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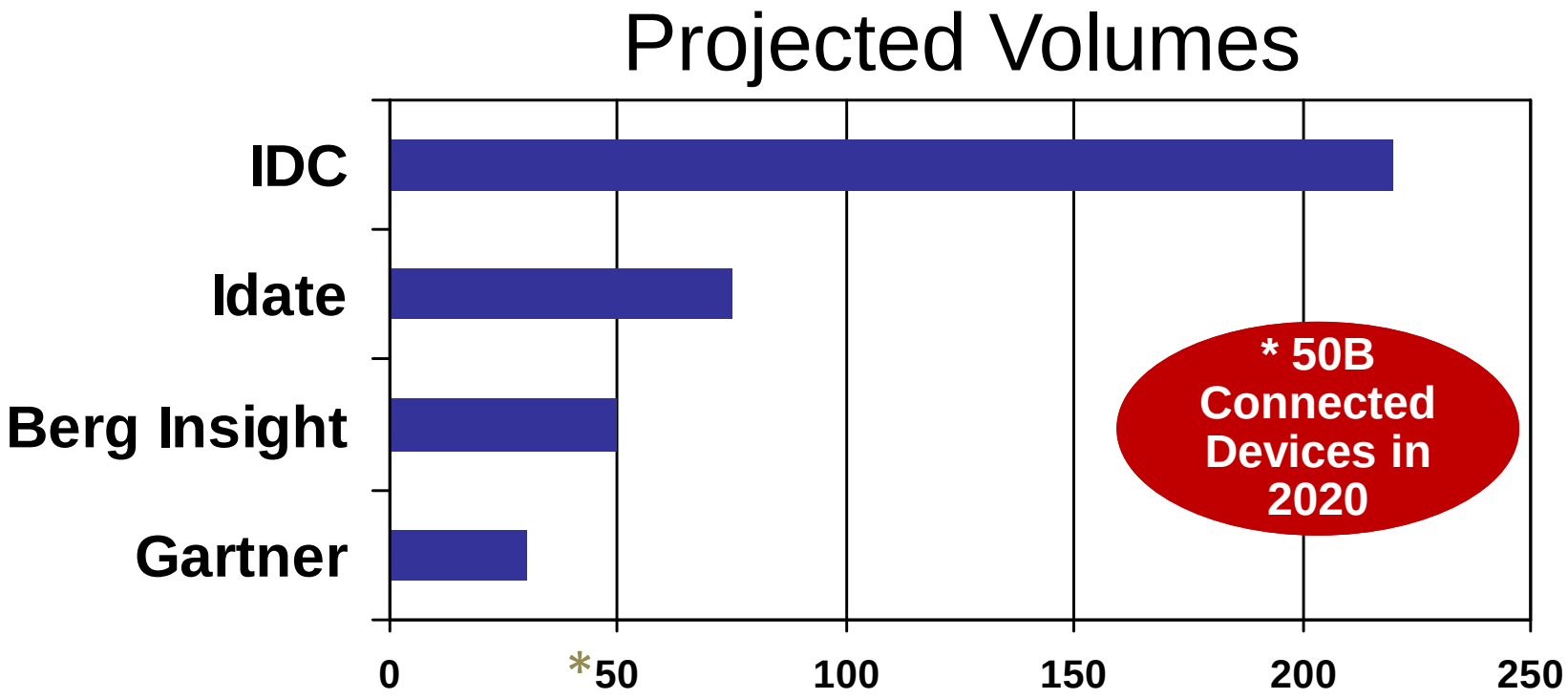
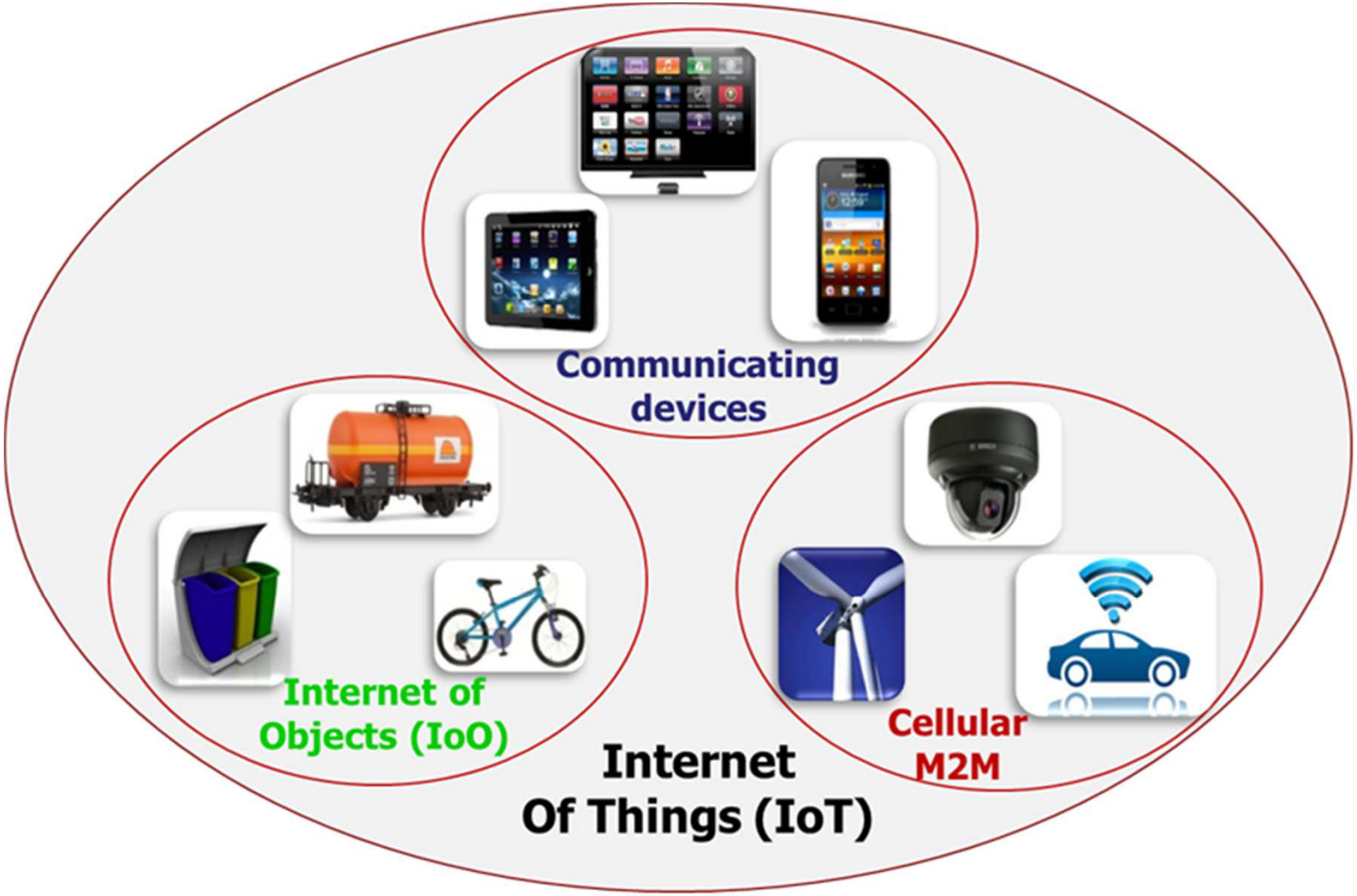
Semtech Concentrator for IOT

Connected Devices: Market

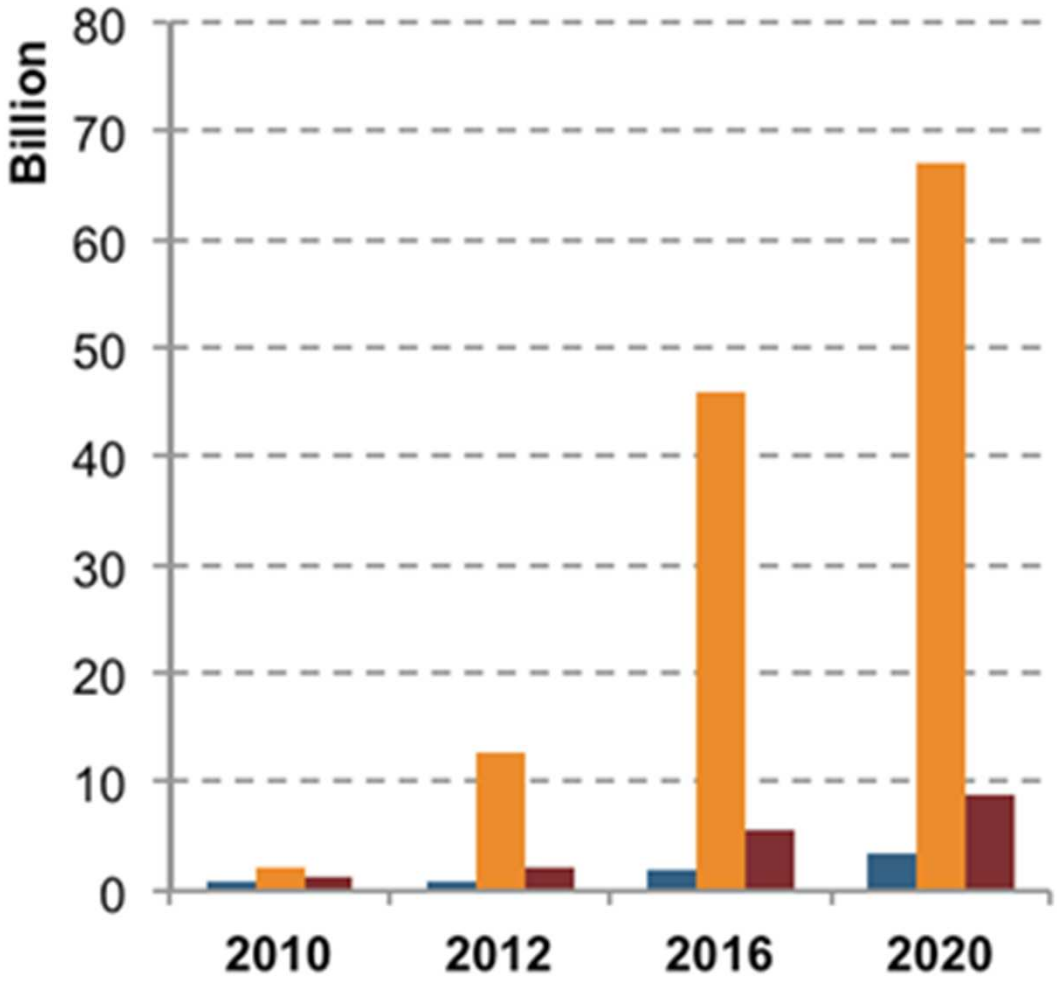


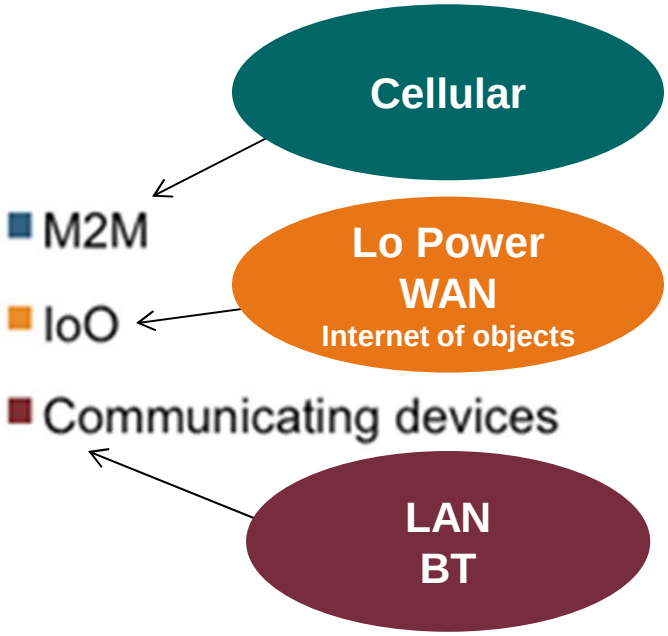
IoT Segments



Connected Devices: Market

Projected by Type





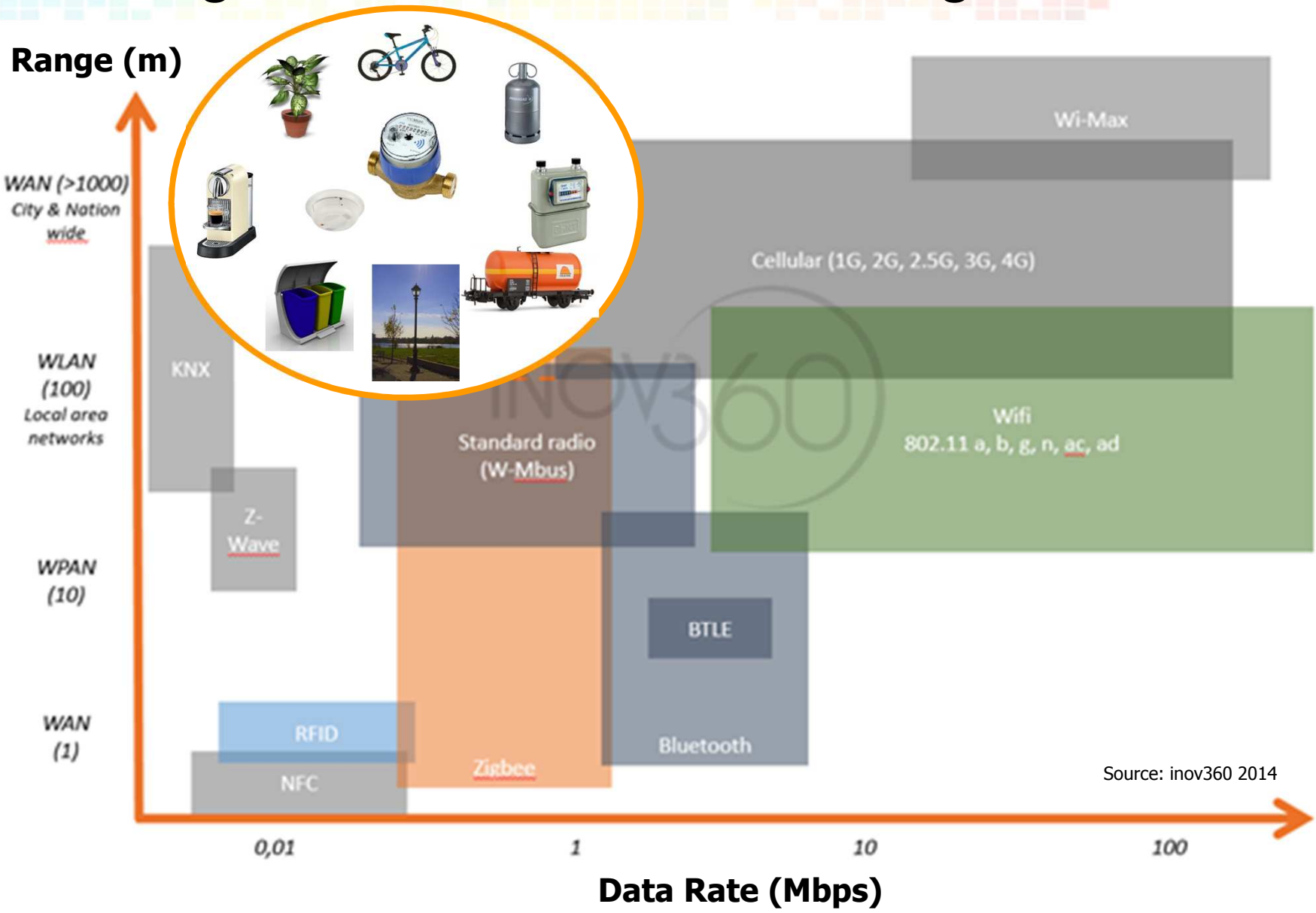
Connectivity is a Challenge

Internet of Objects
80% of volume

Requirements:

- How to connect battery operated low cost assets?
- Outdoor & harsh environments
- Low cost communication
- Low cost infrastructure
- Low power technology
- Robust communication
- Permits mobility
- Scalable system

Existing Communication Technologies



Source: inov360 2014

Connected Devices: Access

LAN

Short Range
Communicating Devices

35% SOM

- ✓ **Well established standards**
- ✓ **Good for:**
  - **Mobile devices**
  - **In-home**
  - **Short range**
- ❑ **Not good:**
  - **Battery life**
  - **Long range**

Lo Power WAN

Long Range w/ Battery
Internet of Objects

55% SOM

- ✓ **Emerging PHY solutions /** Undecided
- ✓ **Good for:**
  - **Long range**
  - **Long battery**
  - **Low cost**
- ❑ **Not good:**
  - **High data-rate**

Cellular

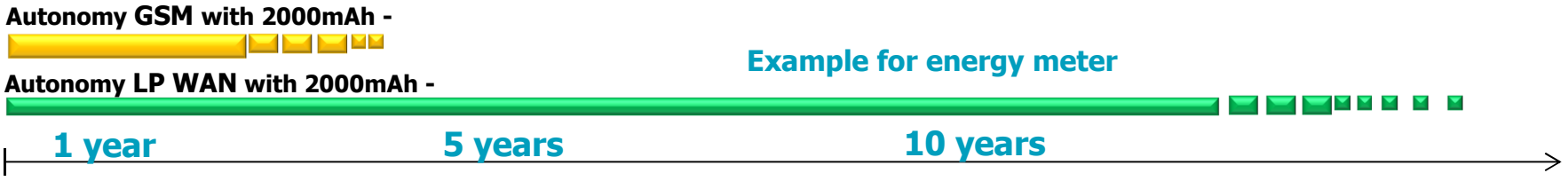
Long Range w/Power
Traditional M2M

10% SOM

- ✓ **Well established standards**
- ✓ **Good for:**
  - **Long range**
  - **High data-rate**
  - **Coverage**
- ❑ **Not good:**
  - **Battery life**
  - **Cost**

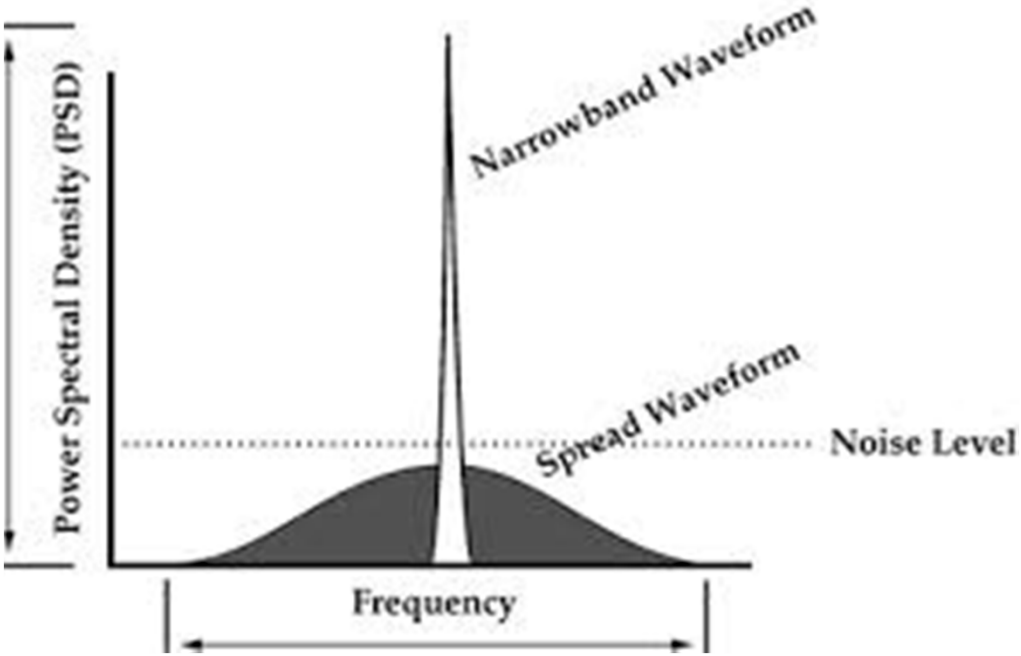
Low Power WAN: Network (Node)

Technology	2G	3G	LAN	ZigBee	Lo Power WAN
Range (I=Indoor, O=Outdoor)	2-15km	2-15km	O: 300m I: 30m	O: 90m I: 30m	**Better than 2G/3G**
Tx current consumption	200mA-500mA	500mA – 1000mA	50mA	35mA	**28mA**
Standby current	2.3mA	3.5mA	NC	0.003mA	0.001mA
Energy harvesting (solar, other)	No	No	No	Possible	Possible
Battery 2000mAh (LR6 battery)	4-8 hours(com) 36 days(idle)	2-4 hours(com) X hours(idle)	50 hours(com) X hours(idle)	60hours (com)	120 hours(com) 10 year(idle)
Module Revenue Annually	12 $	20 $	4 $	$3	3 $



LoRa Overview

- **LoRa utilized a spread spectrum based modulation**



Advantages

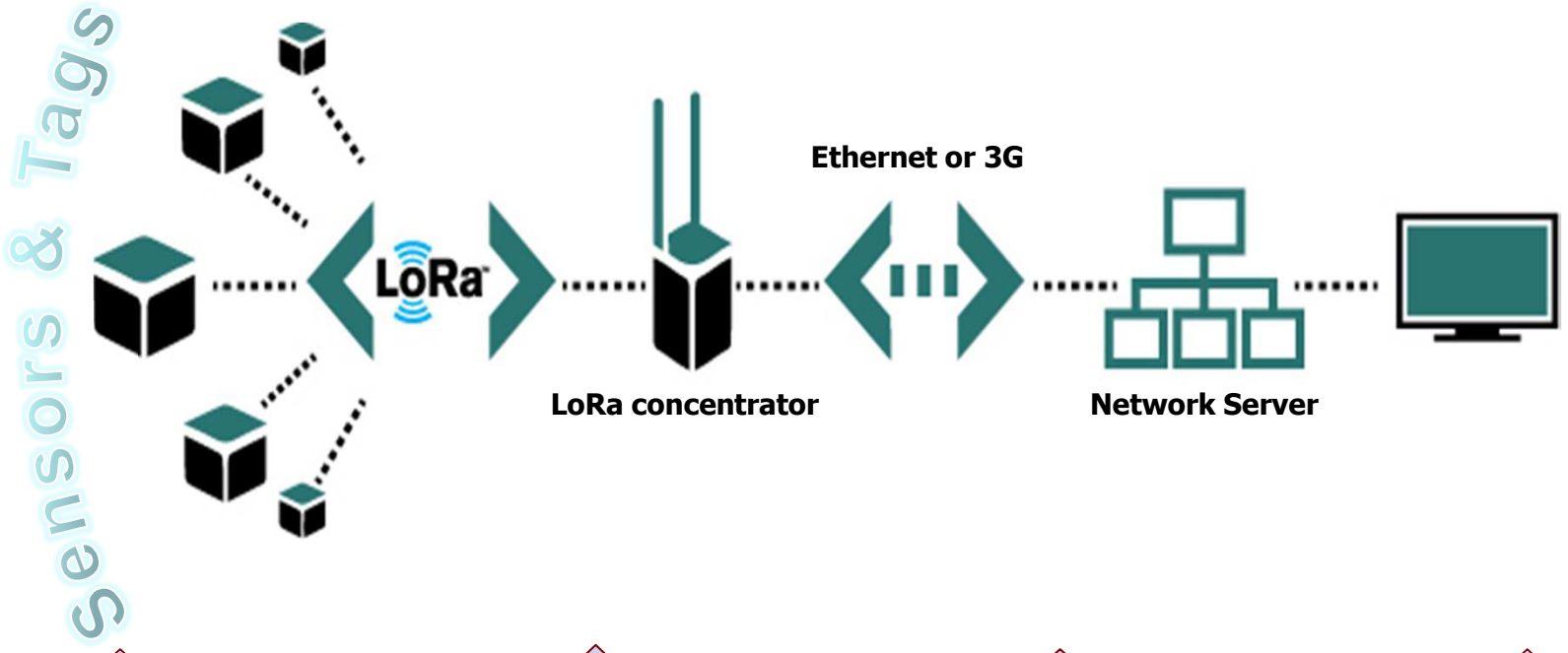
- Demodulate below noise floor – 30dB better than FSK
- Better sensitivity than FSK (better Eb/No)
- More robust to interference, noise, and jamming
- Spreading codes orthogonal – multiples signals can occupy same channel
- Tolerant to freq offsets (unlike DSSS)

LoRa Network Attributes

Key Features	Attribute/Benefit
157 dB link budget	Long range 
>15 km range	
Minimal infrastructure	Ease of deployment 
Concentrator with capacity	
>10 yrs battery lifetime	Long battery life 
RX - 10 mA, sleep <200 nA	
Unlicensed spectrum	Low cost 
Low infrastructure cost	
Low end-node cost	

- A long range star architecture with high capacity
- Supports both mobile and fixed nodes
- Supports variable data rates and multi-channel simultaneously
- Complete solution with both end node (SX127x) and concentrator (SX1301)

Network Architecture



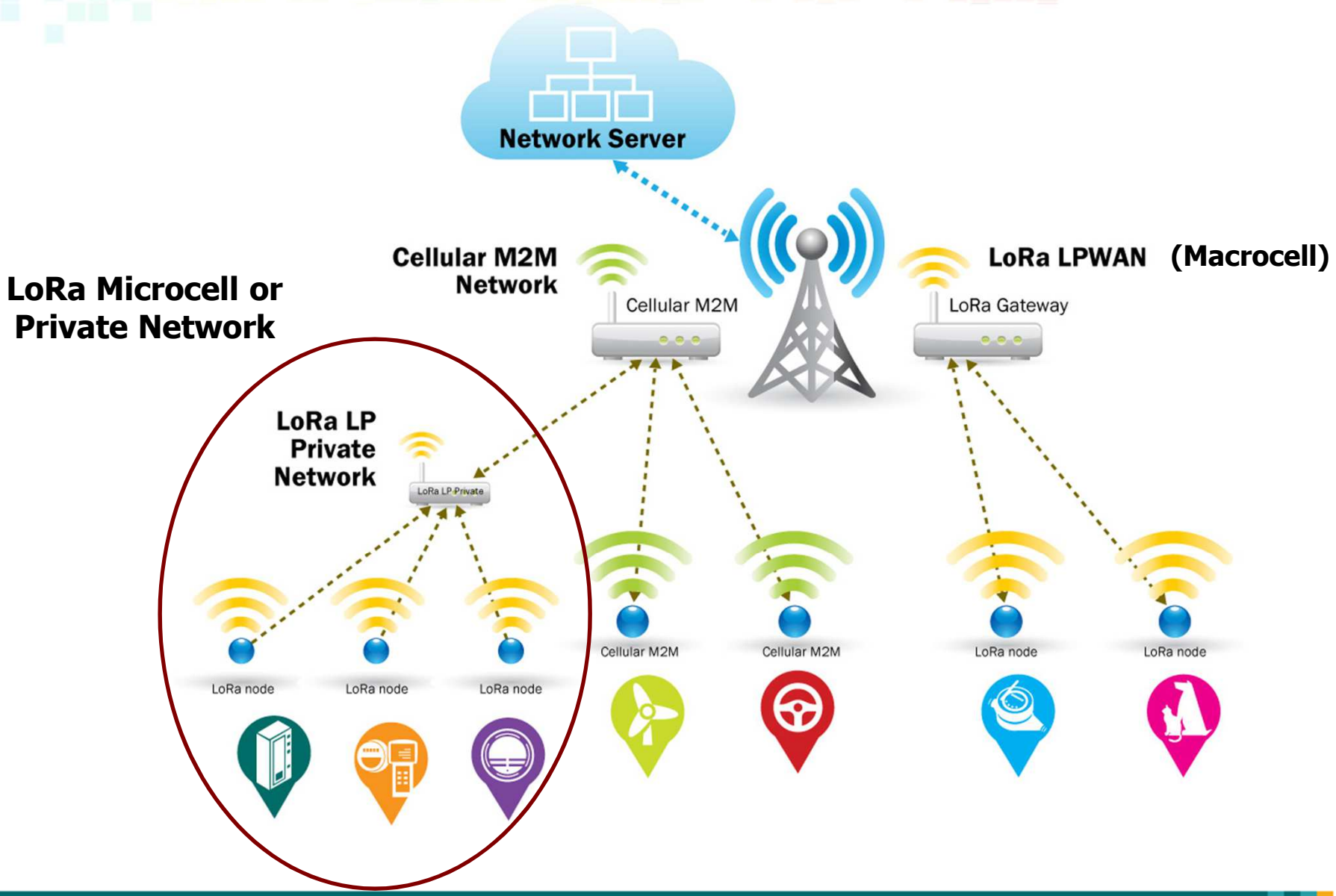
Unique ID
Encryption
2 way
Low Cost Low Power

Star network
Packet Forwarder
Full IPV6
Low Filtering

Protocol
Commissioning
Provisioning
Network Security
Data Integrity

Private Security
Data Analytics

Network Options



AN **OPERATED** NATIONAL NETWORK TO COLLECT DATA FROM MILLIONS OF DEVICES

Applications are many:

- Metering
- Tele- management
- Maintenance / Supervision
- Alerting
- Identification / géolocalisation
- Back up for GSM existing solutions

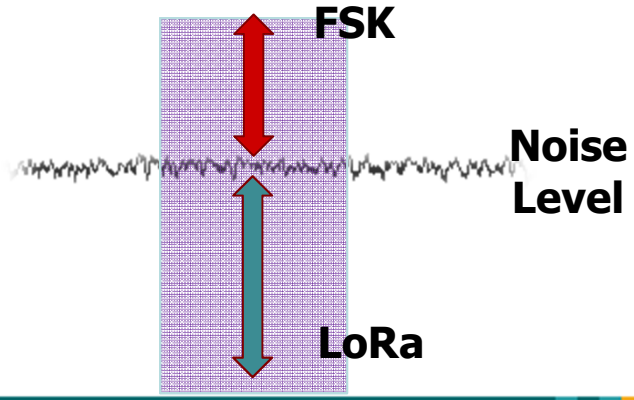
Main asset of our solution:

No Network Infrastructure to build or manage for the Customer

LoRa Parameters and Interference Immunity

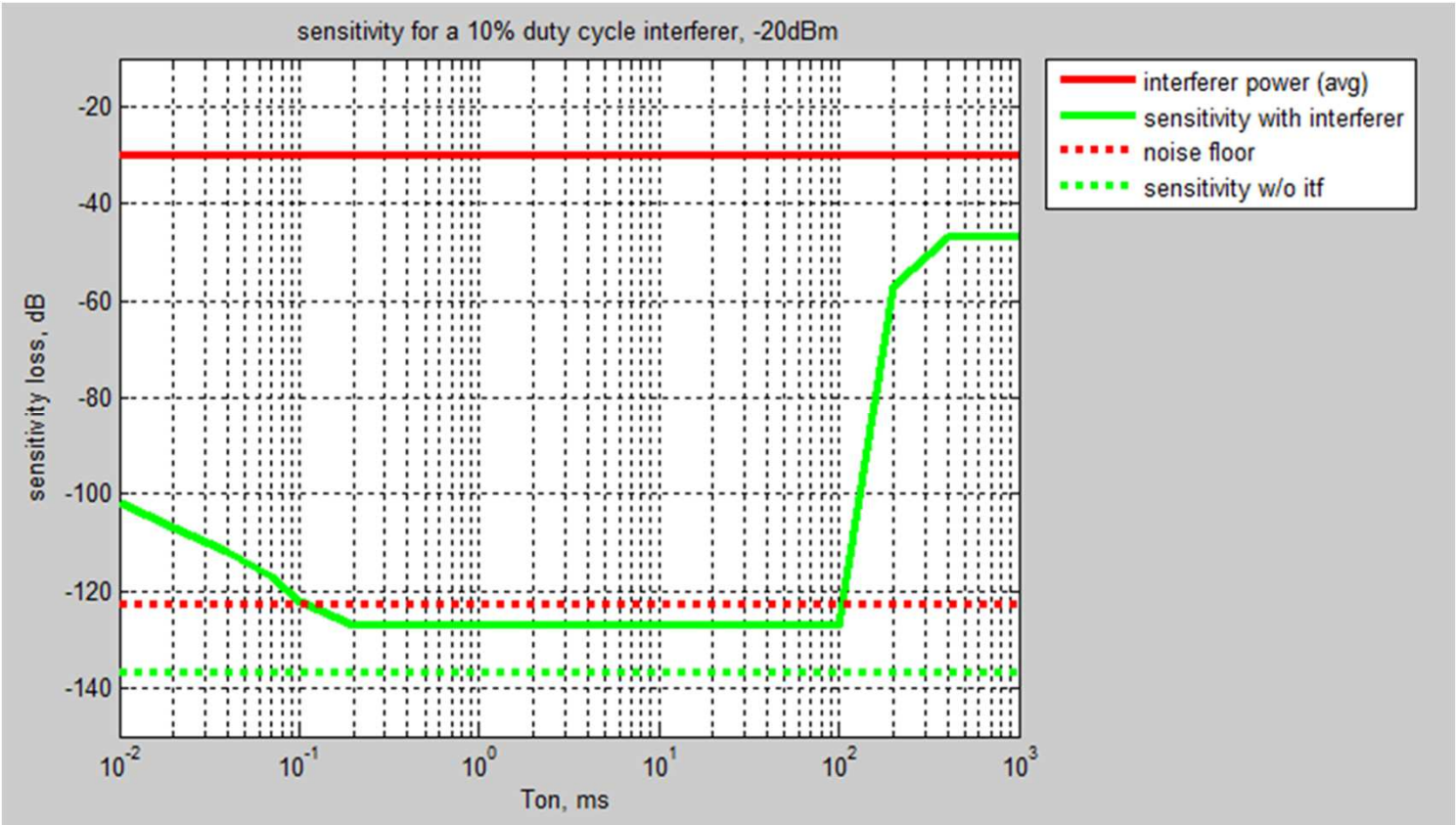
Parameter	Range	Effect	Change (125kHz)
Spreading Factor (SF)	7-12	DR	300bps – 9.6kbps
		Sensitivity	-138dBm to -121dBm
Bandwidth (BW)	125K typ 10-500kHz	DR vs sensitivity	300bps – 22kbps
Error correction	4/5 to 4/8	DR, time on air	
Freq	138M-1GHz		Freq agnostic

Interfere	LoRa Co-Channel	FSK Co-channel
CW/FSK/GFSK	-5 to -20	+8 to +10



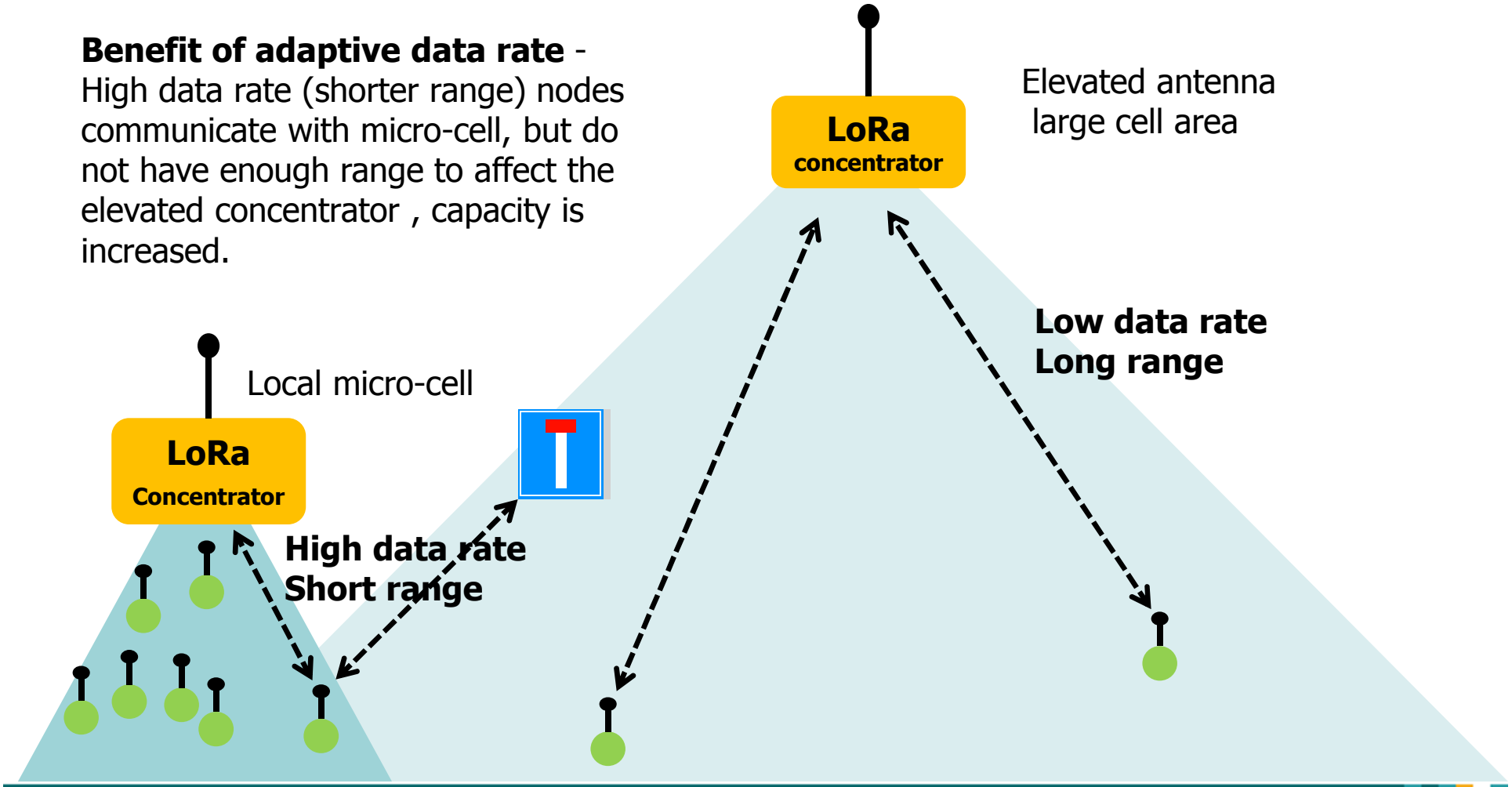
Interference Immunity

- Co-channel interference performance and error correction give LoRa licensed band QOS
- Multiple channels and network management at server allow for additional or adaptive QOS features



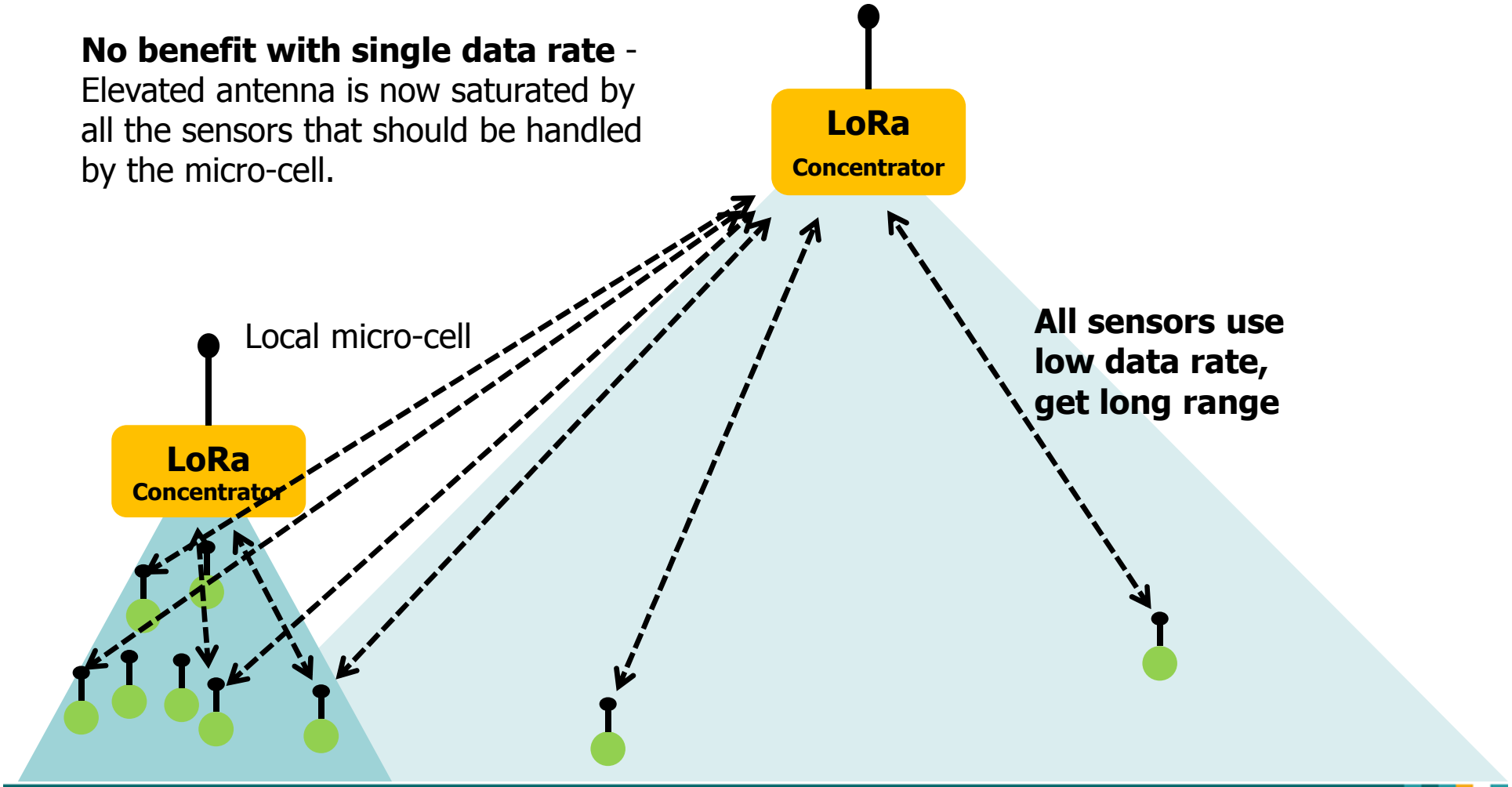
Network Capacity: Adaptive Data Rate

Benefit of adaptive data rate - High data rate (shorter range) nodes communicate with micro-cell, but do not have enough range to affect the elevated concentrator , capacity is increased.

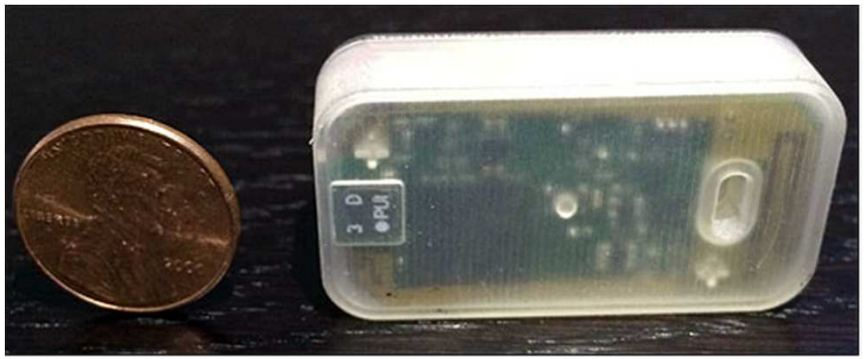


Network Capacity: Single Data Rate

No benefit with single data rate - Elevated antenna is now saturated by all the sensors that should be handled by the micro-cell.



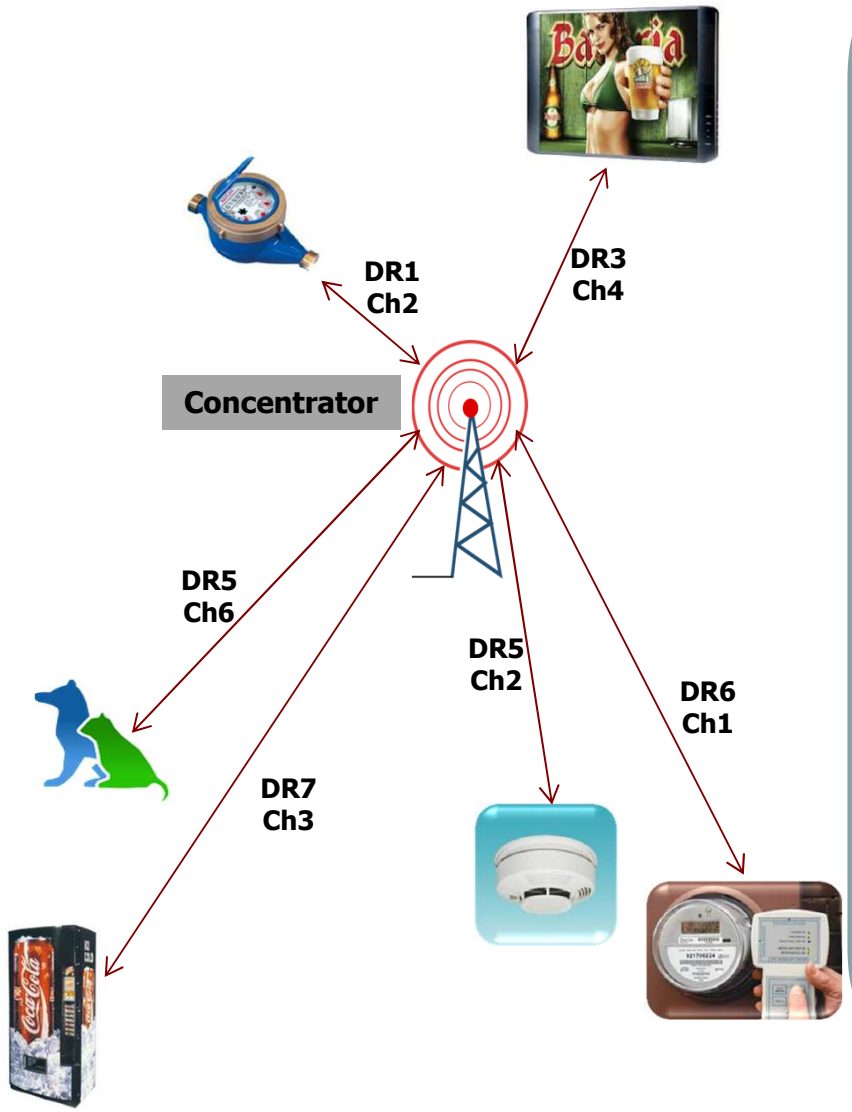
LoRa End Node



- Partner module solution for NA
- TX = 1W, GPS+sensors, battery
- Fully Compliant with FCC

- Partner Module for EU
- ST Micro(STM32) + SX1272

LoRa Concentrator – SX1301

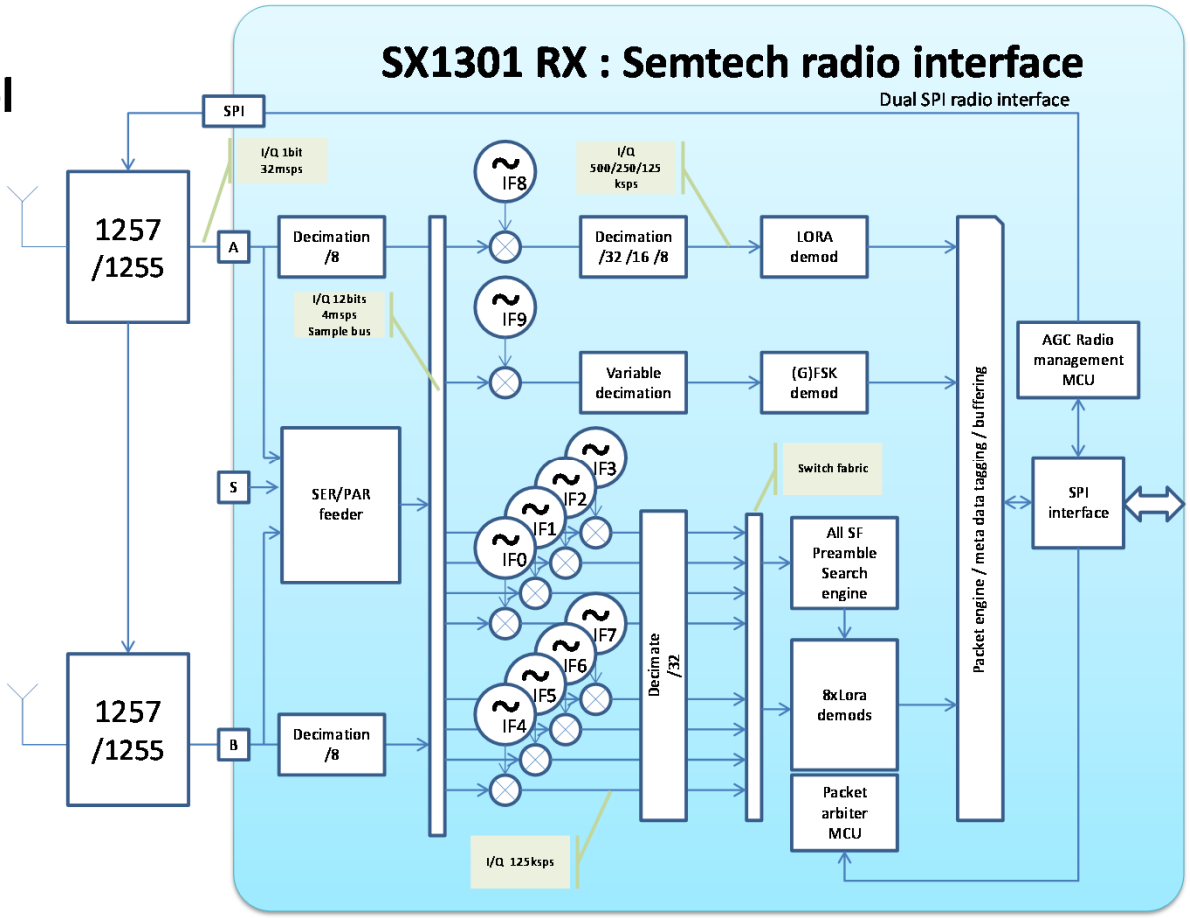


Superior System

- **Multi-modem/channel concentrator**
  - Improved network capacity
    - Simultaneous reception on same channel
    - Easily scalable to add more capacity
  - Simultaneously demod - 2MHz spectrum
  - Simple star network – no latency
  - Adaptive link rate
  - 5 million node transactions per SX1301
  - Easily scalable for more capacity
- **Localization**
  - The feature everyone wants
- **Solves all system desires**
  - Range, battery lifetime, capacity, cost
- **Reduces design cycle**
  - System HW and MAC provided

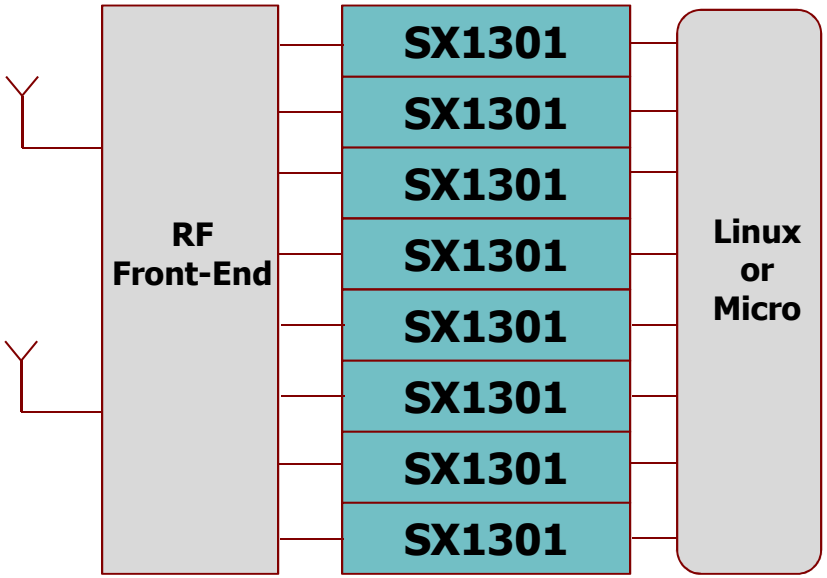
EU Concentrator Overview

- **Multi-Modem/Multi-channel**
  - 10 channels
  - 9 LoRa modems
  - 1 FSK modem
- **Very high capacity**
- **Adaptive link rate**
  - Optimize capacity
  - Scalable
- **2MHz of spectrum**
  - Wide FE can be used



Semtech NA Concentrator

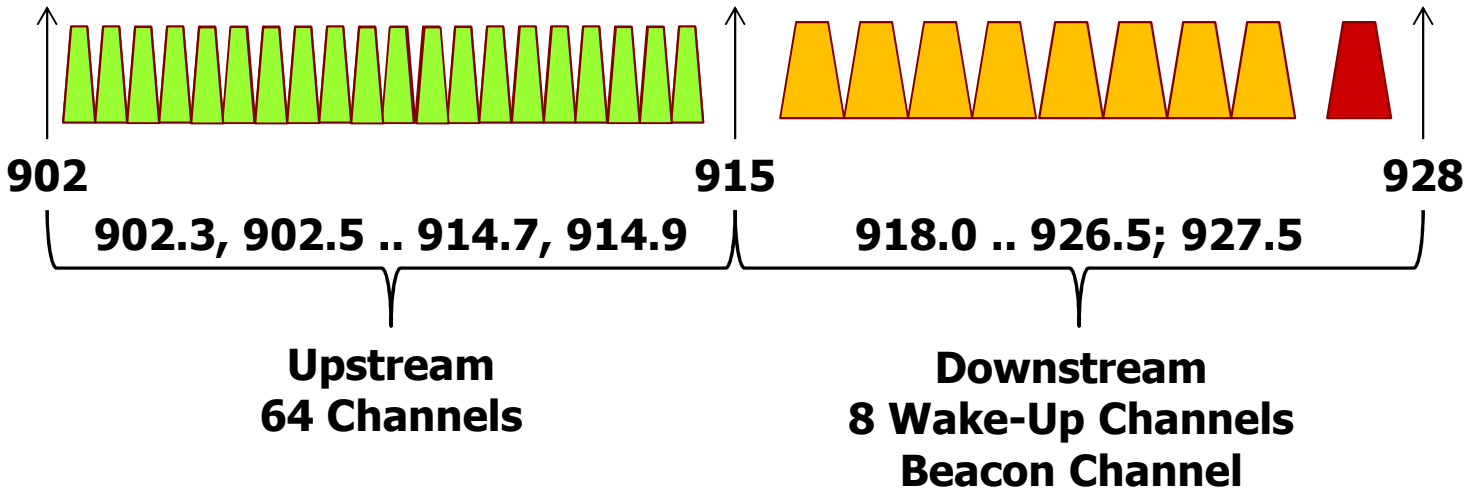
- **FCC requirements**
  - Frequency hopping, 902-928MHz
  - 400msec max channel dwell time
  - 1W max output power
- **Gateway**
  - Embedded Linux
  - 8x SX1301
- **PHY parameters**
  - Number of Channels: 64 Upstream, 2 down
  - Number of Modems: 64 Rx Modems + 2 Tx
  - Channel BW: 125 KHz Up and 500KHz Down
  - RF Power: +20dBm up and +27dBm down (+36 with max antenna gain)
  - Half Duplex (Possibility to split band and enable partial full duplex)
  - Data rates up-link: 4 (SF7 – SF10)
  - Data rates down-link: 4 Down (SF7 – SF10)
- **Protocol parameters**
  - Asynchronous on all 64 channels



LoRaMAC North America

- **Upstream – 64 parallel channels using 125 kHz BW, ADR**

- **Downstream -**
  - Unicast on same channel as Upstream
  - Beacon channel for network status and group ACK
  - 8 Wake-Up channels using 500 kHz BW



Concentrator Summary

	EU	NA	China
Number of SX1301	1	8	8
Channels Up	10	64	64
Channels Dn	1	2	2
RX modems	10	64	64
Channel BW Up	125kHz	125kHz	125kHz
Channel BW Dn	125kHz	500kHz	125kHz
TX Power Up	+14dBm	+20dBm(or +30)	+20dBm
TX Power Dn	+14dBm	+27dBm	+20dBm
SF Up	7-12	7-10	7-12
Link Budget Up	155dB	154dB	161dB
Link Budget Dn	155dB	157dB	161dB
Capacity	10-50K nodes	100-300K nodes	100-300K nodes

What is LoRaMac?

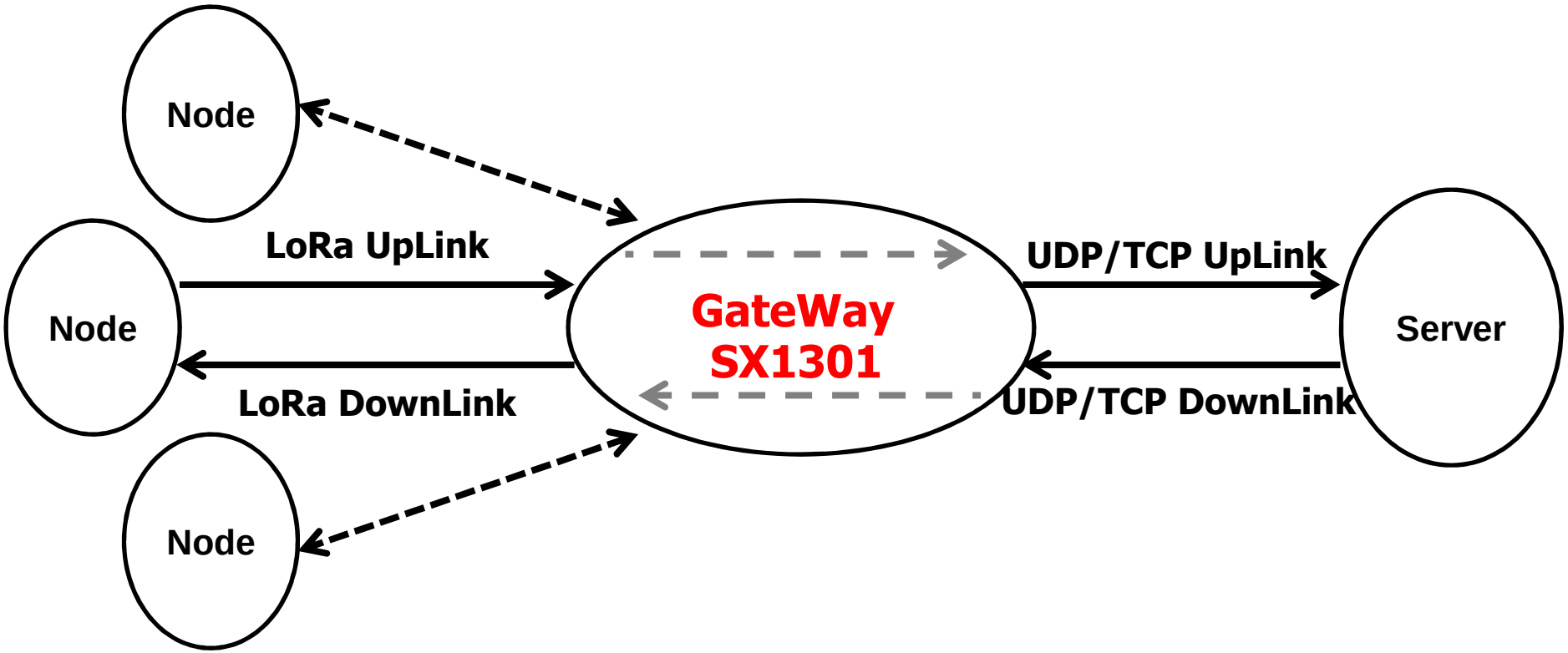
- **LoRa Based**
  - LoRa™ is a wireless modulation for long-range low-power low-data-rate applications developed by Semtech.
- **Protocol**
- **MAC Layer of OSI Model**
- **Specification Team: Semtech, IBM, Actility(ThingPark)**
- **Lora Alliance**

Feature

- Long Range
- Star network
- Low Power
- Adaptive Data Rate
- Multi Channels

LoRaMac System Structure

- Node
- Gateway
- Server

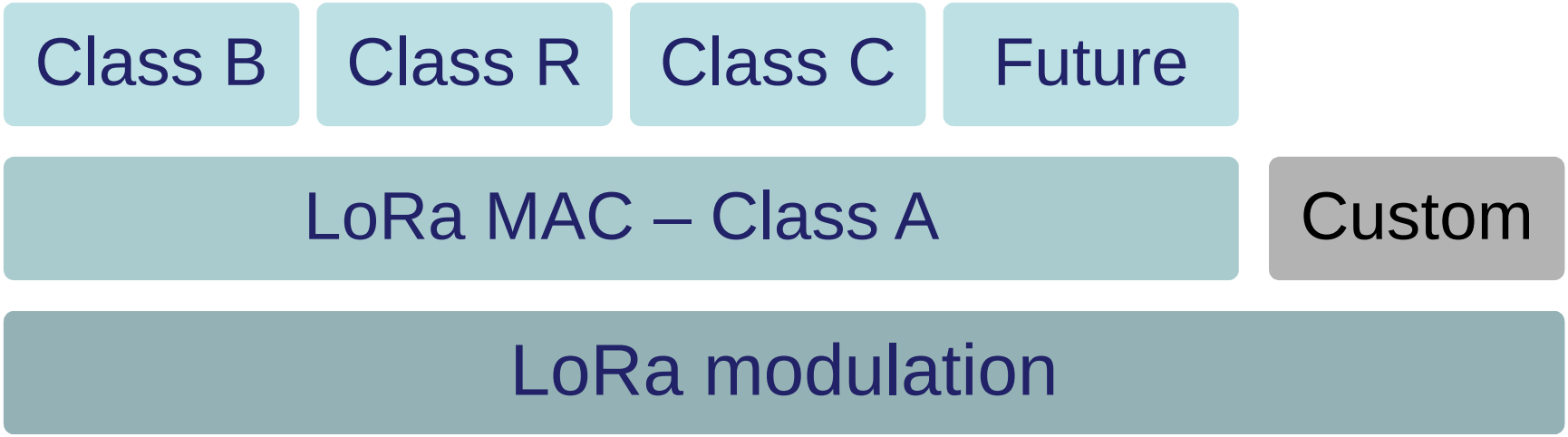


LoRaMAC - Node

- **Light weight protocol for nodes and server**
- **Developed in collaboration with 3rd party**
- **Semtech provides an open source reference**
  - https://github.com/Lora-net
  - IBM provides a commercial implementation of the specification
- **Securely transfer data to the network**
  - Two layers of AES128 to provide secure network management and private data
- **Maximize battery life**
  - Simple Aloha style network
- **Provides for two basic classes**
  - Class A nodes are typically sensors.
    - Node Wakes up, sends data, sleeps for 1 second, and then wakes for any network traffic, goes back to sleep until next reporting cycle
  - Class B nodes are typically actuators
    - Node wake up at scheduled times and the network uses this opportunity to initiate down stream traffic.
    - As a special case, some nodes may be listening at all times

Device Type

- **Class A – Bi-Directional Active Mode (Released)**
- **Class C – Enter *RX* Mode when IDLE (Powered Node) (Un-Released)**
- **Class B – Receive periodically. (Beacon) (Developing)**
- **Class R – Join new Network, keep current one. (Idea)**



Frame Formats

- Uplink (Sent by node)
- Downlink (Sent by gateway) – No CRC Filed

  Make frame short to save band.

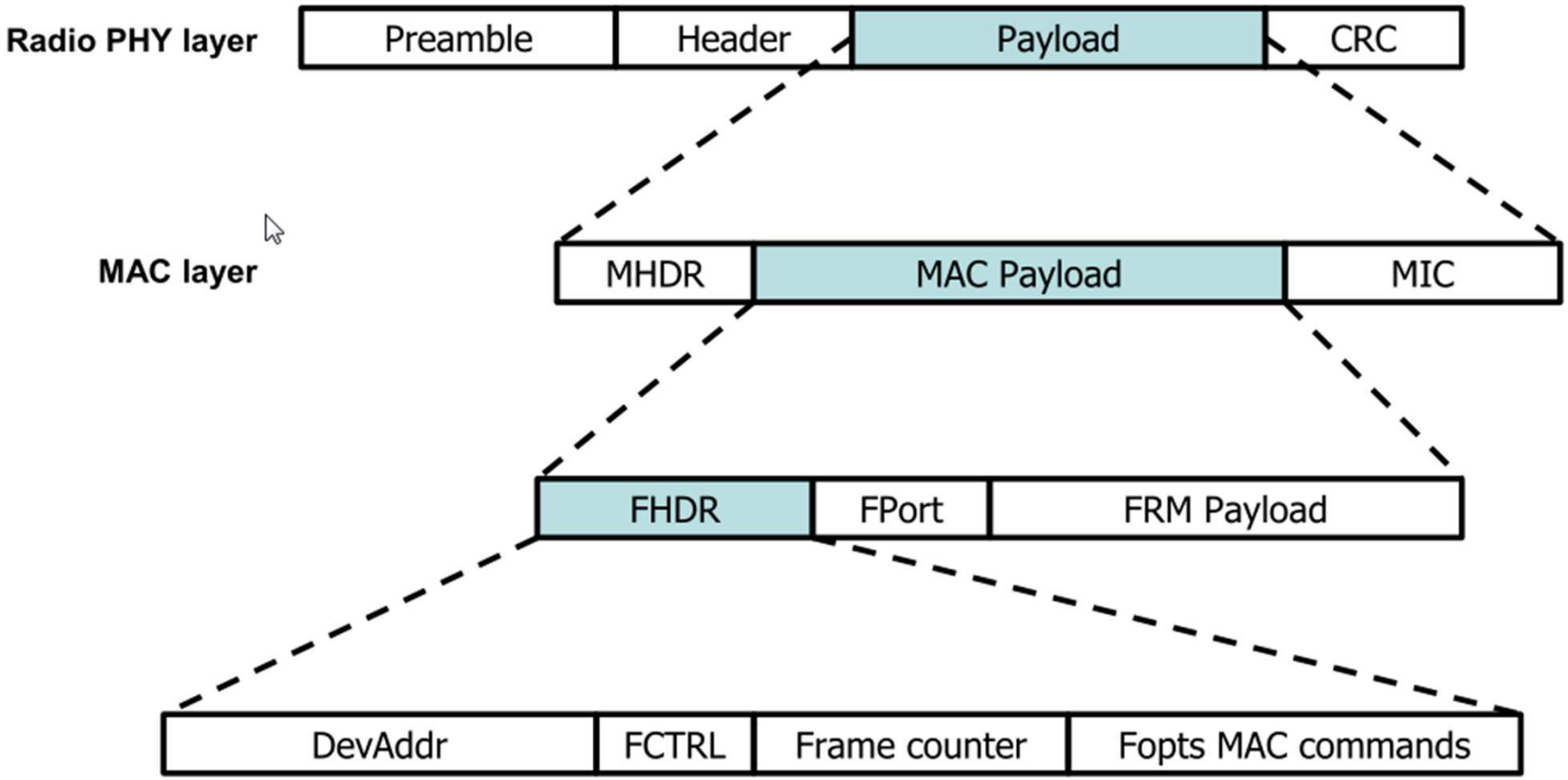
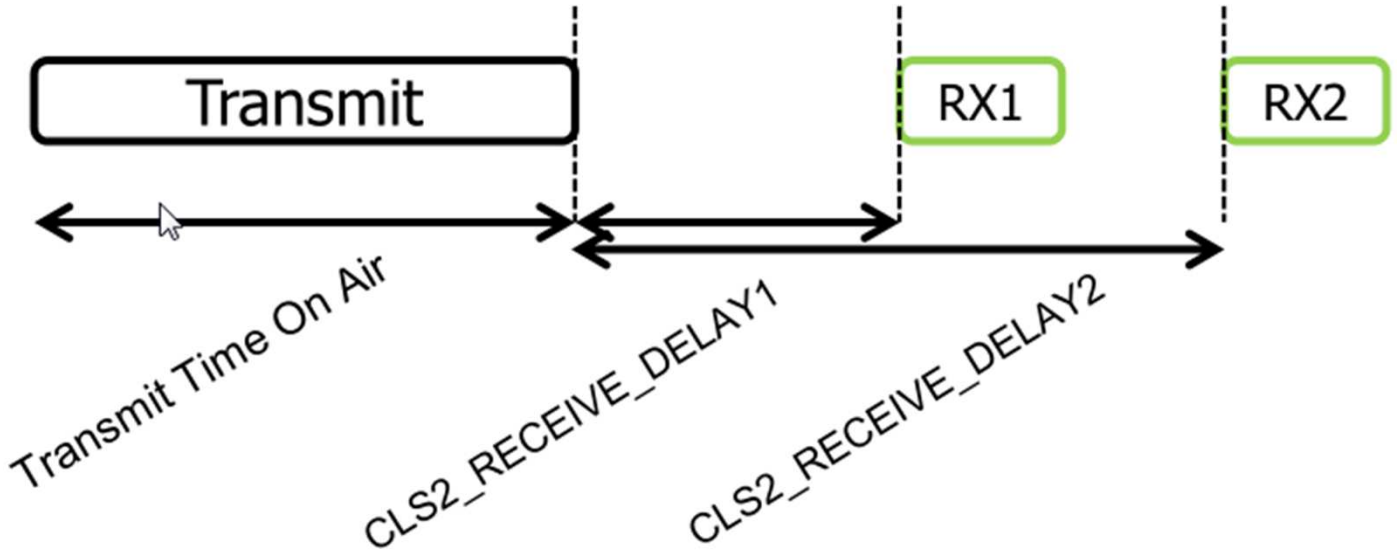


Figure 2 LoRa message format

Class A


Transmit
RX1
RX2
Transmit Time On Air
CLS2_RECEIVE_DELAY1
CLS2_RECEIVE_DELAY2

Adaptive Data Rate

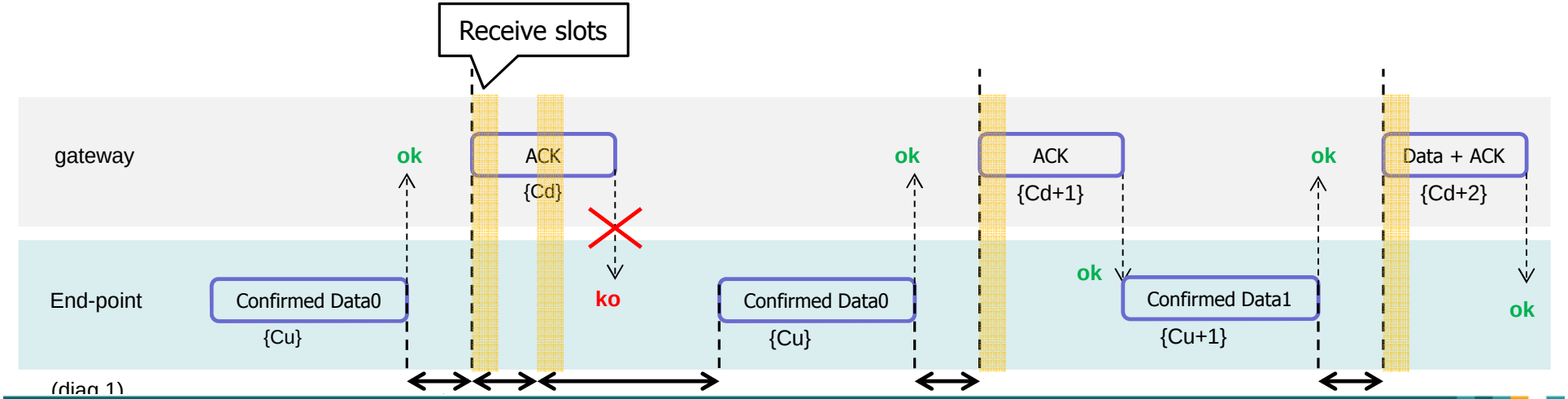
- Terminology
  - SF/Date Rate/Output power
- Gateway sends ADR packet periodically
- Node decreases data rate if no ACK received for some times.

CCA(空闲信道检测)

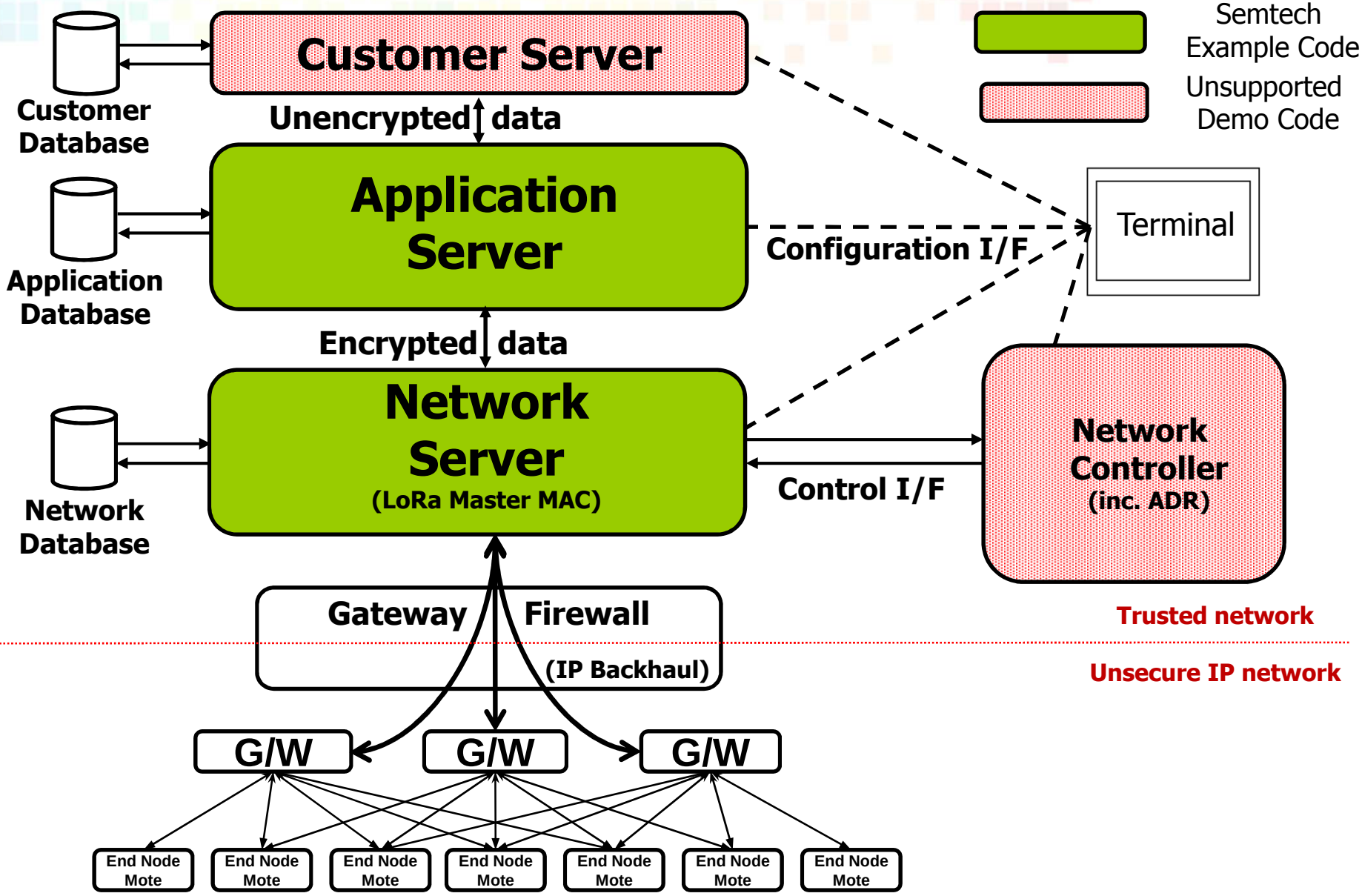
- ALOHA 算法 (successor :CSMA/CD)
- Listen before talk
- Re-transmit with a random delay and channel when collision occur

LoRaMAC – Server

- **Provides a single network controller**
  - Concentrators do not administer a subnet
  - Concentrators forward packets to server after appending meta data.
  - Server forwards data to other back-end servers and application servers
- **Packets may be forwarded by several GW**
  - Remove duplicates
  - Select best down stream path based on meta data
- **Schedule downstream traffic**
  - Concentrators have accurate timing in order to transmit messages when nodes are scheduled to be awake



Semtech Class A Network Server Overview



Overview of elements

Network Server

- Keeps a list of the Motes (End Nodes) accepted in network
- Consolidates all Mote messages received via different gateways
- Validation of network authentication
  - Decryption for MAC commands sent to Port 0 (No application message)
- Stores and forwards downstream application data and Mac commands to Mote
- Determines Gateway to use for downstream transmission to Mote

Application Server

- Decryption of the Application layer encryption
- Passes decrypted Mote payloads to Customer Server
- Forwards downstream Customer application data to Network Server

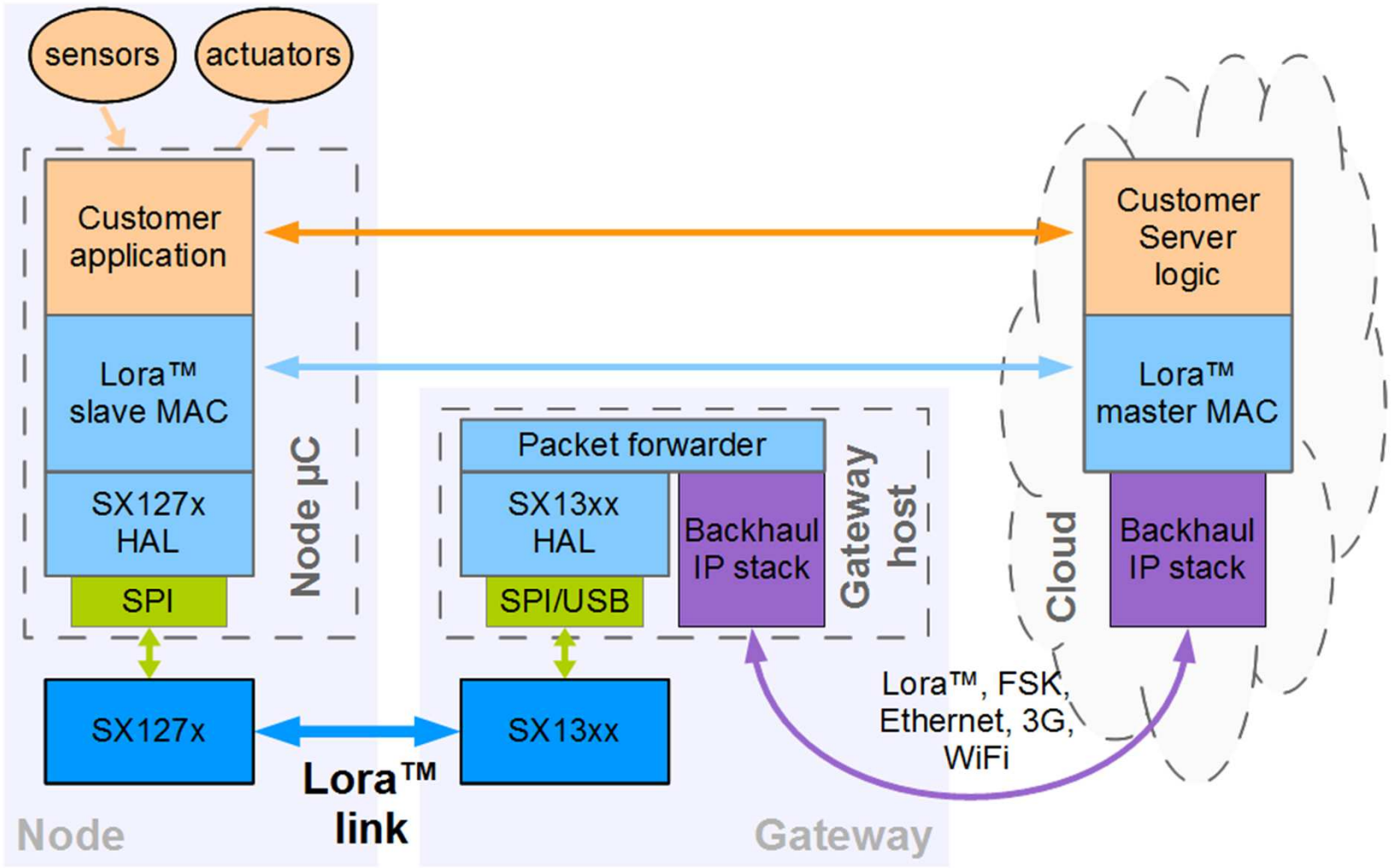
Customer Server

- Keeps an active list of all Motes in Network.
- Payload data from the Application Server stored it in Customer Database.
- Passes downstream payload data to Application Server for transmission to Mote

Network Controller

- Set up the network
- Implement the operator's network rules on ADR
- Receives error messages from the NetApp Server .

Semtech Contribution



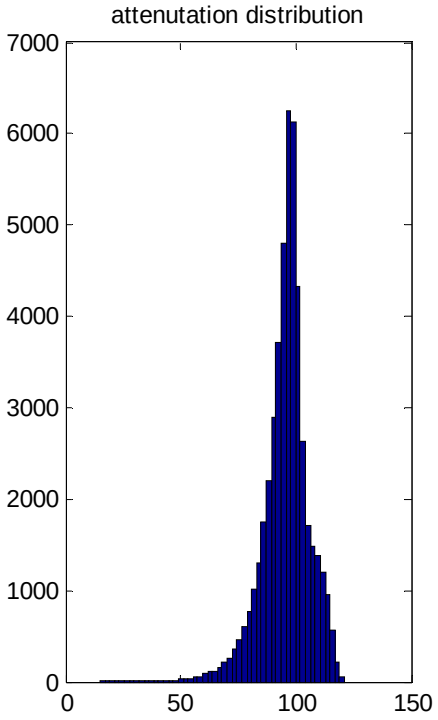
LoRa Network Capacity

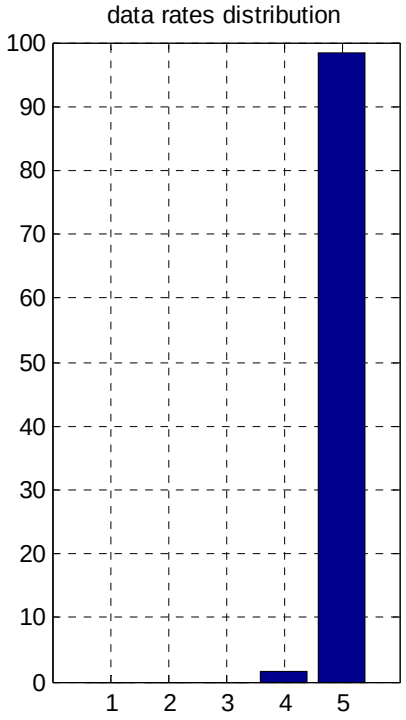
- **Using existing LTE Microccell and Macrocell parameters**
  - Microcell – 500m concentrator spacing w/ ~3000 nodes
  - Macrocell – 1700m concentrator spacing w/ 12000 nodes
  - Similar path loss models for dense urban environments
- **Reporting data hourly w/ 32 bytes of data**
- **64 channels in 902-928MHz**

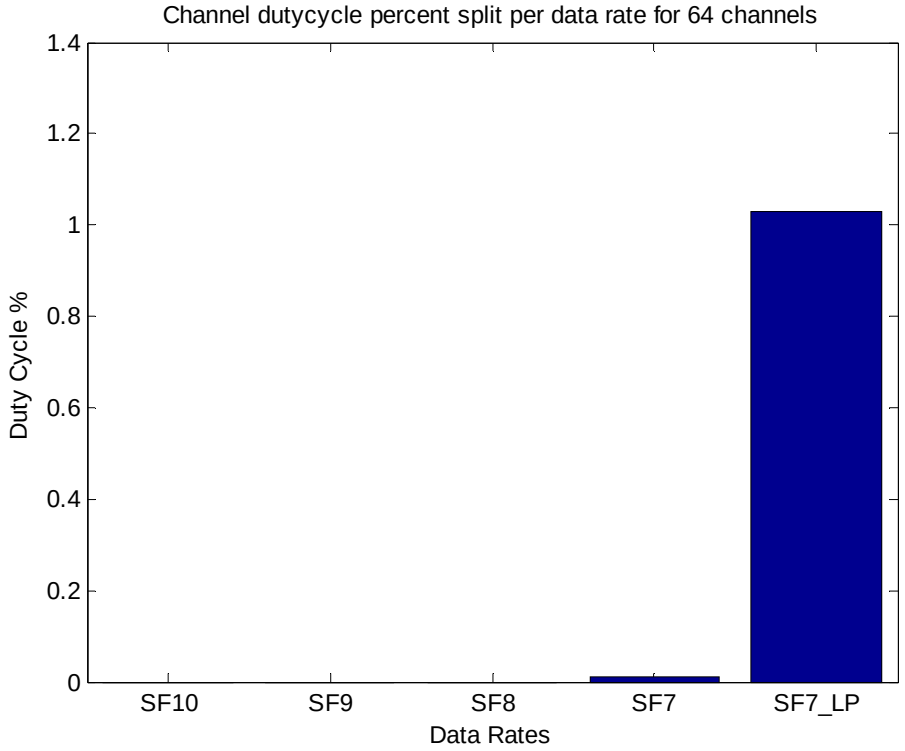
	LoRa Microcell 1	LoRa Microcell 2	LoRa Macrocell 1	LoRa Macrocell 2
Concentrator spacing	500m	500m	1700m	1700m
Nodes per concentrator	3000	16000	12000	48000
Output Power	10 dBm	10 dBm	19 dBm	19 dBm
Network Utilization (Duty cycle)	1.04%	5.57%	1.67%	6.63%

MicroCell Model – Results 1

- **500m spacing, 3000 nodes, 32 byte payload, TX =10dBm**
- **Results : 64 channel network, TX once per hour**
  - End nodes not connected (percent): 0.00
  - System Redundancy (# of nodes received vs planned) : 8.63
  - Duty cycle per RF Channel : (percent) 1.04

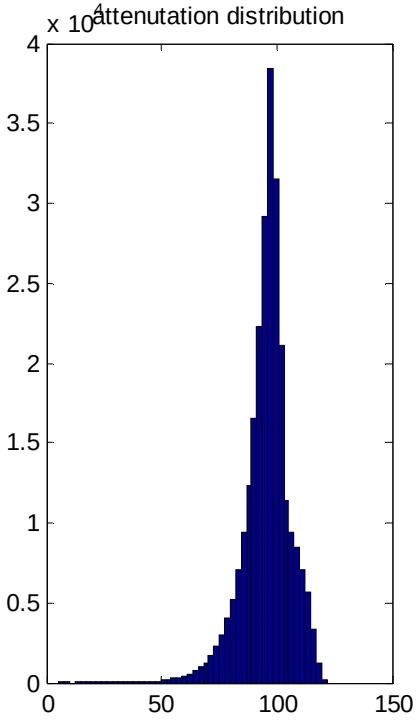


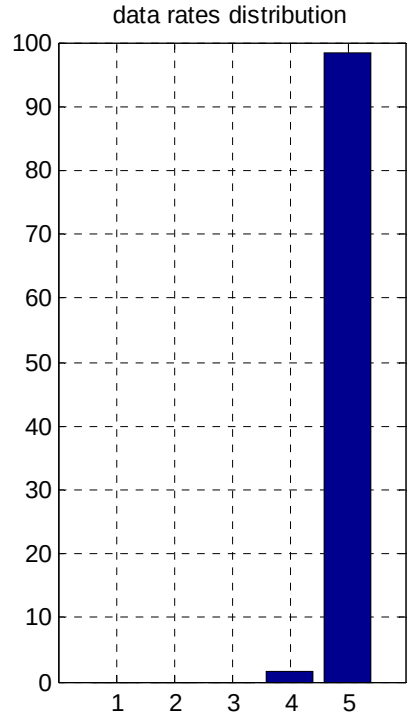


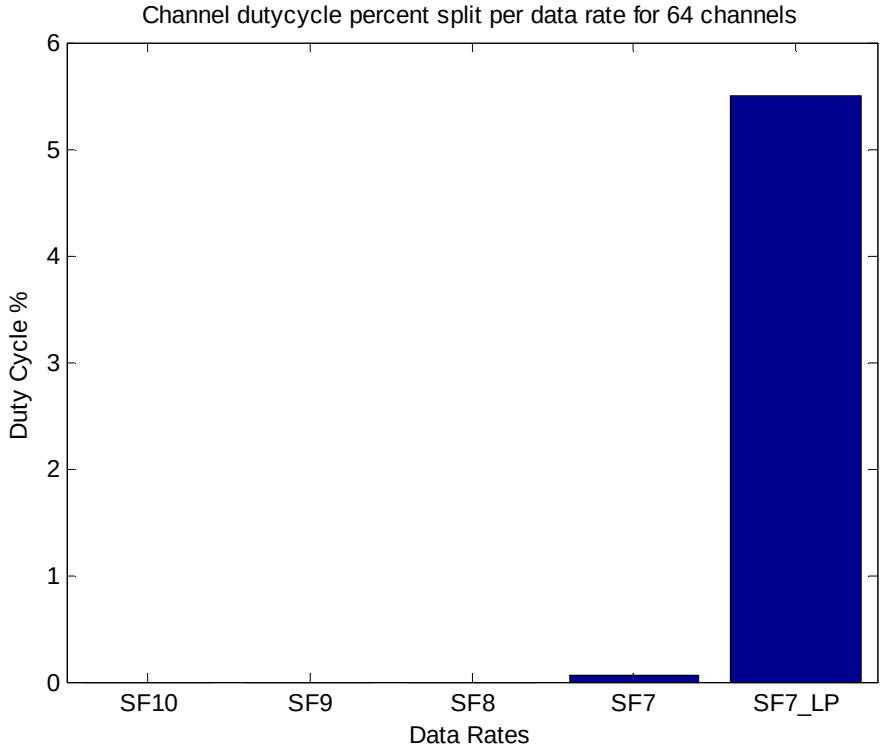


MicroCell Model – Results 2

- **500m spacing, 16000 nodes, 32 byte payload, TX =10dBm**
- **Results : 64 channel network, TX once per hour**
  - End nodes not connected (percent): 0.00
  - System Redundancy (# of nodes received vs planned) : 8.85
  - Duty cycle per RF Channel : (percent) 5.57

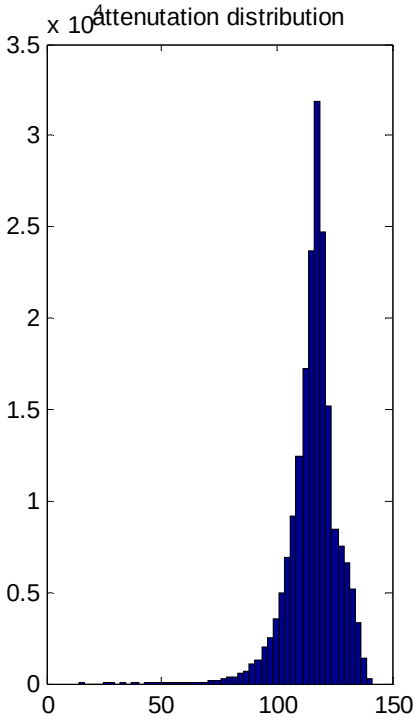


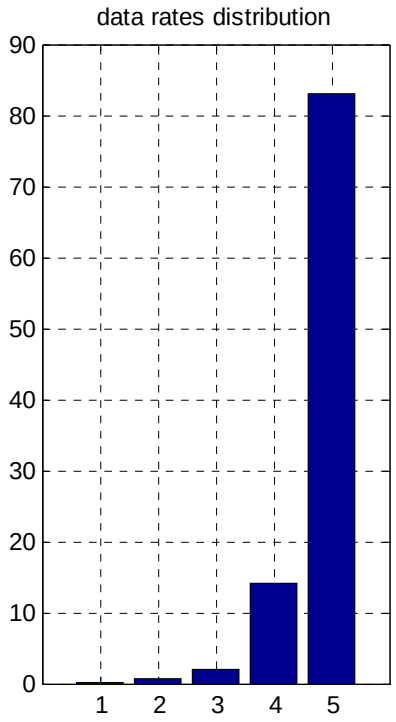


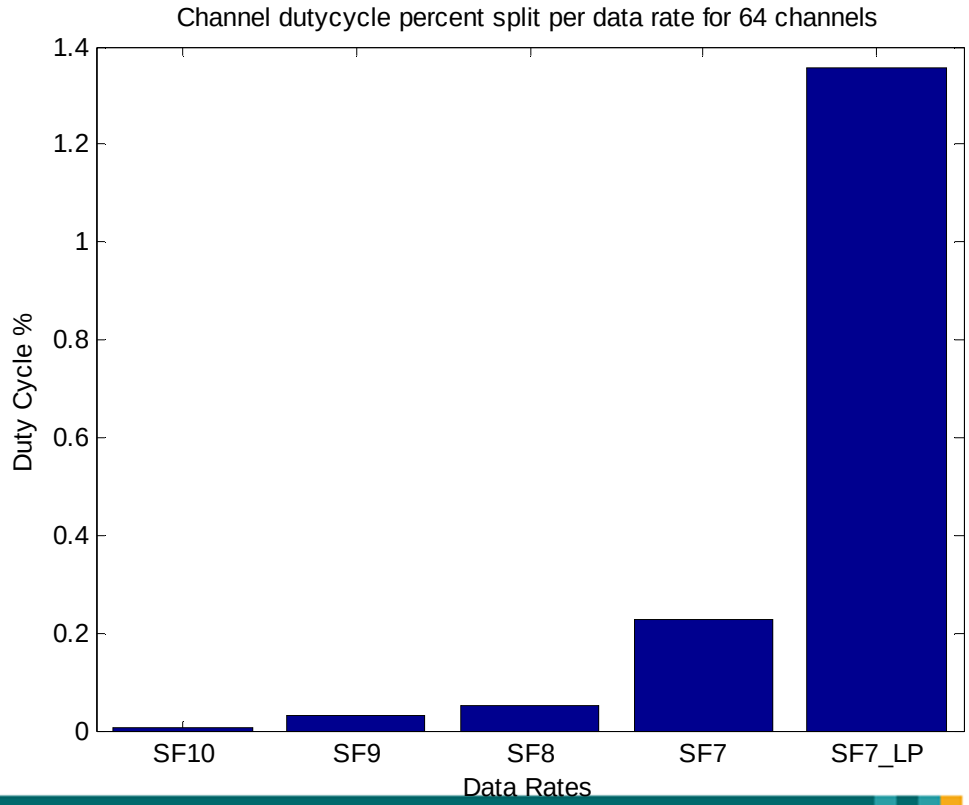


MacroCell Model – Results 1

- **1732m spacing, 12000 nodes, 32 byte payload, TX =19dBm**
- **Results : 64 channel network. TX once per hour**
  - End nodes not connected (percent): 0.00
  - System Redundancy (# of nodes received vs planned) : 3.43
  - Duty cycle per RF Channel : (percent) 1.67

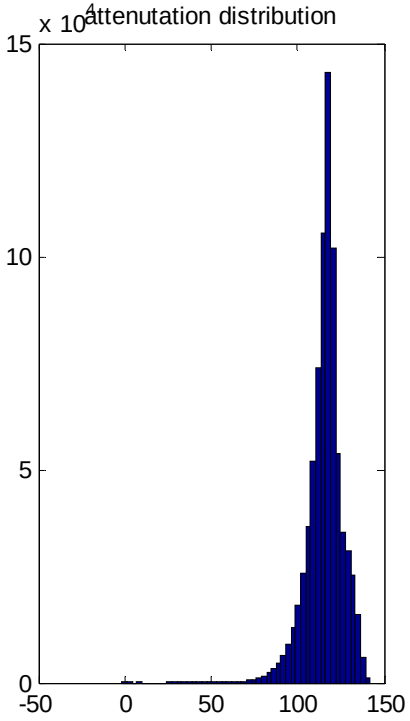


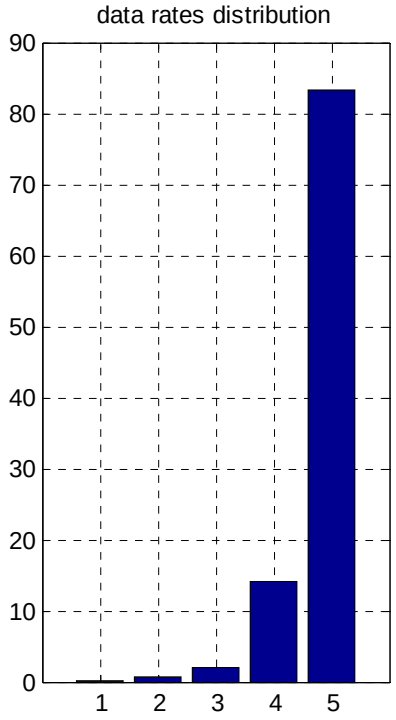


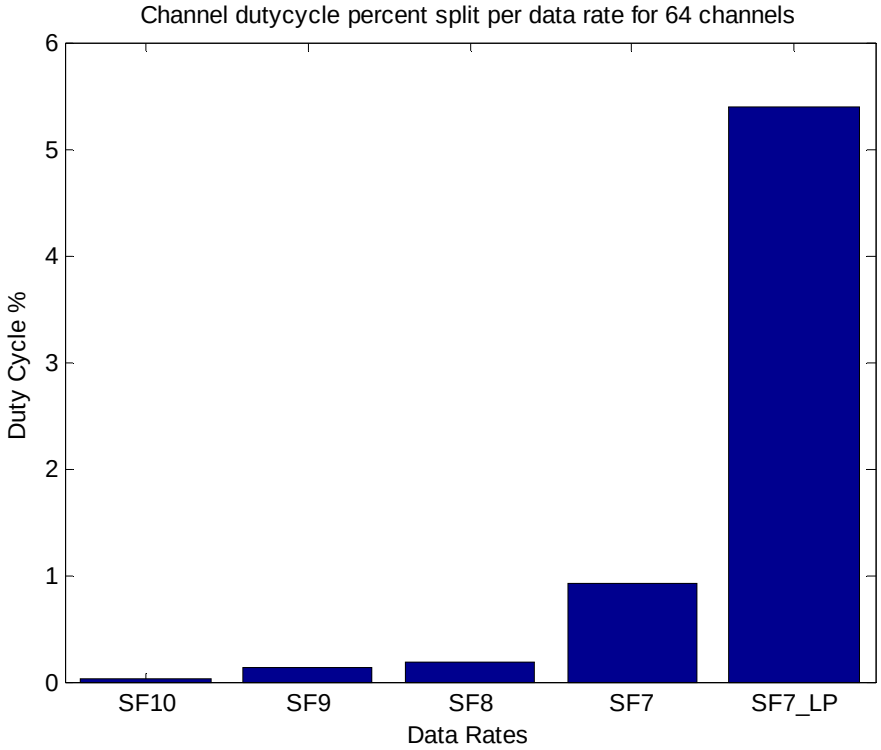


MacroCell Model – Results 2

- **1732m spacing, 48000 nodes, 32 byte payload, TX =19dBm**
- **Results : 64 channel network, TX once per hour**
  - End nodes not connected (percent): 0.00
  - System Redundancy (# of nodes received vs planned) : 3.39
  - Duty cycle per RF Channel : (percent) 6.63







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