

White Paper

How to Deploy a LoRa Network for your IoT Application

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Table of Contents

Benefits of LoRa	4
Introduction to Dots on a Map	5
The Applications for Dots on a Map	6
The Sensor Nodes	7
The Gateway Nodes	9
Renesas IoT Sandbox	11
The User Portal	13
How to Deploy	17
Conclusion	17
References	18

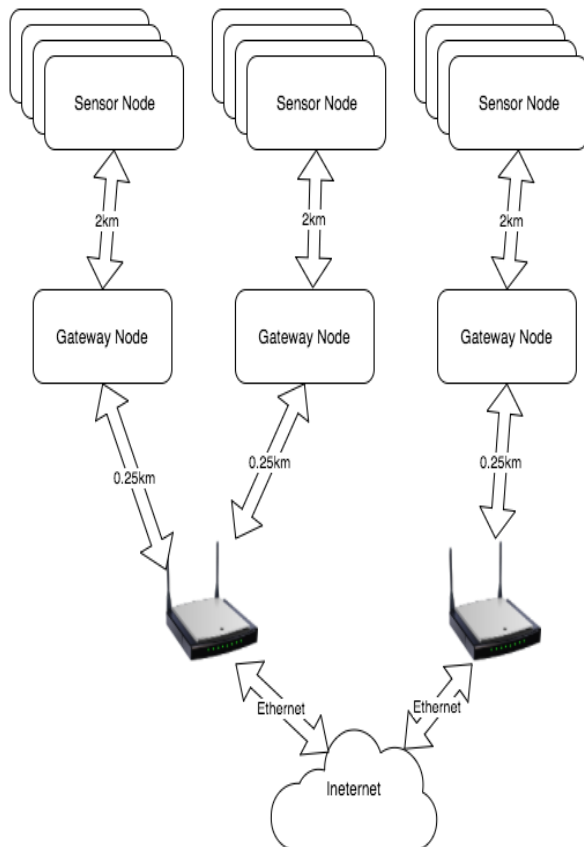
How to Deploy a LoRa Network for your IoT Application

Renesas partners with Medium One to provide a complete LoRa-based IoT solution that can be applied to many use cases.

The LoRa-based IoT solution developed by Renesas and Medium One, named “Dots on a Map”, leverages the advantages of a LoRa network, the RX family of MCUs developed by Renesas, an array of powerful sensors, and the cloud solution offered by Medium One to provide smart sensor-rich nodes sending data over long distances to be monitored and analyzed in the Cloud in real-time.

The goal of the Dots on a Map solution is to provide the user with rich sensor data from a widespread set of locations that may not be reachable with normal Ethernet, WiFi, or even cellular uplinks, without requiring an expensive infrastructure. Another goal is to provide the user with an intuitive means to analyze the data and to make the data actionable.

The Dots on a Map hardware solution architecture is shown on the right. Many sensor nodes can be connected to the internet by placing them within the radius of a gateway node. Multiple gateway nodes can be supported in this solution. Each gateway node is placed within the radius of a WiFi access point. Finally, the WiFi access point provides the uplink to the internet for the data to reach the powerful Dots on a Map Cloud. This flexible architecture allows for a scalable IoT solution to be implemented without significant capital costs.

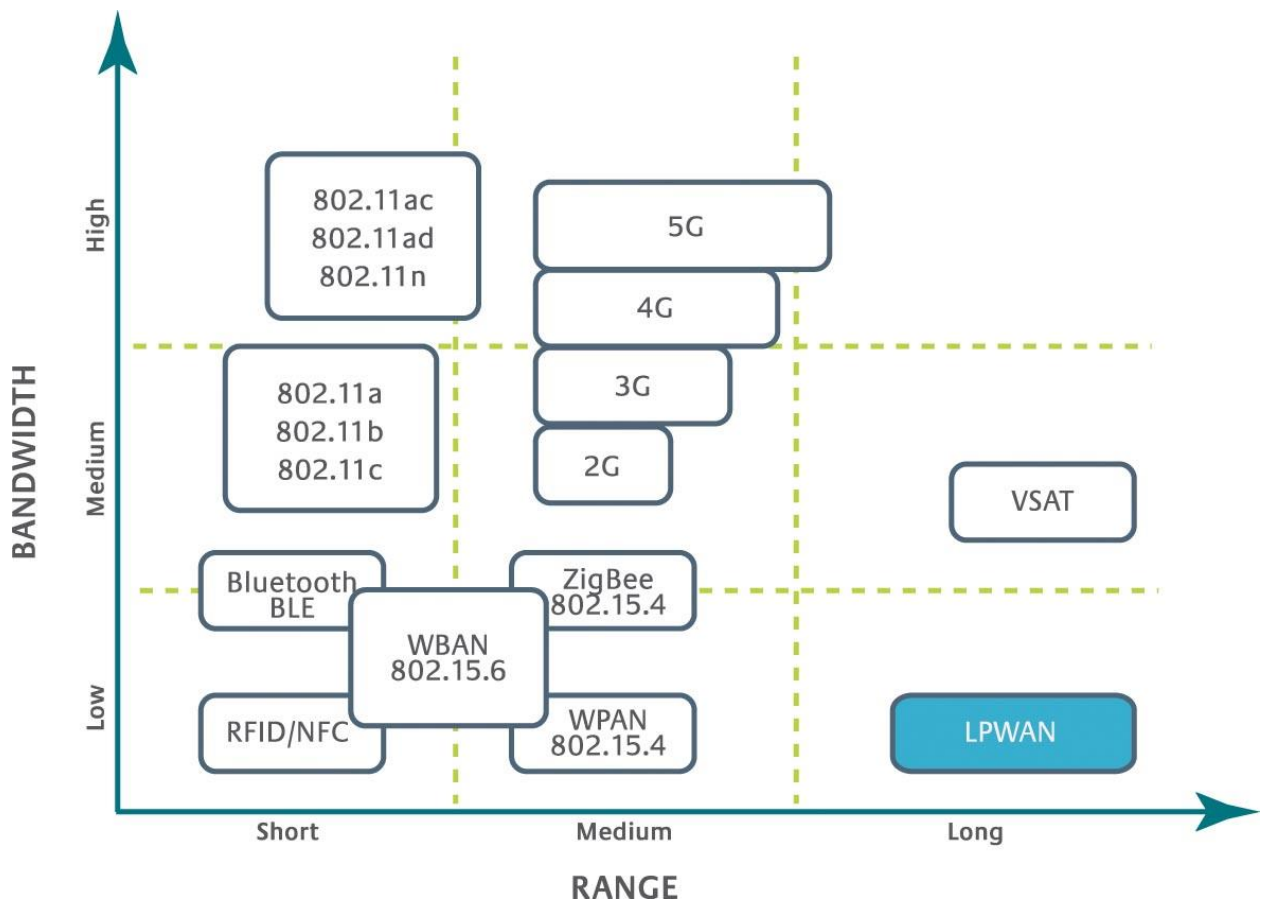


Each part of this solution is designed to meet the stated goals while also being cheaper to deploy and maintain than similar solutions based on alternative technologies. The following sections describe each component of this solution in more detail.

Benefits of LoRa

LoRa is the communication technology used in this solution to connect the sensor nodes to a gateway. There are competing technologies that may surpass LoRa in certain aspects, but for the goals of this solution, LoRa was found to be an ideal technology.

LoRa is an LPWAN technology, which falls into the class that provide long range or wide area networks at low power. The typical ranges of communication are from 2 to 1000 km, dependent on technology. As a consequence of their higher range and lower power, LPWAN technologies typically have very low bandwidths.



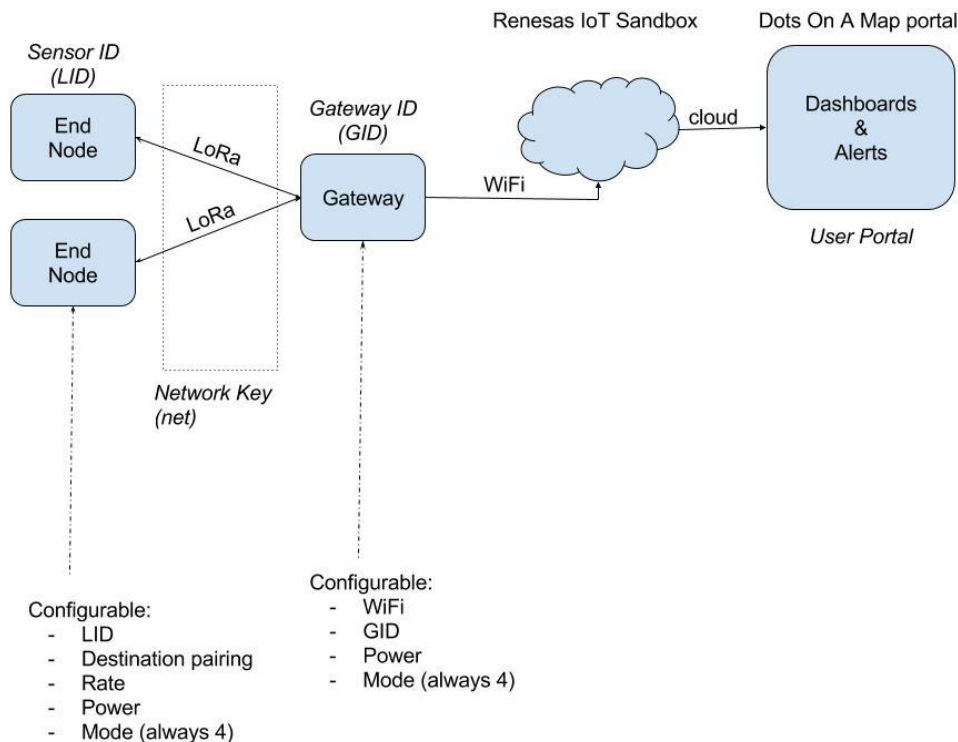
LoRa, in particular, has two main benefits over its competitors in the LPWAN space. The first benefit is that the LoRa radio used in the end nodes and the gateway is one and the same; this reduces cost as the same design can be reused between the end node and gateway. Also, while the gateway is generally more expensive due to its higher processing performance and connectivity requirements, a more expensive radio than the end nodes is no longer required. Another benefit of LoRa is that it is driven by the LoRa Alliance, whose committees provide the standards to which all LoRa vendors adhere.

In addition, LoRa also features reliable bi-directional messaging capability. While not demonstrated in the Dots on a Map solution, this feature can be used to implement advanced functions in the end-nodes by relying on receiving messages from the Cloud, relayed to the end-nodes via the gateway.

Introduction to Dots on a Map

Though initially designed with asset tracking in mind, Dots on a Map is a system that can generally monitor and report data about many distant locations, and such data can also be aggregated and analyzed to help accomplish operational goals. The customized portions of the system consist of two hardware units, the End Node and Gateway, and the User Portal.

The End Node and Gateway units are based on the Renesas RX Series of MCUs. The RX231 based end node, or sensor node, is equipped with a GPS radio and many sensors, including air quality, temperature, humidity, and light, in addition to the LoRa radio. The RX65N based gateway is equipped with the same LoRa radio and a WiFi radio to send data to the Renesas IoT Sandbox in the Cloud.



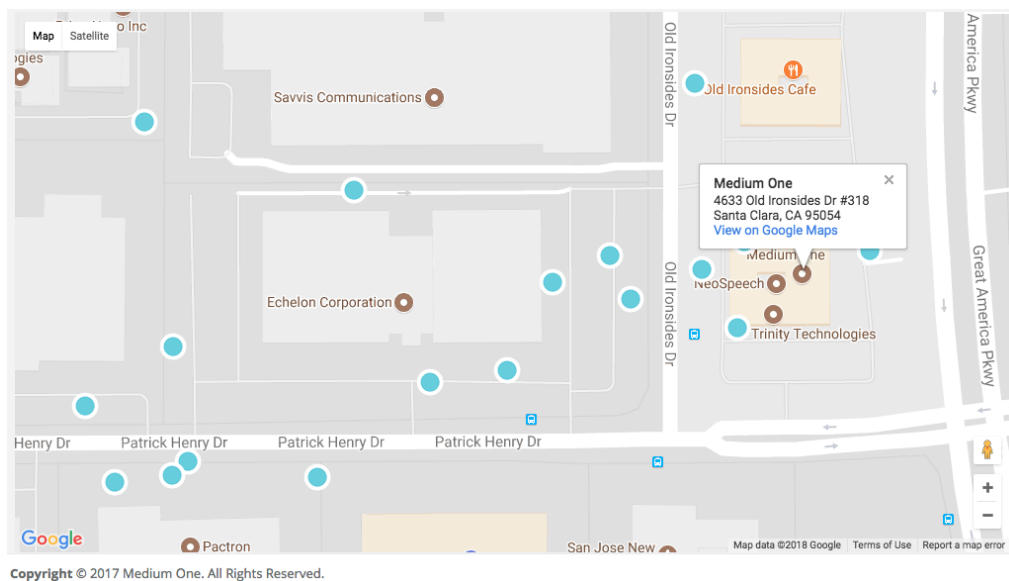
The IoT Sandbox stores the data and runs python-based workflows, which transform and normalize the data, analyze the data for alert conditions, send out notifications, and more. The last component, the User Portal, is a highly customizable web interface developed by Medium One. It has many features that make it easy to customize for any application, including the Dots on a Map solution. The User Portal is a customer interface that

provides high value information back to the customer and allows them to control their experience with the solution.

The Applications for Dots on a Map

There are several use cases to which the Dots on a Map solution can be applied. To generalize, the use cases fall into the categories of asset tracking and remote asset control.

Asset tracking is the ability to monitor critical pieces of information regarding your assets. For example, the trucks in a retailer's trucking fleet are valuable assets and, in more cases than not, many fleet owners would like real-time information on their trucks. The most critical piece of information is typically the truck's current location, but additional data is also often desired such as the location over time, fuel efficiency, tire wear, etc. In other asset tracking applications, geo-fencing a set of assets to ensure that they stay within a certain area provides the most value to the organization.

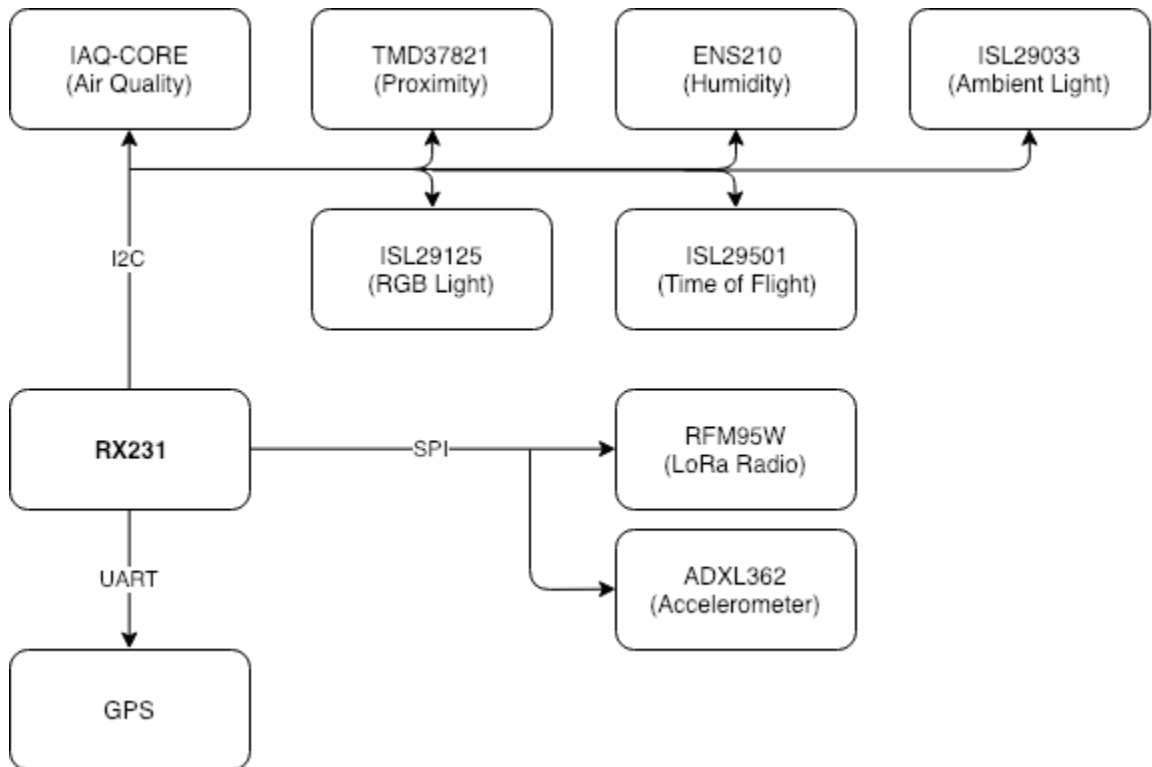


However, location is not always the critical piece of information. The desired data could be anything. One possible metric is power consumption, such as for smart power meters deployed by a city power company. Other assets may need to relay audio signals or the current level of air quality. Subject to the range limitations of the technology, the Dots on a Map solution can be applied to solve these kinds of applications.

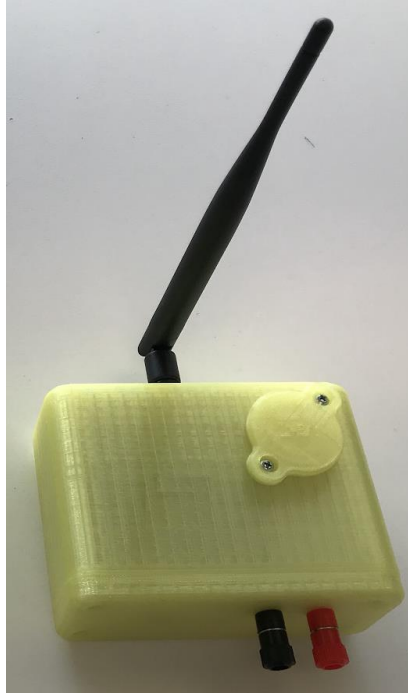
Asset control is the ability to control the behavior of the asset by sending commands to the gateway with a specific end node as the intended recipient. The gateway then sends the commands to the end node. While the Dots on a Map solution does not currently support cloud-to-device communication, the end node firmware can easily be extended to achieve this, allowing use-cases like smart street lighting to be solved.

The Sensor Nodes

The sensor nodes of the Dots on a Map solution are where all of the data sampling takes place. As such, each node contains a wide array of sensors so that many use-cases can be addressed with a single hardware design. The RX231 is the central component of the sensor end node. All of the sensors are connected to the RX231, the majority via I2C interfaces, while the others are connected through SPI and UART interfaces. The RX231 is responsible for sampling all of these sensors and then communicating the sensor data to the gateway through the LoRa radio. Refer to the following block diagram for more detail.



Each sensor node is designed to operate both indoors and outdoors using an enclosure that has ventilation and moisture protection. A standard SMA connector is exposed for attaching a LoRa antenna, and both micro-USB and banana plug options are exposed for providing power to the unit.



Leveraging the RX231 allows the sensor node to have enough processing power to sample all the connected sensors. Sampling the sensors involves more than just the communication over the wire protocol. Often times sensor readings must be decoded, which can involve mathematical computations including floating point operations. The RX231's RXv2 32-bit core with improved FPU is well suited for this workload. Additionally, the RX231's low power consumption supports the option of running on a battery supply. Thus, the option to power the sensor node from a single-cell lithium-ion battery was designed in, including the circuitry to recharge and gauge the battery. This allows for effective energy harvesting in use-cases that can take advantage of it, such as those with sufficient solar exposure. Of all the included sensors, the GPS radio consumes the most power. To handle this concern, the node was designed in a way that allows the RX231 firmware to control the active state of the GPS radio, allowing further power savings when GPS is not required.

Each sensor node must be configured to communicate with a gateway by setting the destination gateway ID. When communicating with a gateway, each sensor node is identified by two pieces of information; one is a user-specifiable LoRa Node ID, and the other is a unique ID written permanently to the device by Renesas during manufacturing. When the node sends sensor data to the Cloud via the gateway, it identifies itself by including a hash of its unique ID. The Cloud, in turn, checks this unique ID hash and creates a corresponding device in the sandbox if one doesn't exist for the node already. This allows for automatic support of additional sensor nodes in the Cloud.

Since LoRa bandwidth is limited, a compact but simple protocol is used to transfer sensor data from the sensor node to the gateway. The following are the sensors currently sampled in the available Dots on a Map firmware:

- Humidity (and Temperature)
- Air Quality

- Ambient Light
- GPS

The following is a sample sensor node payload that includes data from all of the above sensors:

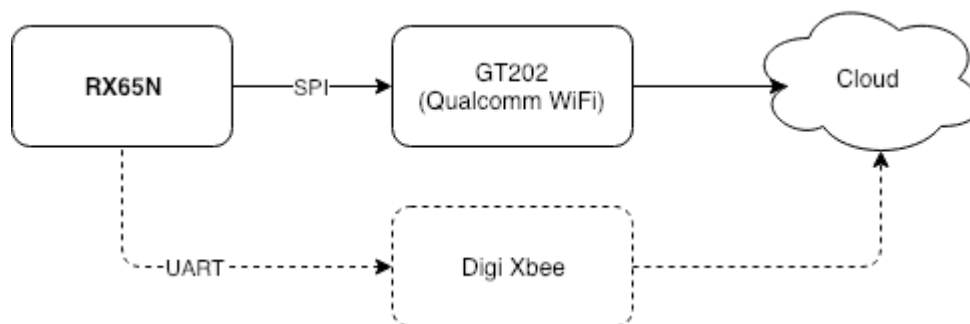
```
T28.6;H31.9;X-121.980020;Y37.396648;Z3.9M;S3;D50.0;Q697;A82;#MNPAHSEA
```

The payload follows a scheme of tokens separated by semicolons, where each token represents a sensor value. The type of sensor value represented depends upon the first character of the token. The following shows the possible first characters for a token:

- T: Temperature
- H: Humidity
- X: Longitude
- Y: Latitude
- Z: Altitude
- S: GPS Satellites Locked
- D: Horizontal Dilution
- Q: Air Quality
- A: Ambient Light
- #: Unique ID Hash

The Gateway Nodes

Gateway nodes operate as the relay between sensor nodes and the Cloud. In the default Dots on a Map solution firmware, the RX65N MCU connects to the configured WiFi access point via the GT202 WiFi chip. It then establishes a secure MQTT connection to the Sandbox MQTT Broker. The gateway then listens for any sensor node payloads and immediately forwards them to the Cloud.



Conversely, the gateway can also listen to messages from the Cloud to relay to sensor nodes over the same secure MQTT connection.

The RX65N was chosen due to its higher performance and operating frequency while still leveraging the power efficiency of the RXv2 CPU core. As the gateway is responsible for the more processing intensive management of the secure TCP connection to the Cloud

and the handling of payloads from many sensor nodes, its higher performance is suited for this workload.

The distance between any given sensor node and its gateway should be no more than 2 km; however, this distance could increase or decrease depending on the specific environmental factors present between gateway and sensor node. A clearer line of sight allows the gateway and sensor node to be further apart more reliably.

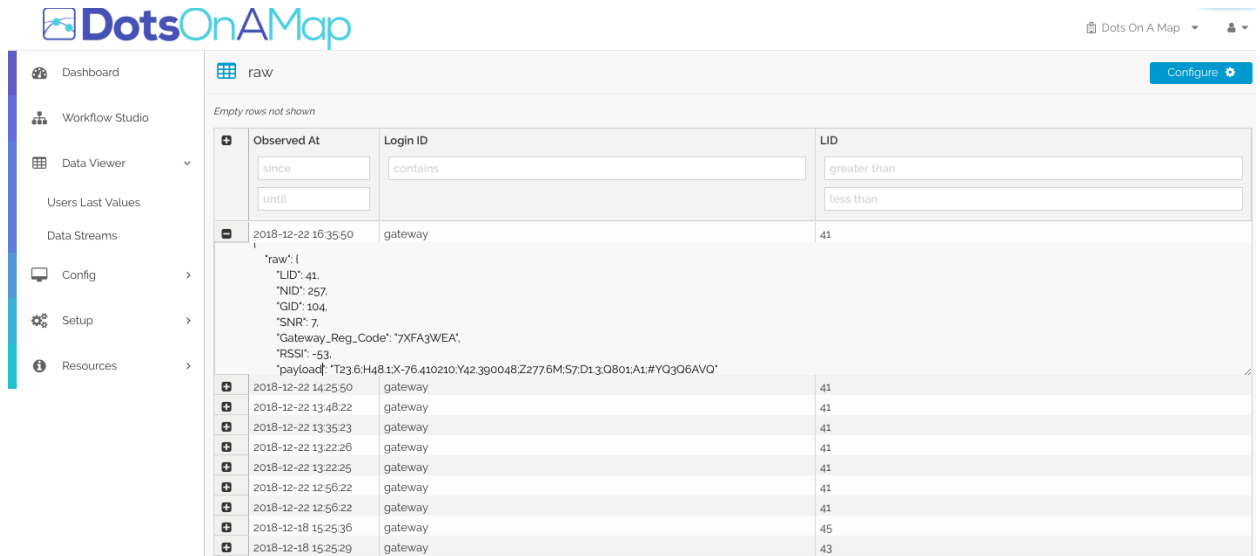


An alternative to the WiFi uplink to the internet is a cellular uplink. This option has already been tested with the Dots on a Map solution using a Digi Xbee3 Cellular LTE-M module. In this case, after the Xbee3 is registered on the cellular network, it establishes the secure MQTT connection with the Sandbox MQTT broker. Following that, the Xbee3 listens for payloads from the RX65N Gateway MCU over UART. The RX65N was accordingly changed to forward sensor node payloads over UART to the Xbee3 instead of directly to the Cloud. All other aspects of the solution remain the same, making the change from WiFi to cellular simple to implement and proving the versatility of the Dots on a Map solution.

Renesas IoT Sandbox

The Renesas IoT Sandbox is the cloud component through which the gateways communicate. It stores and processes all the sensor data to provide customized data intelligence based on the workflows that have been written.

The data is stored in various streams, including the *raw* data:



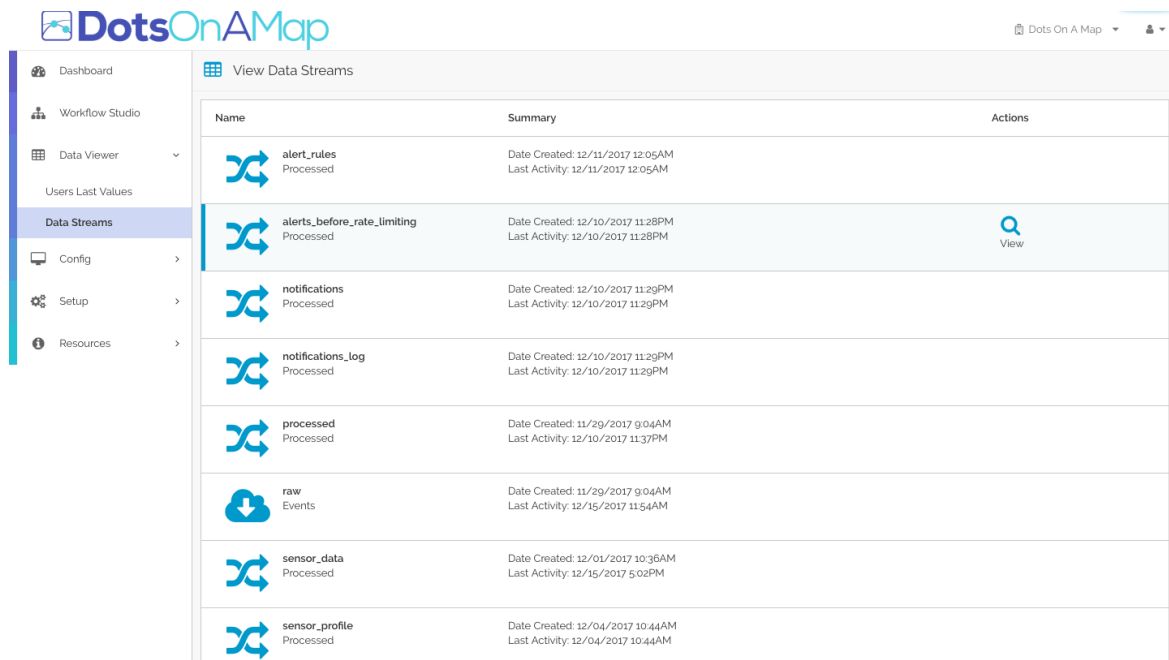
The screenshot shows the DotsOnAMap interface with the 'raw' data stream selected. The table below represents the data shown in the interface:

Observed At	Login ID	LID
2018-12-22 16:35:50	gateway	41
2018-12-22 14:25:50	gateway	41
2018-12-22 13:48:22	gateway	41
2018-12-22 13:35:23	gateway	41
2018-12-22 13:22:26	gateway	41
2018-12-22 13:22:25	gateway	41
2018-12-22 12:56:22	gateway	41
2018-12-22 12:56:22	gateway	41
2018-12-18 15:25:36	gateway	45
2018-12-18 15:25:29	gateway	43

The detailed view of a data point shows the following JSON payload:

```
{
  "raw": {
    "LID": 41,
    "NID": 257,
    "GID": 104,
    "SNR": 7,
    "Gateway_Reg_Code": "7XFA3WEA",
    "RSSI": -53,
    "payload": "T236.H481X-76.410210.Y42.390048.Z2776M.S7.D13.Q801.A1:#YO3Q6AVO"
  }
}
```

and derived data in other streams:

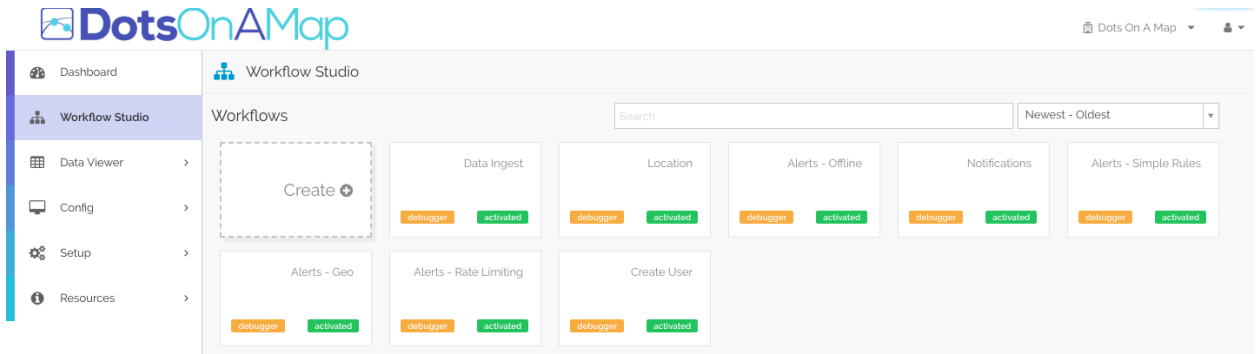


The screenshot shows the 'View Data Streams' page in the DotsOnAMap interface. The table below represents the data shown in the interface:

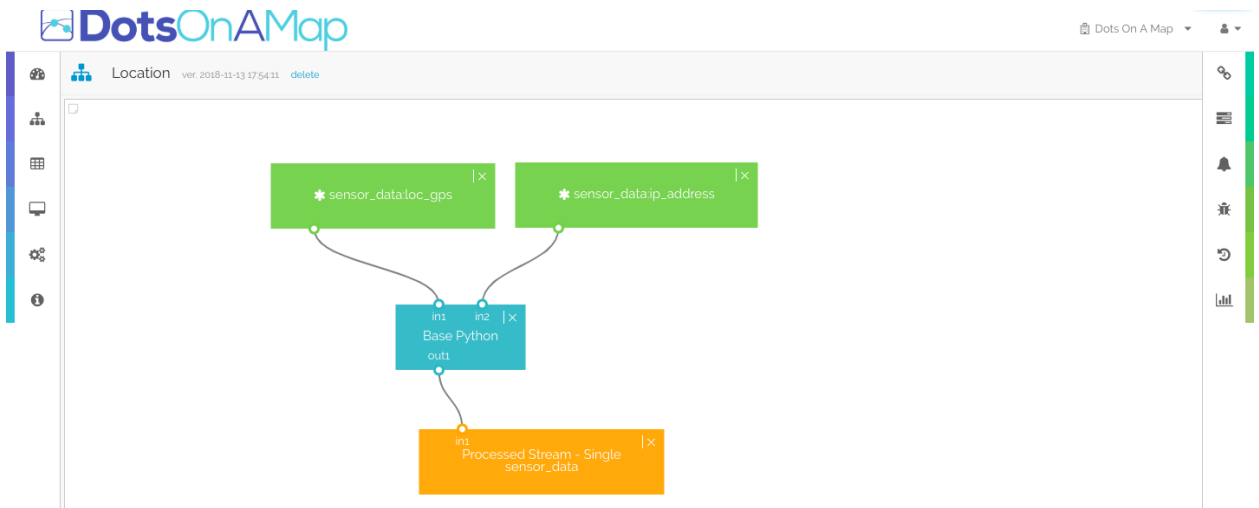
Name	Summary	Actions
alert_rules Processed	Date Created: 12/11/2017 12:05AM Last Activity: 12/11/2017 12:05AM	
alerts_before_rate_limiting Processed	Date Created: 12/10/2017 11:28PM Last Activity: 12/10/2017 11:28PM	View
notifications Processed	Date Created: 12/10/2017 11:29PM Last Activity: 12/10/2017 11:29PM	
notifications_log Processed	Date Created: 12/10/2017 11:29PM Last Activity: 12/10/2017 11:29PM	
processed Processed	Date Created: 11/29/2017 9:04AM Last Activity: 12/10/2017 11:37PM	
raw Events	Date Created: 11/29/2017 9:04AM Last Activity: 12/15/2017 11:54AM	
sensor_data Processed	Date Created: 12/01/2017 10:36AM Last Activity: 12/15/2017 5:02PM	
sensor_profile Processed	Date Created: 12/04/2017 10:44AM Last Activity: 12/04/2017 10:44AM	

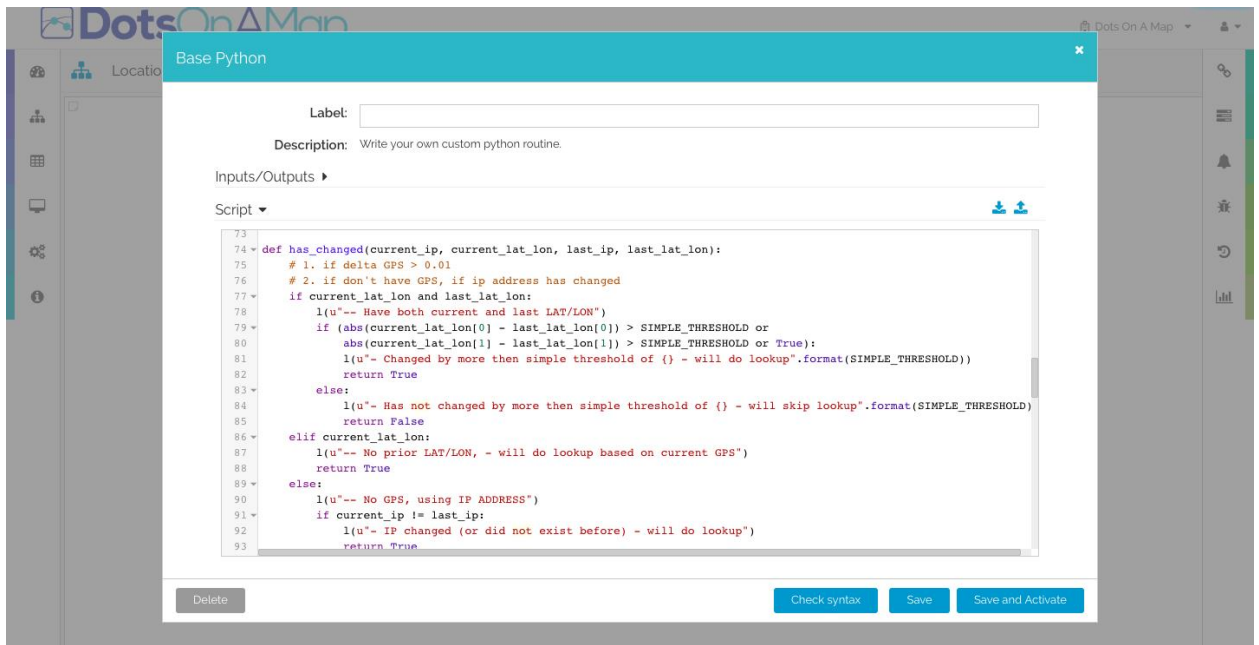
After data enters a stream, it may trigger one or more workflows, which is custom python code that can perform rich processing and actions. The Workflow Studio is a cloud-based

python IDE for developers to implement their real-time cloud applications using built-in data analytics and IOT libraries.



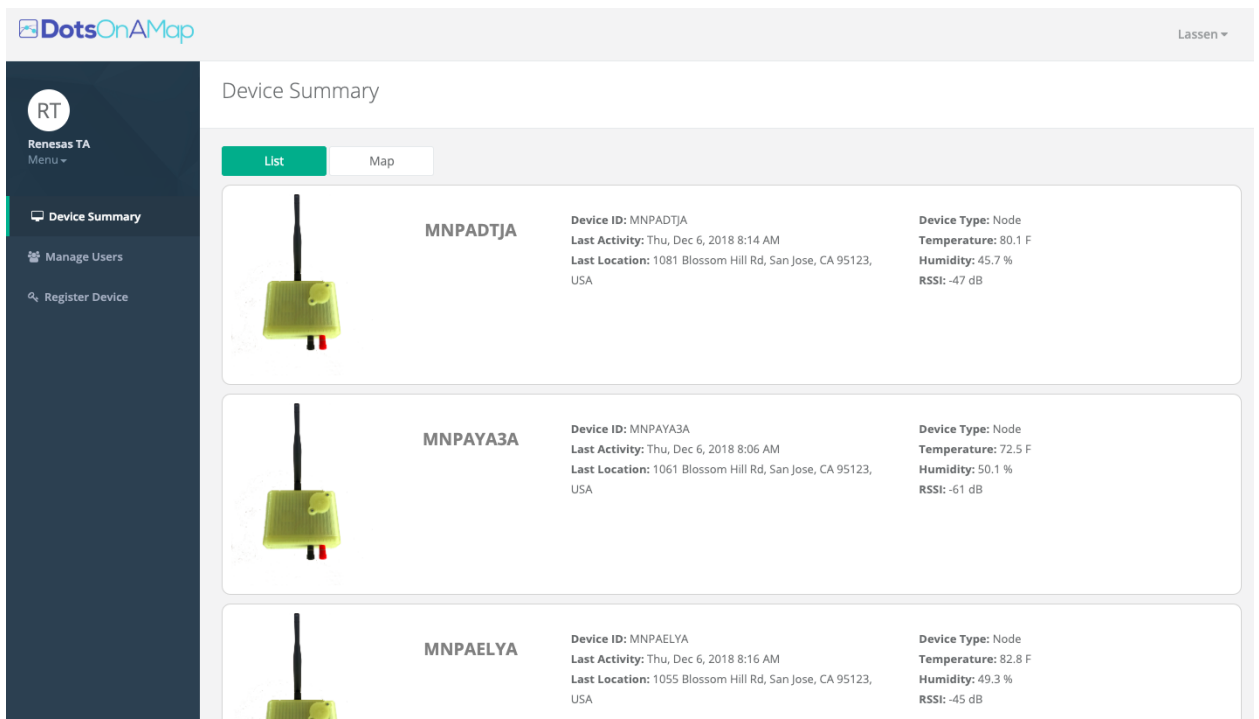
The python code is open and available to modify and customize. Full documentation and specs are available upon request.





The User Portal

The User Portal is the end-customer facing view of the Dots on a Map solution.



Each page the customer interacts with is called a dashboard. The Dots on a Map solution initially starts with two main dashboards. The one seen above is called the Device Summary dashboard. It has both a list view of all devices, showing an image of the

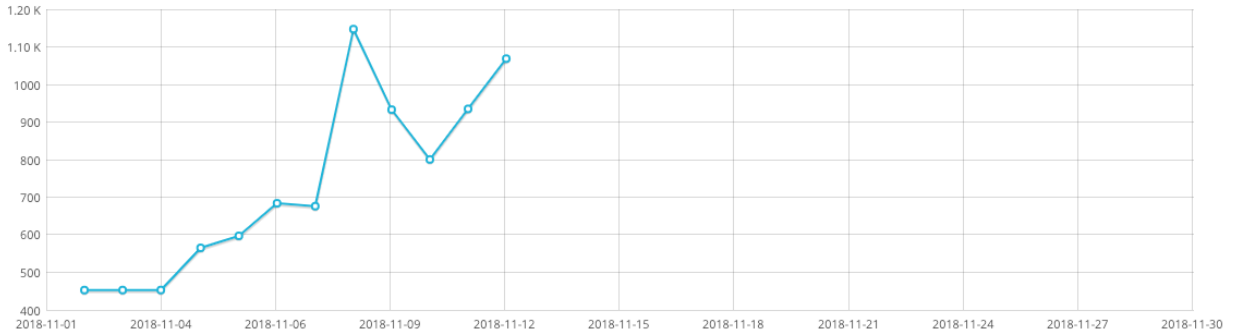
device, and a summary of a few of the sensor values, while also providing a Google Maps view of the location of all the devices based on received GPS data seen below.

The screenshot shows the DotsOnAMap application interface. On the left is a dark sidebar with a menu containing 'Renasas TA', 'Device Summary', 'Manage Users', and 'Register Device'. The main area displays a Google Map with a pop-up window for device 'EMVAQCBA'. The pop-up shows the following data: Air Quality 452 (index), Humidity 48.5%, Temperature 72.5 F, and RSSI -63 dB. The map shows the device's location at the intersection of Blossom Hill Rd and Almaden Expy. A copyright notice at the bottom reads 'Copyright © 2017 Medium One. All Rights Reserved.'

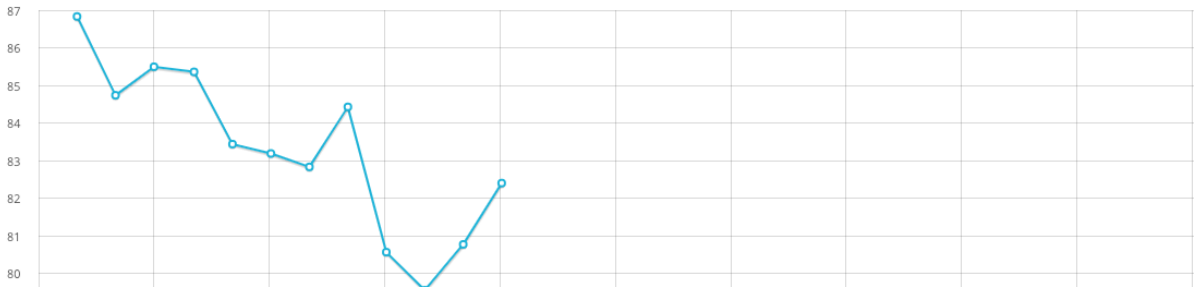
The second main dashboard is the Device Detail page. This page shows all the data provided by the device, including historic data over configurable date ranges.

The screenshot shows the DotsOnAMap 'Device Detail' page for device 'EMVAQCBA'. The page includes a sidebar with a menu and a main content area. The device information is as follows: Device ID: EMVAQCBA, Device Type: Node, Place: Mall, Last Activity: Thu, Dec 6, 2018 8:00 AM, Gateway Device ID: 7XFABZRQ, LoRa Network Key: 257, and LoRa Node Address: 51. There is an 'Unregister device' button in the top right. A Google Map shows the device's location in the Alamo area. At the bottom, five circular gauges display sensor data: Temperature 72.5F, Humidity 48.5%, RSSI -63dB, SNR 8, and Air Quality 452(index). A copyright notice at the bottom reads 'Copyright © 2017 Medium One. All Rights Reserved.'

Air Quality [ppm] (daily average)



Temperature [F] (daily average)



The Device Detail page also allows the customer to configure their own alerts so that they can be notified based on conditions at the sensor node such as bad air quality.

Adding Alert

No alerts configured

Configuration

Name:

Enable:

Rule

Trigger:

Condition:

Value:

Actions

✓ ⌘

Alerts

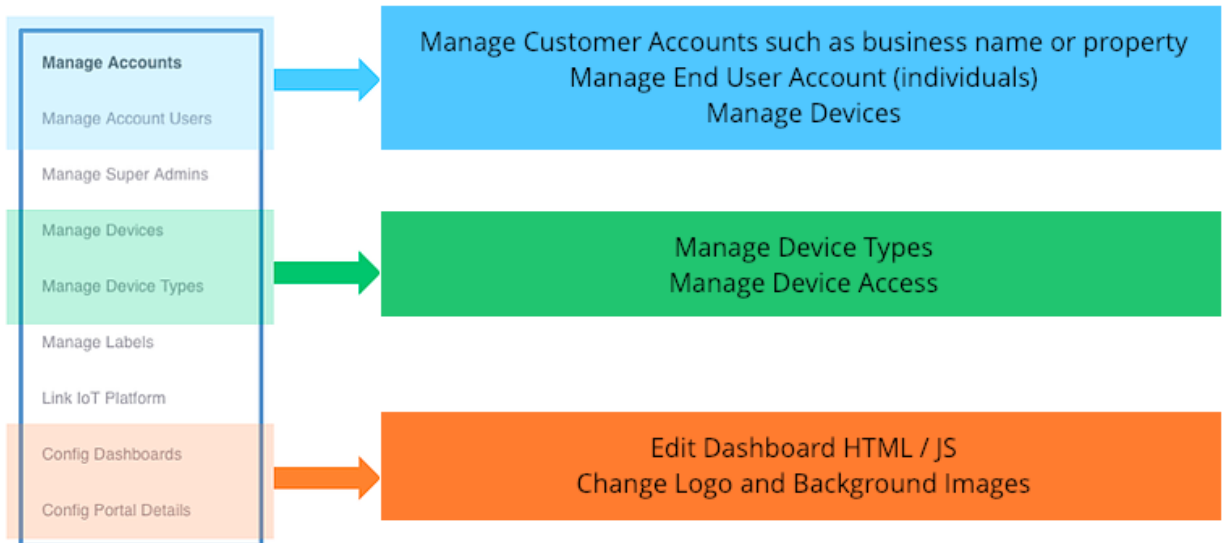
Bad Air Quality - Enabled ✎ 🗑️

Trigger:	Air Quality [ppm]
Condition:	Rises above
Value:	120

Action:	SMS and Email
Max Notification Rate:	Daily

[Add Alert](#)

The Dots on a Map User Portal is a customized deployment of Medium One's User Portal solution. The User Portal is designed to be flexible and easily configurable so that it can be deployed for any application. When a customer is invited to access the User Portal, they are first added to a customer account; e.g., an account could represent the company with which the customer is affiliated. The User Portal handles user roles, permissions, and device management across accounts, and is also designed to be fully multi-tenant so that many customer companies and customer users can be supported on a single deployment with data isolation.



The User Portal directly links to the IoT Sandbox project so that the devices and data are readily accessible in dashboards. The dashboards are easily created and customized simply by editing HTML or JavaScript and uploading it through the User Portal Dashboard Editor.

Page Name: Show page in navigation menu for Make public

URL: <https://portal-tahoe.mediumone.com/web/#app/pages/mydevices>



How to Deploy

The GitHub page <https://github.com/Medium-One/dots-on-a-map> hosts the following resources to enable quick adoption and deployment of the Dots on a Map solution:

- RX231-based Sensor Node schematic and Gerber
- RX231-based Sensor Node firmware source code (IAR project format)
- RX65N-based Gateway firmware source code (IAR project format)

For more information on rapidly deploying with a customized IoT Sandbox and User Portal, contact Renesas (<https://www.renesas.com/us/en/support/contact.html>) or Medium One (<https://www.dotsonamap.io/>).

Conclusion

The Renesas and Medium One partnership has allowed a truly end-to-end solution for the long-range, low-power asset monitoring problem to be available to customers. From sensor-rich and secure hardware to a scalable cloud customized for the end customer, the Dots on a Map solution is ready today for rapid deployment and customer success.

Renesas Electronics supports all aspects of application development for the RX family with products such as the Integrated Development Environments (IDE), real-time OSs, middleware, and programming tools. The RX Family consists of 32-bit microcontrollers that realize both high-performance and low-power consumption with max. 5.8 CoreMark/MHz and max. 44.8 CoreMark/mA. Contact Renesas (<https://www.renesas.com/us/en/support/contact.html>) to learn more about the features of the RX Family that allow you to reduce costs, simplify system design, reduce total power consumption, and implement added value.

Medium One allows developers to rapidly build IoT solutions that leverage leading hardware from our partners, a secure and scalable cloud solution for device communication and data processing, and an end-customer facing User Portal designed

to make life easier for our fellow developers. All the functions needed for development are included – from connecting to the Cloud and processing device data, to IoT-centric libraries with notifications, machine learning, and analytics functions for predicting trends and detecting anomalies. All data is handled in a secure environment with robust multi-layered security features. With Medium One, developers can focus on their application logic while we quickly extract intelligent insights to power their applications.

References

Go to <https://www.dotsonamap.io/> for more information.

- [1] <https://www.renesas.com/>
- [2] <https://www.medium.one>
- [3] <https://www.addvaluetech.com/satcom-iot-via-lora-wan/>
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- [9] https://www.researchgate.net/publication/315757362_Smart_Street_Light_Management_System_Using_LoRa_Technology
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