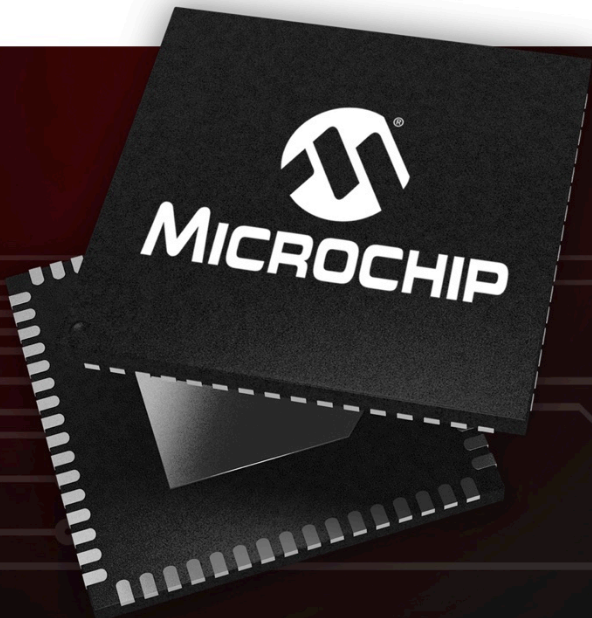
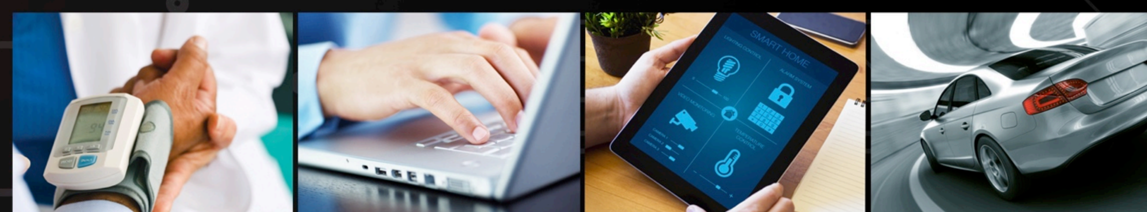


A Leading Provider of Microcontroller, Mixed-Signal, Analog & Flash-IP Solutions



LoRaWAN™ 101 Class

Getting Up and Running with LoRaWAN™ Long-Range Networking

Objectives

- **At the end of this class, delegates will be able to:**
  - Understand the key advantages of the LoRaWAN™ Network Protocol
  - Configure, Activate, and Communicate with the RN2903A Wireless Module Kits

Agenda

- Internet of Things (IoT)
- LoRaWAN™ Networking Standard
- LoRa® Technology Wireless Modules
- Getting Started with RN2903 Module
- Hands-on workshop

LoRa™ Alliance

Wide Area Networks for IoT

The LoRa® Alliance

"ENABLING THINGS TO HAVE A GLOBAL VOICE"

- The LoRa® Alliance (http://lora-alliance.org/) is an **open**, non-profit association of members.
- **Mission**: to standardize Low Power Wide Area Networks
- Alliance members will collaborate to drive the global success of the LoRaWAN™ protocol

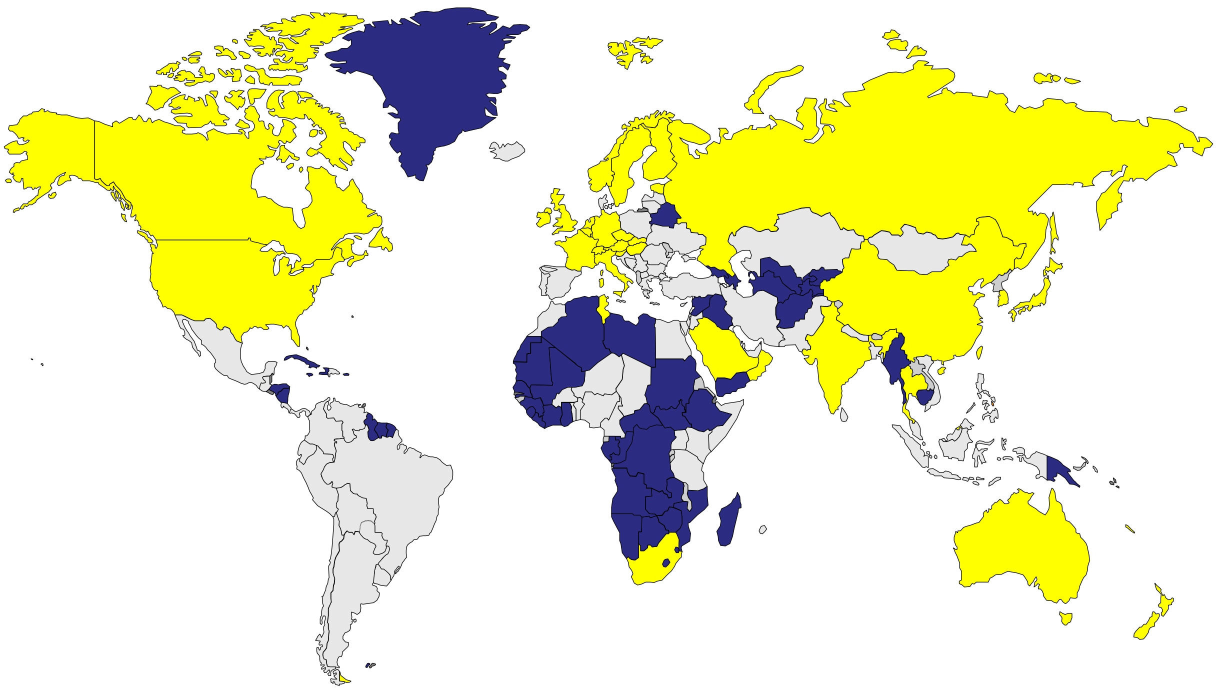
Strategy Committee
Roadmap & security

Technical Committee
Specification & feature updates

Marketing Committee
Brand, media, trade-shows, open house

Certification Committee
Test specs & accreditation

Countries –– LoRaWAN™ Networks



- **76** Network Operators
- Operating in **43** countries
- **57** Alliance Member Operators
- Near **100** Countries with LoRaWAN deployment

Legend:

Alliance Member Public Networks

Other LoRaWAN deployment

March 2018

All information contained herein is current at time of publishing – LoRa Alliance is not responsible for the accuracy of information presented

LoRa® Alliance Ecosystem

500+ members

MICROCHIP

Alliance Member Open Network Operators

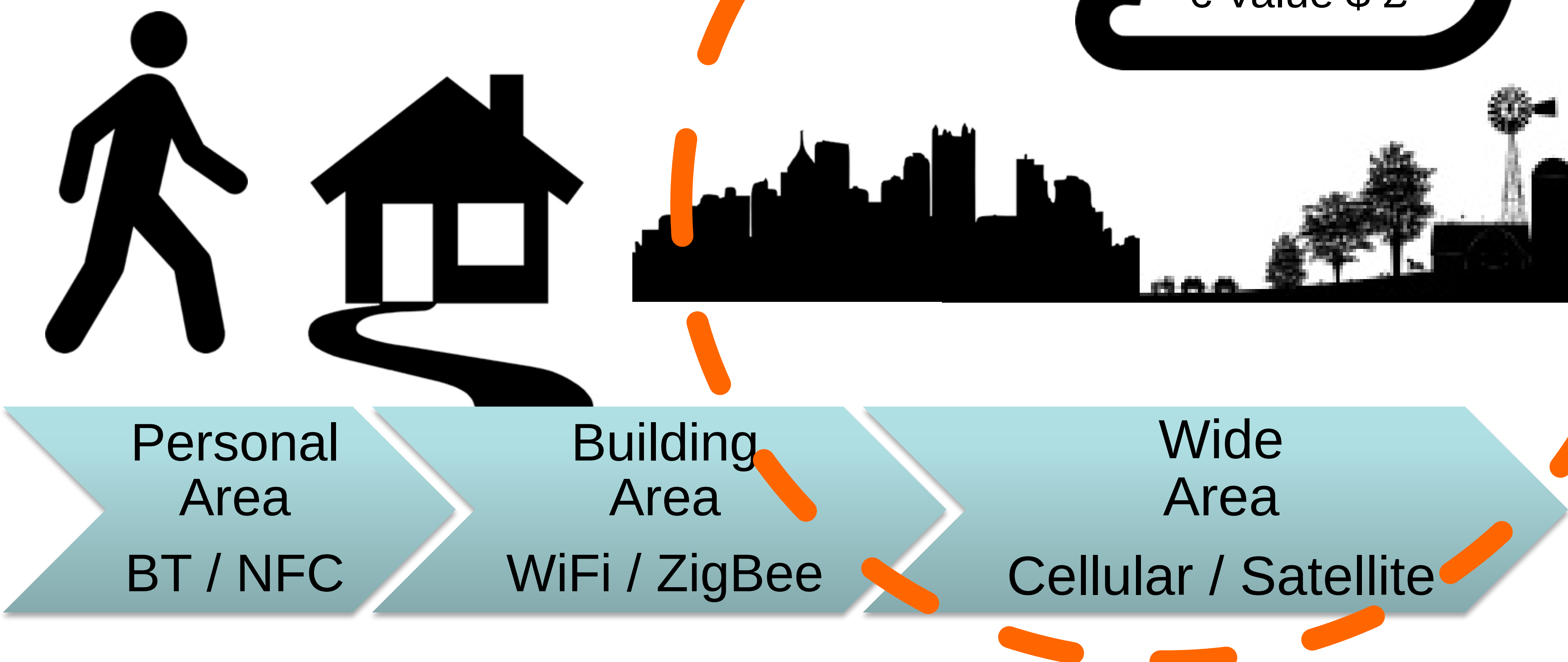
kpn
senet
TATA COMMUNICATIONS
SENSORO
ooredoo
swisscom
UNIDATA
ER-TELECOM
MESHED
COMCAST
orange
lar.tech
ZTE
SoftBank
Kotahi.Net
X-TELIA
Netzikon DAS NETZ DER DINGE
blink services
SOLVERA LYNX
Objenious by Bouygues Telecom
a2a
pixelnetworks
DIGIMONDO
SenRa
eleven-x
ZENNER All that counts.
telbru making a difference
Microtronics We live M2M
CAT
SK telecom
FastNet
machinestalk innovation frontier
slovanet
stream
DIGITA
Gemtek
CATAPULT Digital
DREAM LINE
COMSOL CONNECTED. WITHOUT LIMITS.
NATIONAL NARROWBAND NETWORK Co.
proximus
Spark nz
XATEL
CRA ČESKÉ RADIOKOMUNIKACE
Levikom
IoTCAN
Pervasive Nation
Telemar internet quality provider
antenna HUNGÁRIA
IoTnet. IOT NETWORK AS.
Definium Technologies
LoRa Alliance™

All information contained herein is curr… LoRa Alliance is … of information presented

March 2018

IoT Context … by Range

- Microchip's wireless portfolio serves the personal and local area networks, but what about the wide-area?
- Existing cellular technology is power hungry
- Demand is growing for Low-Power WAN



Different Implementation of NB-IoT

	Stand-Alone Mode	In-band Mode	Guard-band Mode
Regulatory Approval	Yes(depends on license type)	No	Yes (mostly)
Spectrum Cost	High	High	None
Frequency Planning	Huge effort for GSM/UMTS refarming	No planning, upgrade every eNodeB	No planning, upgrade every eNodeB
Co-existance Performance Impact*	~4% GSM outage degradation ~4% UMTS Capacity loss	Interference to neighbor LTE PRB; NB-IoT SNR also impacted	Slightly better coexistance performance than in-band mode
Antenna System	Upgrade (add combiner)	Reuse	Reuse
RF Modules	New	Reuse	Reuse
Baseband Unit	Upgrade	Upgrade	Upgrade
Symmetrical MCL (w/o) Repetitions	151.2~161	138.2~148	138.2~148
Repetitions	Moderate	Excessive	Excessive

** Performance results are taken from 3GPP 36.802 v13.0.0*

LPWAN Comparison

Parameters		LoRa	NB-IoT	Remarks
Spectrum		Unlicensed	Licensed LTE bandwidth	Heavy Investment for Licence of Spectrum
Modulation		CSS	QPSK	
Bandwidth		500 kHz–125 KHz	180 KHz	
Peak Data Rate		290 bps-50 Kbps (DL/UL)	DL:234.7 kbps; UL:204.8 kbps	LoRa Targeting at low Data application
Link Budget		154 dB	150 dB	
Max. # message/day		Unlimited	Unlimited	
Power efficiency		Very High	Medium High	
Mobility		Better than NB-IoT	No connected mobility (only idle mode reselection)	
Battery Lifespan		>10 years battery life of devices	>10 years battery life of devices	More Information needs for this cliam
Spectrum Efficiency		Chirp SS CDMA better than FSK	Improved by standalone, in-band, guard band operation	
Area Traffic Capacity		Depends on gateway type	40 devices per household, 55k devices per cell	
Interference immunity		Very High	Low	Noise Interference
Power Efficiency	Typ Tx Current	124mA (20 dBm)	220 mA (23 dBm)	2x Tx Current
	Transmission Time	0.93 s (16 Bytes payload)	2 sec (for Tx) and 10 secs (for Rx)	5x Time
	Active Mode Current (Rx)	38 mA	46mA	
	Sleep Current	1.8 uA	3 uA	3x Sleep
	Device Class	Class A : Sleep except when Tx	PSM (Power Saving Mode)	
		Class B : Periodically wakes up to listen for	eDRX (Extended Discontinuous	
		Class C : In Rx mode most of the time		

Power Consumption of NB-IoT

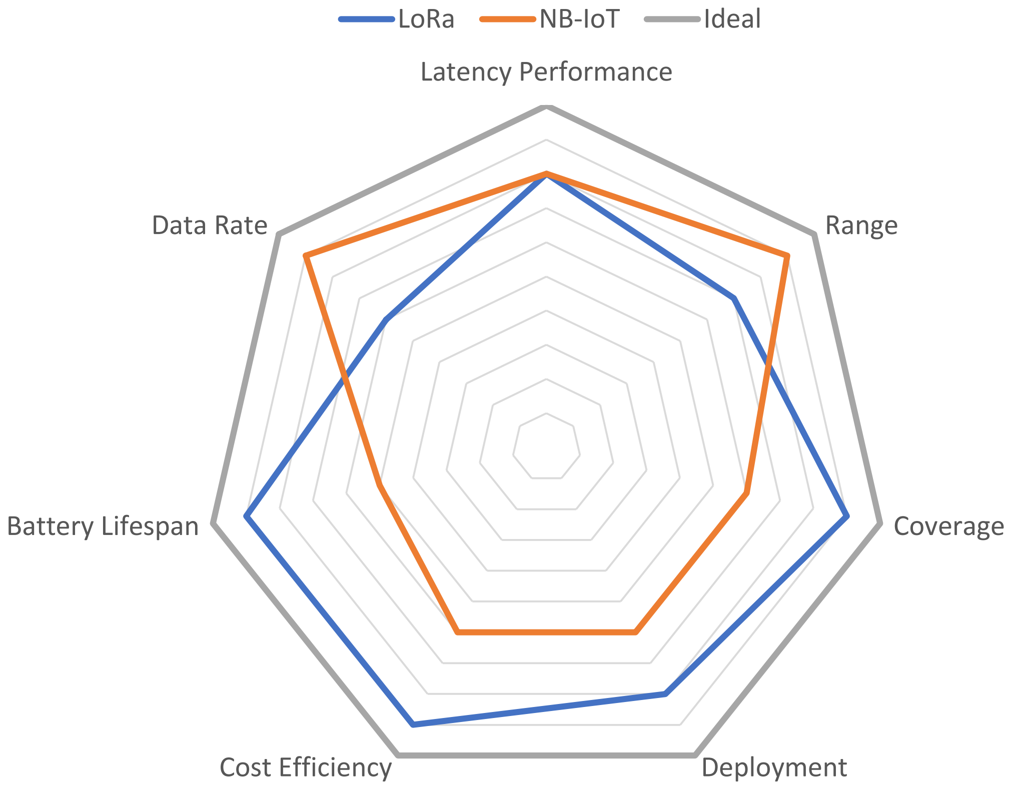
SARA-N2 - Data Sheet

4.2.3 Current consumption

Mode	Band	Condition	Tx power	Min	Typ[3]	Max	Unit
Deep-sleep mode	-	Averaged current over a 10-second period			3		µA
Active mode	-	Averaged current over a 10-second period			6		mA
Rx-mode	All	Averaged current over a 10-second period			46		mA
Tx-mode	All	Averaged current over a 2-second period	-40 dBm		74		mA
			-7 dBm		75		mA
			3 dBm		78		mA
			13 dBm		100		mA
			23 dBm		220		mA

Table 11: VCC current consumption[4]

LoRa vs NB-IoT

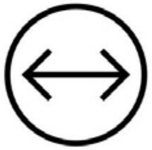


LoRaWAN
Global Standards for LPWAN IoT Networks

Long Range
Provides Long range up to 15km communications.

Licensed-Free Band
Unlicensed spectrum provides low-cost deployment for LoRaWAN ; licensed band results in high investment.

Bidirectional
Provides Uplink and Downlink communication to enables wide variety of uses case.



High Penetration & Low Noise
The LoRaWAN modulation provide high penetration over walls and provide the ability to communicate with indoor monitoring sensors. Innovative & cost sensitive implementation providing Demod signals below the noise floor, improving sensitivity by ~20dB

Open Source Standard
LoRaWAN standard is based on an open protocol approach managed by a strong team of Alliance members.

Power Consumption
LoRaWAN data transmission and reception requires ultra low power and providing battery operation an excellent feature for long lifespan.

Cost
LoRaWAN open standard combined with cost-free operations frequencies and cost-effective base-stations allowing public networks and private networks to be roll out in a very short timeframe. Provides a Opex business model over Capex

Unique Value Proposition
Unlike NB-IoT where it is limited to locations where 4G/LTE base stations can be set up. The number of base stations is about 7 – 10 times less compared to NB-IoT.

Application

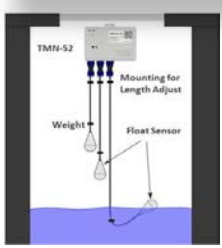
Covering diverse applications with a common air interface and network architecture

Huge amount of devices with small data and delay tolerant traffic

Smart Metering
- Small amount of uplink only
- Every 15 min
- Rare handover

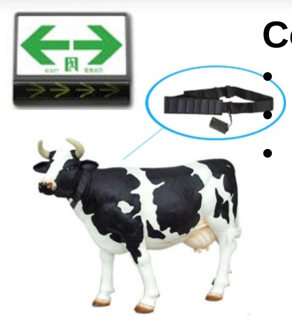
Connected Trash Cans
- Small amount of uplink only
- Spontaneous communication
- Rare handover

Devices running on Battery only – sometimes in difficult environment



Smart Metering (Flood/Water/…)
- 10 year battery life time
- Located in the basement
- Rare handover

LoRa



Connected Herd
- Small amount of uplink only
- Spontaneous & Periodic communication
- Rare handover (coverage)

Deployment – Nationwide
Australia & New Zealand

New Zealand telecommunications carrier Spark has partnered with Activity to build a LoRa® IoT network across the country by 2018.

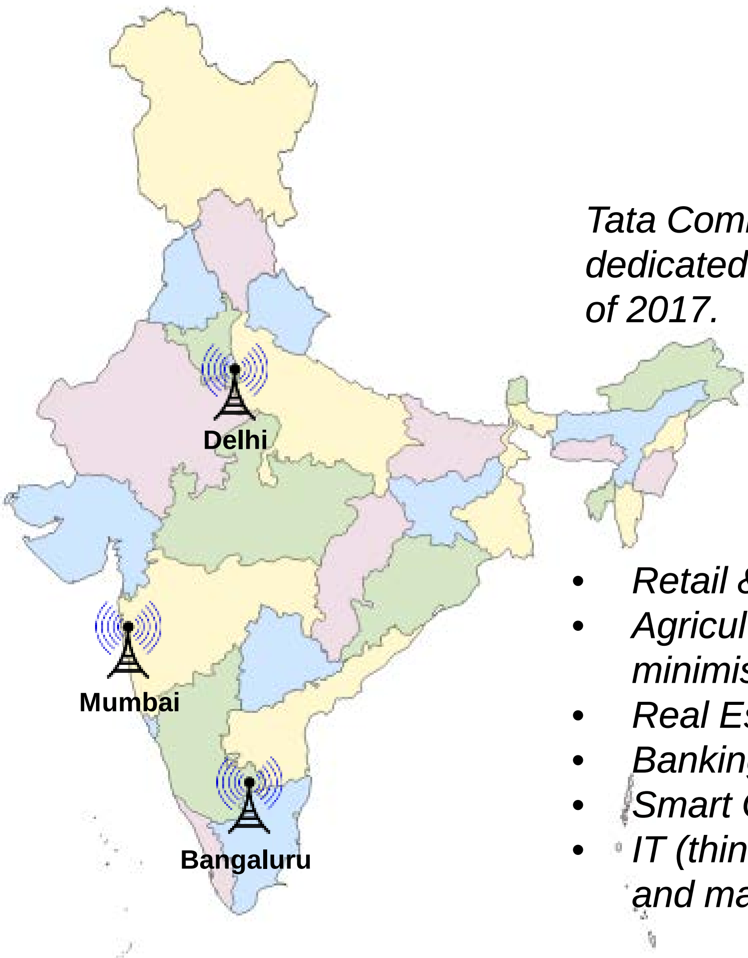
NNNCo announces rollout of LoRaWAN™ network comes six months after the trial of the LoRaWAN™ technology.

KotahiNet aims to expand their LoRa® deployment to Auckland, Hamilton, Taranaki, Christchurch, and rural Canterbury over the next year, and go nationwide after that.

Deployment – Private & Public
West Malaysia & Brunei

Telekom Brunei Berhad (TelBru) is moving forward to facilitate alternative resources of technological assurances with the introduction of long-range, low-powered, low-bandwidth and low-cost sensors.

Deployment – Nationwide
India



Tata Communications plans to expand its LoRaWAN™ network dedicated solely for the Internet of Things to 60 cities by the end of 2017.

- *Retail & Wholesale Trade (think Logistics, Asset Tracking)*
- *Agriculture (Smart Farming to improve crop yields and minimise pest infestation)*
- *Real Estate (Smart Building and Employee Safety)*
- *Banking & Insurance (think Asset Tracking)*
- *Smart Cities (Street Lightings, Traffic Light)*
- *IT (think the IoT ecosystem to support the design, deployment and management of IoT solutions)*

Agenda

- Internet of Things (IoT)
- **LoRaWAN™ Networking Standard**
- LoRa® Technology Wireless Modules
- Getting Started with RN2903 Module
- Hands-on workshop

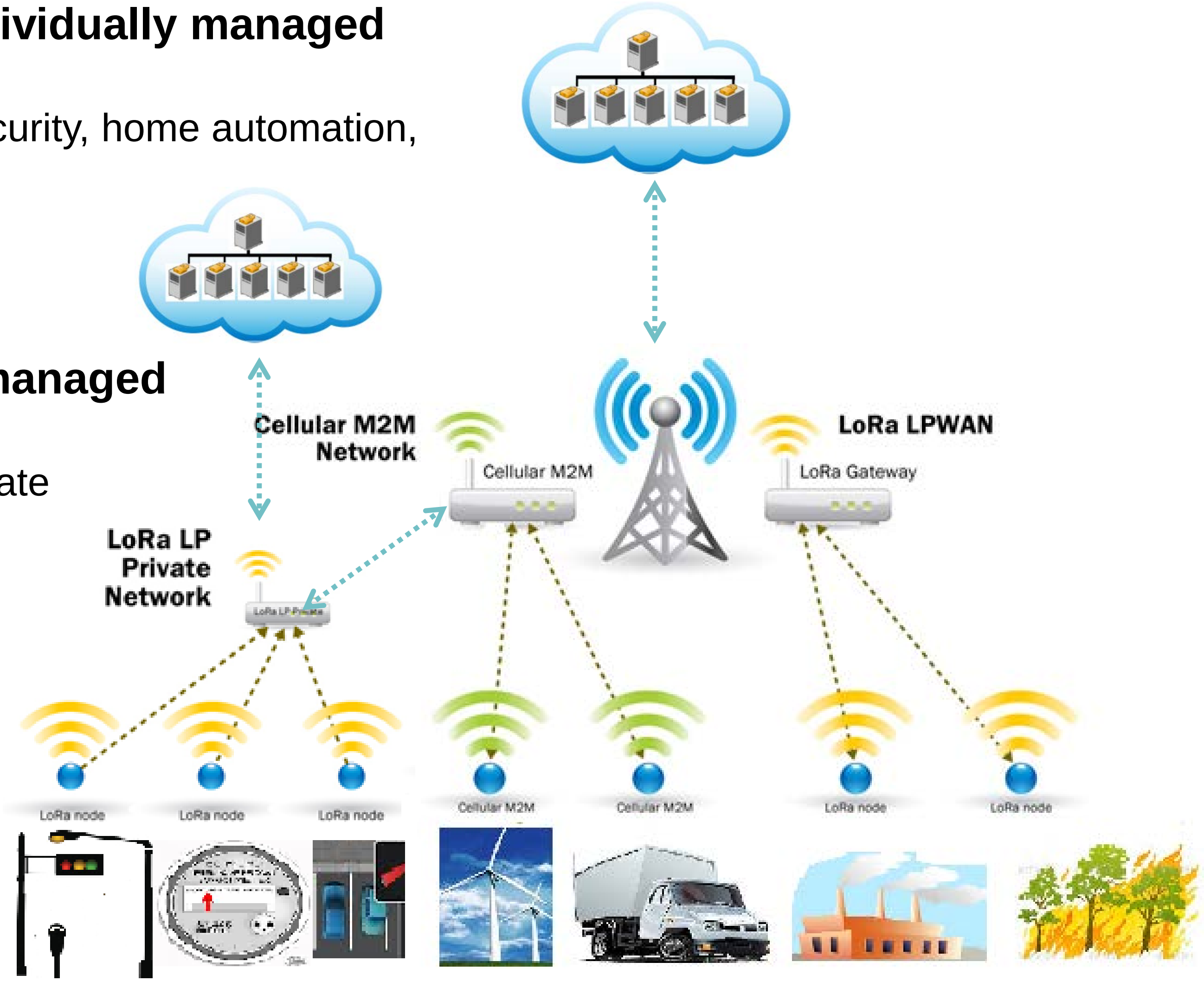
Introducing LoRa/WAN

- **LoRa® Technology**
  - Long-range, low-cost spread spectrum modulation
- **Trades low data rate for long range & battery life**
- **LoRaWAN™:**
  - High-capacity cellular network protocol & topology
  - Based on gateways & network servers
- **Driven by an open Alliance**
- **Cloud emphasis makes this a pure IoT technology**
- **Promotes an Op-Ex, not Cap-Ex model for customers**

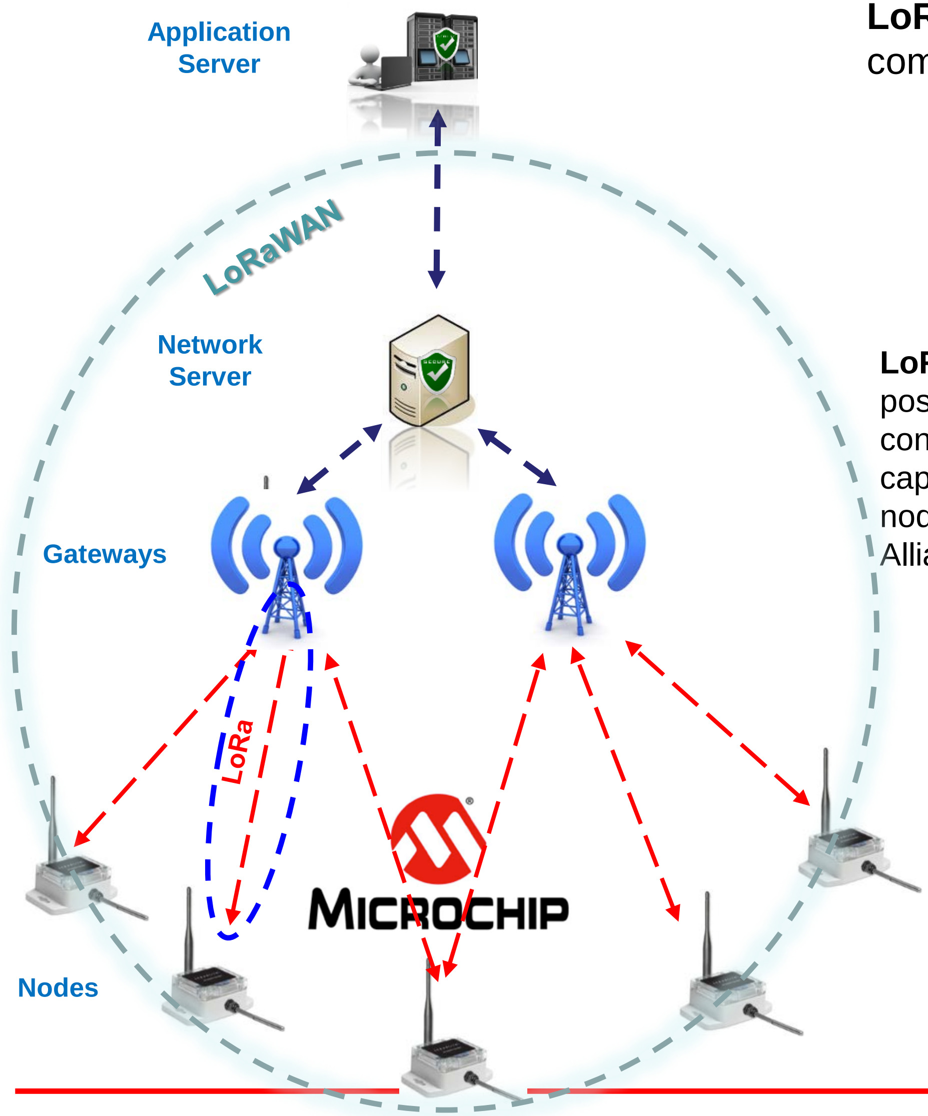
LoRaWAN™ Network Deployment

- ❑ **Private network- individually managed networks**
  - Smart city, Metering, security, home automation, industrial control
  - Local network

- ❑ **Public network- Telecom/operator managed networks**
  - Includes traditional private networks
  - Permits numerous new applications
  - A much more scalable model
  - Nationwide network



LoRa & LoRaWAN™ Overview



LoRa contains only the link layer protocol used in P2P communications between nodes.

LoRaWAN™ includes the LoRa & network layer together so it is possible to send the information to any Base Station already connected to a Cloud platform. It is the MAC protocol for high capacity, long range, low power, Internet of Things network of LoRa nodes. It is an open LPWAN standard maintained by the LoRa Alliance.

- Star topology in which gateways is a transparent bridge relaying messages between end-devices and a central network server in the backend.
- Gateways are connected to the network server via standard IP connections while end-devices use single-hop wireless communication to one or many gateways.

Sub-Agenda

- **LoRaWAN™ Network Protocol**
  - How does LoRaWAN Technology Work?
  - End-Device Classes
  - End-Device Activation (Joining)
  - Security

Sub-Agenda

- **LoRaWAN™ Network Protocol**
  - How does LoRaWAN™ Technology Work?
  - End-Device Classes
  - End-Device Activation (Joining)
  - Security

LoRaWAN™ Network Protocol
LoRa® Technology Modulation

LoRa Modulation is set by the following settings :

- **Spreading Factor (SF) ;** logarithm in base 2
  - Programmable SF:

    7, 8, 9, 10, 11, 12
  - The higher the SF the more information transmitted per bit; therefore higher processing gain
- **Bandwidth (BW)**
  - Programmable signal BW settings:

    125 kHz, 250 kHz, 500 kHz
  - For a given SF, a narrower BW = increased receive sensitivity; however, increased time on air
- **Forward Error Correction (FEC) Code Rate (CR)**
  - Additional coding rate provides more redundancy to detect errors and correct them

LoRaWAN™ Network Protocol Modulation Settings AS923

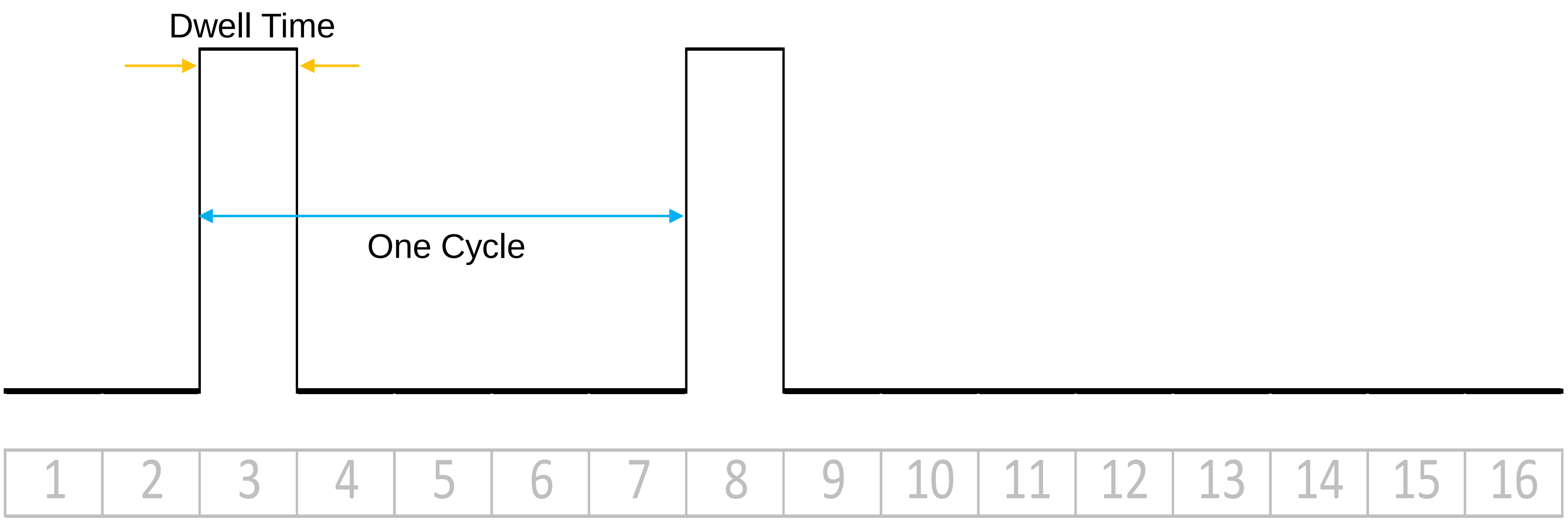
Longest Distance on LoRa® Modulation

- **Data Rate (DR) = 0**
  - LoRa® modulation
  - Spreading Factor (SF) = SF10
  - Bandwidth (BW) = 125 kHz
  - Coding Rate (CR) = 4/5

- **Bit Rate = 976 bps**

$$\boxed{R_b = SF \times \frac{BW}{2^{SF}} \times CR}$$

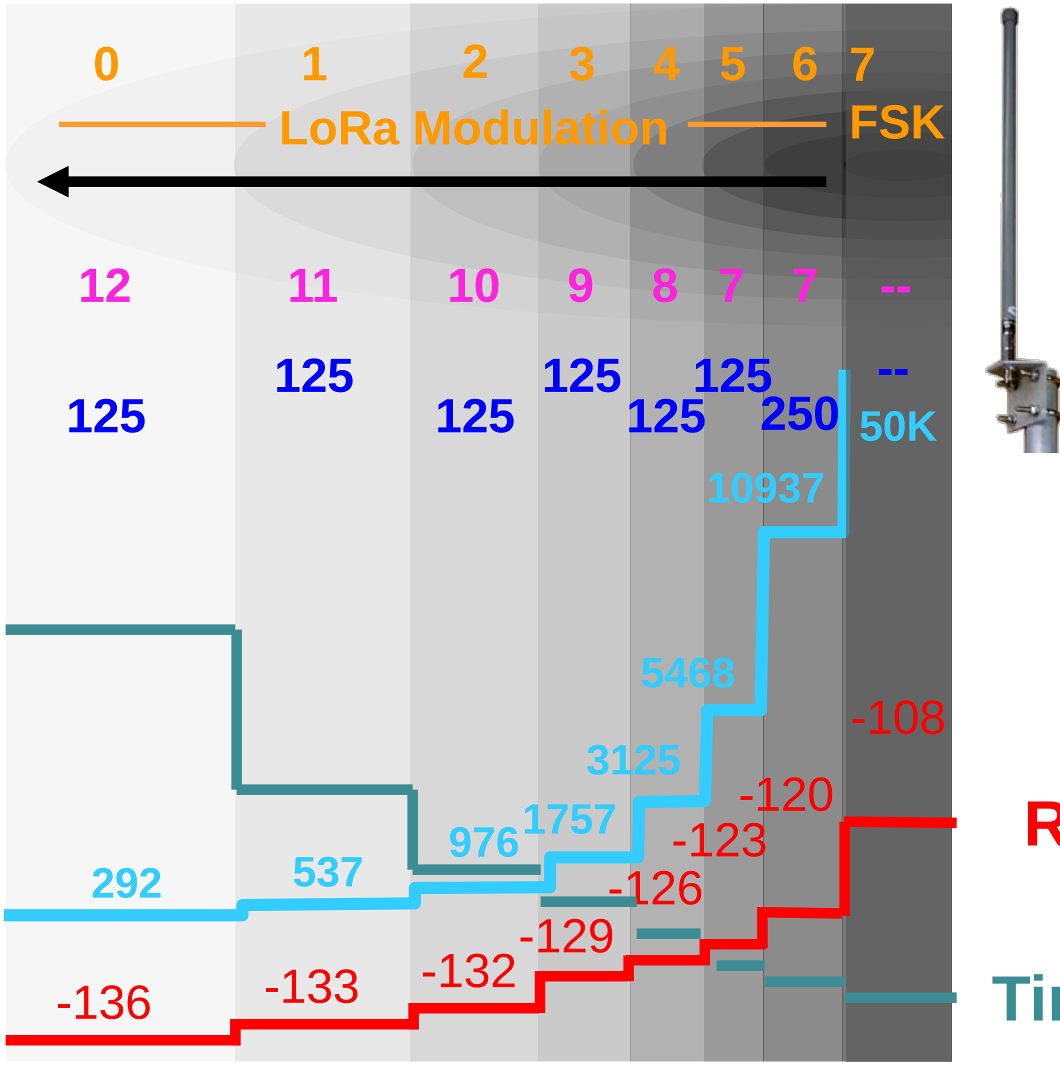
Duty Cycle & Dwell Time



Duty cycle is the ratio of transmission time to the time of the next transmission.
AS923 Duty Cycle is at 1%.
For every 400ms, the device cannot Tx on the same channel until 40 secs later.

Dwell Time is the time take to transmit Tx. Also known as Time on Air.
AS923 Limits Dwell Time to 400ms

LoRaWAN™ Network Protocol Modulation Settings AS923



Data Rate (DR)

Range

Spreading Factor (SF)

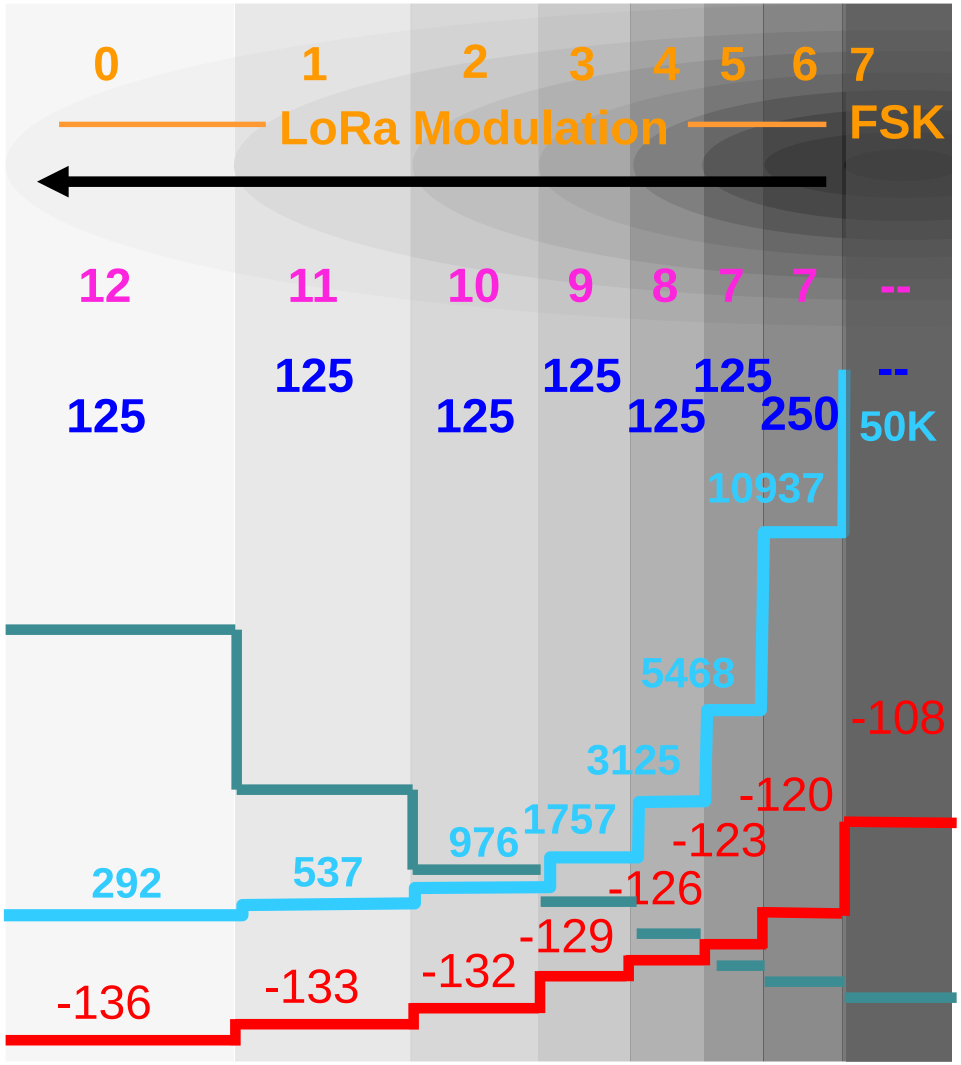
Bandwidth (BW) (kHz)

Bitrate (BR) (bps)

Receive Sensitivity (dBm)

Time-on-air & consumption

LoRaWAN™ Network Protocol Modulation Settings AS923



DataRate	Configuration	Indicative physical bit rate [bit/s]
0	LoRa: SF12 / 125 kHz	250
1	LoRa: SF11 / 125 kHz	440
2	LoRa: SF10 / 125 kHz	980
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
8..15	RFU	

Payload (AS923)

DataRate	*Uplink MAC Payload Size (M)*		*Downlink MAC Payload Size (M)*	
	UplinkDwellTime = 0	UplinkDwellTime = 1	DownlinkDwellTime = 0	DownlinkDwellTime = 1
0	59	N/A	59	N/A
1	59	N/A	59	N/A
2	59	19	59	19
3	123	61	123	61
4	230	133	230	133
5	230	250	230	250
6	230	250	230	250
7	230	250	230	250
8:15	RFU		RFU	

Table 53: AS923 maximum payload size

Time on Air (AS923)

Payload (Bytes)	PHY (Bytes)	PHY (Bits)	SF12	SF11	SF10	SF9	SF8	SF7	Spreading Factor
			250	440	980	1760	3125	5470	bps
4	17	136	0.544	0.309	0.139	0.077	0.044	0.025	Time (sec)
8	21	168	0.672	0.382	0.171	0.095	0.054	0.031	
16	29	232	0.928	0.527	0.237	0.132	0.074	0.042	
24	37	296	1.184	0.673	0.302	0.168	0.095	0.054	

https://docs.google.com/spreadsheets/d/1QvcKsGeTTPpr9icj4XkKXq4r2zTc2j0gsHLrnplzM3I/edit#gid=0

LoRaWAN™ Network Protocol
LoRaWAN Channels

- **License free Sub-GHz Frequencies**
  - Asia AS923 (LoRaWAN102)
  - Network channels can be freely attributed by the network operator
  - 2 mandatory channels that all Network Gateways should constantly receive:

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	923.2 923.4	DR0 to DR5 / 0.3-5 kbps	2	< 1%

  - End-devices must be capable of at least 16 channels
  - The default JoinReq Data Rate is DR2 (SF10/125KHz), this setting ensures that end-devices are compatible with the 400ms dwell time limitation until the actual dwell time limit is notified to the end-device by the network server via the MAC command “TxParamSetupReq”. (Used by the network server to set the maximum allowed dwell time and Max EIRP of end-device, based on local regulations)

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	923.2 923.4	DR2	2	< 1%

AS923 ISM Band Channel Frequencies

This section applies to regions where the frequencies [923…923.5MHz] are comprised in the ISM band, which is the case for the following countries:

- Brunei [923-925 MHz]
- Cambodia [923-925 MHz]
- Hong Kong [920-925 MHz]
- Indonesia [923-925 MHz]
- Japan [920-928 MHz]
- Laos [923-925 MHz]
- New Zealand [915-928 MHz]
- Singapore [920-925 MHz]
- Taiwan [922-928 MHz]
- Thailand [920-925 MHz]
- Vietnam [920-925 MHz]

Sub-Agenda

- **LoRaWAN™ Network Protocol**
  - How does LoRaWAN™ Technology Work?
  - End-Device Classes
  - End-Device Activation (Joining)
  - Security

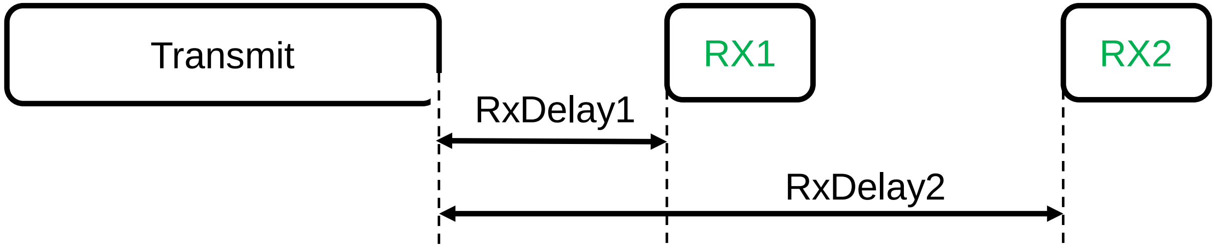
LoRaWAN™ Network Protocol
End-Device Classes

- **Each end-device class has different behavior depending on the choice of optimization:**
  - Battery Powered – Class A
  - Low Latency – Class B
  - No Latency – Class C

LoRaWAN™ Network Protocol

End-Device Classes

- **Battery Powered – Class A**
  - Bidirectional communications
  - Unicast messages
  - Small payloads
  - Long intervals
  - End-device initiates communication (uplink)
  - Server communicates with end-device (downlink) during predetermined response windows:



LoRaWAN™ Network Protocol

End-Device Classes

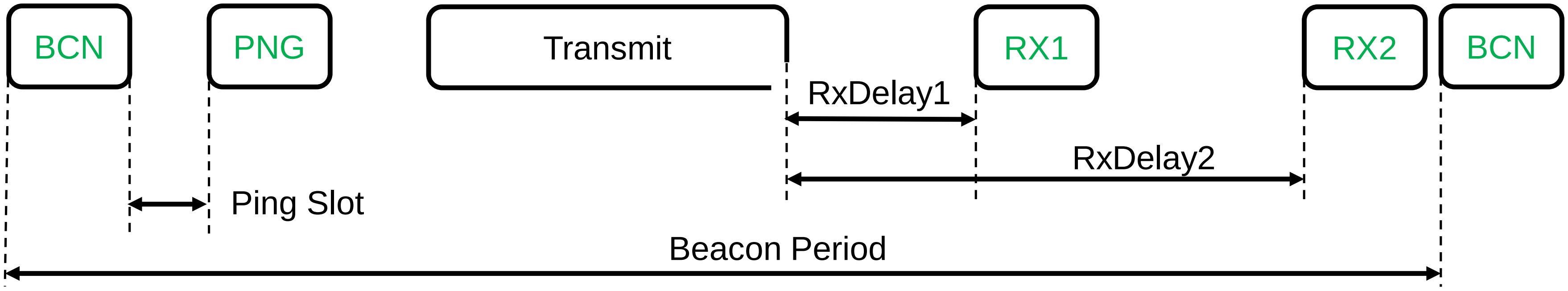
- **Battery Powered – Class A**
  - **Pros**
    - Lowest power consumption = longest battery life
    - Higher Density of Nodes to Gateway ; Network Management, More Channels availability
  - **Cons**
    - Long latency

- **Examples**
  - Node Trigger Events
    - Battery powered Sensors
    - Environmental Sensors

LoRaWAN™ Network Protocol

End-Device Classes

- **Low Latency – Class B**
  - Bidirectional with scheduled receive slots
  - Unicast and Multicast messages
  - Small payloads
  - Long intervals
  - Periodic beacon from gateway
  - Extra receive window (ping slot)
  - Server can initiate transmission at fixed intervals



LoRaWAN™ Network Protocol

End-Device Classes

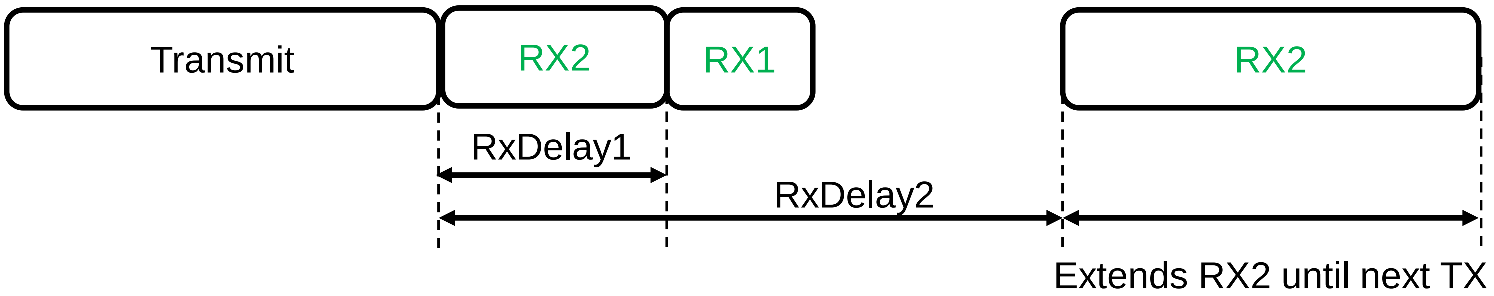
- **Low Latency – Class B**
  - **Pros**
    - Deterministic latency
  - **Cons**
    - Higher power consumption

- **Examples**
  - Battery powered actuator end-device
  - Eg Solar Panel as secondary source sensors that requires monitoring from network servers
    - Irrigation System

LoRaWAN™ Overview

End-Device Classes

- **No Latency – Class C**
  - Bidirectional communications
  - Unicast and Multicast messages
  - Small payloads
  - Server can initiate transmission at any time
  - End-device is constantly receiving



LoRaWAN™ Network Protocol

End-Device Classes

- **No Latency – Class C**
  - **Pros**
    - Lowest receive latency
    - End-device has continuous receive window
  - **Cons**
    - Highest power consumption
      (expect end-device to be mains powered)

- **Examples**
  - Mains power low-latency actuator end-device
  - Eg Smart E-meter or Street Lighting Control

LoRaWAN™ Network Protocol

End-Device Classes

Device Class	LoRa Class A	LoRa Class B	LoRa Class C
Latency	High Latency	Low Latency	No Latency
Communication Direction	Bidirectional communications	Bidirectional with scheduled receive slots	Bidirectional communications
Packet Delivery	Unicast messages	Unicast and Multicast messages	Unicast and Multicast messages
Payload Size	Small payloads, long intervals	Small payloads, long intervals, Periodic beacon from gateway	Small payloads
Communication Initiative	End-device initiates communication (uplink)	Extra receive window (ping slot)	Server can initiate transmission at any time
	Server communicates with end-device (downlink) during predetermined response windows	Server can initiate transmission at fixed intervals	End-device is constantly receiving

Sub-Agenda

- **LoRaWAN™ Network Protocol**
  - How does LoRaWAN™ Technology Work?
  - End-Device Classes
  - End-Device Activation (Joining)
  - Security

LoRaWAN™ Network Protocol End-Device Activation (Joining)

- **Before an end-device can communicate on the LoRaWAN network, it must be activated**
- **The following information is required:**
  - Device Address (DevAddr)
  - Network Session Key (NwkSKey)
  - Application Session Key (AppSKey)

Let's look at each of these in detail…

LoRaWAN™ Network Protocol End-Device Activation (Joining)

- **Device Address (DevAddr)**
  - 32-bit identifier
  - Unique within the network
  - Present in each data frame
  - Shared between End-device, Network Server, and Application Server
- **Differentiates nodes within the network, allowing the network to use the correct encryption keys and properly interpret the data**

LoRaWAN™ Network Protocol
End-Device Activation (Joining)

- **Network Session Key (NwkSKey)**
  - 128-bit AES encryption key
  - Unique per end-device
  - Shared between end-device and Network Server
- **Provides message integrity for the communication**
- **Provides security for end-device to Network Server communication**

LoRaWAN™ Network Protocol End-Device Activation (Joining)

- **Application Session Key (AppSKey)**
  - 128-bit AES encryption key
  - Unique per end-device
  - Shared between end-device and Application Server
  - Used to encrypt / decrypt application data messages
- **Provides security for application payload**

LoRaWAN™ Network Protocol End-Device Activation (Joining)

- **To exchange this information, two activation methods are available:**

Over-the-Air Activation (OTAA)	**Activation By Personalization (ABP)**
- Based on Globally Unique Identifier - Over the air message handshaking 	- Shared keys stored at production time - Locked to a specific network 

LoRaWAN™ Network Protocol End-Device Activation (Joining)

Over-the-Air-Activation (OTAA)

- End-device transmits Join Request to application server containing:
  - Globally unique end-device identifier (DevEUI)
  - Application identifier (AppEUI)
  - Authentication with Application key (AppKey)
- End-device receives Join Accept from application server

(continued…)

LoRaWAN™ Network Protocol End-Device Activation (Joining)

Over-the-Air-Activation (OTAA)

- End-device authenticates Join Accept
- End-device decrypts Join Accept
- End-device extracts and stores Device Address (DevAddr)
- End-device derives:
  - Network Session Key (NwkSKey)
  - Application Session Key (AppSKey)

Security Keys

LoRaWAN™ Network Protocol End-Device Activation (Joining)

Activation By Personalization (ABP)

- The following information is configured at production time:
  - Device Address (DevAddr)
  - Network Session Key (NwkSKey)
  - Application Session Key (AppSKey)
- No over the air handshaking
- Device is ready to communicate on the network without any additional procedure.
- Note that the end result is the same, the DevAddr and security keys are now known to the end-device

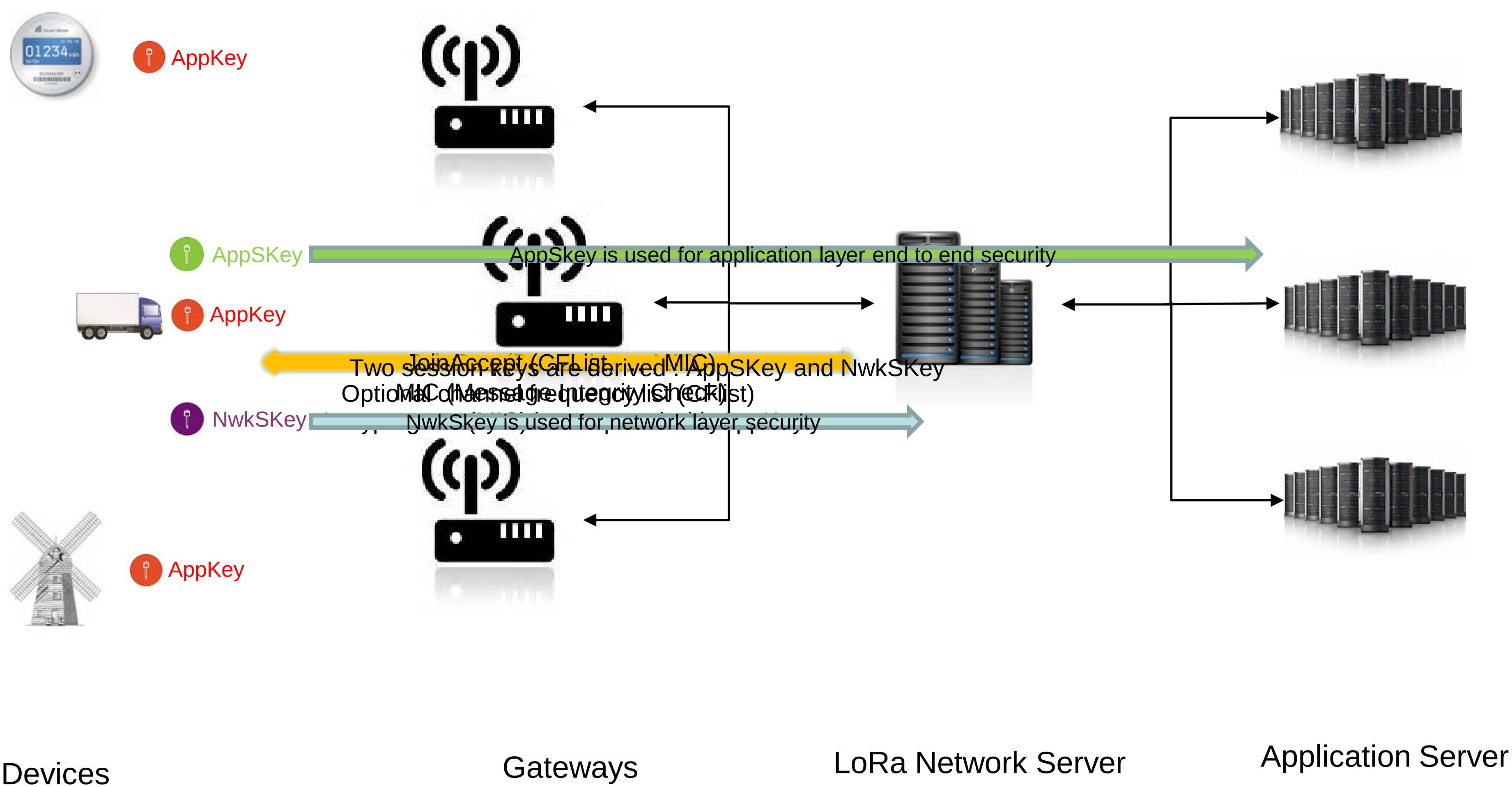
Sub-Agenda

- **LoRaWAN™ Network Protocol**
  - How does LoRaWAN™ Technology Work?
  - End-Device Classes
  - End-Device Activation (Joining)
  - Security

LoRaWAN™ Network Protocol Security

- **Based on 802.15.4 Security**
  - AES-128
- **Enhancement**
  - Network Session Key (NwkSKey)
  - Application Session Key (AppSKey)
  - Network Server authenticates Application Data
  - Network Server cannot decrypt Application Data

LoRaWAN Security: Network Connection



Sub-Agenda

- **LoRaWAN™ Network Protocol**
  - How does LoRaWAN™ Technology Work?
  - End-Device Classes
  - End-Device Activation (Joining)
  - Security
  - End-Device Data Communication
  - Adaptive Data Rate (ADR)

LoRaWAN™ Network Protocol
Adaptive Data Rate (ADR)

- **LoRaWAN can manage**
  - Data rate and
  - RF power output

  for each end-device to
  - Optimize for fastest data rate,
  - Maximize battery life, and
  - Maximize network capacity

  based on range from gateway

More information available on below link on how ADR works.
http://sakshamaghoslya.blogspot.com/p/how-does-lorawan-nodes-changes-their.html

Summary

- **LoRaWAN™ Network Protocol**
  - How does LoRaWAN™ Technology Work?
  - End-Device Classes
  - End-Device Activation (Joining)
  - Security

Agenda

- BREAK

Agenda

- Internet of Things (IoT)
- LoRaWAN™ Networking Standard
- **LoRa® Technology Wireless Modules**
- Getting Started with RN2903 Module
- Hands-on workshop

Introducing RN2903A-I/RM FCC LoRaWAN™ Modem

Key Features

- LoRaWANv1.0 Class-A "*Golden Unit*" Stack
- 915MHz, external antenna
- Integrated filtering and matching circuits
- I/O Expansion: 6x analog, 6x digital, UART, I2C
- Compact size: 27 x 18 x 3.2 mm
- FCC Modular Certification

Complete Solution!

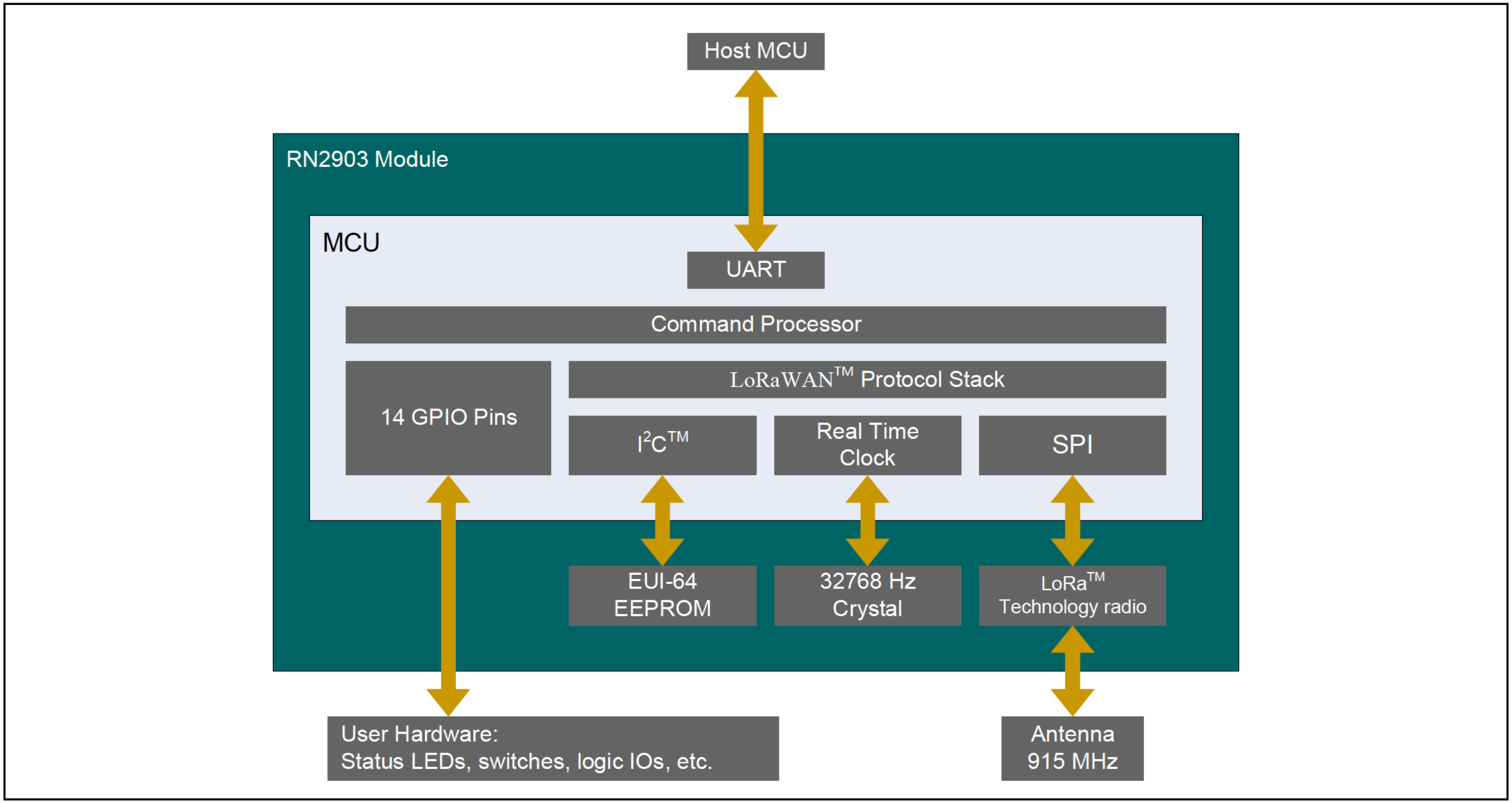
- Integrates LoRa® Radio, PIC MCU & LoRaWAN Stack
- Pre-tested against all major LoRaWAN gateways & servers
- Simple ASCII Command Set
- Optimized for Embedded Designs
- Quick Time-to-Market

Development Tools

- PICtail for Microchip MCU kits
- Mote for portable testing
- Both support USB Interface
- Demo Code available

Introducing RN2903
FCC Modem Block Diagram

FIGURE 1-3: RN2903 BLOCK DIAGRAM



RN2xx3A Modem Family
Key Features

	434 MHz	868 MHz	915 MHz
High Tx OP Power	+10 dBm	+14 dBm	+18.5 dBm
High Sensitivity	-137 dBm	-136 dBm	-132 dBm
Link Budget	147 dB	150 dB	150 dB
Tx Current (Max Power)	33 mA	39 mA	124 mA
Rx Current	14.2 mA		13.5 mA
Sleep Current	1.8 uA		2 uA
Embedded LoRaWAN Features	Complete LoRaWANr1.0 Class-A Functionality (E.g. ABP, OTAA, ADR …)		
Modulation	LoRa & FSK (Selected automatically by DR)		LoRa
Test Modes	‘Radio Mode’ for functional test & range trials		

Firmware Support Availability

Channelization	RN2483A	RN2903A	SAMR3xM	Countries	Remarks
915MHz		✓	✓	US / FCC	
868/433MHz	✓		✓	EU /ESTI	
AS923		✓	✓	Vietnam, Thailand, Lao, Singapore, Indonesia, Hong Kong, Aust, NZ, Brunei, Cambodia	
		×	✓	Japan	With LBT
KR923		×	✓	Korea	With LBT
MY919		✓	×	Malaysia	Will be moving to AS923
AU915		✓	×	Aust	Will be moving to AS923
IN865		✓	✓	India	

Collateral Available
See www.microchip.com/RN2903

- ☑ RN2903 Modules - In Mass Production
- ☑ RN2903 Datasheet - Online
- ☑ RN2903 Command Ref Users Guide – Online
- ☑ FCC Certifications – Completed & Online
- ☑ Product Landing Page - Live
- ☑ $65 PICTAIL Kit & Users Guide - Available
- ☑ $70 MOTE Kit & Users Guide – Available

RN-2903-MOTE Kit (DM164139)
See www.microchip.com/RN2903

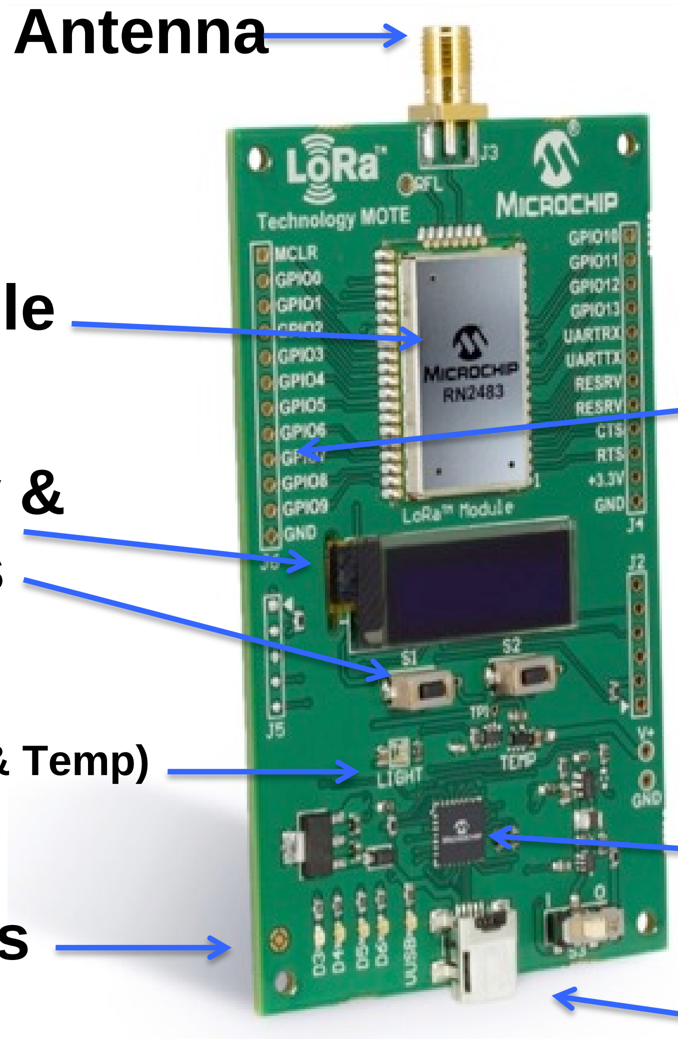
915 MHz SMA Antenna

RN2903 Module

OLED Display & Menu Buttons

Sensors (Light & Temp)

LED Indicators



Battery (reverse)

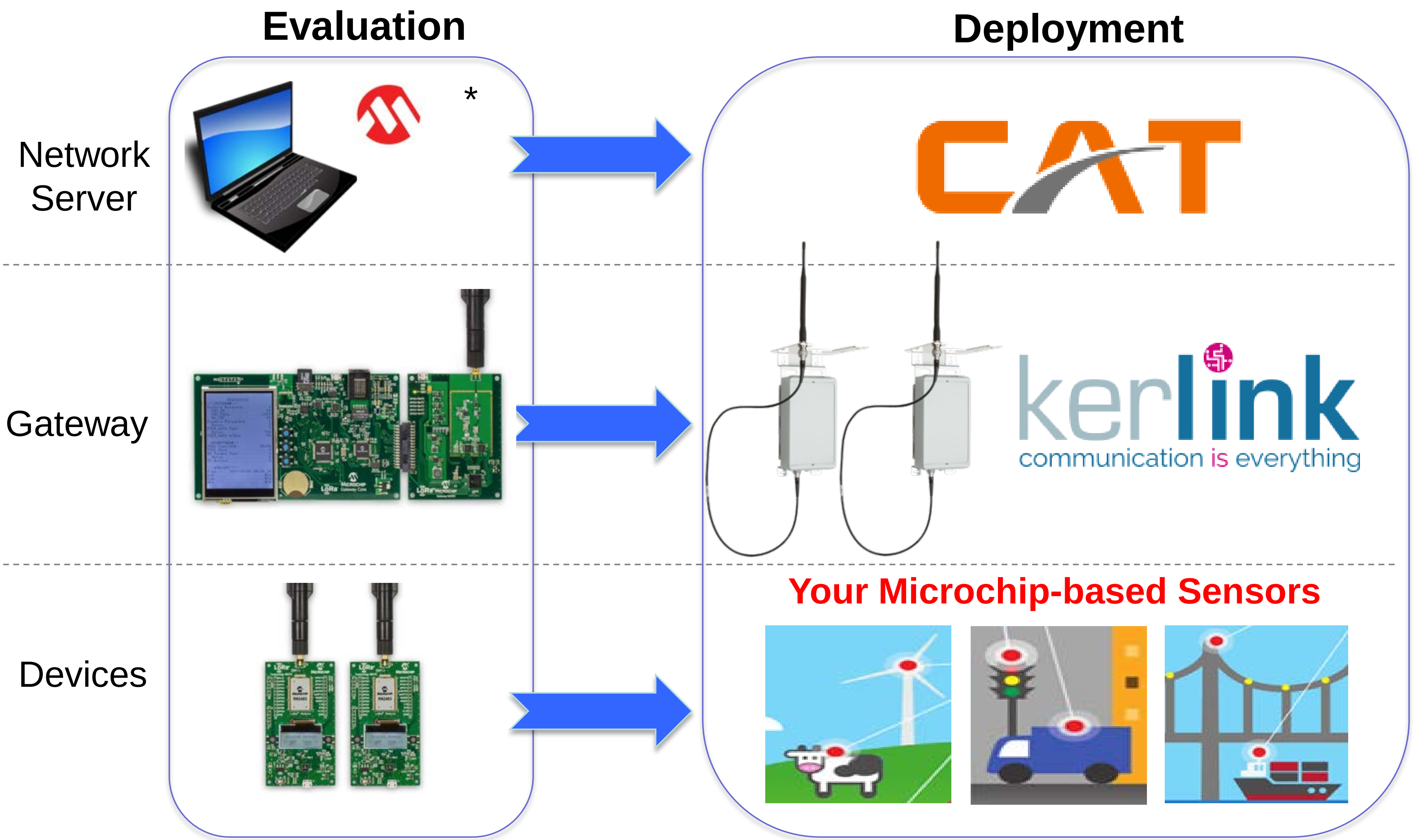
GPIO Test Points

ICSP (App/USB)

USB-UART Bridge

USB Port (micro)

R&D Evolution
Transition to LoRaWAN Ecosystem



* PC Not Included

Specification Status

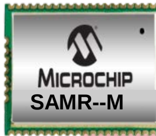
- **1R0 - Original Release, mid 2015**
  - EU, NA, China bands
  - Certification released Nov 2015
- **v1.0.1 – Minor editorial updates, April 2016**
  - Adds Korea & Australia
  - EU Certification released mid 2016
  - US Certification released Jan 2017
- **v1.0.2 – Separated Regional Parameters, Oct 2016**
  - Accelerates regional releases outside of 60day IPR review
  - Adds multiple regional channel plans
  - Certification due soon, inc class C
- **V1.1 – Major Updates (in IPR review now)**
  - Standardises back-end interfaces for roaming & join servers
  - Formalises class B

Other Ecosystem Developments

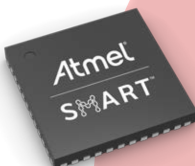
- Geo-location feature is becoming available
- New players for join servers & data brokers
- Multiple demos of firmware OTA updates
  - Relies on spec v1.0.1 with class C & multi-cast
- Additional PHY layers being discussed
- Most collaborations are Cortex-focused
- PoCs & trails are moving to scale

LoRa Roadmap Strategy

- Easy to use Modules
- LoRa Alliance Certified
- Regulatory Certified
- Custom Code Development
- Reduce Cost and Size



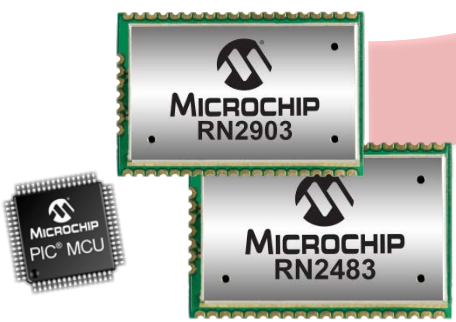
ARM-based Module – Available 2H'18
- SiP feature set in module form-factor
- Size & cost optimized
- Enhanced crypto/authentication options



ARM-based SiP – Available 1H'18
- Cortex M0+ MCU + Radio
- Atmel Studio + ASF LoRa Library
- Low power Sleep
- Smallest form-factor

Open Modules or Discrete MCUs – Available Now!
- Application & LoRaWAN Library merged inside module
- Eliminates external MCU
- Delivered via MPLAB + **M**icrochip **C**ode **C**onfigurator (MCC)
- Also supports 1000's of MCUs for discrete designs

Not Recommended

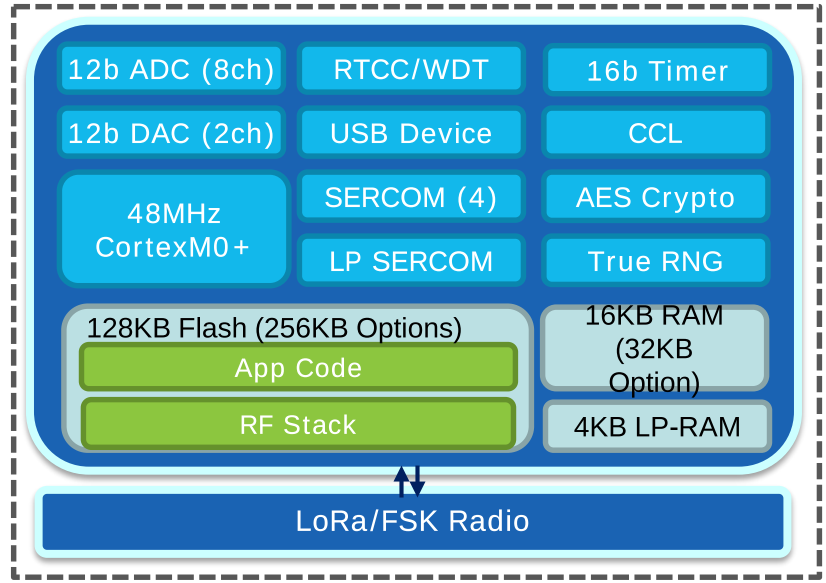


Network Co-Processor (NCP) Modules – Certified & Available Now!
- LoRaWAN stack running on module
- Application running on external MCU
- Easiest path to integrate LoRaWAN

Single-chip MCU with LoRa™ Transceiver

Highly Integrated Solution

- Cortex M0+ MCU & LoRa™ Radio in a compact BGA package!
- Family of cost optimized variants:
- 64 / 128 / 256 KB flash
- USB (SAMR34) & non-USB (SAMR35)
- Ultra Low Power Consumption
  - << 1 uA sleep with RTC & LPRAM retention
- Backup RAM retention for frame counters
- Hardware AES crypto accelerators
- True Random Number Generator
- High performance ADC and analog peripherals for sensor nodes
- 169, 433, 78[illegible] & 915MHz band support

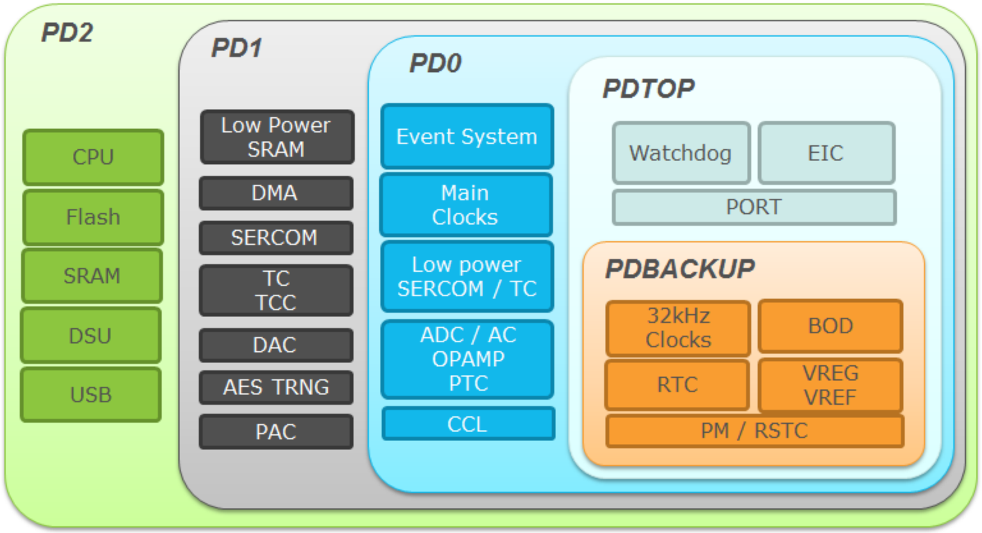


- 6 x 6 x 1.2 mm 64-ball TFBGA package
- Free access to Microchip-maintained, Alliance-certified ‘Golden’ LoRaWAN stack
- Complimentary module family with certifications

The worlds lowest power Cortex M0+
Design methodology for picoPower devices

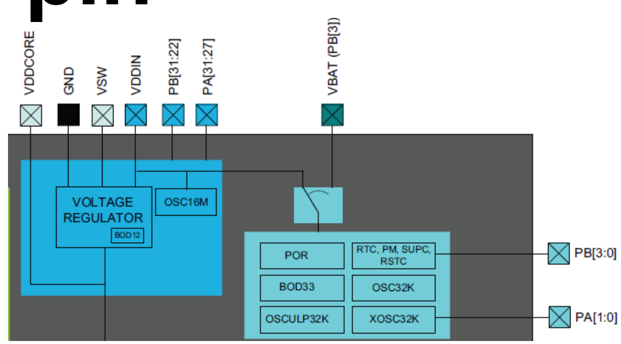
- **Industry first Ultra Low Power, Large Flash Cortex M0+ MCUs**
- **Targeted for LPWAN wireless applications**
- **Designed with emphasis on ultra low power process:**
  - Low active mode power consumption
  - Smart low power peripherals, with Event System & Sleepwalking
  - Industry leading RAM retention numbers
- **Multiple power sources and clocking options**
- **Flexible Sleep Modes**
- **Multiple Domains**
  - Power & clock gating
- **picoPower Peripherals**
  - SERCOM, PTC & TC
- **Low Power Analog**

Overview of SAM L21 Power Domains



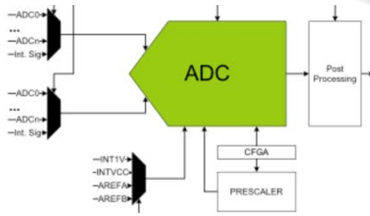
Battery Backup Modes
For LoRaWAN Radio State Retention

- Brown-out or Automatic Power Switch can switch the backup domain to VBAT pin automatically
- Retains battery backup registers and RTC
- Backup domain can be forced to run from VBAT pin



Wireless Sensor-Node Features
Enabling highly optimized designs

Precision ADC



- 12bit 10K-to-1M sps
- Input Sequencing
  - More flexible than input scan, as inputs do not need to be in a continuous sequence
- Flexible Power / Rate Management

Crypto Engine

- Decrypt and Encrypt
- 128 bit block of input data
- 128/192/256 bit keys supported
- Encryption time of 77 cycles with 256-bit key

True Random Number Generator

- Generates a new 32-bit random number every 84 CLK cycles
- Optional Interrupt when a new random number is available
- Used to generate inputs for Authentication challenges

Integrated Op-Amps

- 3 low power rail-to-rail OpAmps
- Internal resistors to form different OpAmp feedback circuits
- GPIO, DAC, Gnd Inputs available
- Output available on GPIO and ADC
- Low power configuration options
  - Performance vs power

Atmel Studio 7
World-class tool chain for Atmel MCUs

- **Available for free at atmel.com**
- **Powerfull**
  - Based on Visual Studio 2015 frontend
  - Supports 8/32-bit AVR and ARM development and debugging for Atmel MCU targets
  - Supports project migration from earlier Studio versions
- **Easy to use**
  - Extensive embedded software library
  - Integrated training modules and examples
- **Extensible**
  - Rich 3rd-party ecosystem of plugins
  - Configuration tools for Atmel Touch and Wireless technologies
  - Supports data & power visualization

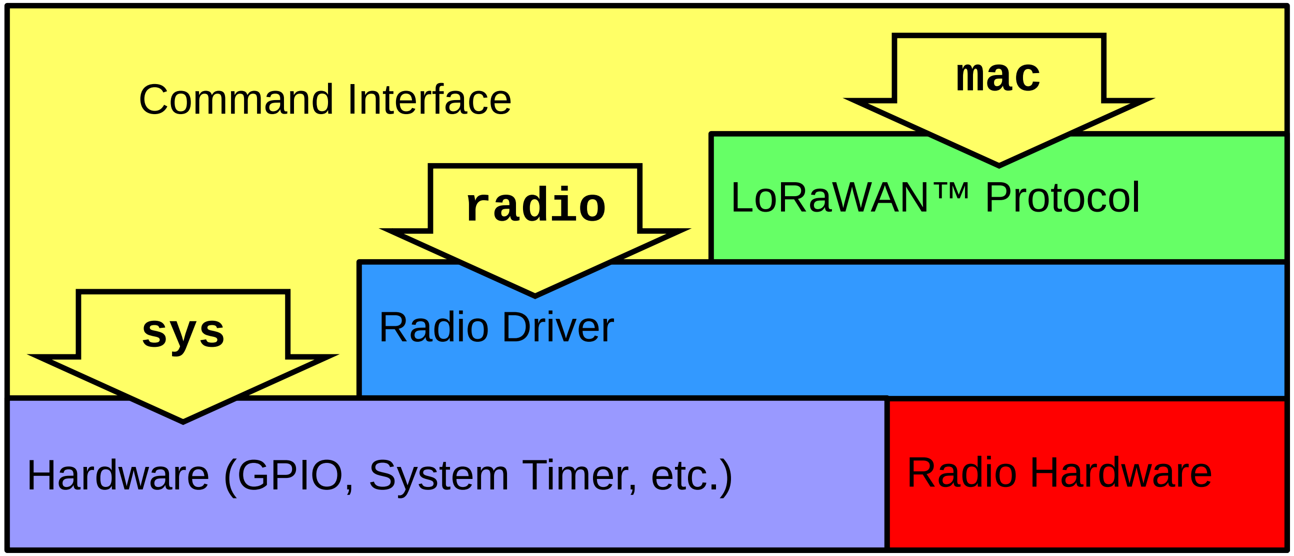
700,000+
Studio downloads since 2012

93%
Users ratings excellent, very good, good

Agenda

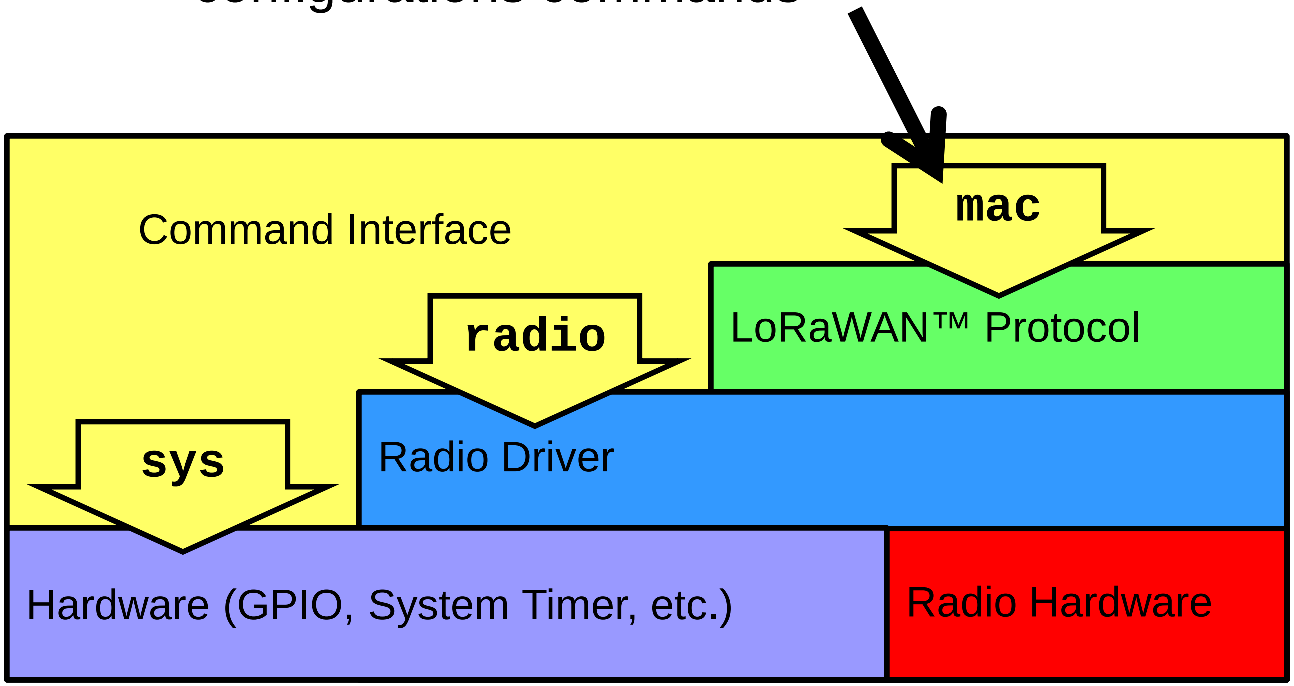
- Internet of Things (IoT)
- LoRaWAN™ Networking Standard
- LoRa® Technology Wireless Modules
- **Getting Started with RN2903A Module**
- Hands-on workshop

LoRa™ RN Modem API:
Command Structure



LoRa™ RN Modem API: Mac-Level Commands

`mac` : Issues LoRaWAN™ Class A protocol network communication behaviors, actions and configurations commands



LoRa™ RN Modem API: Mac-Level Commands

`mac` : Issues LoRaWAN™ Class A protocol network communication behaviors, actions and configurations commands

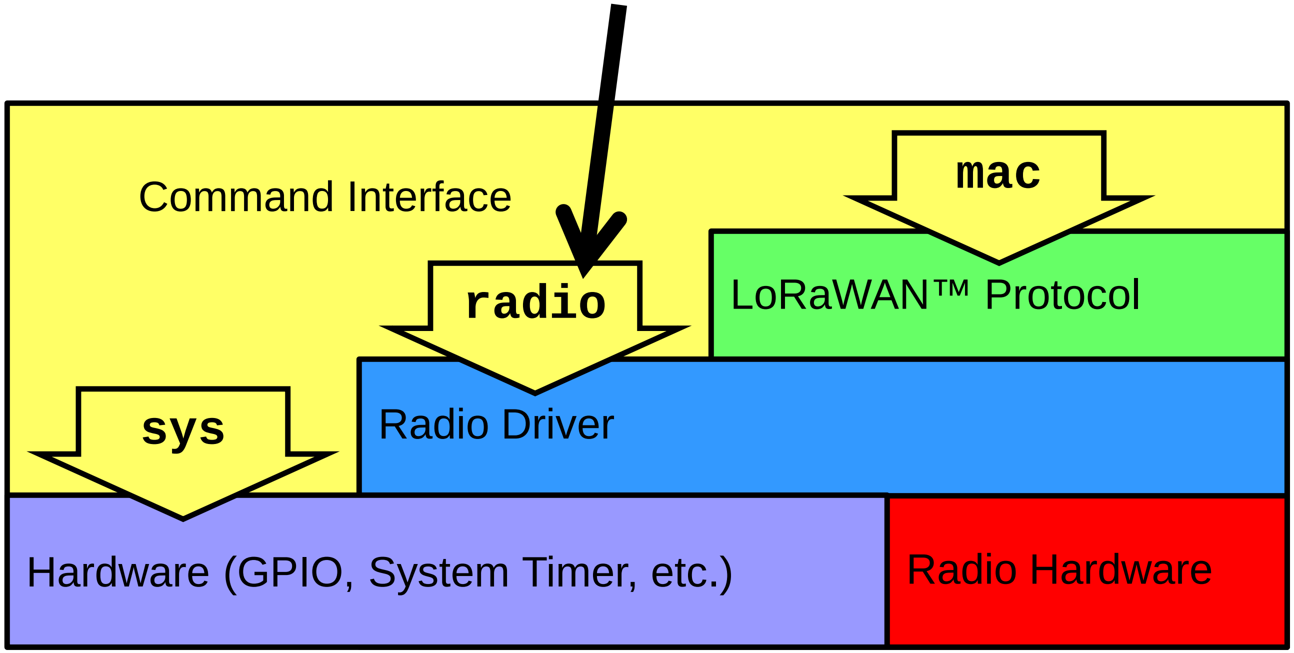
Parameter	Description
`reset`	Resets the RN2903 module.
`tx`	Sends the data string on a specified port number and sets default values for most of the LoRaWAN parameters.
`join`	Informs the RN2903 module to join the configured network.
`save`	Saves LoRaWAN configuration parameters to the user EEPROM.
`forceENABLE`	Enables the RN2903 module after the LoRaWAN network server commanded the end device to become silent immediately.
`pause`	Pauses LoRaWAN stack functionality to allow transceiver (radio) configuration.
`resume`	Restores the LoRaWAN stack functionality.
`set`	Accesses and modifies specific MAC related parameters.
`get`	Reads back current MAC related parameters from the module.

LoRa™ RN Modem API:
Mac-Level Commands

```
< mac set devaddr 048E436E
> Ok

< mac set nwkskey 01234567012345670123456701234567
> Ok

< mac set appskey 01234567012345670123456701234567
> Ok

< mac join abp
> ok
> accepted
```

LoRa™ RN Modem API: Radio-Level Commands

`radio` : Issues radio specific configurations, directly accessing and updating the transceiver setup



LoRa™ RN Modem API: Radio-Level Commands

`radio` : Issues radio specific configurations, directly accessing and updating the transceiver setup

Parameter	Description
`rx`	This command configures the radio to receive simple radio packets according to prior configuration settings.
`tx`	This command configures a simple radio packet transmission according to prior configuration settings.
`cw`	This command will put the module into a Continuous Wave (cw) Transmission for system tuning or certification use.
`set`	This command allows modification to the radio setting directly. This command allows for the user to change the method of radio operation within module type band limits.
`get`	This command grants the ability to read out radio settings as they are currently configured.

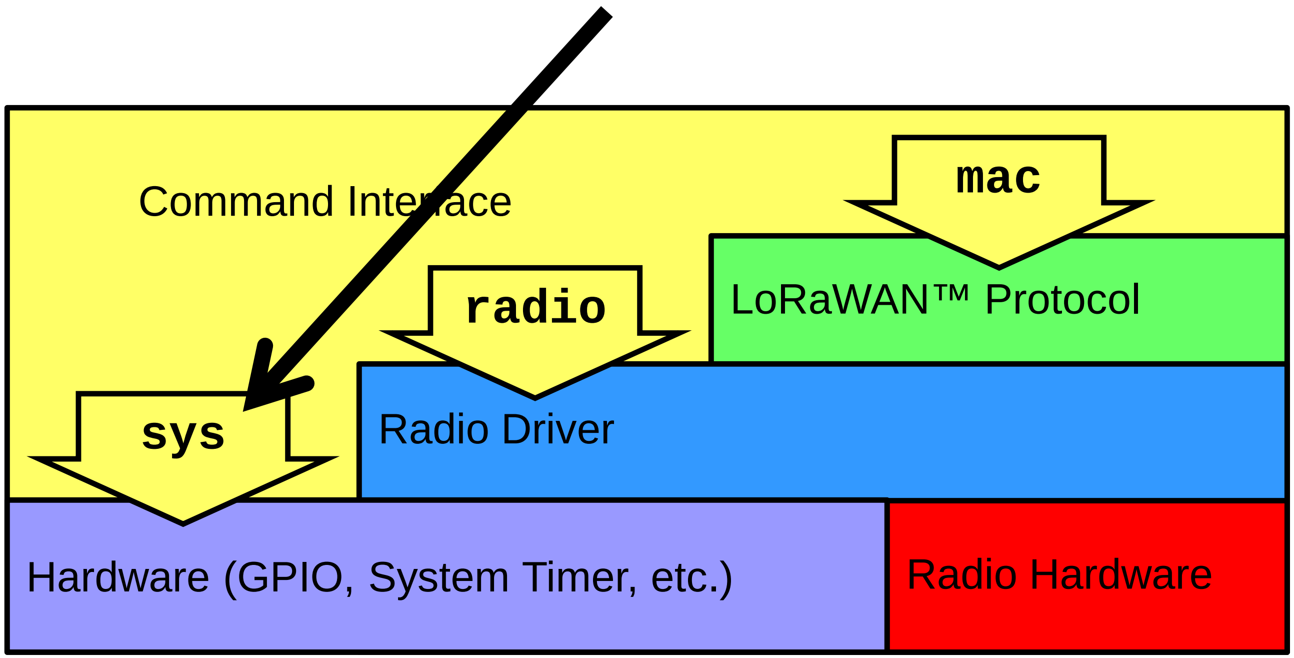
Note 1: The `mac pause` command must be called before any radio transmission or reception, even if no MAC operations have been initiated before.

LoRa™ RN Modem API:
Radio-Level Commands

```
< radio cw on
> ok

< radio get mod
> lora
```

LoRa™ RN Modem API: Sys-Level Commands

`sys` : Issues system level behavior actions, gathers status information on the firmware and hardware version, or accesses the module user EEPROM memory



LoRa™ RN Modem API: Sys-Level Commands

`sys` : Issues system level behavior actions, gathers status information on the firmware and hardware version, or accesses the module user EEPROM memory

Parameter	Description
`sleep`	Puts the system in Sleep for a finite number of milliseconds.
`reset`	Resets and restarts the RN2903 module.
`eraseFW`	Deletes the current RN2903 module application firmware and prepares it for firmware upgrade. The RN2903 module bootloader is ready to receive new firmware.
`factoryRESET`	Resets the RN2903 module's configuration data and user EEPROM to factory default values and restarts the RN2903 module.
`set`(1)	Sets specified system parameter values.
`get`(1)	Gets specified system parameter values.

LoRa™ RN Modem API: Sys-Level Commands

< sys sleep 5000

> ok

sys sleep <length>

<length>: decimal number representing the number of milliseconds the system is put to Sleep, from 100 to 4294967296.

< sys reset

> RN2903 0.9.5 Sep 02 2015 17:19:55

Summary

- Internet of Things (IoT)
- LoRaWAN™ Network Protocol
- LoRa® Technology Wireless Modules
- Getting Started with RN2903 Module
- Hands-on Labs

Additional Resources

- http://lora-alliance.org/

- http://www.microchip.com/RN2483
- RN2483 LoRa® Transceiver Module Datasheet
- RN2483 LoRa Command Reference User’s Guide

- http://www.microchip.com/RN2903
- RN2903 LoRa Transceiver Module Datasheet
- RN2903 LoRa Command Reference User’s Guide

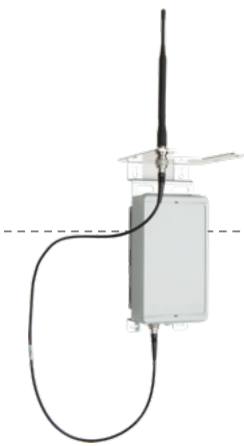
Thank You !

Q & A

Hands-on Workshop
Setting up an End-to-End Solution

	Evaluation		Deployment
Application Server	Cayenne Powered by myDevices	→	Dashboard
Network Server / Gateway	kerlink communication is everything	→	
Devices		→	Your Microchip-based Sensors

Dashboard



Your Microchip-based Sensors

* PC Not Included

Getting Up and Running with LoRaWAN™ Long-Range Networking

Agenda

- Internet of Things (IoT)
- LoRaWAN™ Networking Standard
- LoRa® Technology Wireless Modules
- Getting Started with RN2903 Module
- **Hands-on workshop**
  - Connecting a Mote to the Kerlink's SPN Gateway Network

Homework Preparation

- **You will need:**
  - A Laptop with USB port
  - Microchip USB driver (can auto-install, but slow)
    - www.Microchip.com/MCP2200 (under documentation tab)
  - Any generic "Terminal" app (*but not PuTTY*)
    - Termite (http://termite.soft112.com/)
    - TeraTerm (http://teraterm.software.informer.com/)
    - Coolterm (www.macupdate.com/app/mac/31352/coolterm)
    - Etc
  - **Settings: 57600bps, 8n1, no flow control, echo on, set options to include CR+LF**

Lab Summary

- **In the following labs you will:**
  - Setting up “Serial Terminal” app
    - Simple Commands
  - Setup Account for Application in MyDevice
  - RN2903 Module configuration and Over-the-Air Activation (OTAA)
  - Sending data to Network Application Server

Lab 1

Lab 2

Lab 3

Lab 4

Mote Menus

Starts Here

Joining Method

<- ABP OTAA ->
(S2) (S3)

Mobile Mote - APP

Navigate Select
(S2) (S3)

Select Data Rate

Data Rate: 5
(NAV)
(CNG)

Enter Sleep Mode

(NAV)
(SLP)

Uplink Pckt TYPe
Throu Port# 088
(UNCNF)
(CNF)

SEL

Issue Uplink LoRaWAN Packet

(NAV)
(SEL)

View Downlink Last Message

(NAV)
(SEL)

Sensor Data Display

(NAV)
(SEL)

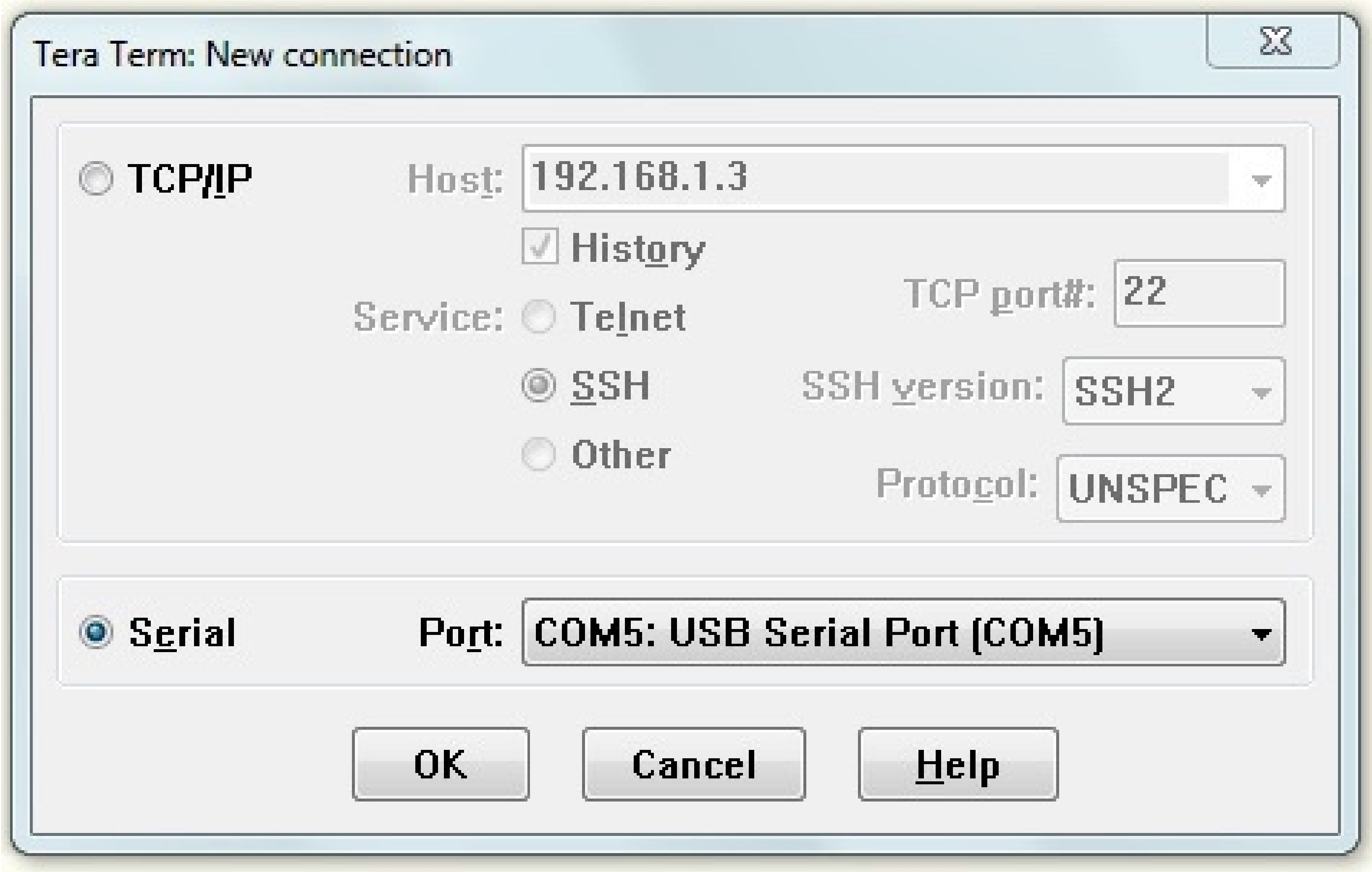
Periodic Uplink Tx Event Timing
Every: 5 mins
(NAV)
(CNG)

NAV

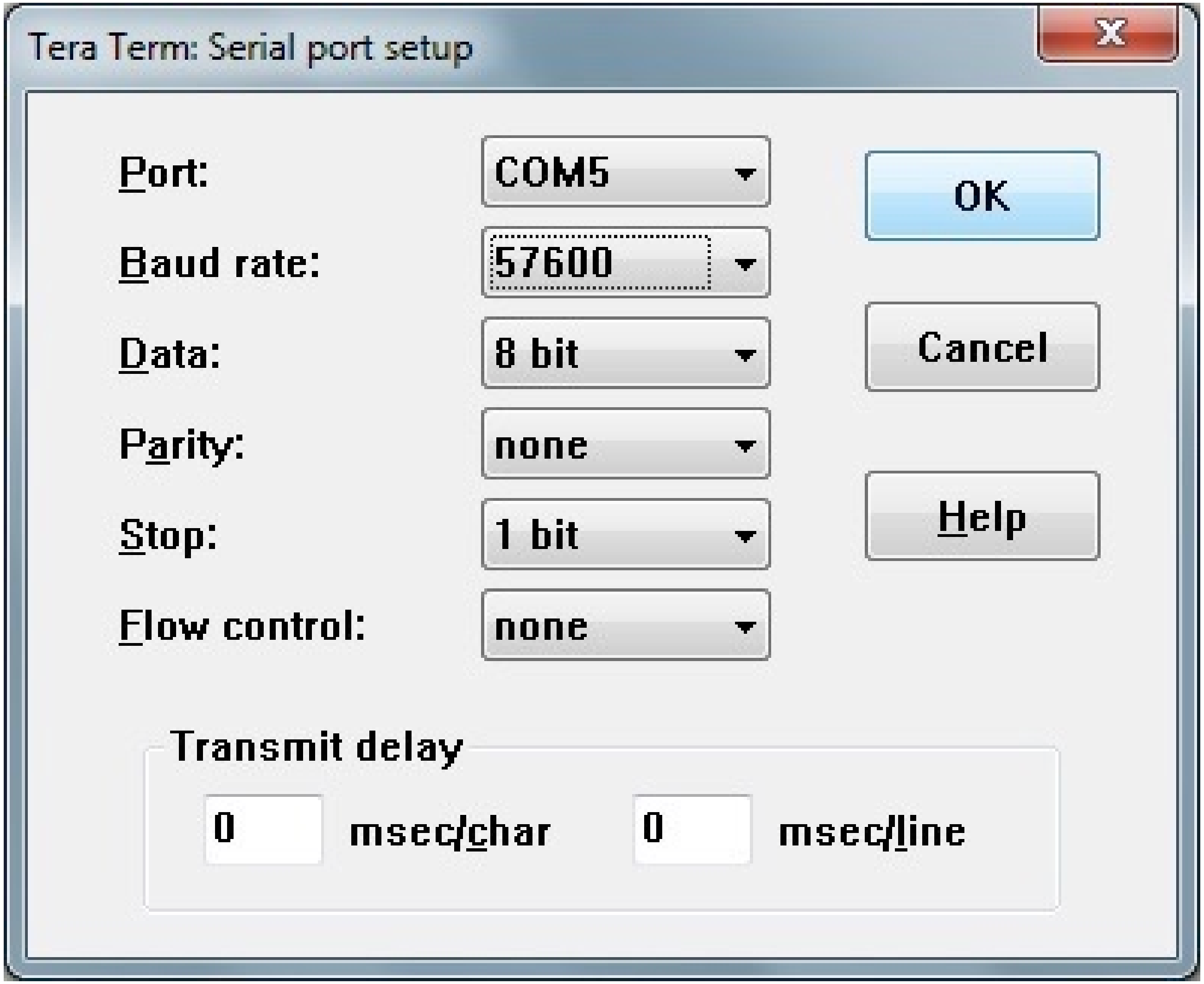
Lab 1:

Setting up “Serial Terminal” app

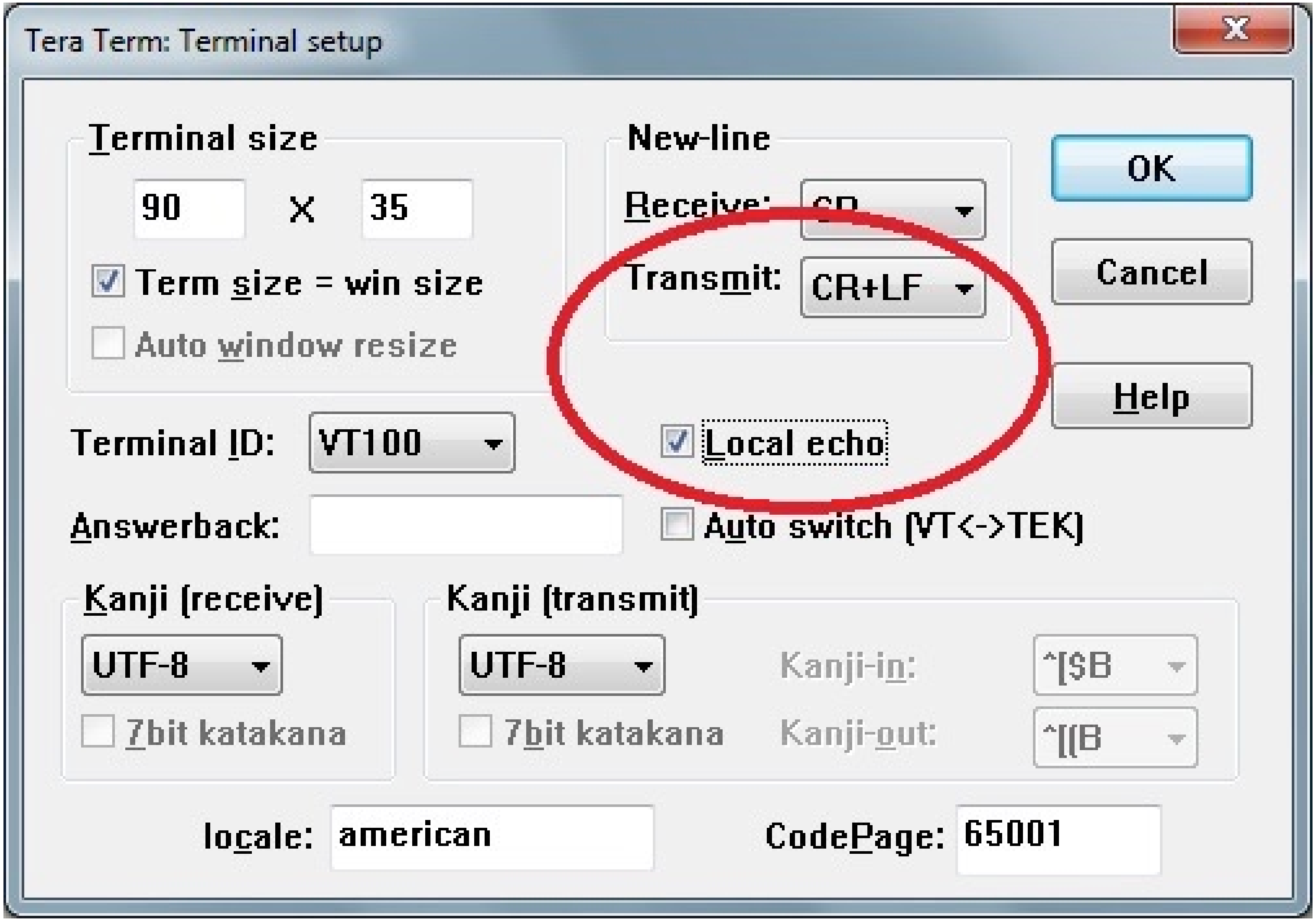
Lab 1 : Comm Port Selection



Lab 1 : Serial Settings



Lab 1 : Terminal Settings



Useful Notes – RN Parser

- **The commands to type are shown as:**
  - This is a command: **`sys reset`**
  - Commands are case sensitive, parameters are not
  - The parser is sensitive to extra blank spaces
    - E.g “**`sys reset`**” works
    - “**`sys  reset`**” or “**`sys reset `**” does not work
  - Copy/paste can introduce additional chars like LF or CR
  - If you see “invalid_params” hit multiple “Enter” to clear

Lab 1: Connecting to the Node

This lab verifies that the USB/UART communication to the LoRa® node is working correctly

0.1 – Connect board to PC via USB cable.

0.2 – Open Device Manager and locate assigned COM port

0.3 – Using a PC terminal program connect on said port **(settings: 57600bps, 8n1, no flow control, echo on, set options to include CR+LF)**

0.4 – Check for communication by using: `sys get ver`

0.5 – The module will return module name, version & compilation timestamp:
`RN2903 0.9.5 Sep 02 2015 17:19:55`

HINT – commands are case sensitive, parameters are not

Lab 1: Basic LoRa® Connectivity (Step 1 – Reset & Find your EUI)

As no two end-devices are allowed the same device address, a unique DevAddr should be used. We can use the **H**ard**W**are **EUI** for this, read from hardware via a command.

Note the HWEUI is 8-bytes whereas devaddr is only 4-bytes. Use the 4-LSBytes (right half of the EUI)

1.1 – Reset module using: `sys RESET`

1.2 – Read the hardware Unique Identifier: `sys get hweui`

HINT – Make a note of your DevAddr – you will need it next

Lab 1 : Resetting Module

- **Reset and restart the RN2903A module.**
- **Type and send the command: sys reset**
- **The module should respond with module name, version and compilation timestamp.**

Example output:

```
< sys reset
> RN2903 0.6.0 Jun 16 2015 14:30:04
```

Lab 1 : Reading hwEUI & devEUI

- **Read the EUI-64 address of the module:**
- **Type and send the command: sys get hweui**
- **The module should respond with an 8-bit hexadecimal number, representing the EUI-64 address of the module, like 0004A30B001A13BB.**
- **The hweui is normally used as deveui.**
  (For this lab learning, we have assigned separate deveui for easy of practice. To set deveui same as hweui 'sys set deveui 0004A30B001B78E4').

```
< sys get hweui
> 0004A30B001B78E4
< sys get deveui
> 0004A30B001B78E4
```

Lab 2:

Setting up account in Application Server

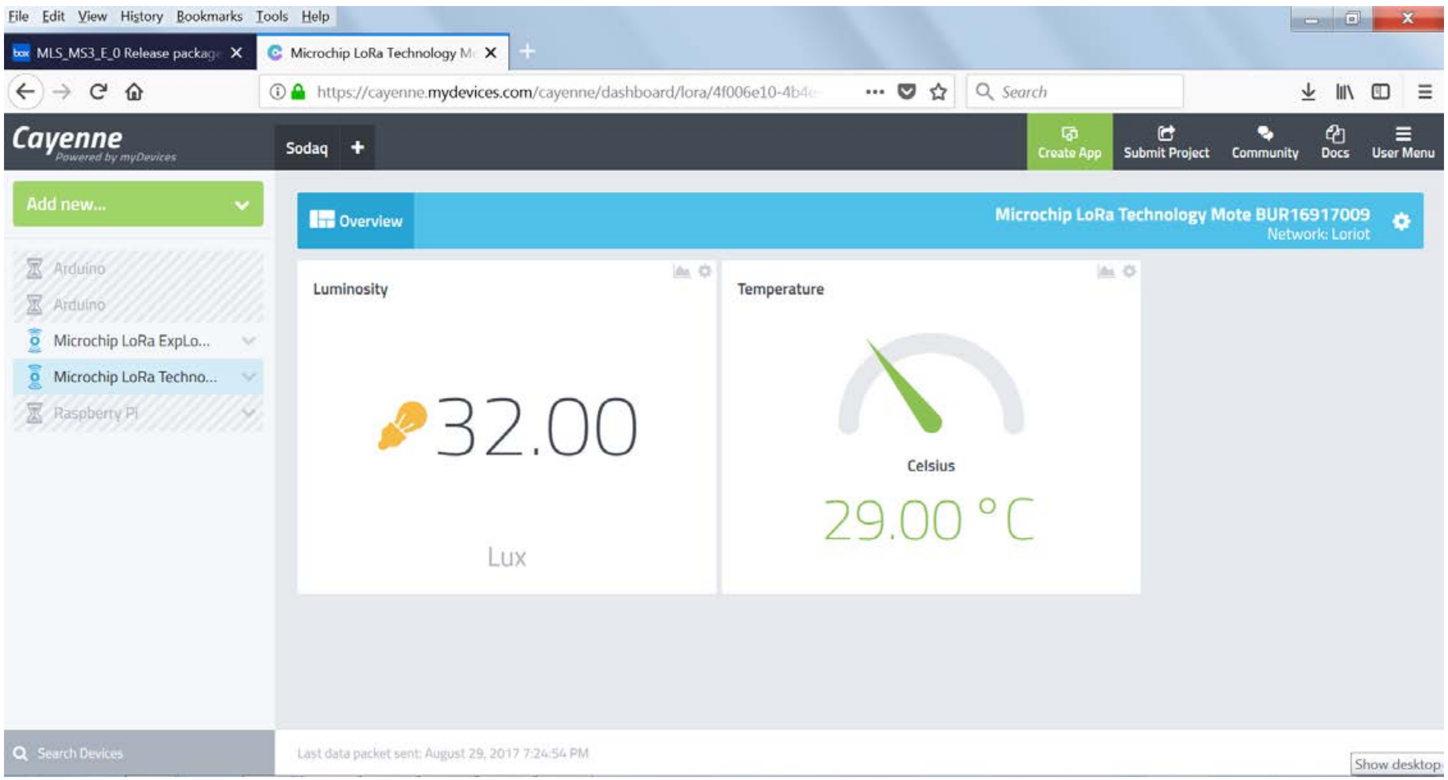
(MyDevice)

MyDevice Dashboard

- **Create a login ID account.**

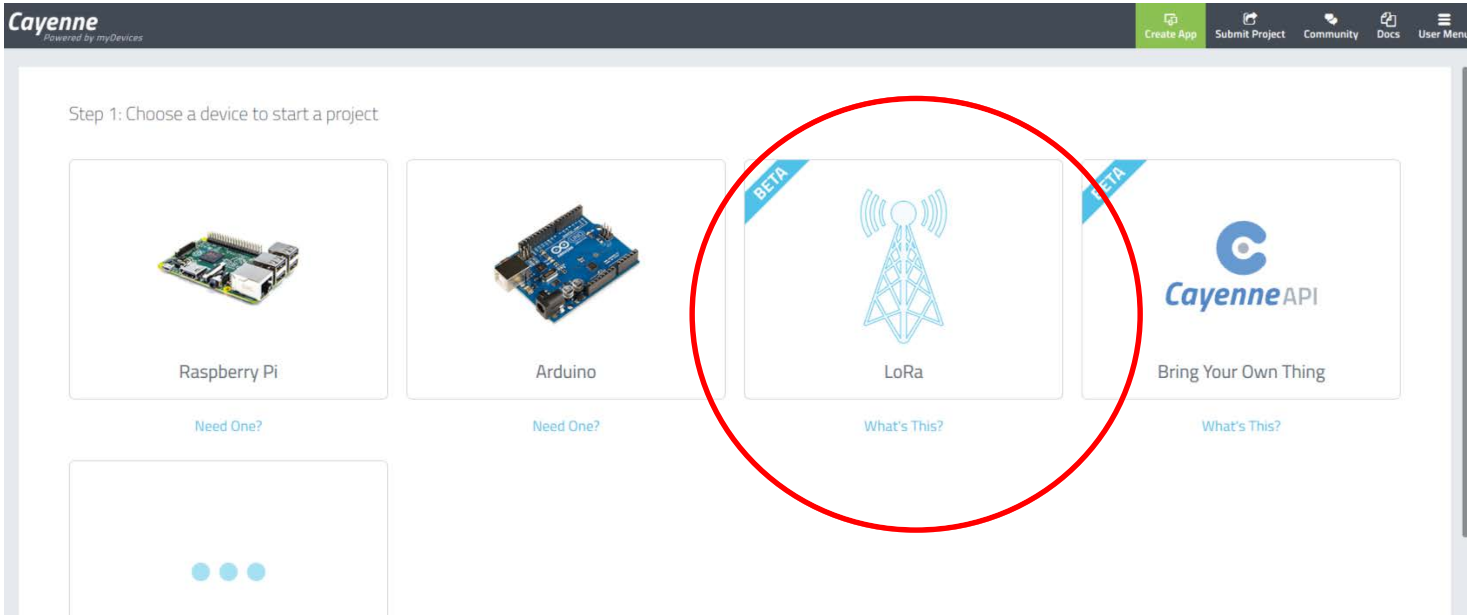
https://cayenne.mydevices.com/cayenne/login

- **You can add 10 devices onto your account free.**

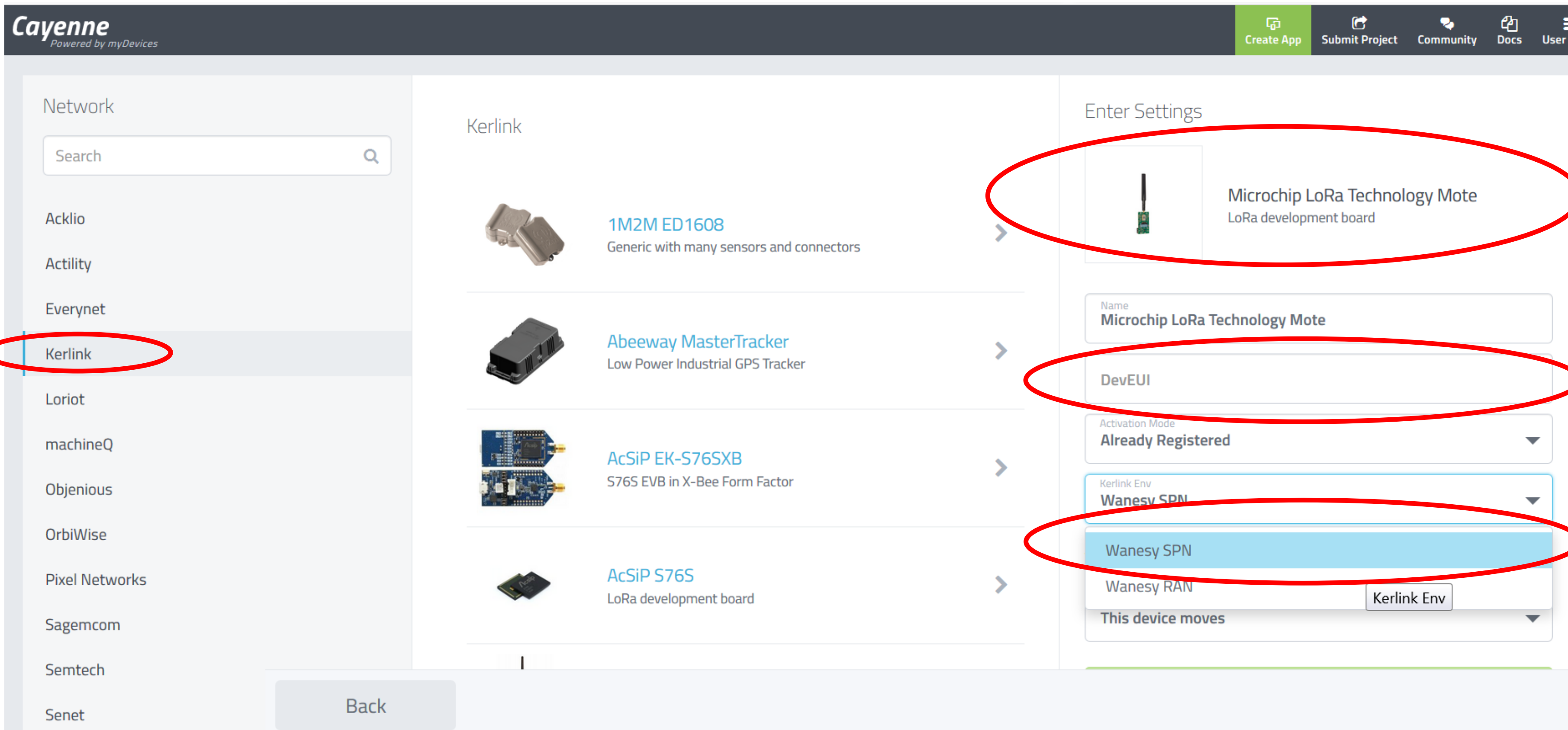


Cayenne MyDevice Setup
Registration of Device

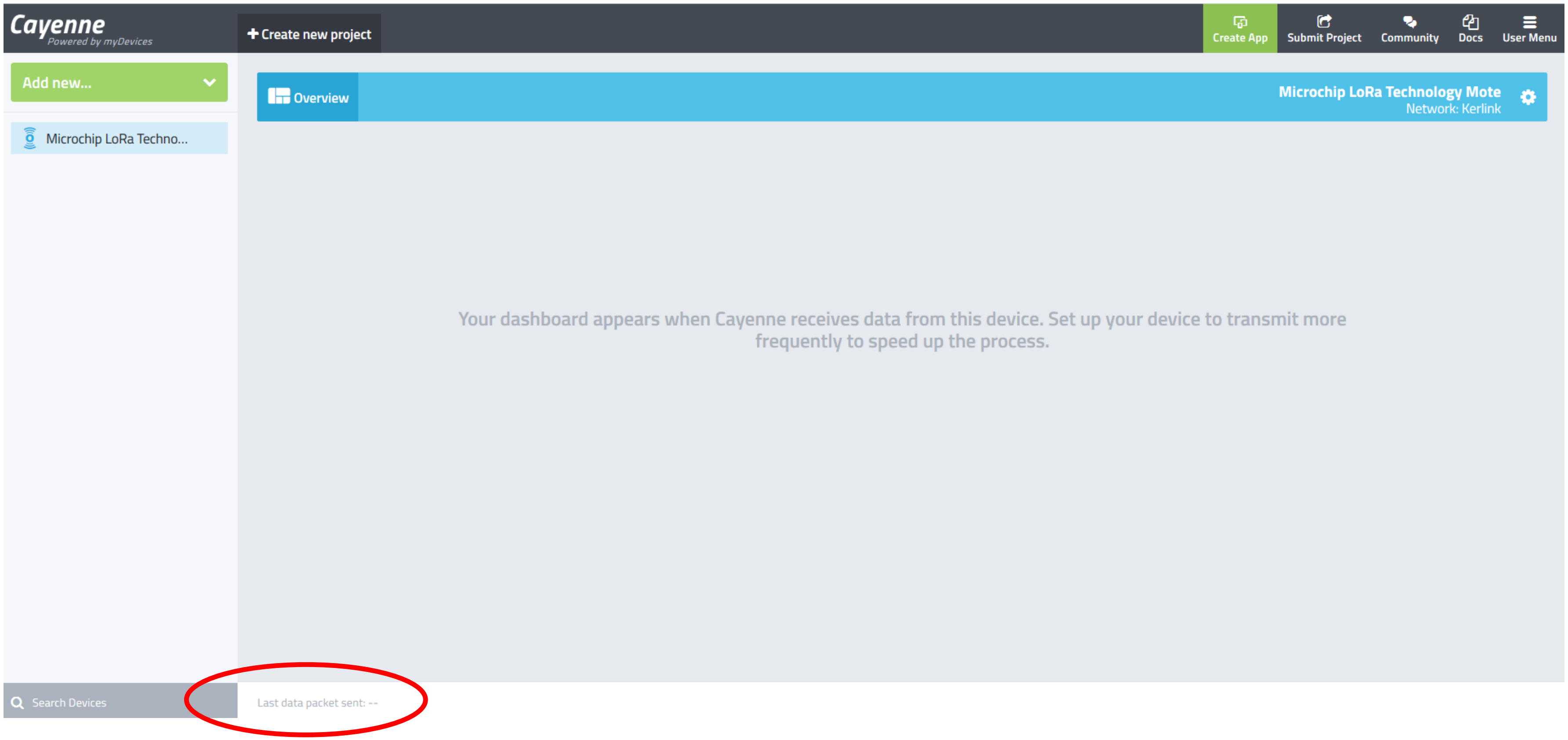
After registration of account



Cayenne MyDevice Setup
Registration of Device

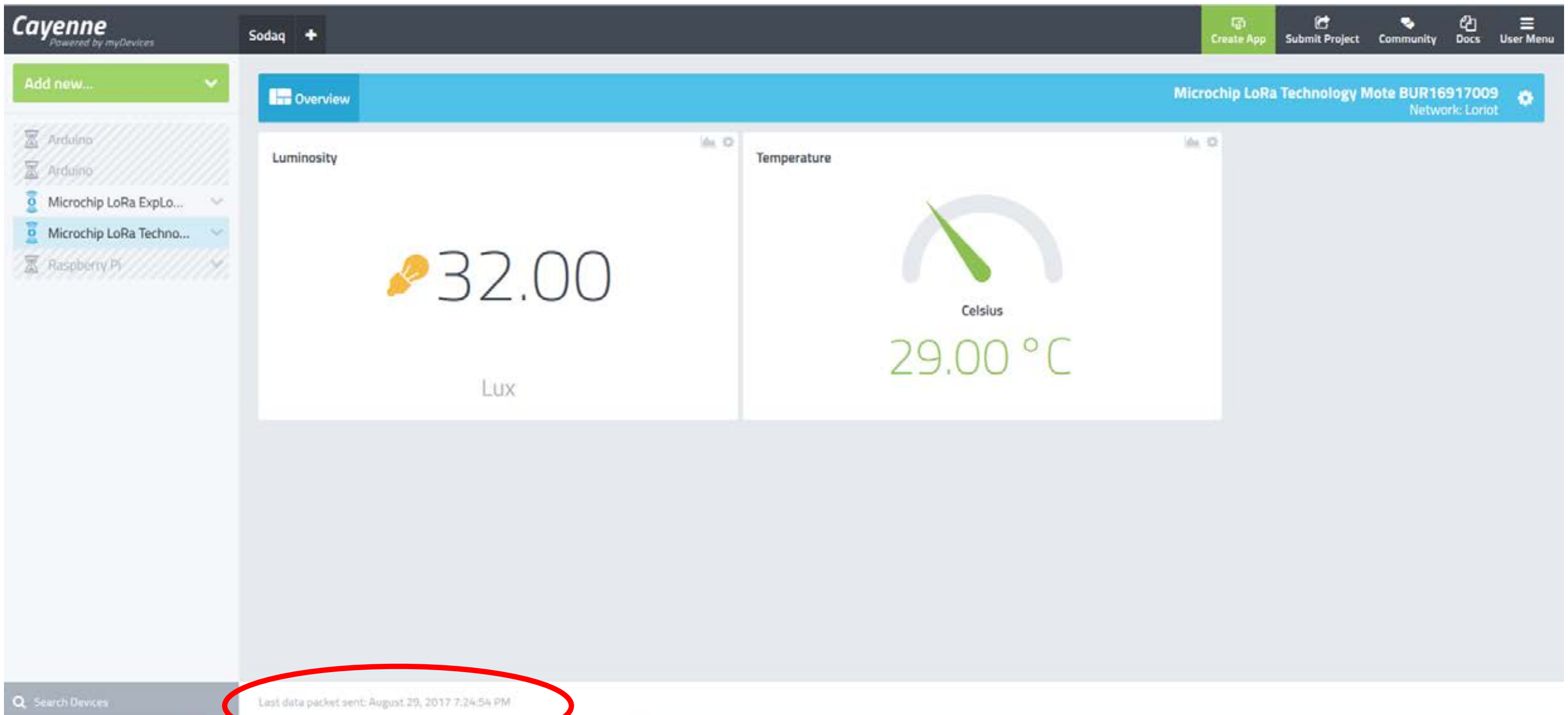


Cayenne MyDevice Setup
Registration of Device



Cayenne MyDevice Setup

Registration of Device



Time stamping of last Tx Data

Lab 3:

RN2903A **Module configuration and Over-the-Air Activation (OTAA)**

Lab 3 Objectives

- Configure the RN2903A Module
- Activate the RN2903A Module using Over-the-Air Activation (OTAA) with the ASCII command set

Lab 3 : End-Device with Over-the-Air Activation (OTAA)

Configure the cryptographic keys for Over-the-Air activation (OTAA). The following keys are needed:

Device EUI, application EUI, application key.

It is recommended to use the EUI-64 address retrieved from hweui as device EUI. This number is UNIQUE for each module and so has to be the device EUI.

For this lab learning, we have set up the deveui for you in your mote board.

Configuration

```
< mac set deveui 0004A30B001B78E4  (DO NOT NEED FOR THIS LAB)
> ok
< mac set appeui 0004A30B00000000
> ok
< mac set appkey 2B7E151628AED2A6ABF7158809CF4F3C
> ok
< mac save
> ok
```

Activation

```
> mac join otaa
< ok
< accepted
```

Lab 4:

Sending data to Network Application Server via host MCU

Lab 3 Objectives

- Configure the RN2903A Module
- Sending data via serial interface to network server

Lab 4 : Sending data to Network Application Server via host MCU

(mac tx <type> <portno> <data>)

<type>: string representing the uplink payload type, either cnf or uncnf

(cnf – confirmed, uncnf – unconfirmed)

<portno>: decimal number representing the port number, from 1 to 223

<data>: hexadecimal value.

Activation by line command

```
> mac join otaa
< ok
< accepted
```

Send Data via unconfirmed message

```
> mac tx uncnf 10 AABBCC
< ok
< mac_tx_ok
```

Send Data via confirmed message

```
> mac tx cnf 5 CCBBAA
< ok
< mac_tx_ok
```

‘mac_err’ if transmission was unsuccessful, ACK not received back from the server

Lab 5:

Sending data to Network Application Server

(MyDevice)

Lab 5 Objectives

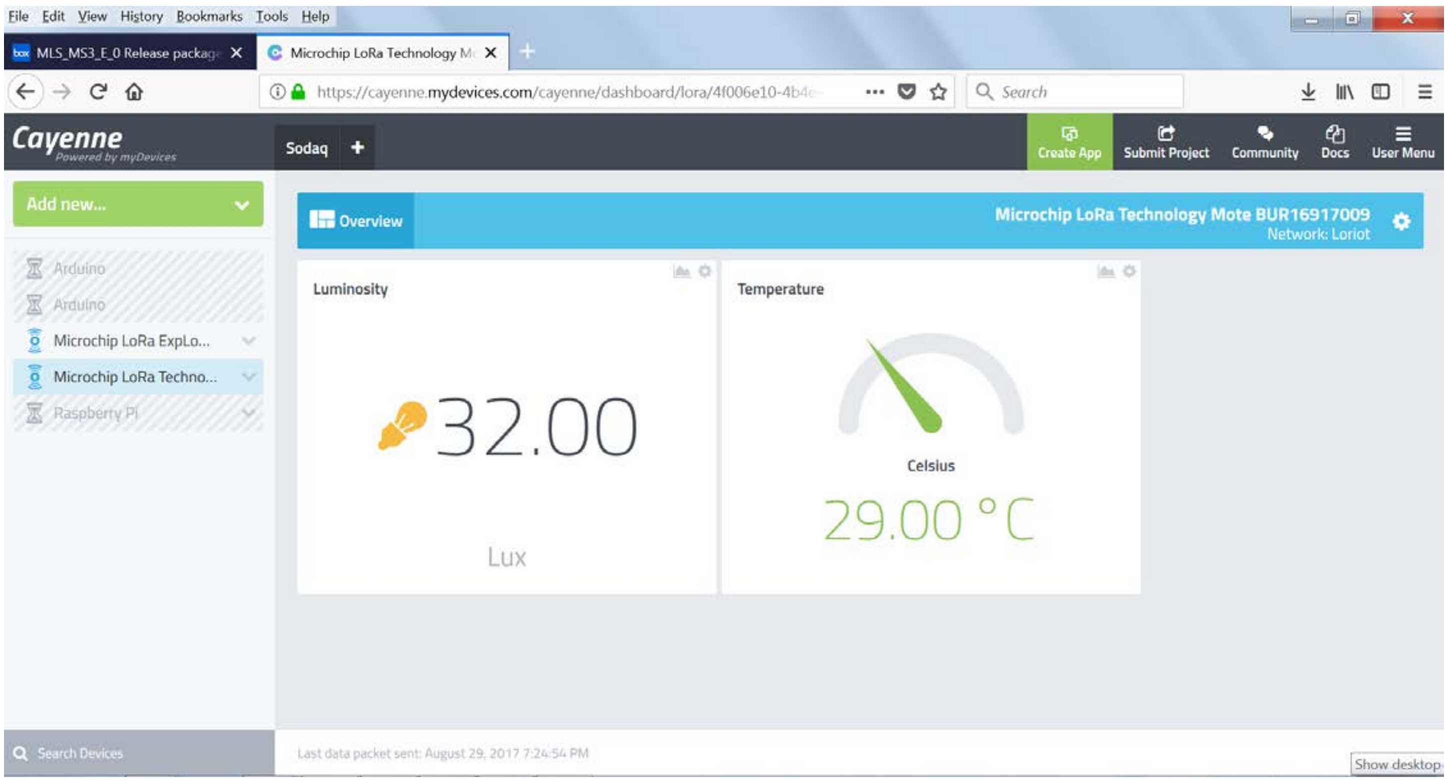
- **Sending data from Mote Board to Network Server and Application**

MyDevice Dashboard

- **Create a login ID account.**

https://cayenne.mydevices.com/cayenne/login

- **You can add 10 devices onto your account free.**



For Further Information:

- **RN2903 Command Reference Users Guide (spec 40001811)**
- **www.Microchip.com/RN2903**
- **50 Pages of Fun!**

Flashing Module Firmware on Mote

<u>Material programmer</u>
PICKit3 or ICD3 or RealICE

<u>Software you need</u>
MPLAB X IDE and specifically MPLAB IPE to program the Firmware

- Connect micro-USB cable from J1 connector to your PC
- Target device: PIC18LF46K22
- PICKit3 to J5 connector

Upgrading Mote Board Firmware

Material programmer
PICKit3 or ICD3 or RealICE

Software you need
MPLAB X IDE and specifically MPLAB IPE to program the Firmware

- Connect micro-USB cable from J5 connector to your PC
- Target device: PIC18LF45K50
- PICKit3 to J5 connector