m	1 KB	Function
Script		
Human_Activity...	3 KB	Script
OpeningExamp...	1 KB	Script
MAT-file		
rawSensorData_...	41.15 MB	MAT-file
rawSensorData_...	16.49 MB	MAT-file
OpeningExamp...	2.32 MB	MAT-file

```

1  %% Human Activity Learning Using Mobile Phone Data
2  % Human activity sensor data contains observations derived from
3  % sensor measurements taken from smartphones worn by people while doing
4  % different activities (walking, lying, sitting etc). The goal of this
5  % example is to provide a strategy to build a classifier that can
6  % automatically identify the activity type given the sensor measurements.
7  %
8  % Copyright (c) 2015, MathWorks, Inc.
9
10 %% Load Raw Sensor Data for training
11 load rawSensorData_train.mat
12
13 %% Display data summary
14 plotRawSensorData(total_acc_x_train, total_acc_y_train, ...
15                  total_acc_z_train, trainActivity, 1000)
16

```

OpeningExample.m (Script)

Workspace

Name	Value
body_gyro_x_train	7352x128 double
body_gyro_y_train	7352x128 double
body_gyro_z_train	7352x128 double
humanActivityData	7352x19 table
rawSensorDataTrain	7352x6 table
T_mean	7352x6 table
T_pca	7352x6 table
T_stdv	7352x6 table

Command Window

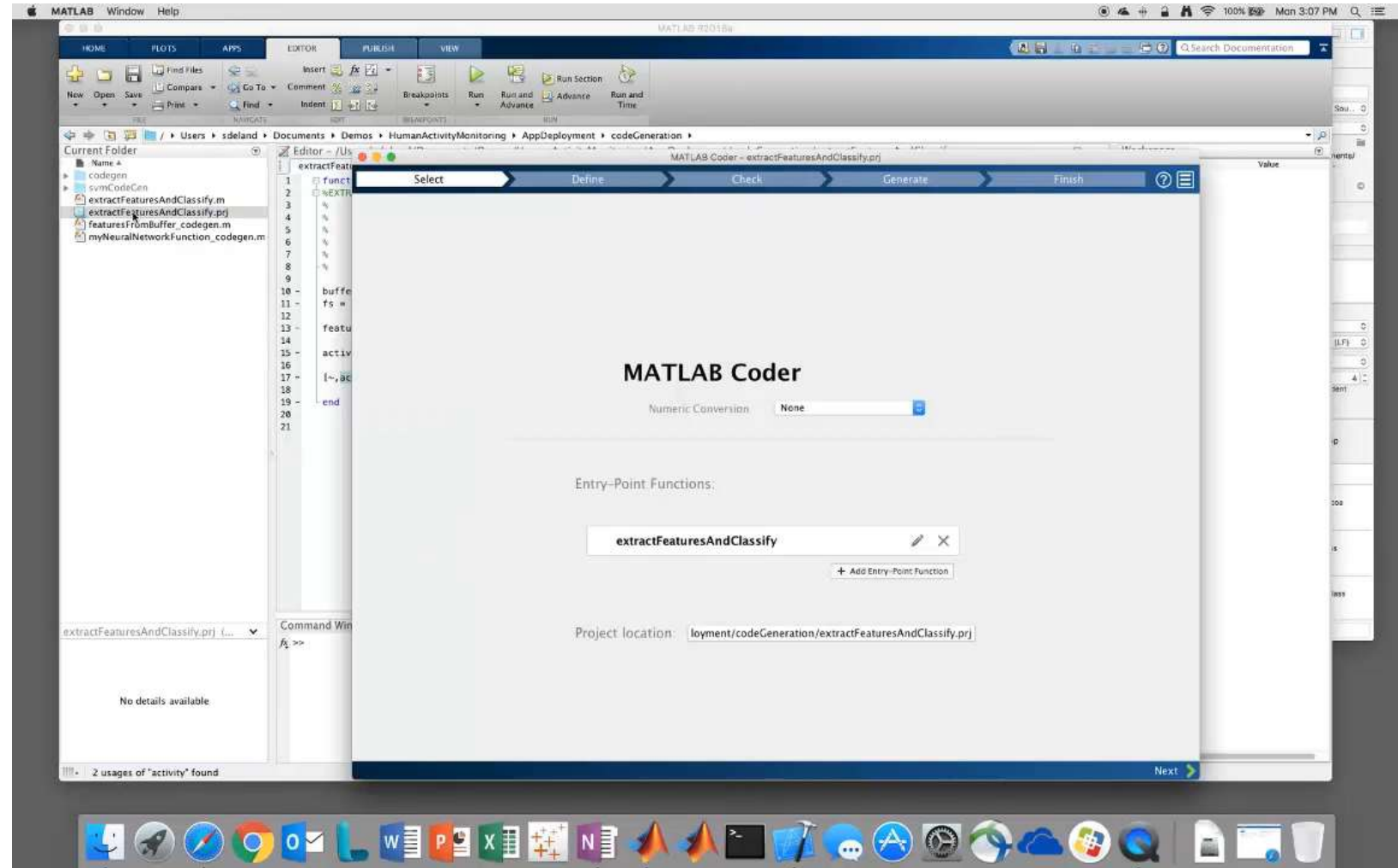
```
fx >>
```

Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow

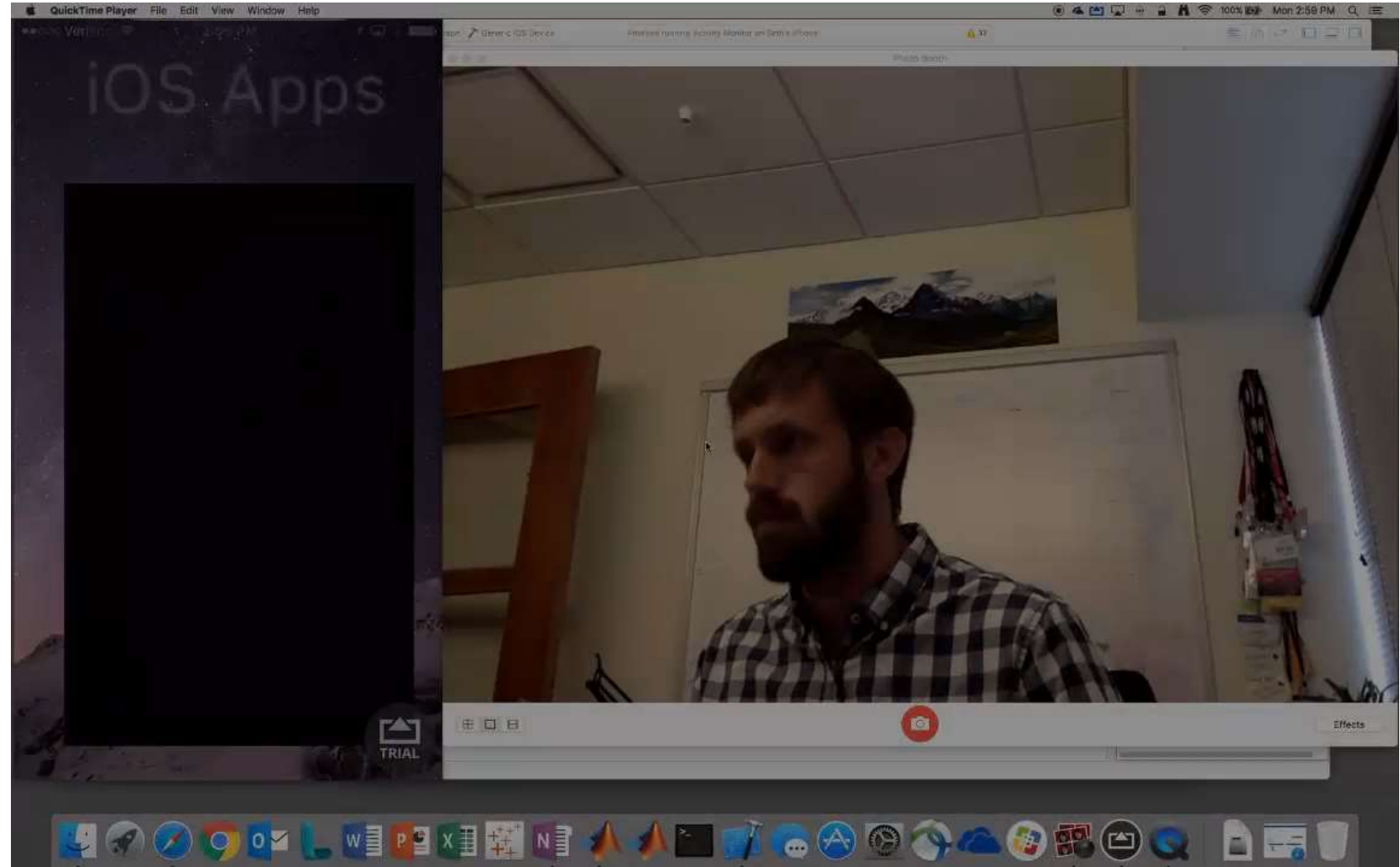
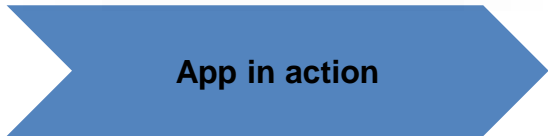


Embedded Implementation

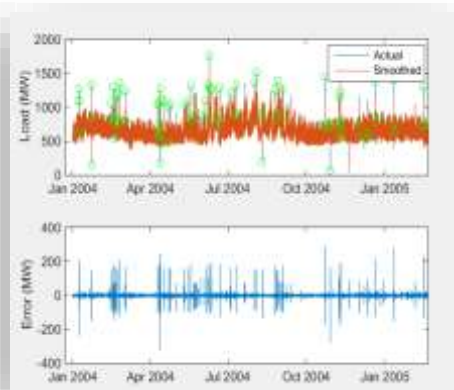
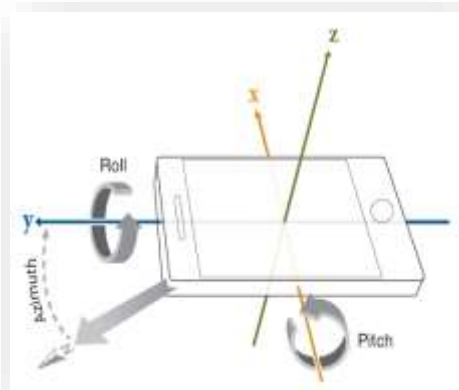
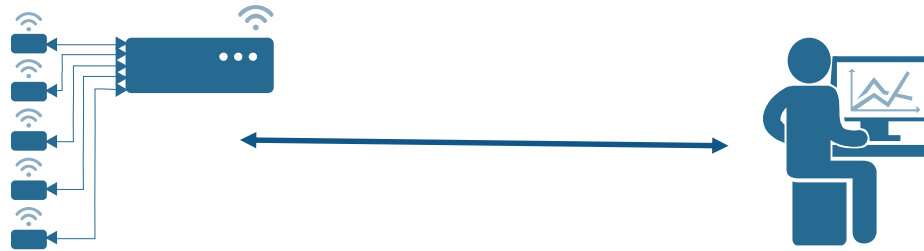
4



Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow



Example 3: Summary of Sensor Analytics Development and Deployment



Connect and Acquire

Signal Processing

Machine Learning

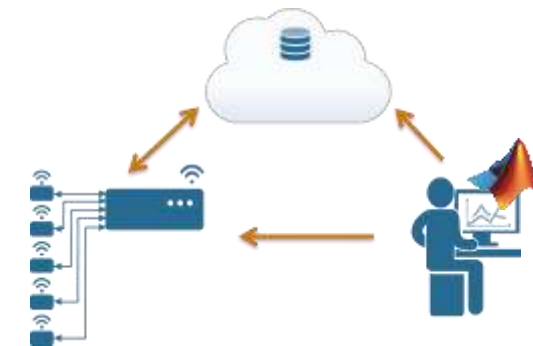
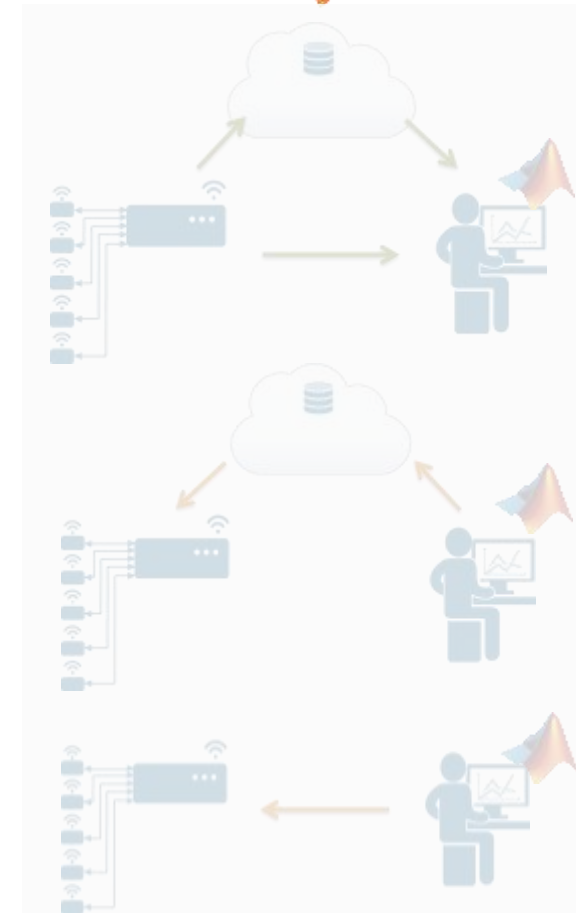
Embedded Implementation

Code Generation using MathWorks Product

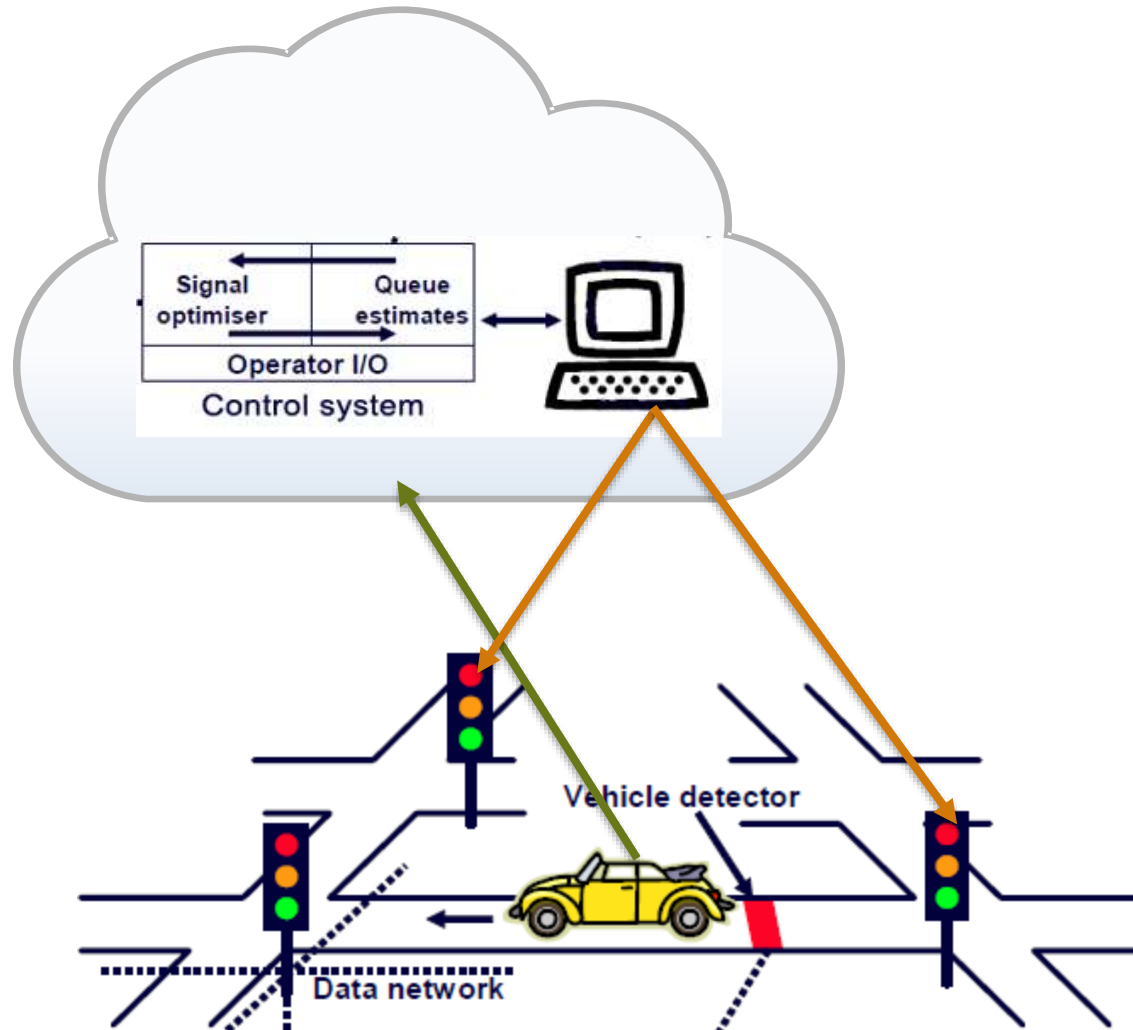
*“Embedded Coder generated C code that was **error-free and efficient**—so much so that the team only needed to write code for our device drivers. **This saved us 6 months of development time.**” - Dr. Christian Robl, System Architect at Vodafone Group R&D.*

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Example 4: Traffic monitoring can be used for smart traffic light management



Example 4: Traffic Monitoring

Objectives

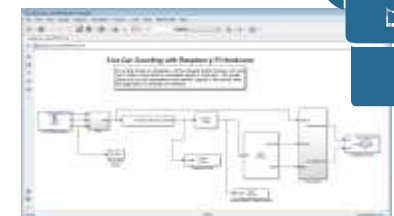
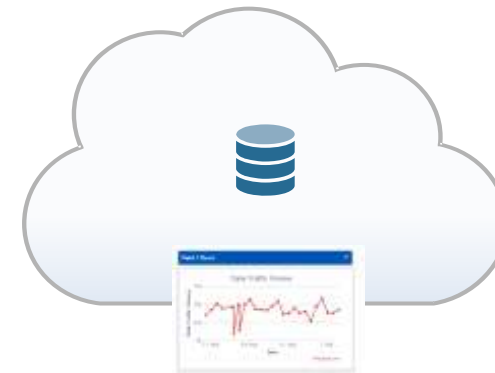
- Measure, explore, discover traffic patterns
- Provide live local traffic information service

Solution

- RaspberryPi + webcam
- Automated deployment of vision algorithms on embedded sensor**
- Full example available at makerzone.makelabs.com



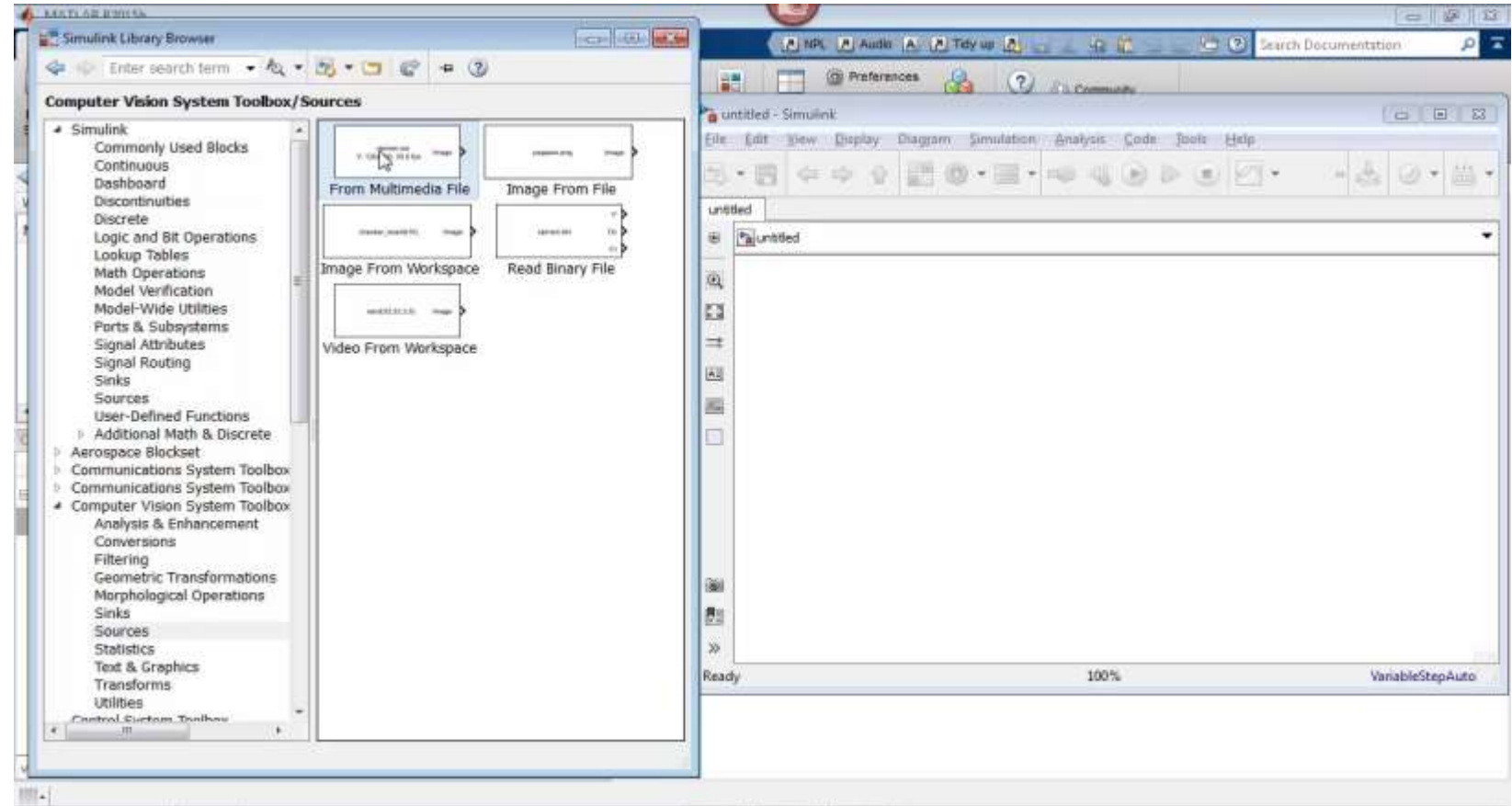
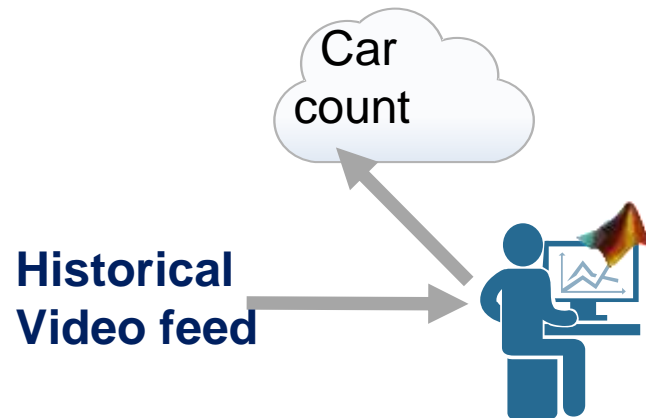
Cloud needs only car count and not all video data



Example 4: Traffic Monitoring - Approach

Step 1: Prototyping

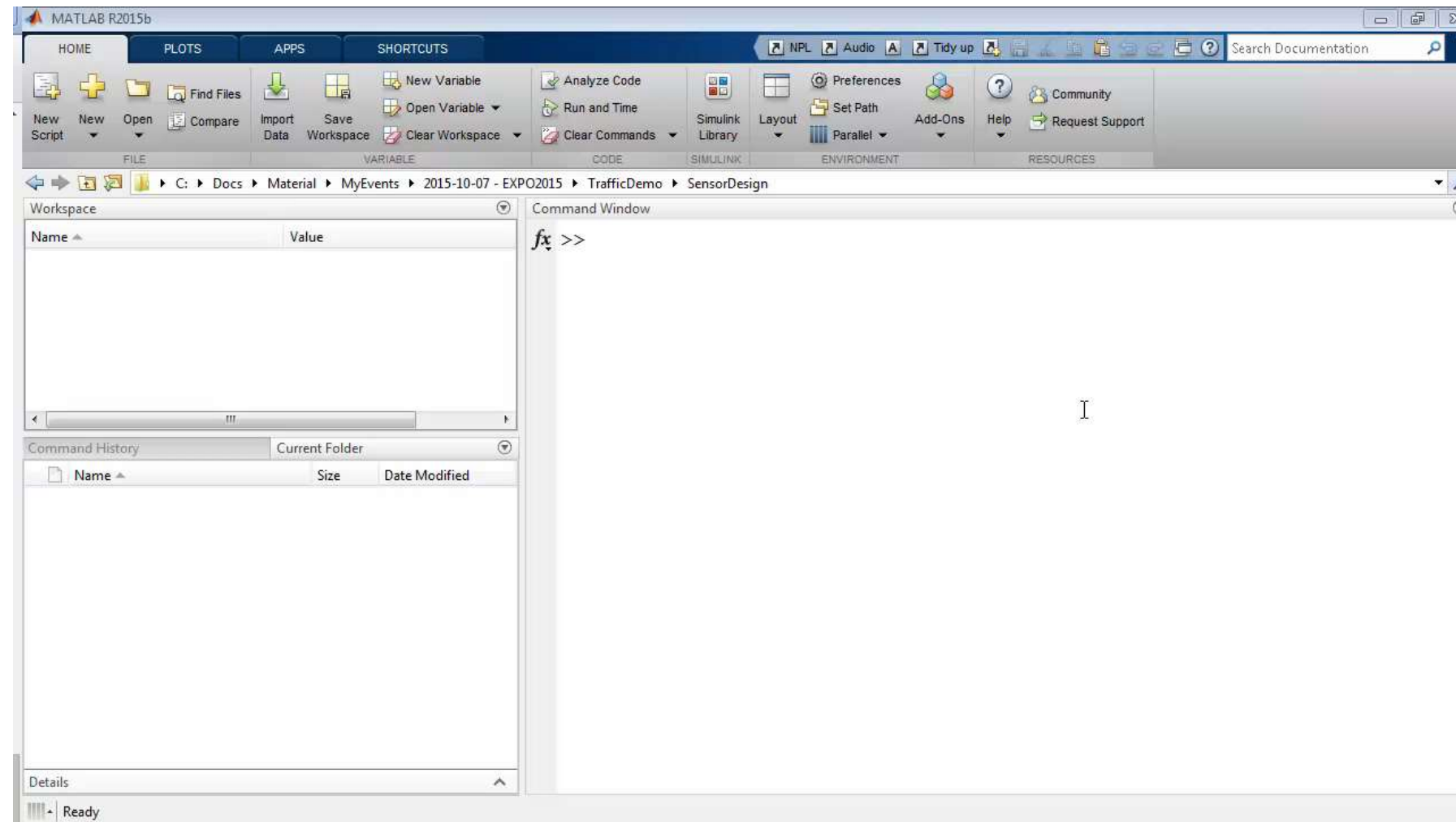
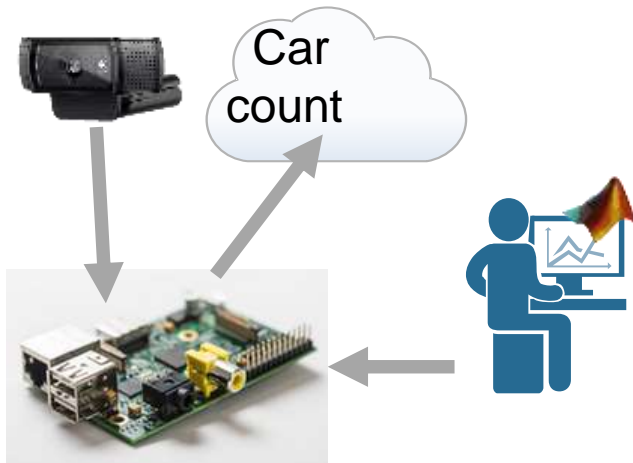
- Create a prototype in Simulink and develop a logic
- Just Simulink and a camera feed



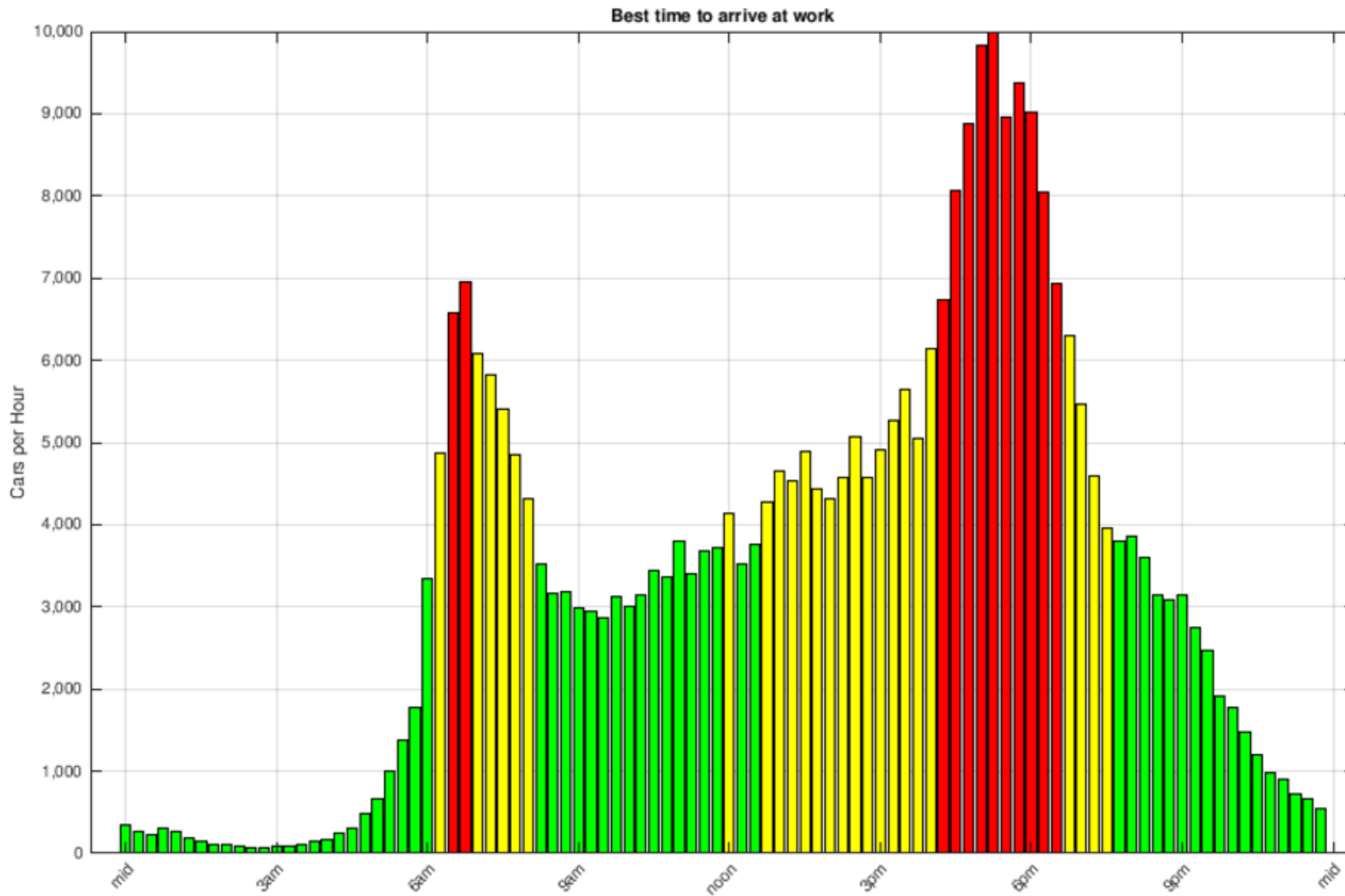
Example 4: Traffic Monitoring - Approach

Step 2: Port it to Raspberry Pi

- Use the code generation capabilities of Simulink to deploy this algorithm onto the Raspberry Pi

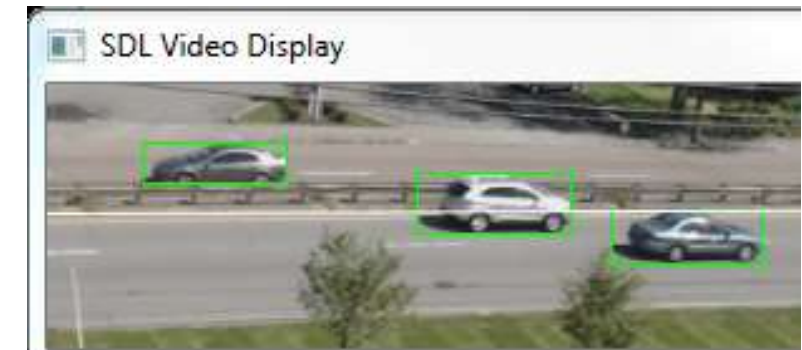


From Data to Insight



When should I start for home?

Well, I better start early from office or stay back late in the office



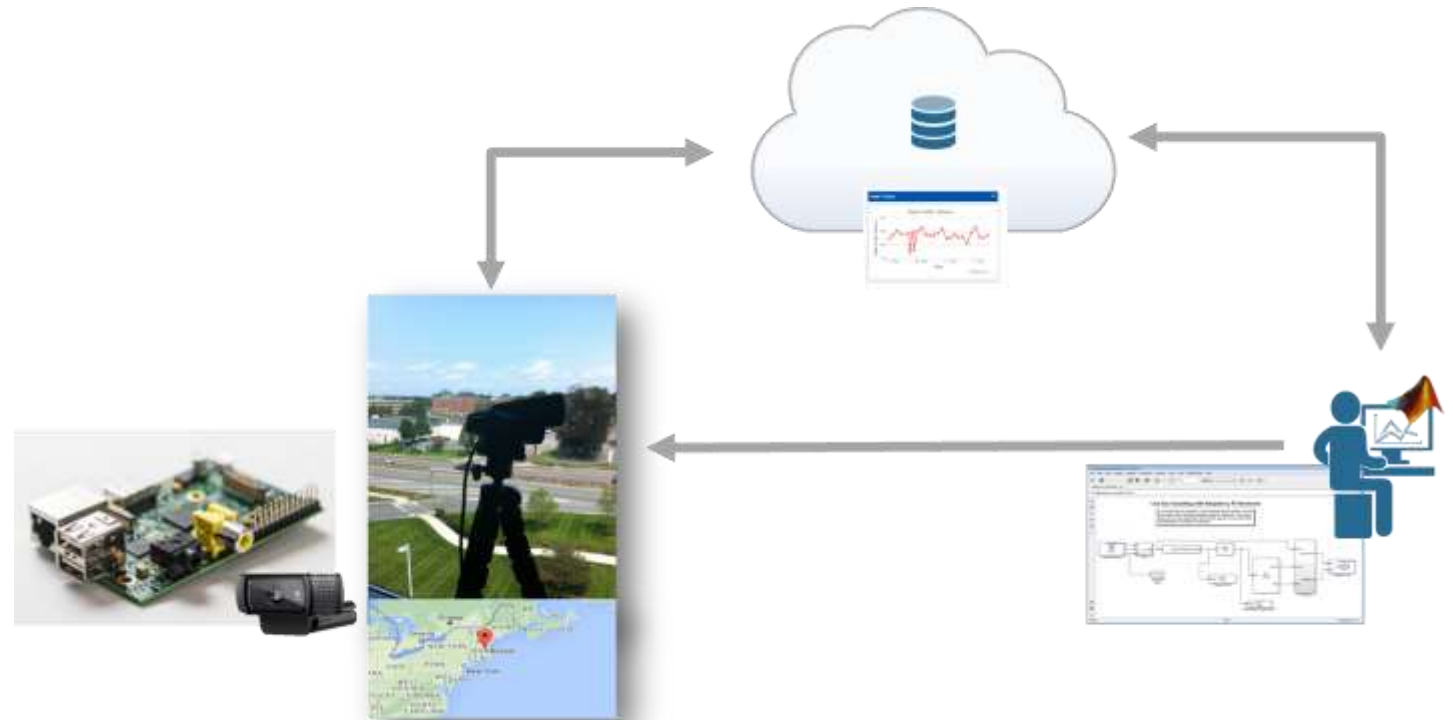
Example 4: Summary – Developing smart devices

Step 1: Prototyping

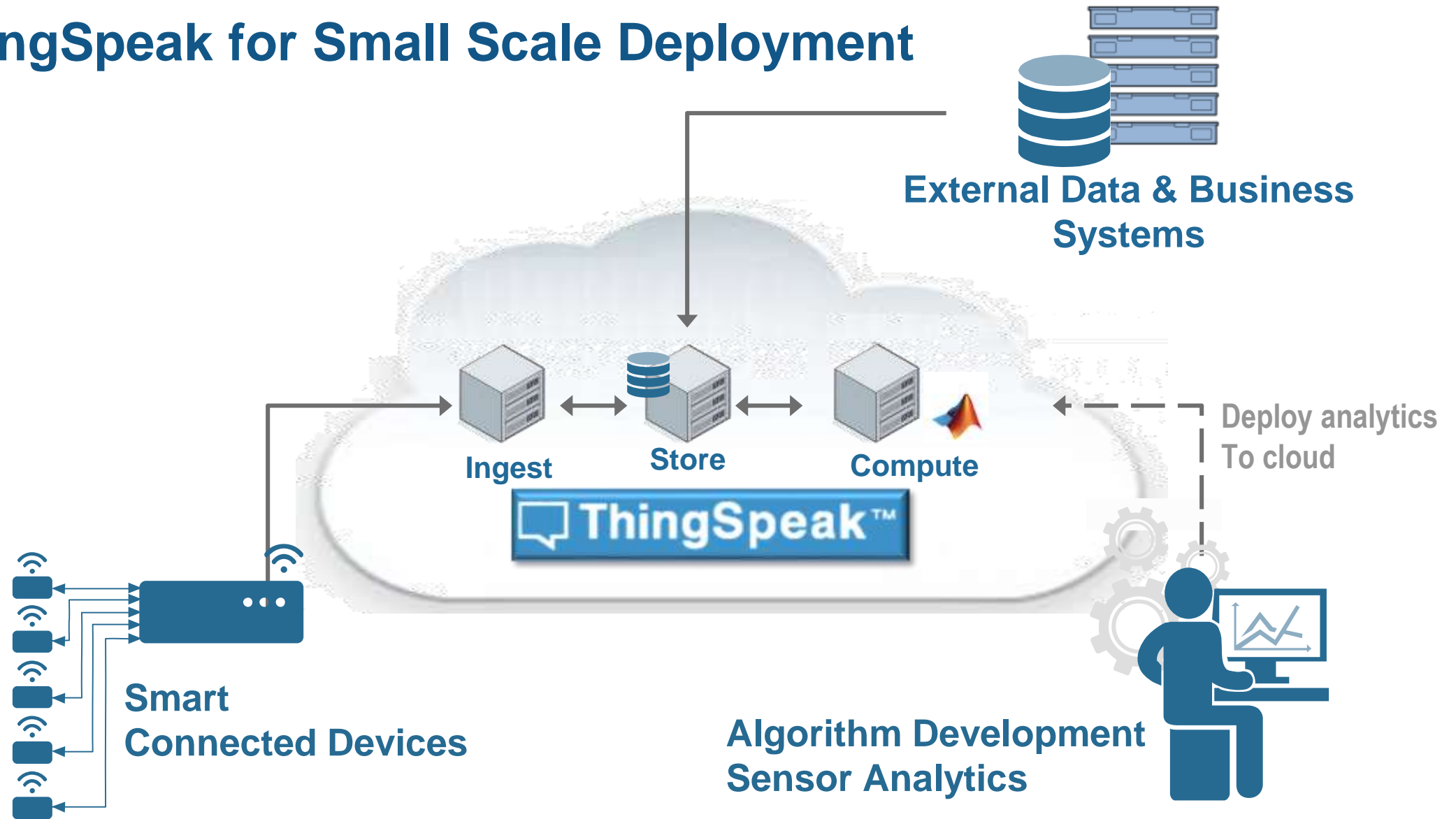
- Create a prototype in Simulink and develop a logic and send count to cloud
- Need only Simulink and a camera feed to start with

Step 2: Port it to Raspberry Pi

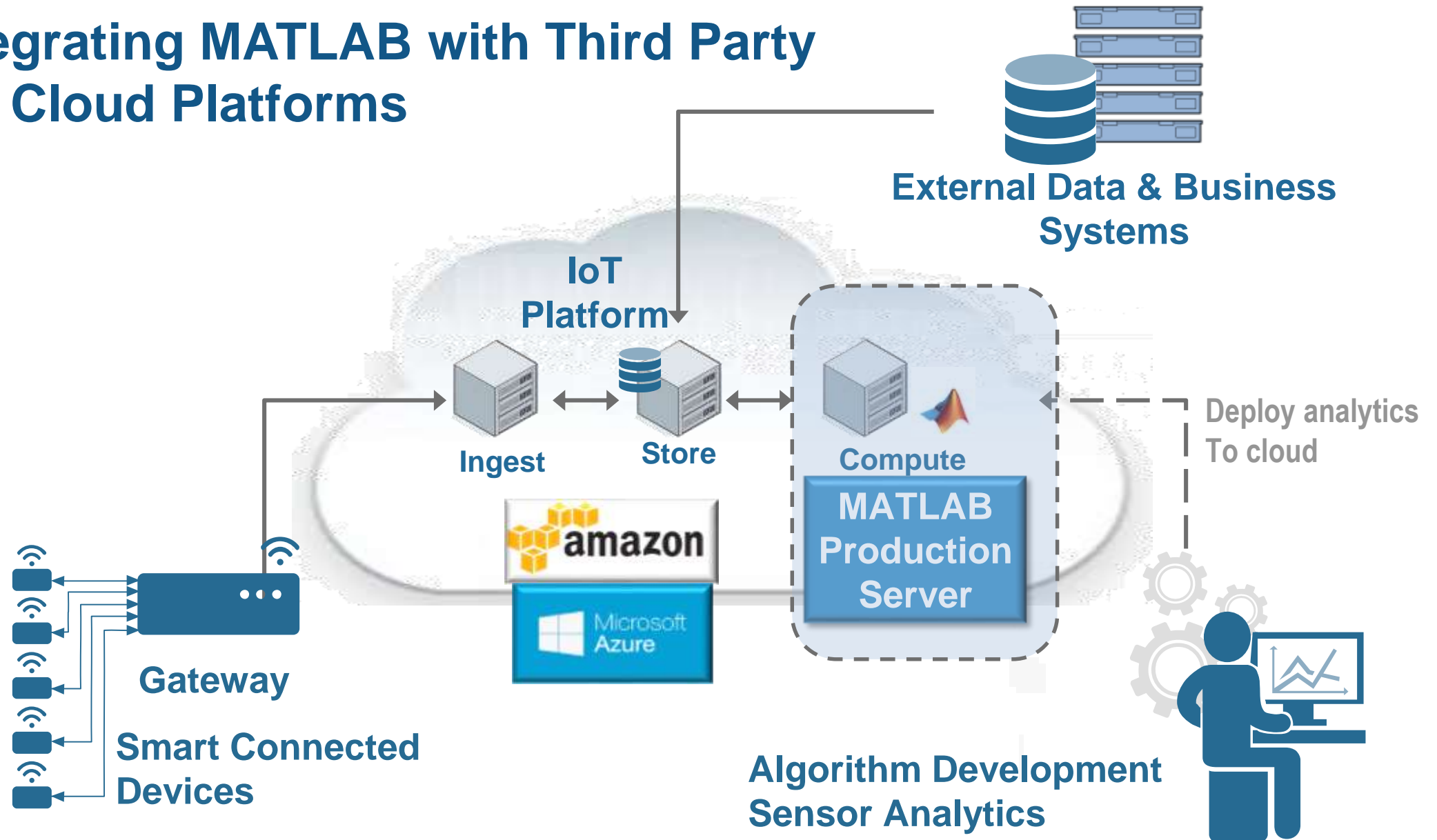
- Use the code generation capabilities of Simulink to deploy this algorithm onto the Raspberry Pi



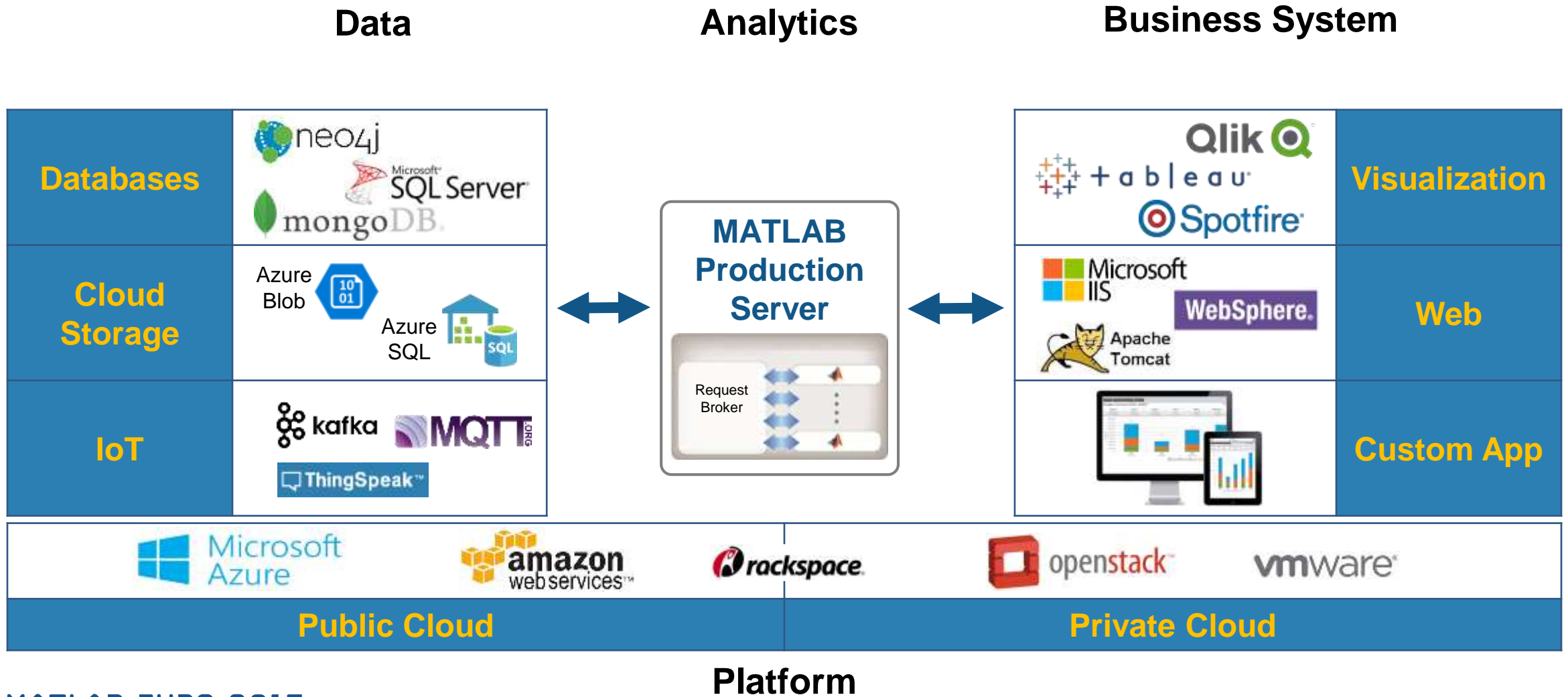
ThingSpeak for Small Scale Deployment



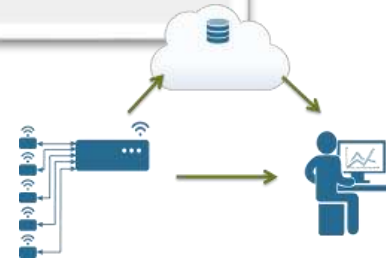
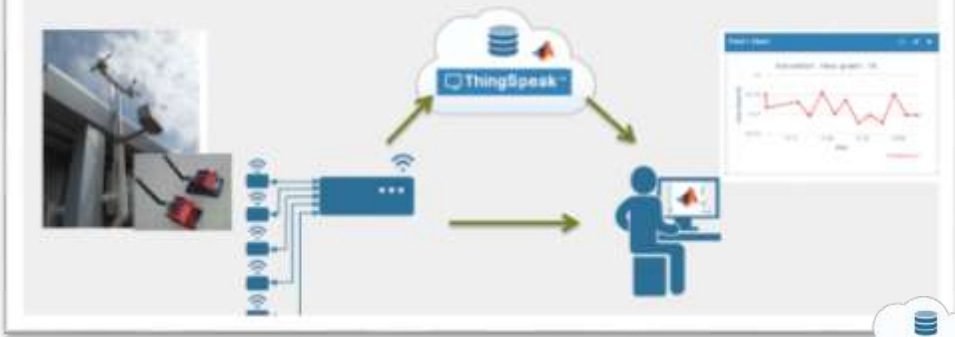
Integrating MATLAB with Third Party IoT Cloud Platforms



Integrating MATLAB in Large Scale Production Systems



Example 1: Weather monitoring using ThingSpeak and MATLAB



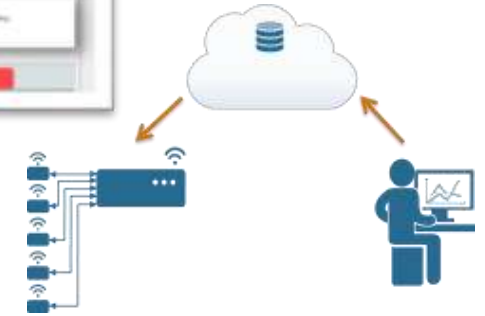
Example 2: Low Tide Prediction Using MATLAB And ThingSpeak

Challenge
Boats get stuck in mud at low tide

Solution
Advance notification of low tide



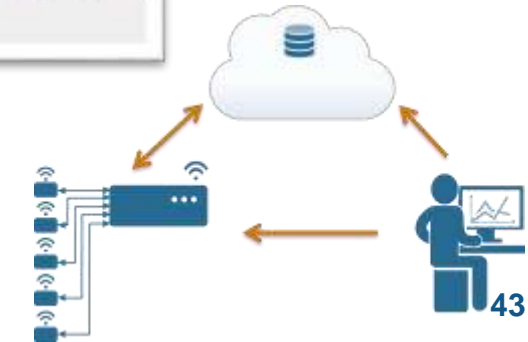
Even cooler... get notifications on mobile



Example 3: Human Activity Analysis and Classification

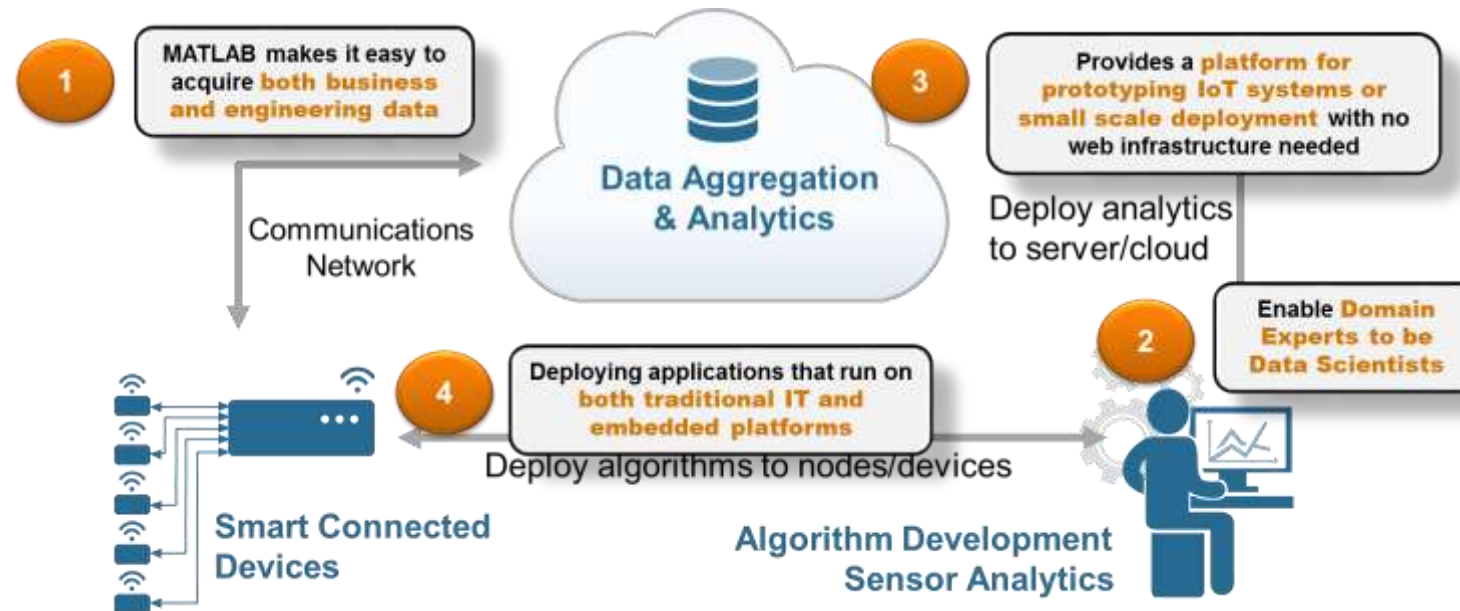


Example 4: Traffic monitoring can be used for smart traffic light management



MathWorks Addresses IoT Challenges

- Quickly **collect and analyze** IoT data with **ThingSpeak** and **MATLAB**
- **Develop analytics** algorithms using **MATLAB** and **toolboxes**
- **Deploy on smart devices** using code generation and embedded target support
- **Deploy on cloud** using **ThingSpeak** and MATLAB Production Server



What You Can Do to Learn More

- [Log-in to ThingSpeak with your MathWorks account and explore](#)
- [View a webinar on Machine Learning with MATLAB](#)
- [Read a Technical Article on Forecasting Tides with MATLAB](#)
- [Read a tutorial on how to send data to ThingSpeak over MQTT](#)



MathWorks®

ThingSpeak

☰ CONTENTS

Getting Started with ThingSpeak

Product Description
System Requirements

Tutorials

Collect Data in a New Channel
Learn how to create a channel, collect data and write it to a new channel.

Analyze Your Data
Learn how to analyze and visualize data using MATLAB®.

Act on Your Data
Set threshold limits on data to send a tweet under certain conditions.

MathWorks Training Offerings

Machine Learning with MATLAB

INTERMEDIATE

This two-day course focuses on data analytics and machine learning techniques in MATLAB using functionality within Statistics and Machine Learning Toolbox™ and Neural Network Toolbox™.

The course demonstrates the use of unsupervised learning to discover features in large data sets and supervised learning to build predictive models. Examples and exercises highlight techniques for visualization and evaluation of results. Topics include:

- Importing and organizing data
- Finding natural patterns in data
- Building predictive models
- Evaluating and improving the model

Prerequisites: *MATLAB Fundamentals*

<http://www.mathworks.com/services/training/>

MATLAB EXPO 2017

Interfacing MATLAB with C Code

INTERMEDIATE

This one-day course covers details of interfacing MATLAB with user-written C code. Topics include:

- Source MEX-files
- Data exchange between MATLAB and MEX-files
- The MATLAB engine interface

Prerequisites: *MATLAB Fundamentals* and a basic working knowledge of the C programming language



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