

RL78 LoRa[®]-based Solutions

Introduction

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MCU Product Marketing Department
MCU Device Solution Business Division
IoT and Infrastructure Business Unit

Wireless Technology Department
Shared R&D Core Technology Division
IoT and Infrastructure Business Unit

Renesas Electronics Corporation

INTRODUCTION

This guide provides an overview of the LoRa[®]-based communication standard and introduces our LoRa[®]-based development environment, protocol stack, and wireless evaluation tools. Read it before beginning development of applications based on LoRaWAN[®] and LoRa[®]. This document covers the following topics:

- Overview of LoRa[®]-based communication standard
- LoRa[®]-based development environment
- LoRa[®]-based software
- LoRa[®]-based evaluation tools

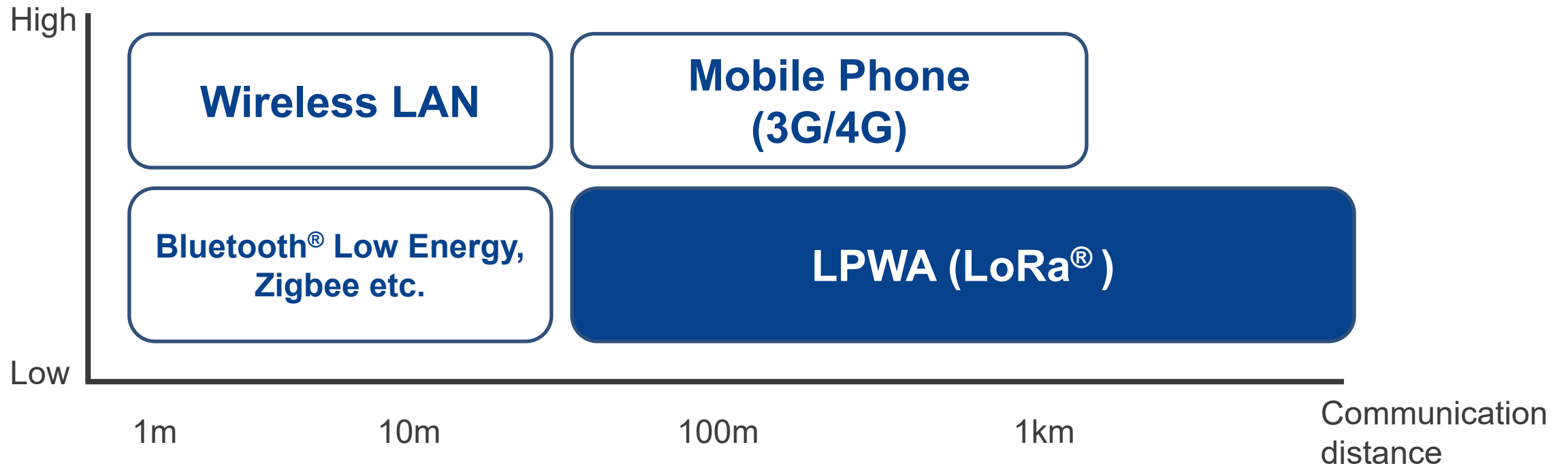
Note that [blue+underlined text](#) indicates a link to a web page or document.

Overview of LoRa[®]-based Communication Standard

WIRELESS STANDARDS

LoRa[®] is a long-distance communication standard suitable for control and sensing. LoRa[®] covers a transmission distance of about 10-15 km in rural areas.

Communication speed/
Power consumption



ABOUT LoRa[®] AND LoRaWAN[®]

LoRa[®] is a modulation technique, and LoRaWAN[®] is a standard protocol that uses the LoRa[®]-based modulation technique.



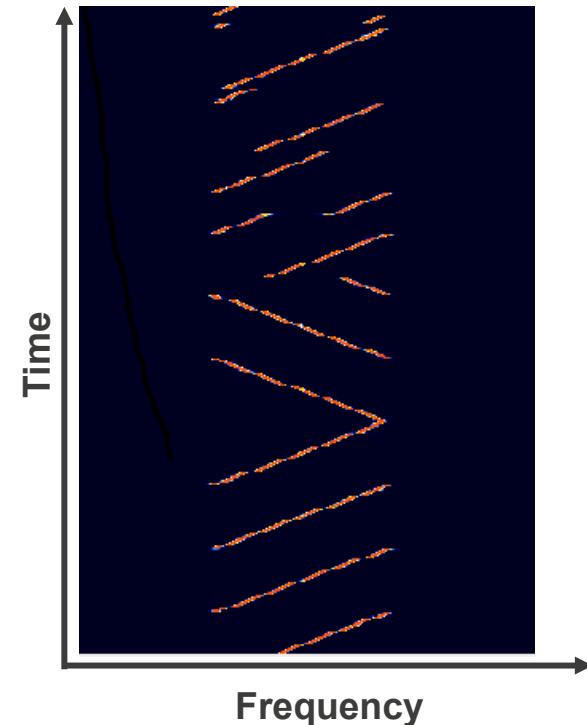
● LoRa[®] (Long Range)

- LoRa[®] is a modulation technique for low-power communication over a long distance (about 10-15 km) at a low data rate (several 100 bps to several 10 kbps). It is based on chirp spread spectrum (CSS).
- A standard protocol (LoRaWAN[®]) that operates over LoRa[®] has been standardized.
- Custom protocols can also be used over LoRa[®].



● LoRaWAN[®] (LoRa Wide Area Network)

- LoRaWAN[®] is a low-power, long-distance communication protocol for IoT devices developed by the LoRa Alliance[®].
- It supports the LoRa[®] and Gaussian frequency shift keying (GFSK) modulation techniques.



LoRa[®] ADOPTION

In 2015, the LoRa Alliance[®], a non-profit organization that supports the standardization and adoption of LoRaWAN[®], was established. It now has more than 500 member companies. **Member companies offer standardized LoRaWAN[®] products and services, forming an ecosystem that makes it easier to build systems.**

Currently, 137 network operators offer LoRaWAN[®] services in 157 countries. **Even more operators offer proprietary communications services based on the LoRa[®]-based modulation technique.**



<https://lora-alliance.org>

137 LoRaWAN[®] Network Operators in **157** Countries

As of June 1, 2020

LoRaWAN® FREQUENCY BAND

LoRaWAN® uses the Sub-GHz frequency band, which offers excellent range and diffraction characteristics. The frequency bands to be used in each country are defined in a specification document entitled LoRaWAN® Regional Parameters.

Sub-GHz band examples:

Country	Frequency
United States of America (US)	902 - 928 MHz
Germany (DE)	863 - 870 MHz
France (FR)	863 - 870 MHz
Singapore (SG)	920 - 925 MHz
India (IN)	865 - 867 MHz
Australia (AU)	915 - 928 MHz
Japan (JP)	920.6 - 928.0 MHz (steps of 200kHz) 920.8 - 927.8 MHz (steps of 600kHz)

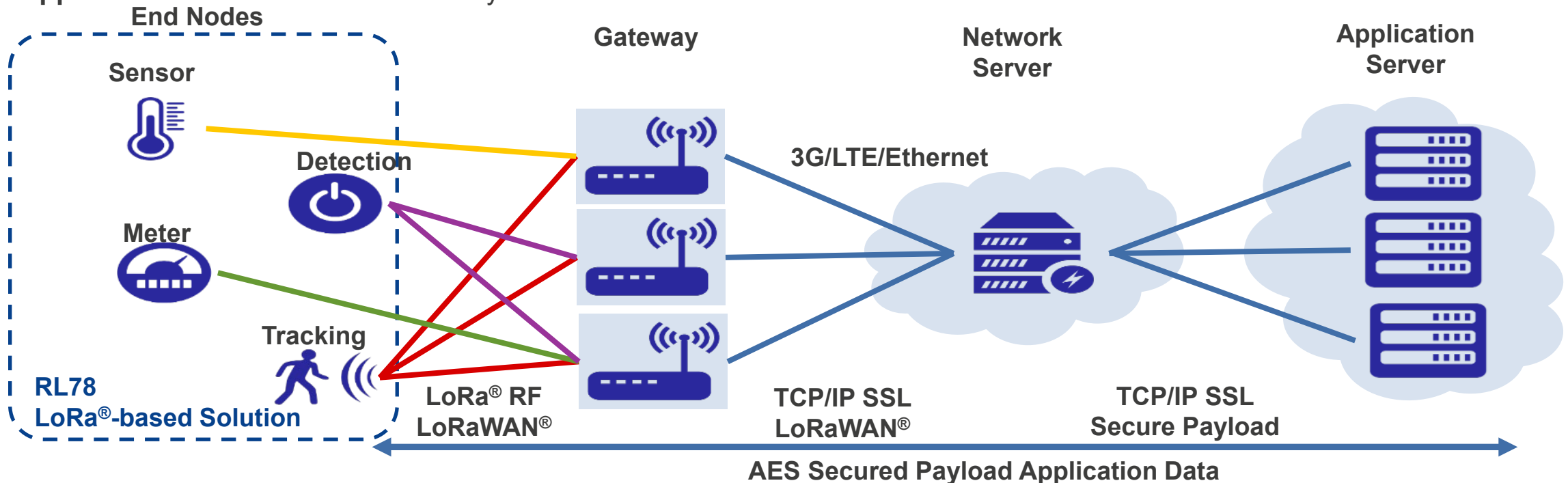
Regional Parameters

<https://lora-alliance.org/search/Regional%20Parameters>

LoRaWAN®: NETWORK CONFIGURATION

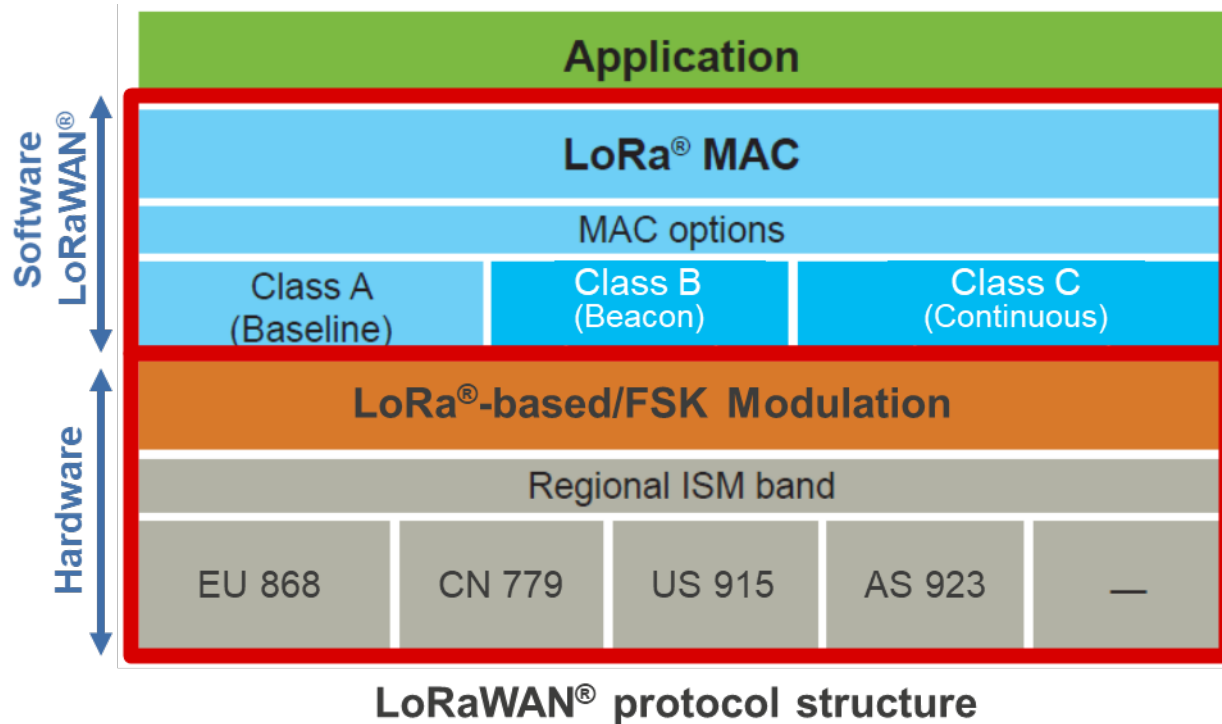
This is the network configuration for LoRaWAN®. The LoRa Alliance® has established a method of communication between end nodes and gateways.

- **End Nodes:** Terminal devices that differ according to use and environment
- **Gateways:** Mediate connectivity to the network server
- **Network Server:** Manages the LoRaWAN® wireless network. Mediates data communication between the end nodes and application server
- **Application Server:** Collects and analyzes data from the end nodes. Controls the end nodes

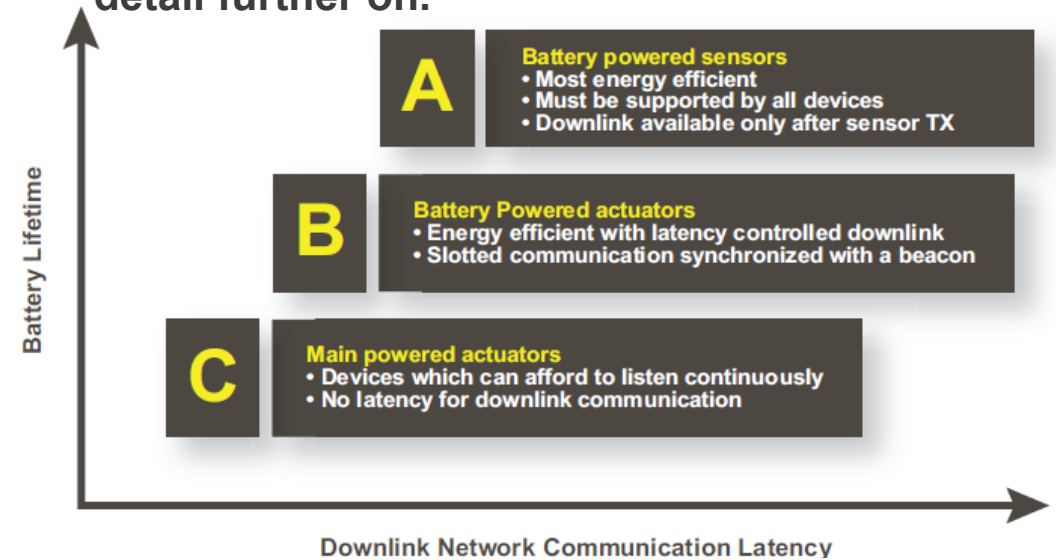


LoRaWAN®: PROTOCOL CONFIGURATION AND END DEVICE CLASSES

The LoRa Alliance® defines the MAC layer. The physical layer is below the LoRa®-based/FSK Modulation layer. Above it, the MAC layer is defined by class. The topmost layer is the application layer.



The MAC layer has three classes. The behavior of each Class is described in detail further on.

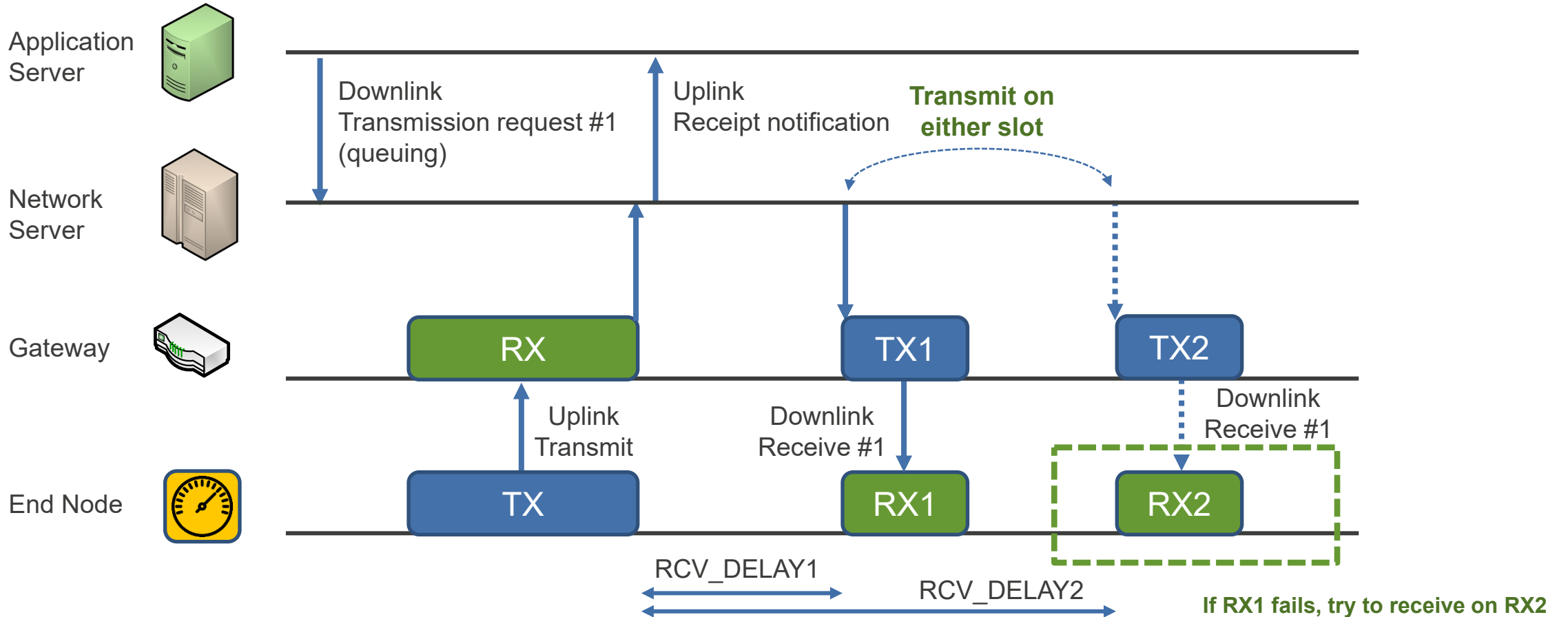


Class	Uplink (transmit)	Downlink (receive)	Operation mode	Battery powered
A	Asynchronous	Transmit then receive	Intermittent operation	Excellent
B	Asynchronous	Synchronous (slot)	Intermittent operation	Yes
C	Asynchronous	Asynchronous	Continuous operation	-

Source: LoRa Alliance® materials

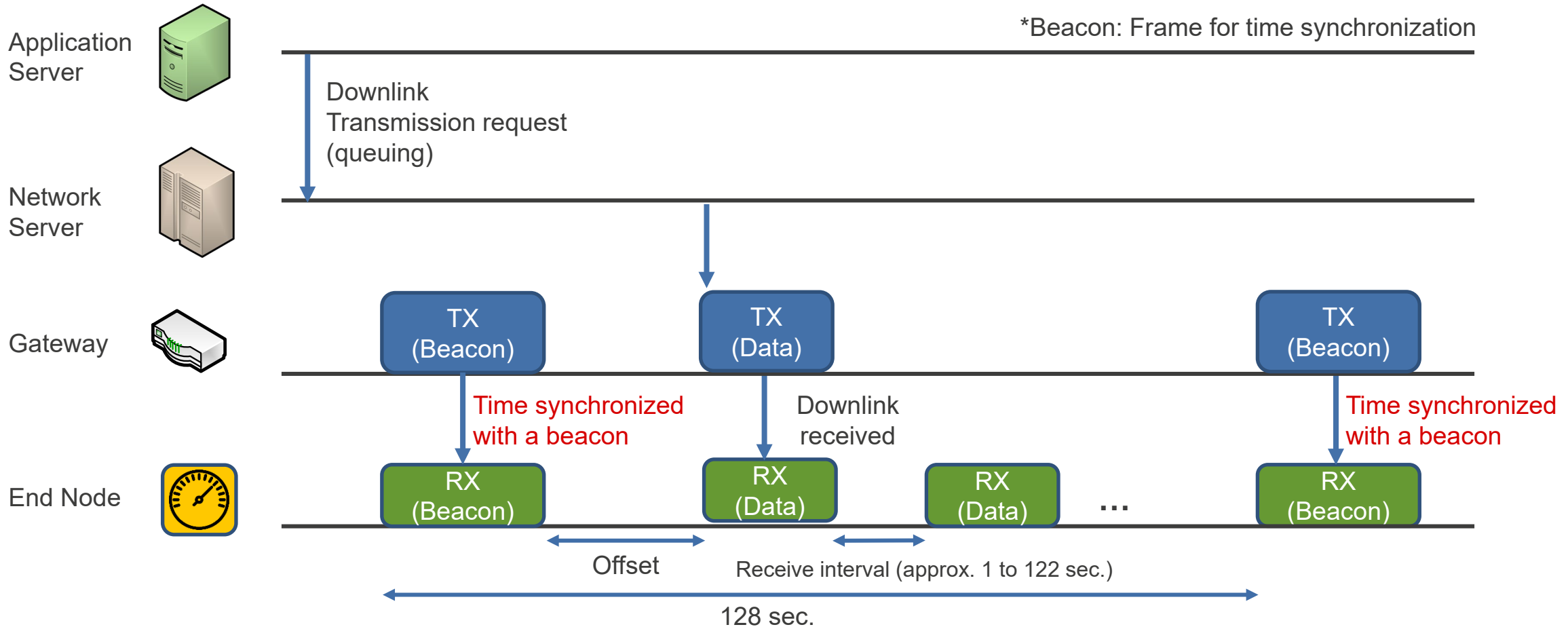
CLASS A: FOR END DEVICES SUCH AS BATTERY POWERED SENSORS

Class A is the most energy efficient class and is supported by all devices. Downlink reception is possible only after transmission. The basic Class A operation is to transmit an uplink and then receive two downlinks (2 slots)



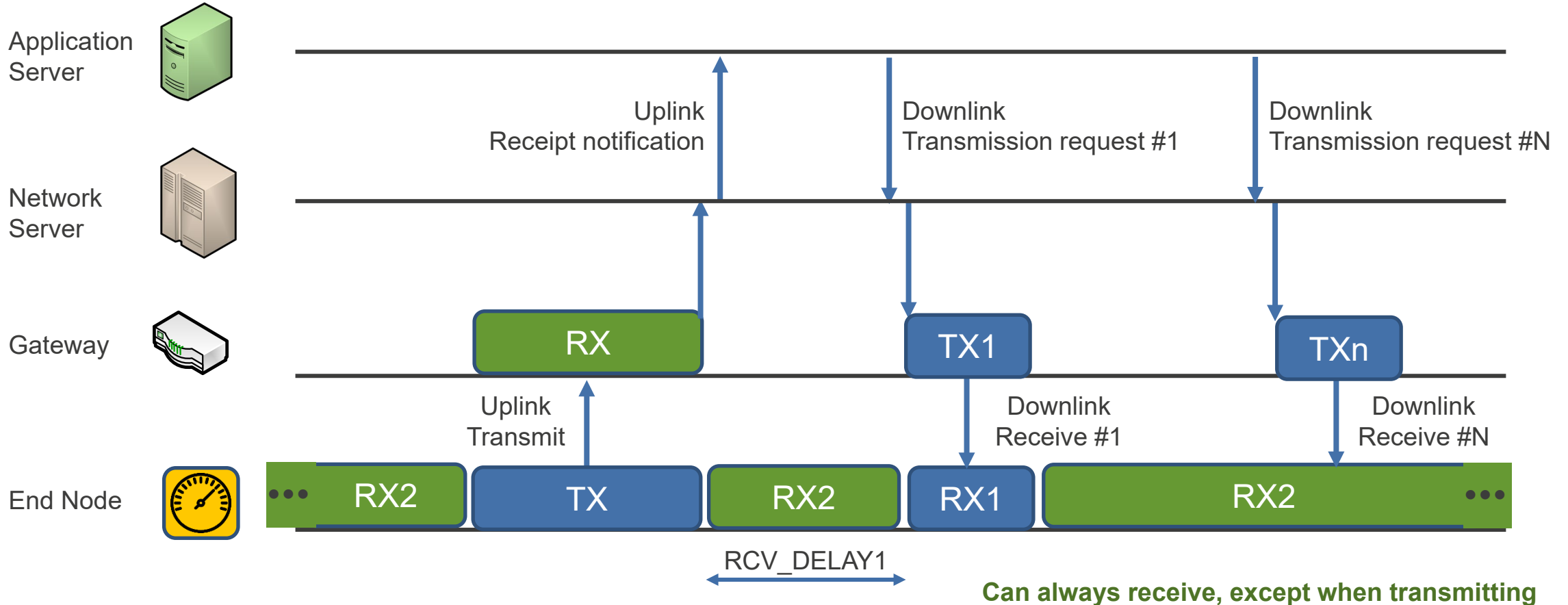
CLASS B: FOR BATTERY POWERED ACTUATORS, METERS, AND SIMILAR END DEVICES

Class B receives at regular intervals while consuming less energy, and has improved downlink latency
The basic Class B operation is the Class A operation with synchronous reception (improved downlink latency)



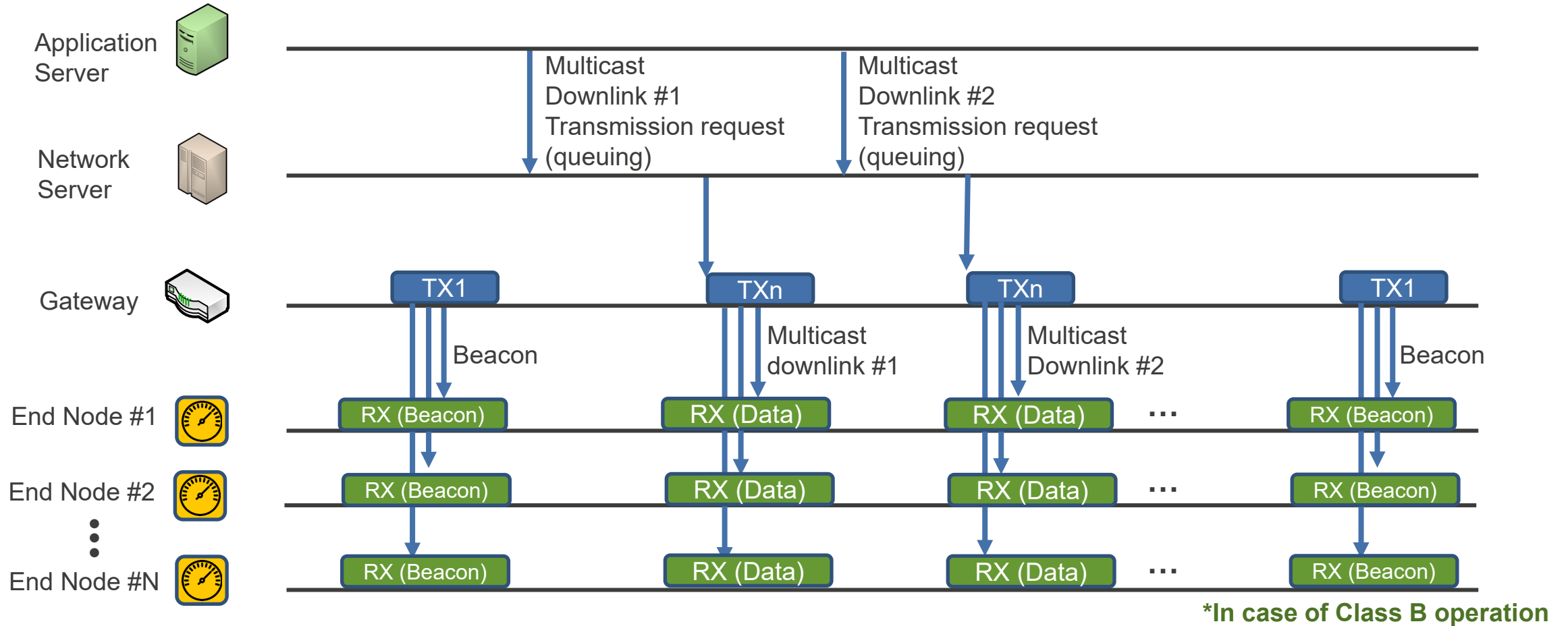
CLASS C: FOR BATTERY POWERED ACTUATORS AND SIMILAR END DEVICES

Class C can always receive, except when transmitting. Downlink communication can be received without latency
The basic Class C operation is the Class A operation with continuous reception



MULTICAST: SIMULTANEOUS DOWNLINK TRANSMISSION

Downlinks can be sent simultaneously from the application server to multiple end nodes. This operation is available in Class B and Class C.



APPLICATIONS SUITABLE FOR EACH CLASS

- **Class A**

Suitable for applications that transmit data periodically from the end node. Consumes less current than other classes, extending battery life. Since the end node can only receive data from the server after it transmits, this class is not suitable for applications that remotely control the end node from the server at an arbitrary timing.

Application example: HACCP management by batch collection of sensor data (temperature, humidity, etc.)

- **Class B**

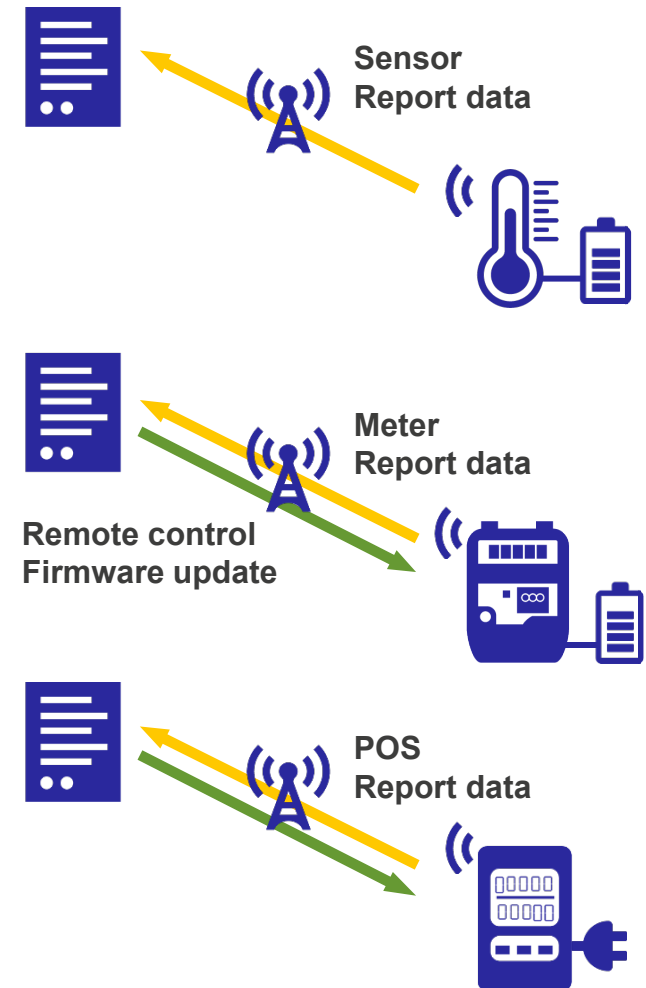
Suitable for applications that transmit data periodically from the end node and that control the end node from the server at an arbitrary timing. Reception occurs at regular intervals with no uplink required. Multicast is also available, enabling tasks like updating the firmware of the end nodes via multicast from the server with low power consumption. Although the current consumption is higher than Class A, battery life remains long. This class offers a good balance of functionality and current consumption.

Application examples: Batch collection of gas meter data, gas shutoff control in case of emergency, etc.

- **Class C**

Suitable for applications in an environment with a constant power supply, since end nodes are always in a receiving state except when transmitting. Class C encompasses the functions of Class A and Class B.

Application example: Point-of-sale data collection for vending machines



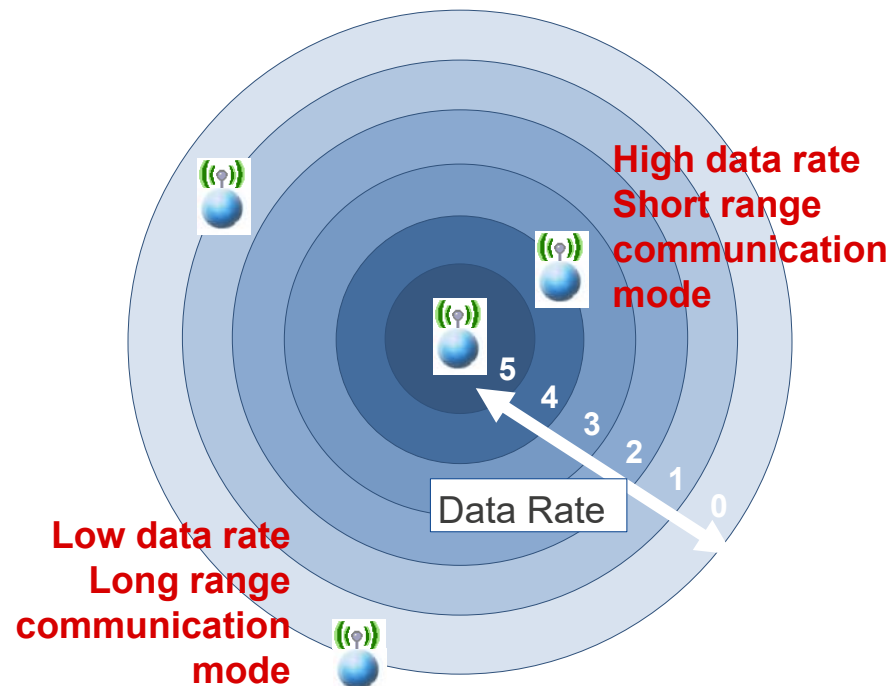
LoRaWAN®: ADR (ADAPTIVE DATA RATE) COMMUNICATION SPEED

LoRaWAN® uses an Adaptive Data Rate (ADR) for efficient communication.

- The data rate is changed under the direction of the network server depending on the signal strength and wireless environment.

High signal strength: Short range communication mode with high data rate, short transmission time

Low signal strength: Long distance communication mode with low data rate, long transmission time



Example: Data rates for AS923

Data Rate (Index)	Spread Factor/ Bandwidth	Physical Bitrate	Distance (image)
0	LoRa: SF12 / 125 kHz	250	Several 10 km
1	LoRa: SF11 / 125 kHz	440	↑ ↓
2	LoRa: SF10 / 125 kHz	960	
3	LoRa: SF9 / 125 kHz	1760	
4	LoRa: SF8 / 125 kHz	3125	
5	LoRa: SF7 / 125 kHz	5470	
6	LoRa: SF7 / 250 kHz	11000	
7	FSK: 50 kbps	50000	Several km

LoRaWAN®: ACTIVATION

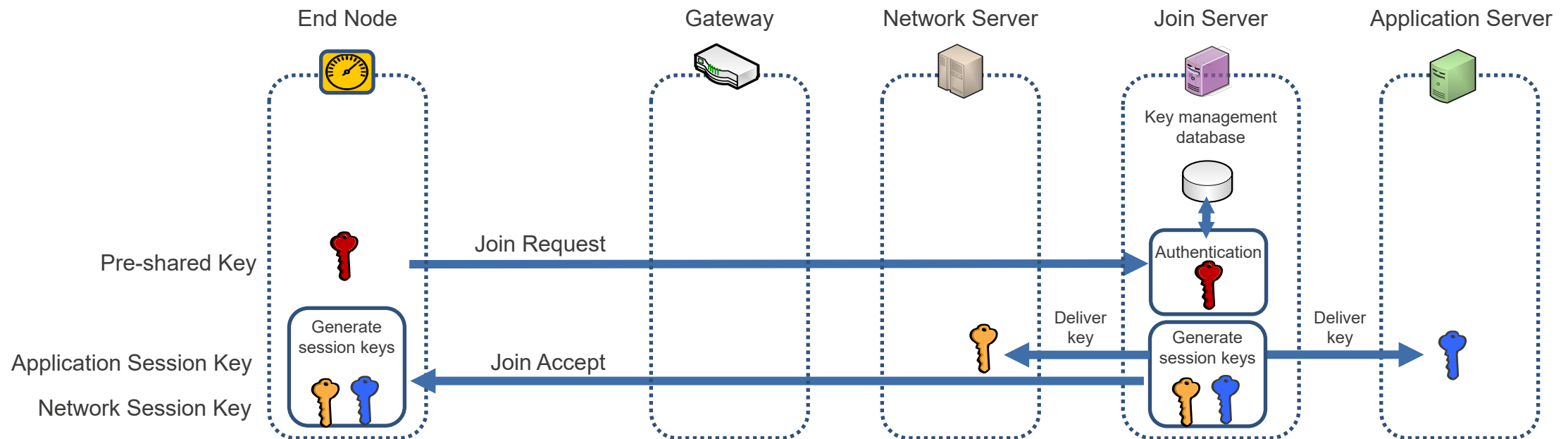
There are two activation methods: OTAA and ABP.

- **Over The Air Activation (OTAA)**

When an end node joins the network, a pre-shared key (PSK) between the end node and the join server is used for mutual authentication and to generate the session keys (application session key and network session key).

- **Activation By Personalization (ABP)**

The end node's session key can be set directly at the time of factory shipment, initialization, etc.



LoRaWAN®: SECURITY

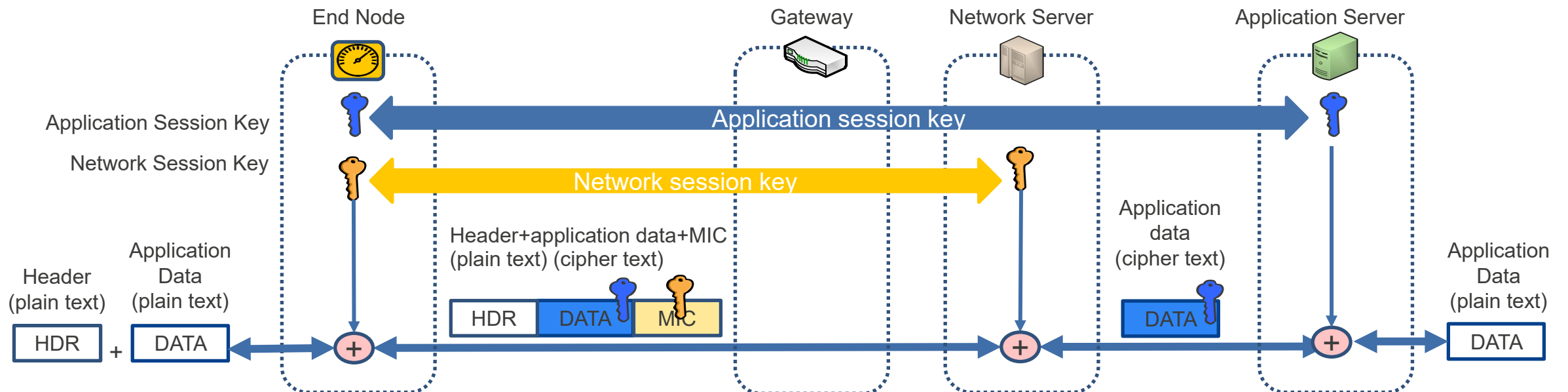
For data communication with encryption and tampering detection, the session key is used to encrypt the application data and append a message integrity code.

- **Application session key**

Encrypts the application data between the end node and application server.

- **Network session key**

Appends a code (MIC) to detect frame tampering between the end node and network server.



LoRa®/LoRaWAN® APPLICATION EXAMPLES

Used in a wide range of applications where small amounts of data are transmitted with lower data rate at infrequent but regular intervals.

Metering

- Collect bulk data from gas (city/propane) and water meters
- Collect point-of-sale data from beverage vending machines, etc.

Industry/Building

- Manage and transmit data from transportation infrastructure (buses, taxis, rental cars, bicycles, traffic signals, street lights, etc.)
- Collect bulk data for structural anomaly detection (aging of tunnels, bridges, buildings, signage, etc.)
- Building management: Send various alerts within the data management area (open/closed/locked doors; management of AC, lighting, and curtain operations; management of elevator/escalator operations/positioning; warehouse inventory management, etc.)
- Agriculture and livestock management: Manage bulk data (water supply, livestock position detection, avian flu detection, etc.)
- Hygiene management: Hazard Analysis and Critical Control Point (HACCP) for food manufacturing

Consumer/Home

- Manage and transmit healthcare data (wearables)
- Monitoring system for children and the elderly



REQUIREMENTS FOR LPWA WIRELESS NETWORK

A low-power wide-area (LPWA) network requires easy network construction and low-power communications.

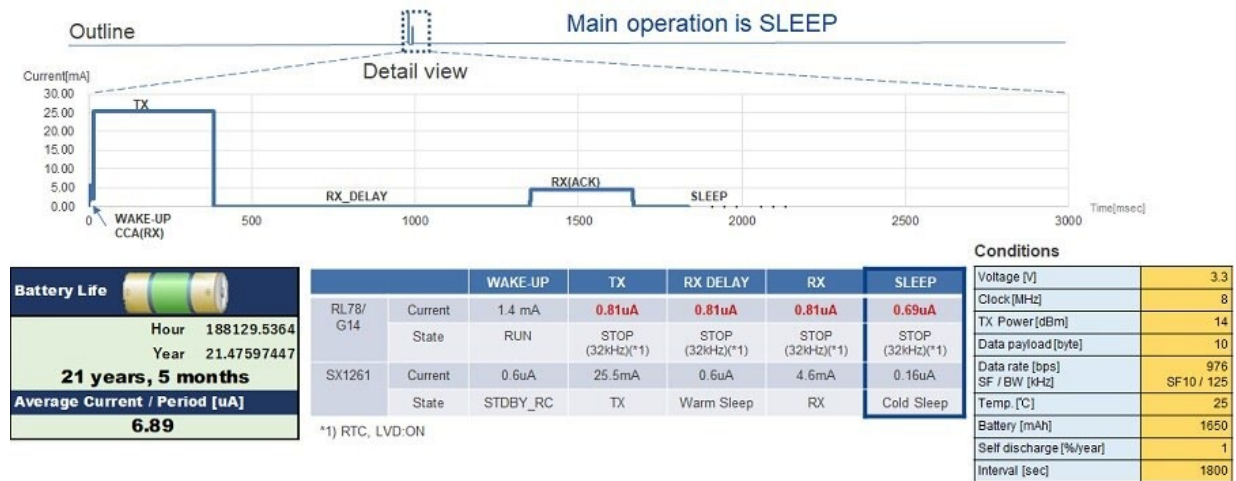
- Easy network construction

A LoRaWAN[®] network is defined by the LoRa Alliance[®]. It is an ecosystem that allows a network to be built by preparing LoRaWAN[®]-compatible end devices, gateways, and network servers. This makes it easy to build a private network compared to other LPWA standards.

- Low power communications

Many LPWA applications send notifications once every few hours.

The main operation is the sleep operation, with minimal real-time clock and low-voltage detection. This requires a microcontroller with low-current sleep behavior.



LoRa[®]-based Development Environment

CONFIGURATION OF THE DEVELOPMENT ENVIRONMENT

Software development can be done by connecting the Semtech SX1261/SX1262 Shield to the RL78/G14 Fast Prototyping Board.

RL78/G14 Fast Prototyping Board

The RL78/G14 Fast Prototyping Board comes equipped with a high-performance RL78/G14 microcontroller and is an evaluation board specialized for prototype development for a variety of applications. It has a built-in emulator circuit that is equivalent to an E2 emulator Lite so you can write/debug programs without additional tools. In addition, with Arduino Uno and Pmod™ interfaces included as standard.



RTK5RLG140C00000BJ

Semtech SX1261 Shield, Semtech SX1262 Shield

The Semtech SX1261/SX1262 Shield features an Arduino Uno interface and a Sub-GHz radio transceiver that supports modulation based on LoRa®.

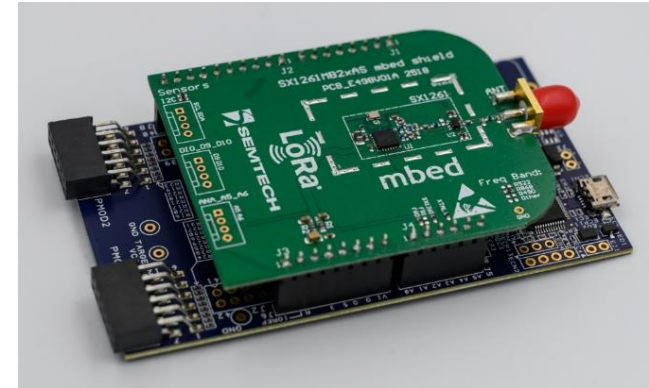


SX1261MB2BAS 868 MHz mbed Shield

SX1262MB2CAS 915 MHz mbed Shield

CONNECTING THE DEVELOPMENT ENVIRONMENT

- Connect the Semtech SX1261/SX1262 Shield to the RL78/G14 Fast Prototyping Board to use it for development work.
- To evaluate control from a PC, you can connect the DIGILENT [Pmod USBUART](#) to the Pmod™ interface.
- To debug with the built-in emulator circuit, which is equivalent to the E2 emulator Lite, simply connect it to your PC with a USB cable.



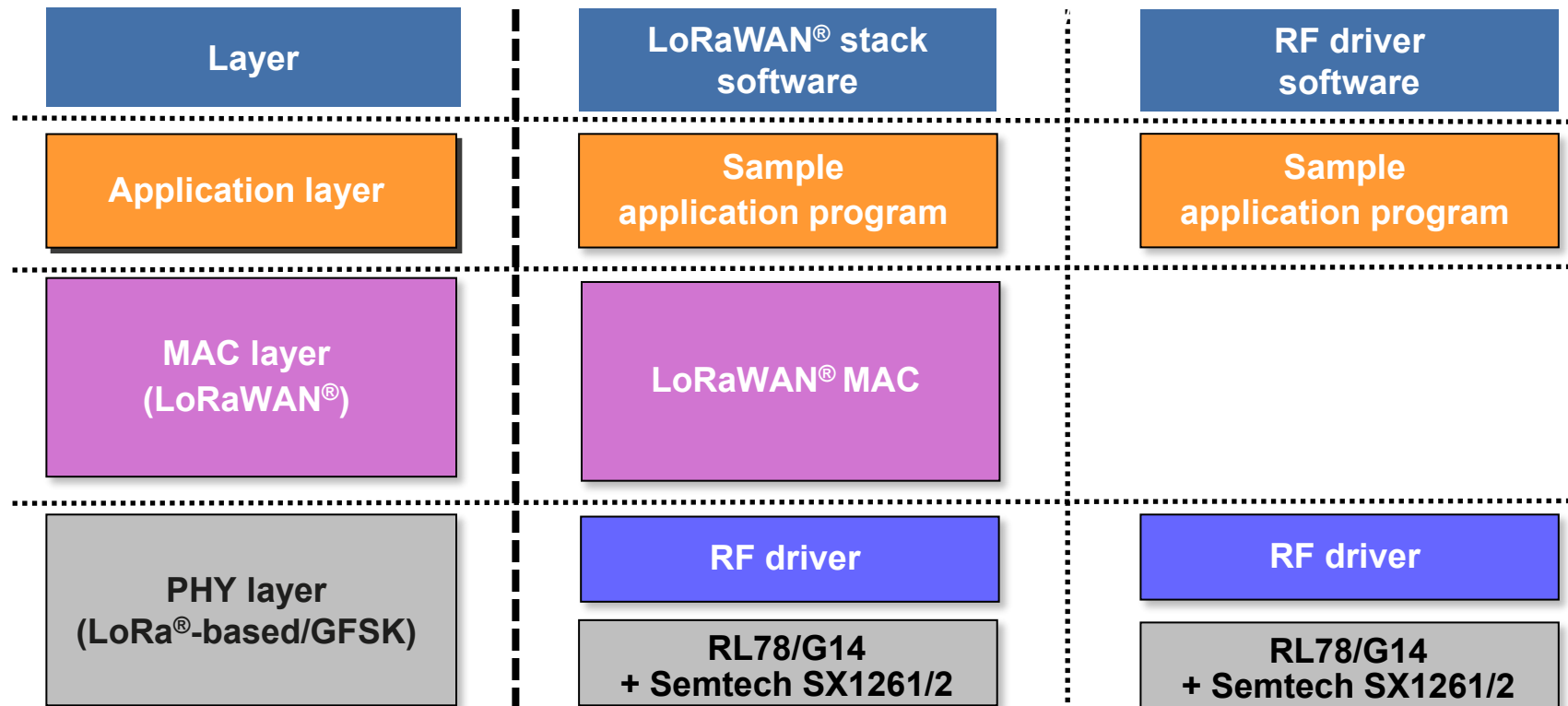
To debug with the IDE (CS+/e2studio), switch the EJ1 pin header to OPEN. To run the stand-alone without an IDE, switch EJ1 to OPEN, write to the flash memory using Flash Programmer, and then short-circuit the EJ1 switch to reset the emulator.

LoRa[®]-based Software

RENESAS LoRa[®]-based COMMUNICATION SOFTWARE

Two types of LoRa[®]-based communication software are available.

- **LoRaWAN[®] protocol stack:** LoRaWAN[®] specification compliant, for applications that require third-party interoperability.
- **RF driver:** Allows use of custom protocols, for applications that do not require third-party interoperability.



NETWORK CONFIGURATION EXAMPLES

Examples of network configurations using the LoRaWAN[®] protocol stack and RF drivers.

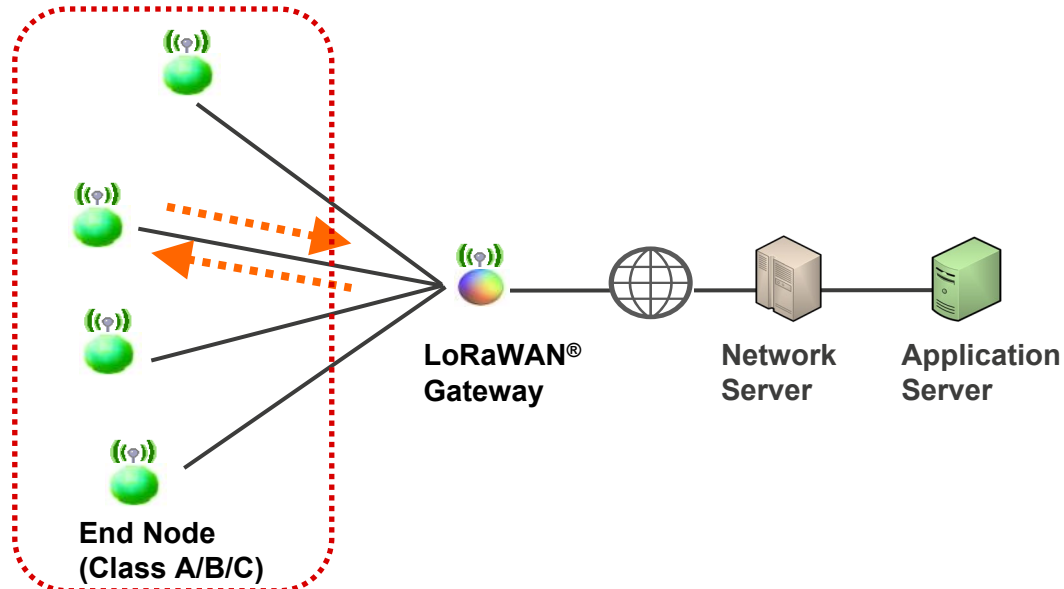
LoRaWAN[®] protocol stack

- Standardized protocol
- Multi-vendor interoperability

RF driver

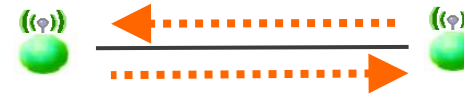
- Allows use of custom protocols
- Flexible support for a wide range of applications

LoRaWAN[®] network

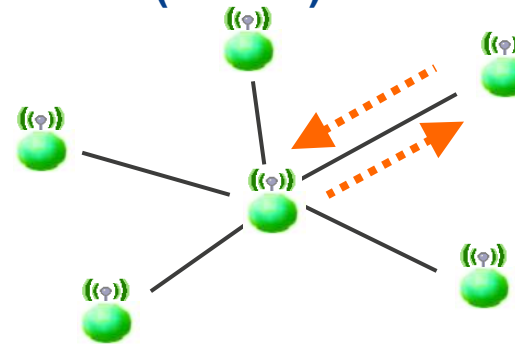


* The LoRaWAN[®] stack supports end nodes

P2P network (1-to-1)



Star network (1-to-N)



USING THE SOFTWARE

The software comes in a single package. You can download it from the following website:

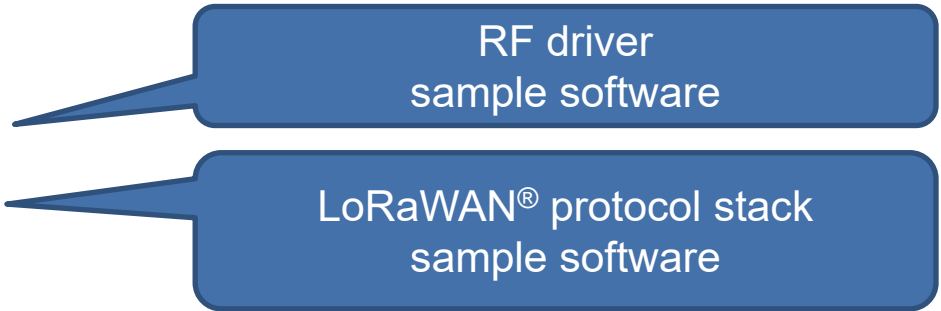
[LoRa®-based Wireless Software Package](#)

To get started, see [LoRa®-based Wireless Software Package Quick Start Guide \(R22QS0033\)](#).

Website: LoRa®-based Solutions <https://www.Renesas.com/application/communications/lora-solutions>

Three types of sample software are available.

- **RadioEvalApp**: AT command-driven RF evaluation program
- **Ping-pong**: Simple application using an RF driver
- **LoRaSample**: AT command-driven LoRaWAN® sample application



RF driver
sample software

LoRaWAN® protocol stack
sample software

Location: samples¥project

DOCUMENTATION

Software-related documentation is available.

- For RF evaluation, see the RF evaluation program documentation.
- For proprietary LoRa[®]-based communication operations, see the RF driver documentation.
- For LoRaWAN[®] operations, see the LoRaWAN[®] documentation.

RF evaluation program documentation

- [Radio Evaluation Program \(R01AN0230\)](#) RF Evaluation Program AT Command Reference Manual

RF driver documentation

- [Radio Driver Reference guide \(R01AN0227\)](#) RF Driver API Specification
- [Radio Driver for Japan Radio Regulations \(R11AN0393\)](#) Information on how to comply with regulations under the Radio Law of Japan

LoRaWAN[®] documentation

- [LoRaWAN[®] stack reference guide \(R01AN0288\)](#) LoRaWAN[®] API Specification
- [LoRaWAN[®] Stack Sample Application \(R1AN0231\)](#) LoRaWAN[®] AT Command Reference Manual

EXECUTION

The **AT command-driven RF evaluation program** and **AT command-driven LoRaWAN® sample application** come with object files that you can try immediately without building. Use Flash Programmer to write the object file to the flash memory and then execute it.

- **RadioEvalApp**: AT command-driven RF evaluation program

Location: samples¥project¥e2studio7¥rl78g14fpb_sx126x¥RadioEvalApp¥DefaultBuild¥

- **RadioEvalApp.mot**: Use together with the Windows GUI application Renesas LPWA Studio

- **LoRaSample**: AT command-driven LoRaWAN® sample application

Location: samples¥project¥e2studio7¥rl78g14fpb_sx126x¥LoRaSample¥DefaultBuild¥

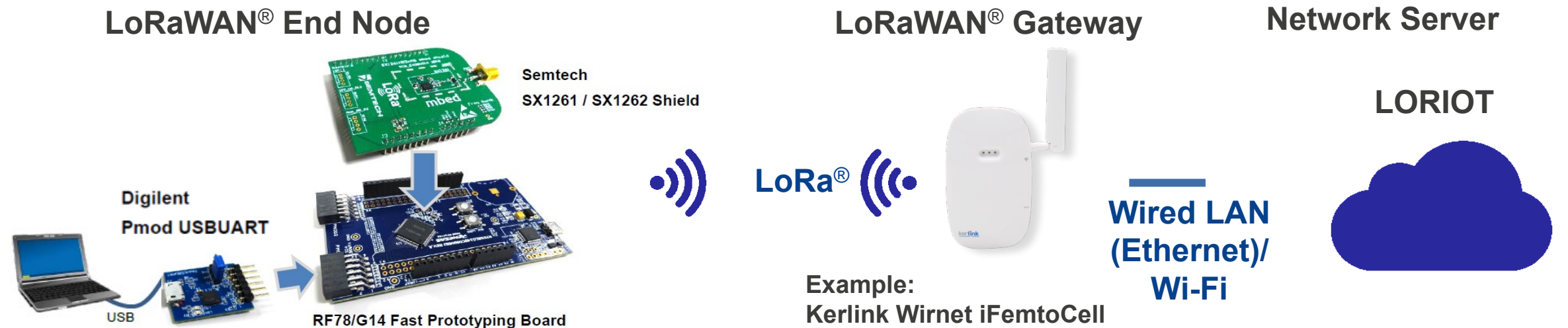
- **LoRaSample.mot**

LoRaWAN[®] ENVIRONMENT

To try LoRaWAN[®], you must prepare the LoRaWAN[®] gateway and network server.

For the gateway, you can purchase a LoRaWAN[®]-compatible product.

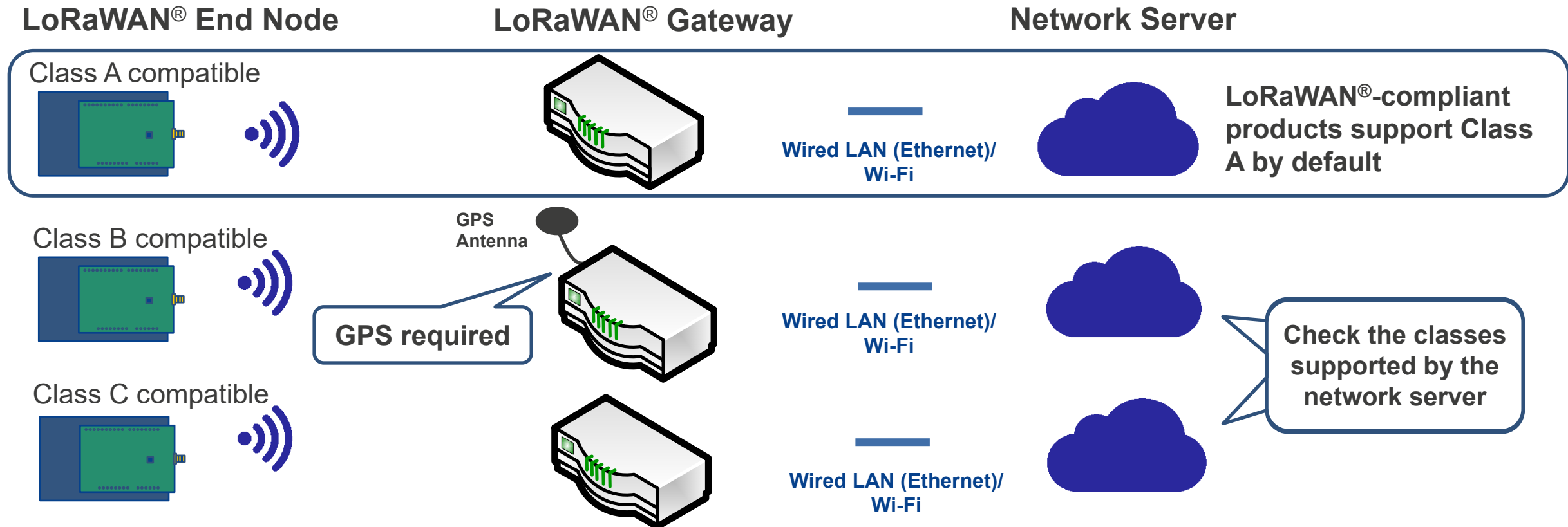
For the network server, some vendors offer services that are free to try for proof-of-concept purposes.



LoRaWAN® ENVIRONMENT (LoRaWAN® GATEWAY/NETWORK SERVER)

The LoRaWAN® gateway and network server may not support the same LoRaWAN® protocol class.

- A LoRaWAN® gateway that supports Class B must be equipped with GPS to support beacon synchronization.
- Check which class is compatible with your network server.



LoRaWAN[®] EXECUTION

An executable example is available in LoRaSample (the AT command-driven LoRaWAN[®] sample application).

For an example of how LoRaWAN[®] Class A works, see the LoRaWAN[®] tutorial.

The example setup uses the [Kerlink Wirnet iFemtoCell](#) gateway and the [Loriot Network Server](#).

Next, the tutorial explains how to implement visualization in [Cayenne for LoRa[®]](#). See the links below.

- Japanese version:
 - LoRaWAN[®] TUTORIAL SETTING AND OPERATION METHOD
 - <https://www.renesas.com/document/gde/lorawan-tutorial?language=ja>
- English version:
 - LoRaWAN[®] TUTORIAL SETTING AND OPERATION METHOD
 - <https://www.renesas.com/document/gde/lorawan-tutorial?language=en>

LoRa[®]-based Evaluation Tools

EVALUATION TOOLS

The tools are included in the [LoRa[®]-based Wireless Software Package](#).

There are two tools:

- **Renesas LPWA Studio:** Functions include Continuous Wave Transmit, Packet Transmit, SNIFFER (Packet Receive), PER/BER Test, and Spectrum Scan.
- **Renesas Power Estimator:** Power consumption estimation tool

Location: samples¥tools

DOCUMENTATION

Renesas LPWA Studio allows you to perform RF evaluation. Two manuals have been prepared.

Renesas LPWA Studio functions include Continuous Wave Transmit, Packet Transmit, Sniffer (Packet Receive), PER/BER Test, and Spectrum Scan. In addition, the Renesas Power Estimator gives you an idea of how long a battery will last so you can consider different battery sizes.

Renesas LPWA Studio

- [Renesas LPWA Studio \(R30UZ0095\)](#) RF evaluation program in the Windows GUI application Renesas LPWA Studio

Renesas Power Estimator

- [Renesas Power Estimator \(R30UZ0096\)](#) Power current consumption estimation tool

PERFORMING RF EVALUATION

EXECUTION OF CONTINUOUS WAVE TRANSMIT, PACKET TRANSMIT, SNIFFER (PACKET RECEIVE), PER/BER TEST, AND SPECTRUM SCAN

Write the hex file for the program below into your development environment.

- **RadioEvalApp**: AT command-driven RF evaluation program

Location: samples¥project¥e2studio7¥rl78g14fpb_sx126x¥RadioEvalApp¥DefaultBuild¥

– RadioEvalApp.mot: Use together with the Windows GUI application Renesas LPWA Studio

- Click setup.exe in samples¥tools¥RLStudio to install Renesas LPWA Studio.

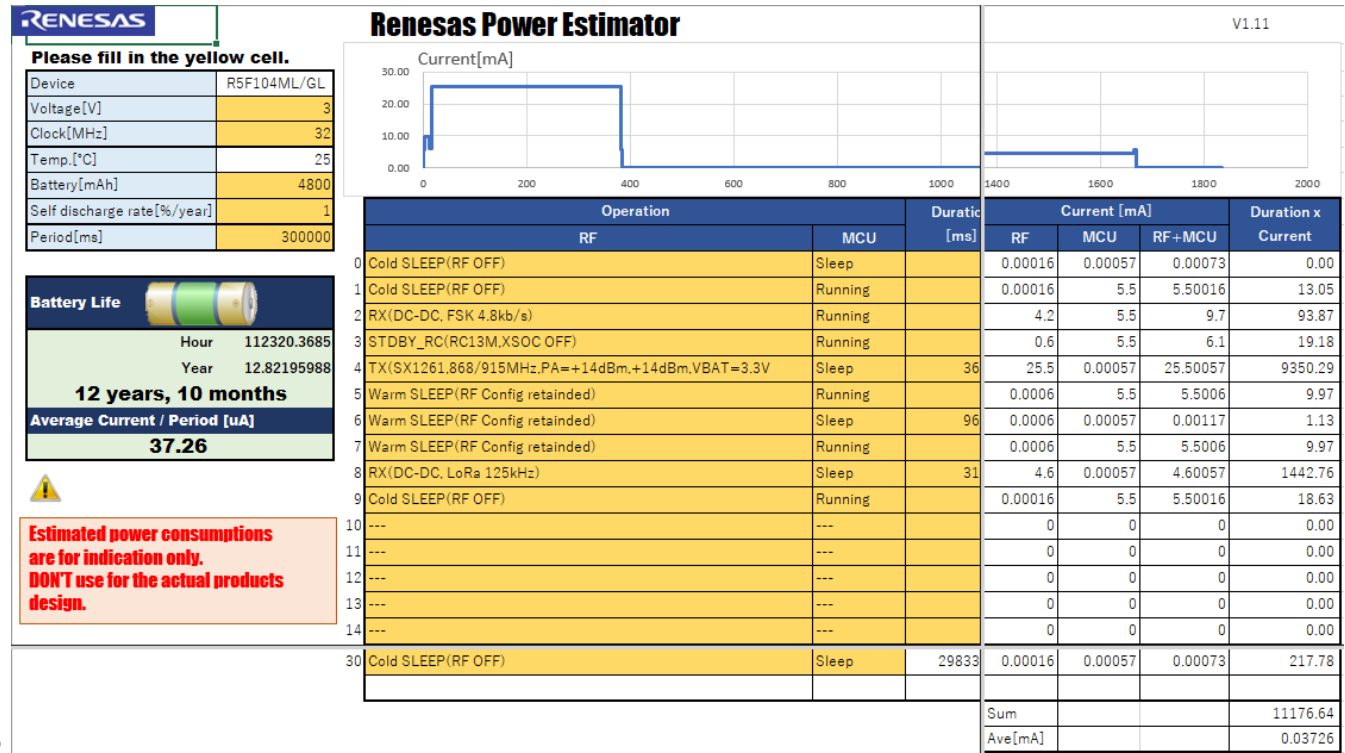
- Refer to the manual below to get started.

[Renesas LPWA Studio \(R30UZ0095\)](#) RF evaluation program in the Windows GUI application Renesas LPWA Studio

ESTIMATING POWER CONSUMPTION

You can estimate the power consumption in Excel.

- Run the following in Excel:
samples¥tools¥RPEstimator
- Set the following parameters:
 - Microcontroller operating frequency
 - Battery parameter settings
 - Select RF and MCU behavior patterns
 - Set the duration of each pattern
- This lets you estimate the battery life. Board conditions may vary, so actual measurements should be taken during evaluation.



Other

LoRaWAN® APPLICATION NOTES

Application notes for LoRaWAN® applications are available.

Application note showing how to visualize sensor data sent from RL78 IoT nodes to the cloud (Azure or AWS) via the LoRaWAN® network

- [LoRaWAN® IoT Demo LPWA IoT Solution with Cloud \(R11AN0412\)](#)

Application note for an application that configures the parameters required for LoRaWAN® communication over Bluetooth® Low Energy and uses LoRaWAN® communication to transmit sensor data to a LoRaWAN® gateway

- [Bluetooth® Low Energy & LoRaWAN® Application \(R01AN5282\)](#)

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