THE LoRaWAN™ SENSOR DESIGN CONVERSION GUIDE

V2

machineQ™

A COMCAST COMPANY

CONTENTS

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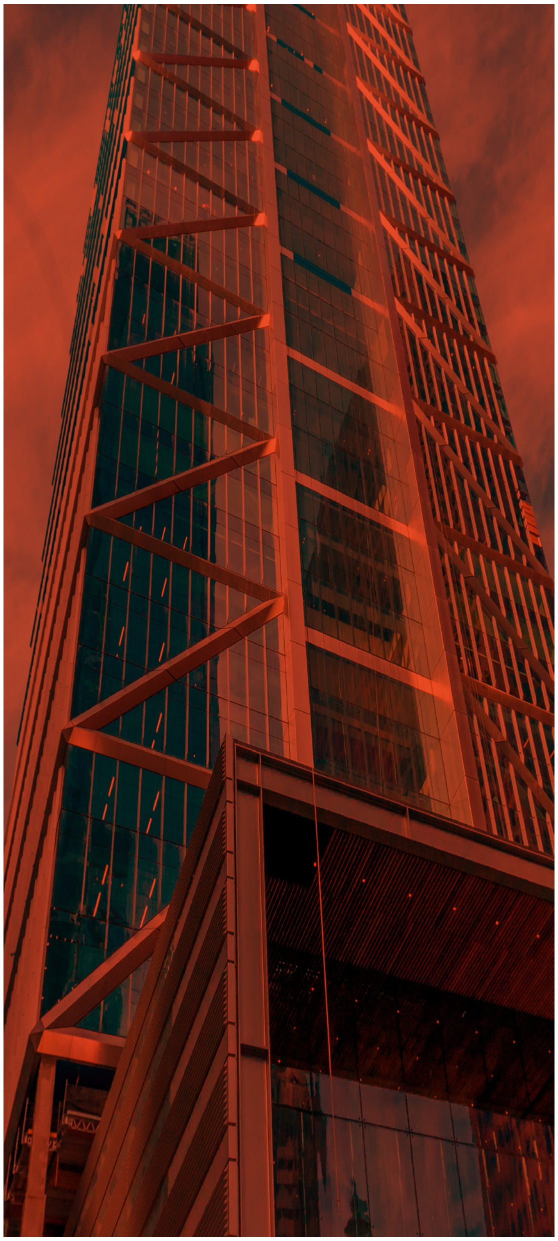


1. ABOUT MACHINEQ™

Welcome to the machineQ™ Sensor Conversion Guide. This technical design guide will help ease the migration of your device to LoRaWAN. It provides the information and resources you need to quickly bring your innovative IoT solution to market with machineQ.

Global adoption of the Low Power Wide Area Network (LPWAN) and Long Range Wide Area Network (LoRaWAN) protocols have grown tremendously. The affordability of LoRaWAN technology (module and costs of connectivity) is driving down total cost of ownership (TCO). Additionally, the specification is backed globally by the LoRa Alliance, the international non-profit devoted to standardizing LoRa®.

MachineQ is a secure, cloud-based, scalable IoT platform offering fully integrated LoRa gateway and device management, monitoring and services for business. This includes:

- A streamlined end-to-end onboarding experience
- A management tool built to monitor sensors and gateways
- Easy-to-use APIs that simplify interaction with your application
- Tools and developer assistance programs

Our IoT platform is well suited for a wide range of use cases including those requiring energy efficiency, wide area coverage outdoors and deep inside buildings.

2 DEVELOPMENT KITS

To build a sensor prototype, our sensor development kits are the easiest way to get started. There are three to choose from: mQSpark, ST Discovery Kit and mQFlex.

2.1 mQSpark

Comcast's machineQ offers a plug-and-play development kit, mQSpark, for the rapid prototyping of IoT solutions (Figure 1).

The dev board is designed as a USB module that is easily plugged into your laptop to configure and power your application. Once configured, the board can be connected to a powerbank for mobility. mQSpark works with the open source Arduino IDE platform, which lets developers tap into a huge community to speed up the development process, and find sample code that supports AT commands.

Figure 1: mQSpark

mQSpark includes the development board and a variety of related Grove sensors, which have an easy-to-use standardized connector, including temperature/humidity, sound, distance, etc. There are over 75 additional Grove sensors for purchase at Seeed Studio.

You can get started with this ultimate Grove sensor-compatible tool in just five simple steps This is one of the quickest ways to get started with prototyping and testing LoRaWAN™. For more information on the mQSpark, please contact info@machineQ.com or visit www.machineQ.com/develop.

2.2 ST Discovery Kit

The ST Discovery Kit is ideal for building sensors from scratch. It requires a more advanced level of technical expertise than mQSpark and is available through well-known distributors, such as Mouser or Digikey.

While the mbed online compilation environment is supported, the recommended integrated development environment (IDE) for professional development is Keil. Keil is the complete software development environment for a wide range of Arm Cortex-M based microcontroller devices.

Figure 2: ST Discovery Board

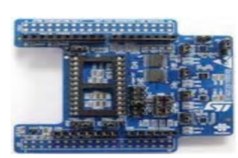


Figure 3: Shield for ST Discovery Board

The ST Discovery Software Development Kit (SDK) supports the Murata module. It includes a special patch file that configures the IO connection between the ST MCU and the Semtech® SX1276 RF IC. The LoRaWAN™ stack is available in I-CUBE-LRWAN firmware package. The SDK is available through the ST website.

For more information on the ST Discovery Kit and its Software Development Kit (SDK), please visit www.machineq.com/develop and the ST website.

2.3 mQFlex™

mQFlex™ is a multi-usage sensor for quick deployment across wide range of IoT use cases. It is a robust LoRaWAN-compliant multi-usage device capable of monitoring temperature, acceleration, pressure, and humidity, and includes a gyroscope and magnetometer.

mQFlex™ is compact and has a long battery life (3-5 years), which makes it a cost-effective solution to collect data and trigger threshold detection mechanisms in a wide variety of applications. mQFlex™ is a low cost, rapid-to-market solution that can support any business model from use case validation to mass implementation with its easy out-of-the-box configurable capabilities.

Figure 4: mQFlex™

Key Benefits:

- Provisioned for machineQ network and optimized for the U.S. market (up to 20dBm transmissions for long-range communications)
- Reduced time to market
- Compact size: 65 x30 x28 mm (LxWxH)
- Robust casing medium meets IP67 specification
- JavaScript application with NFC interface for easy programming and modification

The mQFlex™ can be programmed to showcase machineQ's network capabilities and easily test your network. It is the easiest way to trial a LoRaWAN™ device and bring a realized solution to market.

For more information on the mQFlex™, please contact info@machineQ.com or visit www.machineQ.com/develop.

3. HARDWARE DESIGN CONVERSION

Let's now carefully examine several key aspects of your hardware design. A typical IoT device will have some or all of the components shown in Figure 5.

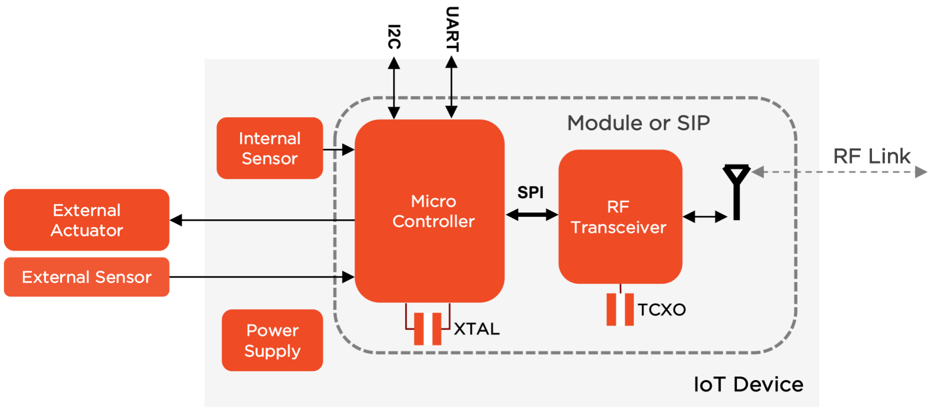


Figure 5: Basic IoT Device Block Diagram

3.1 Hardware Component: Antenna

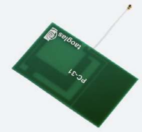
The antenna is a key component for reaching the maximum distance in the wireless communication link between the IoT Device and the LoRaWAN gateway(s) to which it will connect. The goal of an antenna is twofold: to transform electrical signals into RF electromagnetic waves, propagating into free space or transmit (TX) mode, and to transform RF electromagnetic waves into electrical signals or receive (RX) mode. Its type, design, orientation and positioning can make or break your RF link.

Compare Antenna Life

Your current IoT device probably uses one of following types of antennas:

- A simple quarter wavelength wire antenna
- A Printed Circuit Board (PCB) antenna that is printed on the circuit board, either homegrown or purchased as IP from a third-party antenna design company
- A chip-based antenna
- A simple quarter wave coil antenna
- An external quarter wavelength whip antenna

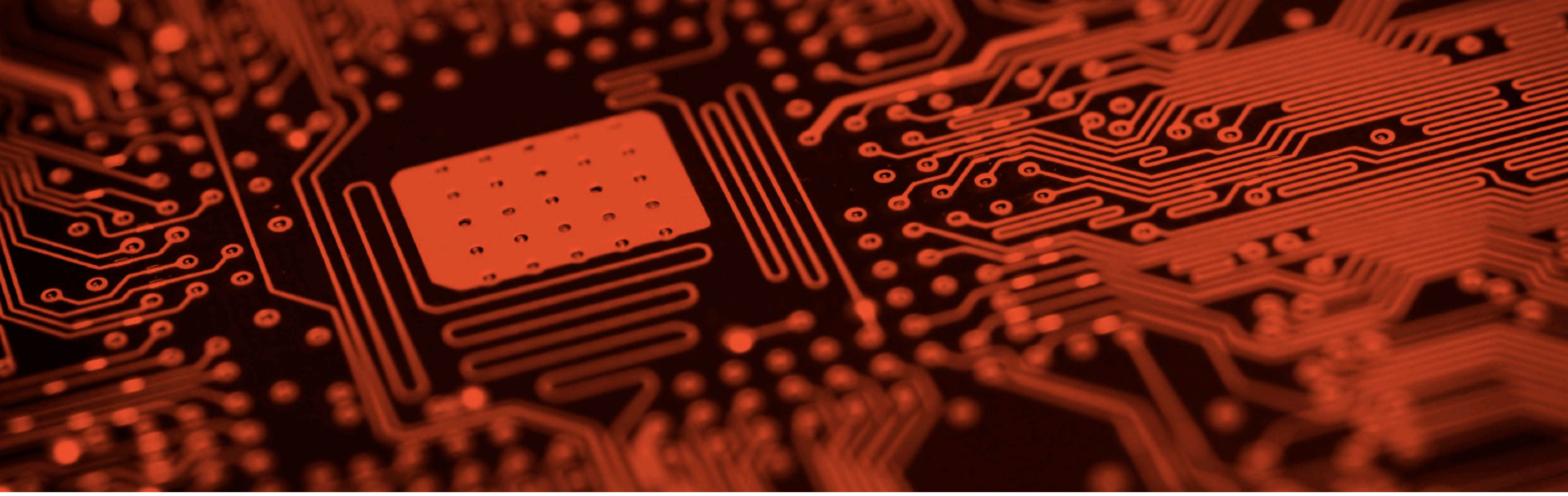
Switching to LoRaWAN will require an antenna with a quarter wavelength tuned specifically for the US LoRaWAN carrier frequency spectrum of 902-928 MHz. Table 1 below shows the pros and cons of each of these types of antennas, which we discuss below. Your antenna choice will ultimately become a trade-off between cost, size and performance.

Antenna Type	Wire Antenna	PCB Antenna	Chip Antenna
Image			
Cost	Lowest	Low (if sufficient PCB are available)	Moderate*
Performance	Moderate	Moderate	Moderate
Additional Details	Easiest implementation Volume manufacturing Performance repeatability	Widely available Requires a relatively large area for a typical IoT PCB design Sensitive to quality of ground plane design and placement of nearby components	Matching circuitry often required to truly meet published chip antenna specs

Antenna Type	Coil (Helical) Antenna	External (Whip) Antenna	IP Antenna (PCB antenna purchased from a 3rd-party)
Image			
Cost	Low (relative to chip antennas)	High	Moderate (relative to chip antennas)
Performance	Moderate	High	Moderate (compared to home grown designs)
Additional Details	Detailed attention must be paid in PCB layout/ placement	Shorter design cycle Placement can be problematic (for small IoT devices) Could require a conducted emissions test External connector is required	Support from IP company

Table 1: Antenna Comparisons

** Relative to chip antenna cost: $0.10-.60*



Quarter wavelength wire antenna: This is the easiest and cheapest solution available. One of the issues in IoT end-device volume production is to minimize variations in antenna placement. Care must be taken in fitting the antenna wire inside the end-node housing to ensure a consistent RF performance on all the devices.

PCB antenna: In essence a copper trace on a printed circuit board tuned for the specific carrier frequency range, 902-928 MHz in our case. If there is plenty of PCB space available, this is a viable option for an antenna. Care must be taken in the design as length, width and thickness of the copper trace all play a part in the efficiency of the antenna. Since the size and shape of the ground plane will affect the antenna radiation pattern, great care must be taken with the ground plane design. The cost of these antennas is typically the same as a chip-based antenna. The major added cost is the additional PCB area needed for the antenna layout. Some design companies sell their PCB antennas as Intellectual Property (IP), and their available support is an advantage over a homegrown PCB antenna.

Chip-based antenna: This antenna takes up a fraction of the board space compared to a PCB antenna but will add BOM and assembly cost. If the available board space is limited, a chip antenna is a viable solution as it allows for small size solutions at 915MHz. Chip antenna specifications are derived from measurements on test boards with a given size thickness, layers, and size. Since the PCB size of your IoT end-node design will differ from the size of the test board, care must be taken in matching the circuitry between your radio and the chip antenna or the published performance parameters will not be met.

Coil (Helical) antenna: A lower cost alternative compared to a chip based antenna. A helical antenna is simply a length of wire that is wound into a coil. The overall length of the wire determines its resonant frequency. Coiling the wire can greatly reduce its physical size. Helical antennas have a narrow bandwidth, which is not a problem for LoRaWAN™ since we only use 903-928Mhz, a narrow part of the ISM spectrum. Coil antennas can be easily detuned by the presence of other objects on the PCB, so care must be taken in the layout of the design.

External quarter wavelength whip antenna: The ideal antenna from a sensitivity and gain perspective, tuned for 915Mhz. But this is also the most expensive solution and the one that takes up the most space. An external whip antenna will add to the cost of the antenna, and increase the BOM cost since an external connector is required (usually an SMA connector). Also, it is likely that in order to pass FCC regulations, a conducted emission tests must be performed even if you use a pre-qualified RF module.

3.2 Hardware Component: Power Supply

The power supply can be an internal battery, an external power source or a combination of both. For example, the device could have a small solar cell connected to a re-chargeable battery. Since one of the key objectives of LoRaWAN technology is to use sensors that can operate on the same battery for years, it is crucial to estimate the battery life for your sensor design.

To estimate the battery life:

1. Determine five main power consumption modes of the hardware (HW):

   OFF/SLEEP: All electronics are turned off or in sleep mode.

   IDLE: Radio, sensor(s) all other electronics turned off except for the Microcontroller.

   RUNNING: The device is operational (no RF transmissions).

   LORA TX: The device is sending data over the LoRa® Radio TX output.

   LORA RX: The device is receiving data over the LoRa Radio RX input.

2. Calculate how much current the device will consume in each mode.
3. Estimate how long the device will be in each mode per hour, day or week.

Compare Battery Life

To further understand battery life, it is helpful to compare your estimation to a worst-case battery life and an average battery life. You can look at a worst-case scenario where all LoRa Radio uplink (UL) packets are sent using the worst-case spreading factor. For instance, SF10 has the longest time-on-air and therefore uses the most power.

Compare this to a scenario where the four spreading factors available for LoRa UL Radio messages are used evenly. For instance, Table 2 shows the four different spreading factors [SF7-SF10] that can be used for UL messages on a 125KHz channel. It shows the equivalent bit rate as well as the estimated range, which depends on the terrain as longer distances will be achieved in a rural environment compared to an urban environment. It also shows the time-on-air (TOA) values for a payload for each of the four spreading factors.

Spreading Factor [for UL at 125Khz)	Bit Rate	Range [dependent on terrain conditions]	Time on Air for an 11-byte payload
SF10	980 bps	8 km	371 ms
SF9	1760 bps	6 km	185 ms
SF8	3125 bps	4 km	103 ms
SF7	5470 bps	2 km	61 ms

Table 2: LoRaWAN™ Spreading Factors with Bit Rate, Range for an 11-Byte Payload

Battery calculators

- MachineQ offers a battery consumption calculator upon request
- Semtech® offers a LoRaWAN™ calculator that provides time-on-air data, energy consumption and help with the evaluation of link budgets for their LoRaWAN transceivers
- For an example, please see the battery life calculator for an Elsys sensor

3.3 Other Hardware Components

Sensors (or Devices): One or more internal and or external sensors that either have an analog or digital interface. Many microcontroller units (MCUs) now come with basic analog-to-digital converter (ADC) functionality, so connecting an analog sensor's input is straightforward.

Actuator(s): One or more usually external actuators like a lock or a valve.

Microcontroller: This device runs software functions such as controlling the end-node; sampling the sensor data; formatting the sensor data into the transmission protocol's payload format; scheduling of radio messages (packets) to some kind of gateway; and communicating with the network controller.

RF Transceiver: This device will convert the digital packetized sensor data to an analog radio signal by modulating it onto an RF carrier frequency. It will also receive incoming RF radio messages, perform de-modulation, convert the analog signals back to digital and forward the incoming radio messages to the microcontroller.

Controller + Transceiver

Often the microcontroller and the RF transceiver for an existing solution are provided as a single "unit." This can either be in a single chip solution or in a module.

> **Using a single chip solution:** From a hardware point of view, the key component that needs to be changed is the RF transceiver. Your current solution could use BLE, Zigbee, Z-Wave or even Cellular. If your IoT device uses a module type design, such as an integrated Microcontroller and an RF Transceiver—it is relatively straightforward to replace this controller/transceiver module with a module from a module manufacturer such as Murata. Please see "LoRa Module Implementation Options" for more details.
>
> **Using a module:** Instead of putting a discrete transceiver like the Semtech® SX1276 directly on your PCB, using a module will allow you to skip most FCC certification as all modules are already pre-certified. A module will also decrease your time to market. Once you have found the right module with the same sensor interfaces as on your existing device, you will have to redesign your PCB to fit the new module or microcontroller/SX1276 combination.

3.4 LoRa Module Implementation Options

Murata Modules enabled by LoRa®

When evaluating modules, consider the fact that the Murata module is one of the smallest high performing modules available today. It provides key advantages for designing sensor products in terms of ease of use and flexibility. It also offers a wide frequency range coverage allowing sensors to be deployed in many countries.

Key Features:

- Semtech® SX1276 RFIC ultra long range spread spectrum wireless transceiver and an ST Micro STM32L0 series Cortex-M0+ CPU with 192KB Flash and 20KB RAM
- Pre-certified radio regulatory approvals for operating in the 868 and 915 MHz industrial, scientific and medical (ISM) spectrum in most geographic regions. This pre-certification allows you to skip most FCC certification and use Certification by Similarity to reduce your time to market.
- Variable RF output power that is variable covering up to 14dBm and up to 20dBm for longer range
- Available peripheral I/O interfaces include SPI, I2C, and UART
- Suitable for a wide range of temperatures: -40°C to +85°C
- 12.5 x 11.6 x 1.8mm size
- Wide operating voltage range of 2.2 to 3.6V
- Two versions are available (view the data sheet here):
  - **MQ100** requires the user to load software (open MCU)
  - **MQ200** is pre-loaded with AT commands to enable simpler code development (modern version)

The next step after the module evaluation is the actual PCB design of the sensor. The Murata module provides significantly more ease of use, as circuit design is not necessary for the RF IC, RF switch, MCU and clocks. It offers quick time to market with fewer design cycles needed as the majority of design is already done within the module.

MachineQ has optimized the firmware for the Murata module, and we have exclusive distribution rights to the module and stack at a reduced price for machineQ customers.

Additionally, Murata provides both hardware and software technical support for machineQ customers. For hardware technical support, schematic and layout review are offered. During this process, Murata can assist in module placement location, RF connection to antenna, and antenna placement.

Murata offers machineQ customers pre-negotiated strategic pricing for a minimum quantity of 1,000 units. To learn more about machineQ's strategic pricing on Murata modules, please contact info@machineQ.com and visit machineq.com/murata-module.

3.5 Ultra Low Power Reference Design

MachineQ also offers an ultra low power reference design for TX-only use cases. This LoRa reference design delivers optimized hardware components at the lowest possible BOM cost—it is ideal for developing and realizing almost any IoT solution, from pest control to leak detection.

Key Features:

- Semtech® SX1260 transceiver
- Atmel ATTINY-1616-MNR MCU
- 915 MHz ceramic ISM antenna
- CR2450 lithium coin cell battery
- Radio: QFN 2.7mm x 2.7mm x 0.9mm
- Up to 14 dBm transmit power (TX only)
- Wide operating voltage range of 2.2 to 3.6V
- I2C compatible

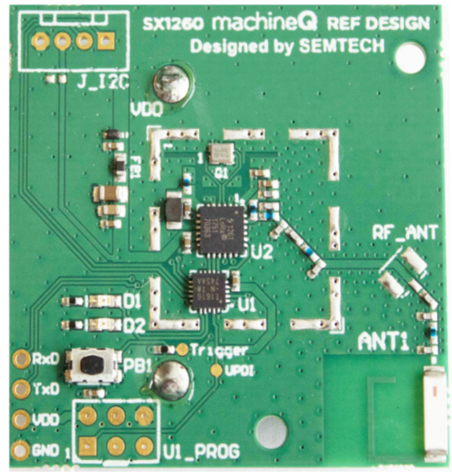


Figure 6: MachineQ Ultra Low Power Reference Design

Sample Use Cases:

- Moisture detection
- Pest control
- Humidity monitors
- Touch sensing
- Motion detection

Key Benefits:

- Total BOM cost: <$3 at volumes above 10K
- Long battery life
- Easy configuration
- Adaptable to a wide range of use cases

The reference design takes the guesswork out of picking the right hardware and integrating it with your existing designs. Contact machineQ to request a sample of the reference design and learn more about our discrete design and module offerings.

4. SOFTWARE DESIGN CONVERSION

A basic IoT device will have typical software (SW) architecture as depicted in Figure 7 to the right.

- First, there is a **hardware (HW) layer**. This is an assortment of lower level device drivers to connect to a USB, a UART, analog or digital interfaces, in essence providing a HW abstraction layer to the middleware.
- **The middleware layer** implements any communication protocol type functions. For example, if you have a Bluetooth connected IoT Device, then the BLE stack will be implemented in this middleware layer.
- Finally, **the application layer** contains the code that implements the device functionality and behavior.

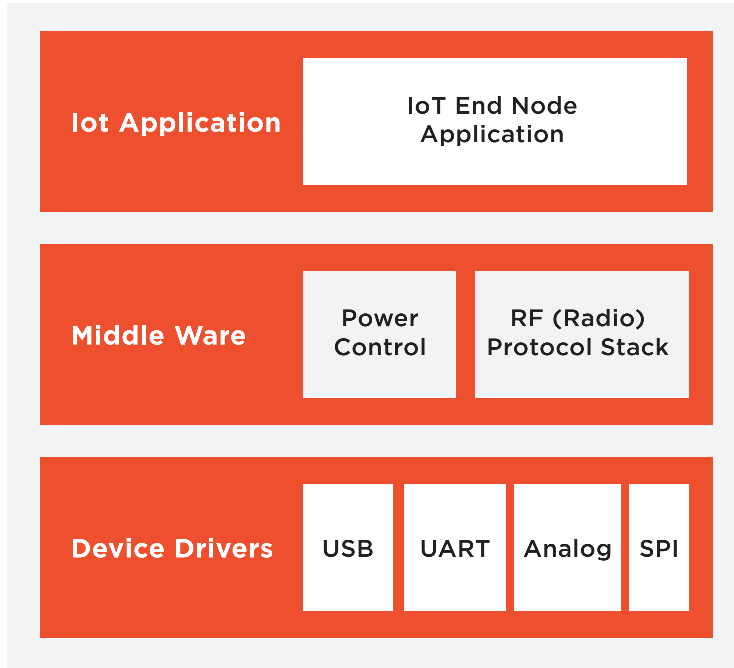


Figure 7: Typical IoT Device Software Architecture

4.1 Development Scope

The scope of the SW development will depend on the implementation of the HW architecture of the LoRaWAN™ end-node. The SW development in a LoRaWAN device conversion involves replacing the current communication protocol stack—for instance, BLE, ZigBee or Z-Wave—with a LoRaWAN protocol stack.

The good news is that HW-independent open source code solutions for this stack are on either Stackforce or Github.

A basic LoRaWAN stack takes up about 55-60KB of code space, so care must be taken in selecting the right MCU memory for your design. Since memory is relatively less costly, more memory is better, especially when considering being able to support firmware over-the-air (OTA) updates.

An OTA firmware update will involve fragmenting a relatively large amount of data in manageable chunks, adding parity information then broadcasting them to all sensors. Even if certain sensors do not receive all the fragments, they will be able to recreate the missing fragments from the added parity information, just like in a system defined as Redundant Array of Independent Disks (RAID System).

4.2 Payload Format

One way to make displaying and processing of information easier is to utilize industry recognized or de facto formats for payload transmission and receipt.

MachineQ is extending and refining well-known payload formats such as Low Power Payload (LPP). The machineQ payload formats, like LPP, provides a convenient and easy way to send data over LoRaWAN™. The machineQ payload format incorporates the payload size restrictions, which can be lowered down to 11 bytes where applicable, and allows the device to send multiple sensor data at one time. Additionally, the transmission of different sensor data in different frames is a must for LoRaWAN implementations.

In order to do that, each piece of sensor data must be prefixed with two bytes:

Data Channel: Uniquely identifies each sensor in the device across frames, such as "indoor sensor."
Data Type: Identifies the data type in the frame, such as "temperature."

If you choose to implement your own payload scheme, note that you will need to provide the app server of your choice with a way to decode your payload.

For additional information on LPP, please visit the following website. Please contact machineQ for details pertaining to machineQ payload formats.

4.3 Optimizing Your Data Transmissions

Because battery consumption will always be a consideration, a best practice is to make data transmission as efficient as possible to make sure power requirements are kept to a minimum. There are five ways to optimize data transmission periodicity for LoRaWAN devices:

1. Bulk transmissions: An application can measure once every minute for 2 hours, taking a total of 120 readings and saving them in RAM as 1 byte. The application transmits a packet of 120 bytes rather than sending 120 individual transmissions.

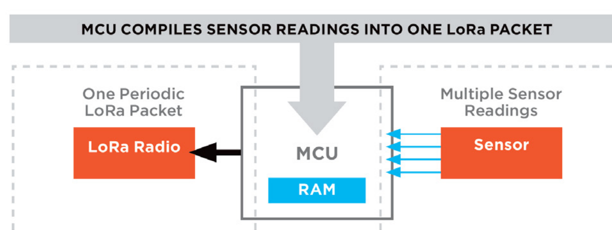


Figure 8: Bulk Transmissions

2. Alerts: Users can define thresholds and receive notifications or alerts when those thresholds have been exceeded. This helps detect sudden changes or anomalies in real time.

3. Avoid unnecessary downstream traffic: The LoRaWAN MAC layer can support two types of payload data messages. *Confirmed messages* require an acknowledgment from the network server, which takes battery power. *Unconfirmed messages* do not require an acknowledgment. By using confirmed messages only for alerts and unconfirmed messages for normal, periodic transmissions, battery power is conserved.

4. Overlapping measurements: Because overlapping readings provide a layer of data redundancy, the sensor does not have to send confirmation messages for periodic transmissions. Retransmissions are not required, even with packet loss.

TIME									
t0	Frame #1	READING 1	READING 2	READING 3	READING 4	READING 5			
t1	Frame #2		READING 2	READING 3	READING 4	READING 5	READING 6		
t2	Frame #3			READING 3	READING 4	READING 5	READING 6	READING 7	
t3	Frame #4				READING 4	READING 5	READING 6	READING 7	READING 8

Figure 9: Overlapping Measurements

5. Heartbeats: The sensor should send a heartbeat once a day regardless of whether it has any readings to send. This shows the network and application servers that the device is still online.

5. CONNECTING TO MACHINEQ

The next step in the sensor conversion process is connecting your device to machineQ.

How do you optimize your LoRaWAN device for machineQ?

When migrating your existing IoT device to LoRaWAN, you will need to carefully analyze your message payload requirements, as well as the periodicity of these messages. Assuming you have a battery-operated device, an optimized LoRaWAN device can ideally fit all its data into an 11-byte payload (or multiple 11-byte payloads) with an average radio message transmit periodicity measured in minutes, hours or days.

To highlight the LoRaWAN™ network, we have re-configured the end-node IoT Technology stack as depicted below.

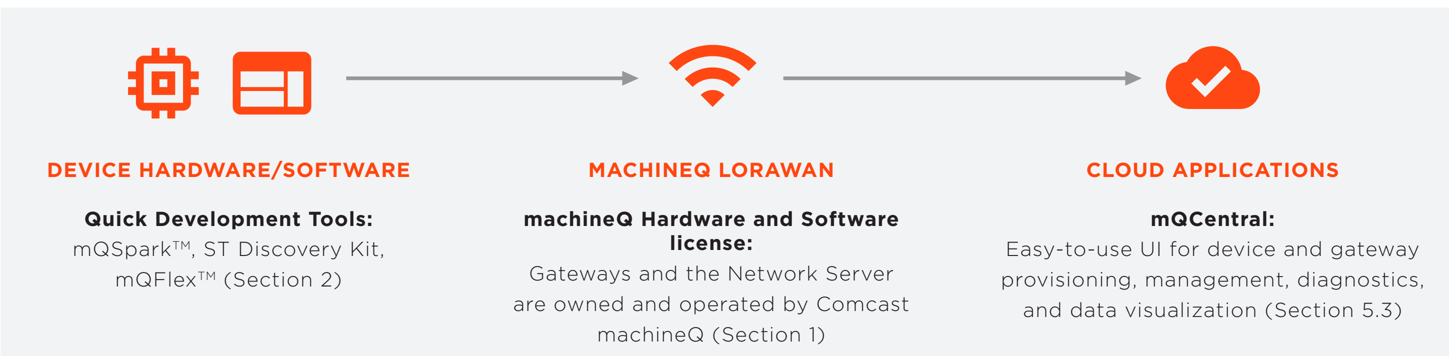


Figure 10: LoRaWAN IoT End Node Technology Stack (proprietary to machineQ)

5.1 How to Add a Device to machineQ

There are two methods to connect a LoRaWAN IoT device to a LoRaWAN network:

- The default method is through a procedure called Over the Air (OTA) Activation.
- The second method is Activation by Personalization (ABP).

Over the Air Activation Method

In the OTA Activation method, each IoT Device will send out a Join Request message to the Network Server, which then forwards this message to a Join Server, as shown below.

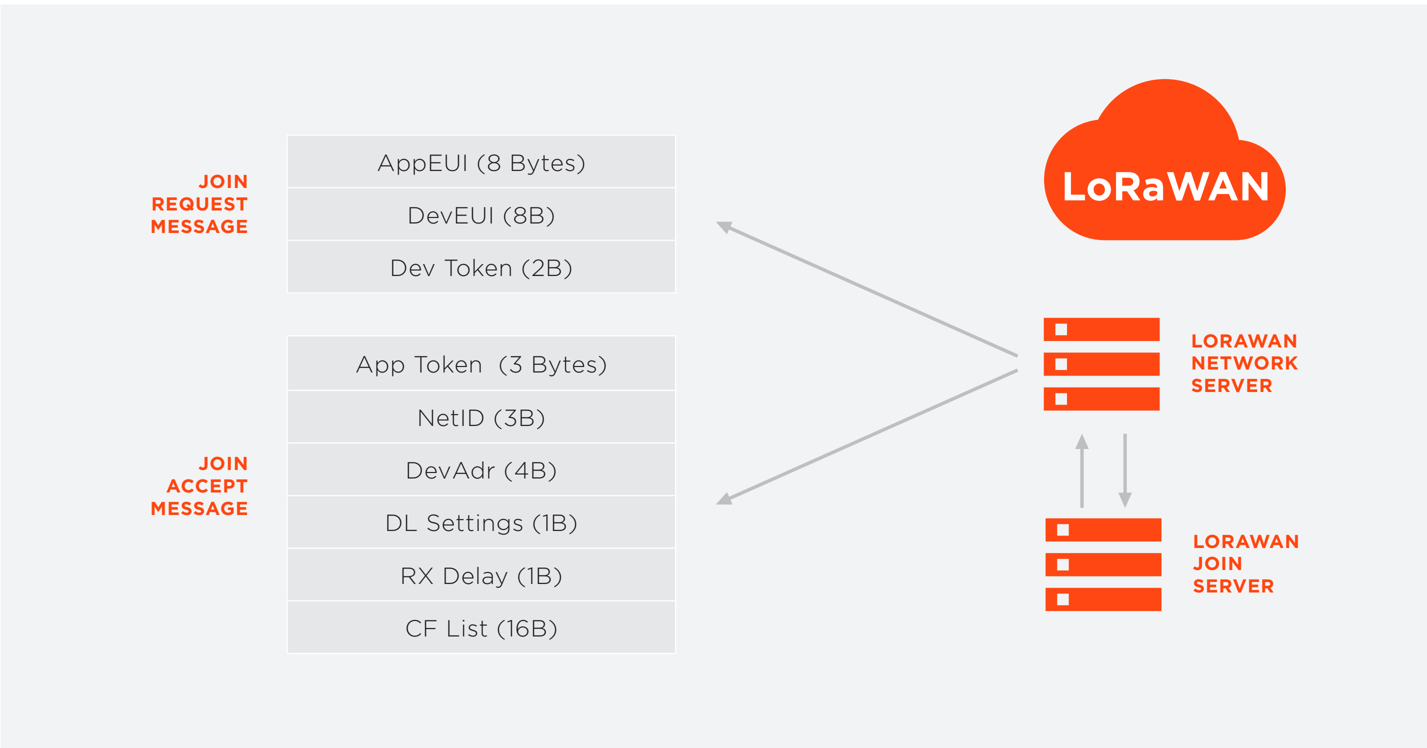


Figure 11: Join Request and Join Accept Message Formats

This Join Request MAC command will contain three data fields:

- An IEEE-defined 64-bit DevEUI that uniquely identifies this specific LoRaWAN™ sensor. Think of it as an "Ethernet MAC" address for LoRa® Devices.
- It will also send a unique AppEUI identifying the Application Server to which this specific sensor wants to connect.
- The final data is a random 2-byte Device Nonce.

The Join Server will store these random Device Nonces from previous Join Request messages from each sensor. If the Join Server receives a future Join Request from a specific end-node with a Device Nonce identical to a recently received one, the Join Server will ignore the Join Request.

Ignoring the request: This action will prevent "Replay Attacks" where a hacker could capture a Join Request radio message from a particular end-node and retransmit that message with the intent of disconnecting the original end-device from the LoRaWAN™ Network. If this occurs, the network server will not clear the previous session state until a valid UL is received which a replay attacker would not be able to generate.

Authenticating the request: Only if the Join server is able to authenticate the combination of DevEUI and AppEUI will it then issue a unique Device Address, Network ID and Application token. These parameters will be received by the end-node in a Join Accept command from the Network Server as shown in Figure 11 above.

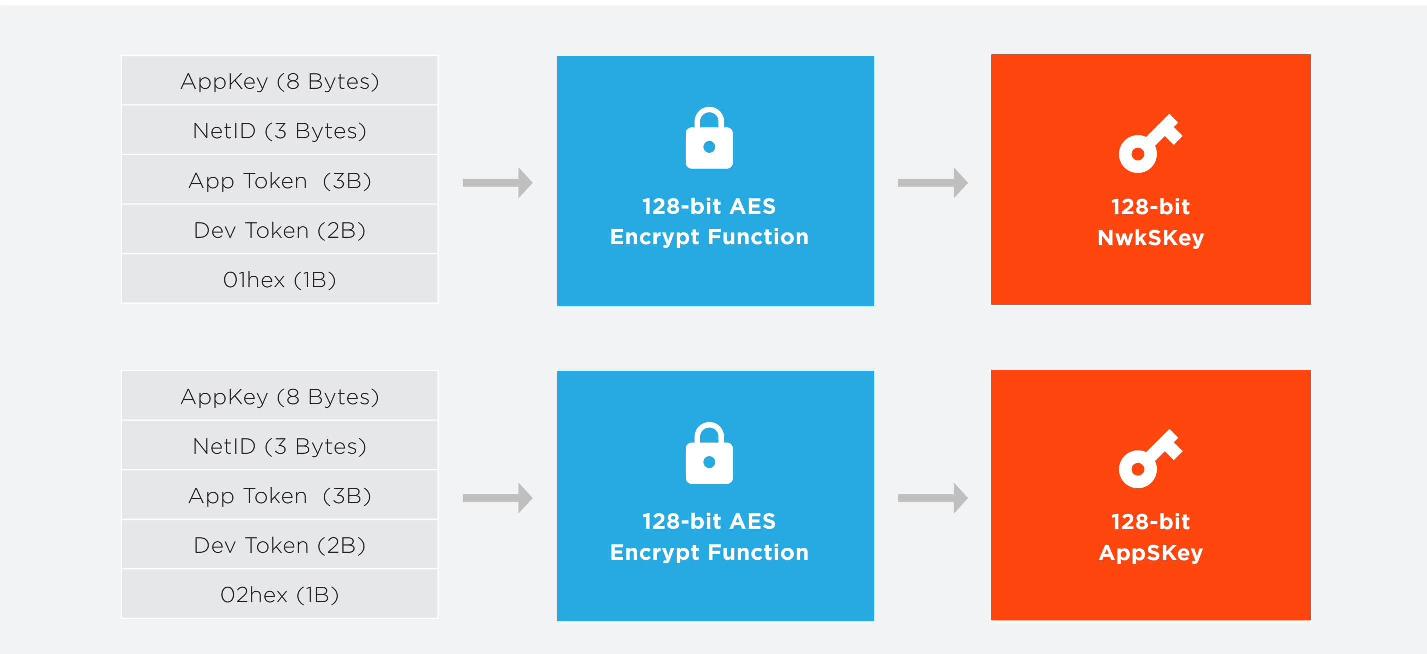


Figure 12: NwkSKey and AppSKey Generation (LoRaWAN™ 1.02 spec)

Security keys: The end-node can then generate its own security keys. Security keys are never sent over the air in the clear. Figure 12 above shows what fields are used to generate both the Application Session Key (AppSKey) and the Network Session Key (NwkSKey). One of the key fields to generate these keys is the AppKey, which is a 128-bit fixed value that is unique for each end node.

Reactivation: Besides the three data fields, the Join Accept message will also inform the LoRaWAN device which channel plan to use and provide other RF-provisioning parameters. Each time the end-node loses network connectivity and/or power, it can try to reactivate itself by transmitting a new Join Request message.

ABP Method

The second method to connect to the LoRaWAN Network is called Activation by Personalization (ABP). In this method, the Network Session Key and the Application Session Key are already stored in the end node together with a unique 32-bit Device Address and a unique 24-bit Network ID that identifies the specific LoRaWAN Network to which the device is meant to connect.

5.2 Application Server (AS)

mQCentral, an easy-to-use UI built for device and gateway management, provides users the ability to provision devices and gateways, run health diagnostics, manage users, and enable custom notifications. Depending on the use case and needs of the customer, device data (e.g. temperature) can be sent to either a machineQ application server for data visualization or to another AS of your choice.

machineQ AS: mQCentral is machineQ's powerful connectivity health, provisioning and debugging tool, designed to monitor devices and gateways, supply debugging assistance, and provide easy-to-use APIs to simplify interactions with your application.

mQCentral provides a platform to visualize device and gateway health over time, enabling users to pinpoint and address any issues as they arise. Custom rules ensure that our customers are notified immediately of critical alerts. mQCentral's customizable grouping features simplify the customer onboarding process for both devices and gateways.

Other AS: To facilitate the use of a non-machineQ AS, we have made machineQ APIs available to flow data to services like Azure, AWS, and SAP, where it can be processed and stored as needed via an mQCentral Output Profile.

For access to the machineQ API, please refer to the machineQ API documentation.

5.3 How to Create Secure Devices and Transmit Secure Data

A key element of the LoRaWAN™ network protocol is security. Its baseline authentication and security framework is based on the AES-128 encryption scheme. The National Institute of Standards and Technology (NIST) recommendation for key management approves AES-128 bit encryption beyond 2031. This is the same level of recommendation for AES-256 and the strongest recommendation they offer. By using separate keys for user data encryption and authentication/network integrity, LoRaWAN offers the ability for customers to not share the cryptographic key used for application payload encryption with the network operator.

The LoRaWAN architecture shows the two layers of network security:

- A control data layer between the devices and the NS for authentication and Integrity
- A user data layer that is transported from the devices to the AS (and back)

As such, there are two specific 128-bit AES encrypted keys defined, the Network Session Key (NwkSKey) and the Application Session Key (AppSKey). Each IoT Device will have its own unique NwkSKey and AppSKey, so if an attacker compromises the device keys of an end node, it will not affect the security of any other device on the network.

5.4 Testing and Certifications

The LoRa Alliance™ performs device testing, and will certify devices if they meet alliance standards.

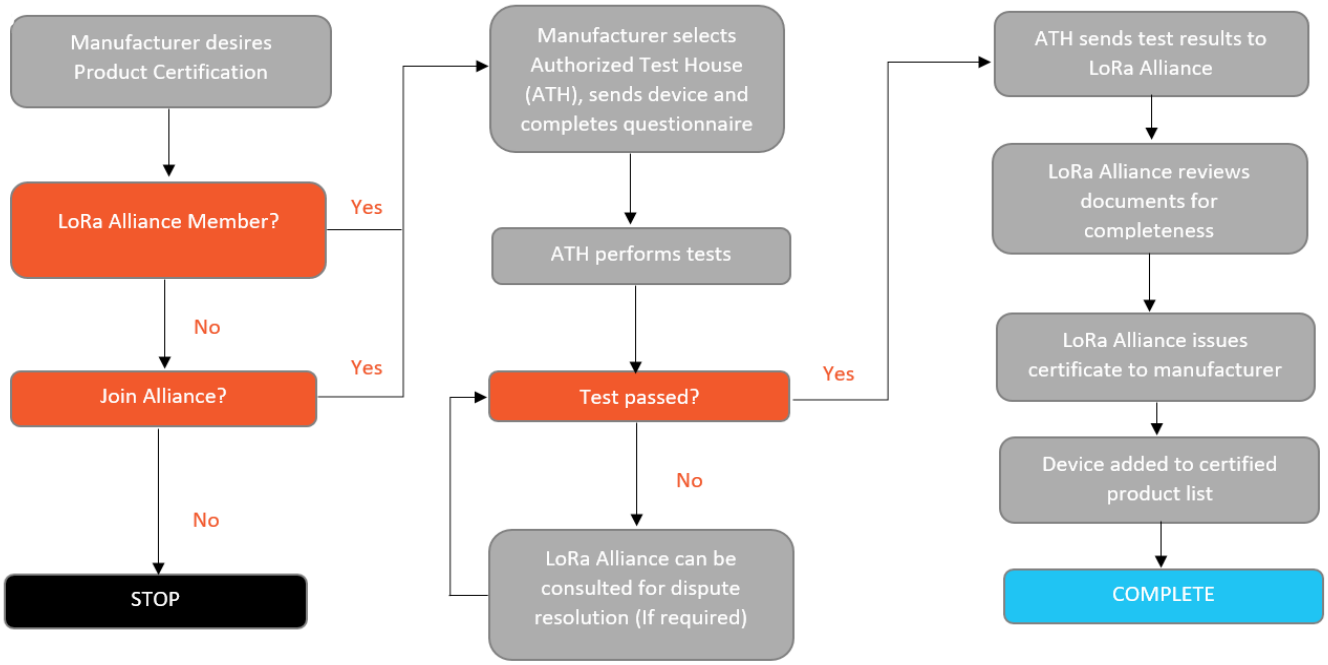


Figure 13: LoRa Alliance Certification Procedure

If you are using a previously certified module, you can use certification by similarity. To be certified, the manufacturer must:

- Be a member of the LoRa Alliance. Check the members list.
- Complete the declaration here.
- Complete the questionnaire here.
- Pick a test house to review your documents. The list of Authorized Test Houses (ATH) is available here.
- The test house signs off on the documents and sends them to the alliance. Alliance signs off and issues certification by similarity

If you require additional testing and/or certification assistance, Metova is a world-leading app and IoT development company that can help you test and certify your devices. MachineQ works with Metova to develop test procedures and perform testing against our own LoRa Device Implementation Guide requirements. To learn more about Metova, please visit its website and contact machineQ.com.

6. GATEWAY COVERAGE TOOL

In addition to all the tools and guidance machineQ can provide for your sensors, it now has added an online propagation tool to facilitate the placement of both indoor and outdoor gateways. This wizard allows you to enter information about your location and receive advice on the optimal placement.

For indoor installations, the tool provides several sample buildings to help you determine where to place your gateways and sensors, and recommends the number of gateways you will need for your deployment.

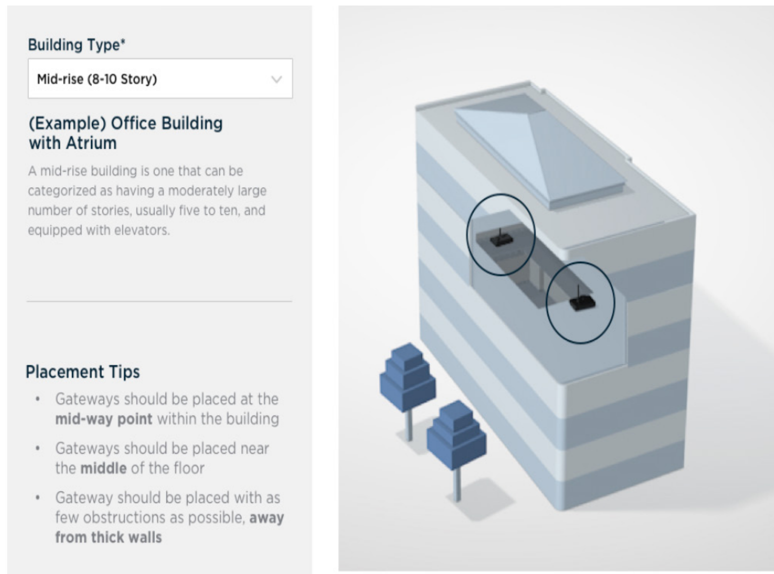


Figure 14: Gateway Coverage Estimates for an Indoor Installation

For outdoor installations, the tool provides an estimated range for your gateway—all you have to do is provide basic information about your setup.

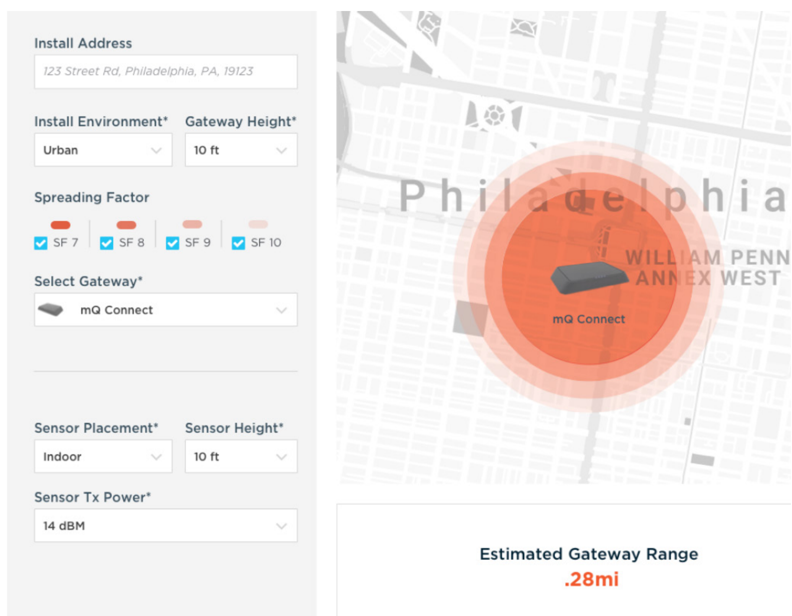


Figure 15: Gateway Coverage Estimates for an Outdoor Installation

For more information, see https://connectivityondemand.machineq.com/.

7. NEED ASSISTANCE CONVERTING?

If you require additional assistance in the sensor conversion process, machineQ has a diverse set of resources available to help you achieve your goals. Our services include dedicated engineering experts who can respond to technical questions, have vetted 'design and build' firms who can assist with your LoRaWAN migration, and provide documentation to help you get started.

Simple. Agile. Easy to use. MachineQ offers a secure, scalable IoT platform supported by the power of Comcast.

- Best in class hardware and pricing
- Management and monitoring software
- Easily accessible engineering resources
- Access to Comcast sales channels

For more information on how to take the next step on getting started, contact us at **info@machineQ.com** and visit our website at **www.machineQ.com**.

Visit www.machineQ.com for more information