Getting Started in LoRaWAN Hands On

Class 1: An Overview of Low-Power IoT Technologies

November 27, 2017

Charles J. Lord, PE
President, Consultant, Trainer
Blue Ridge Advanced Design and Automation

Presented by:

DesignNews

Blue Ridge Advanced Design and Automation
Asheville, North Carolina

CEC CONTINUING EDUCATION CENTER

Digi-Key ELECTRONICS

This Week's Agenda

11/27 An Overview of Low-Power IoT Technologies

11/28 Introduction to LoRa and LoRaWAN

11/29 The design of a LoRaWAN node, hands-on

11/30 No Service? No Problem!

Building your own LoRaWAN server

12/1 Testing Our LoRaWAN design

This Week's Agenda

11/27 An Overview of Low-Power IoT Technologies

11/28 Introduction to LoRa and LoRaWAN

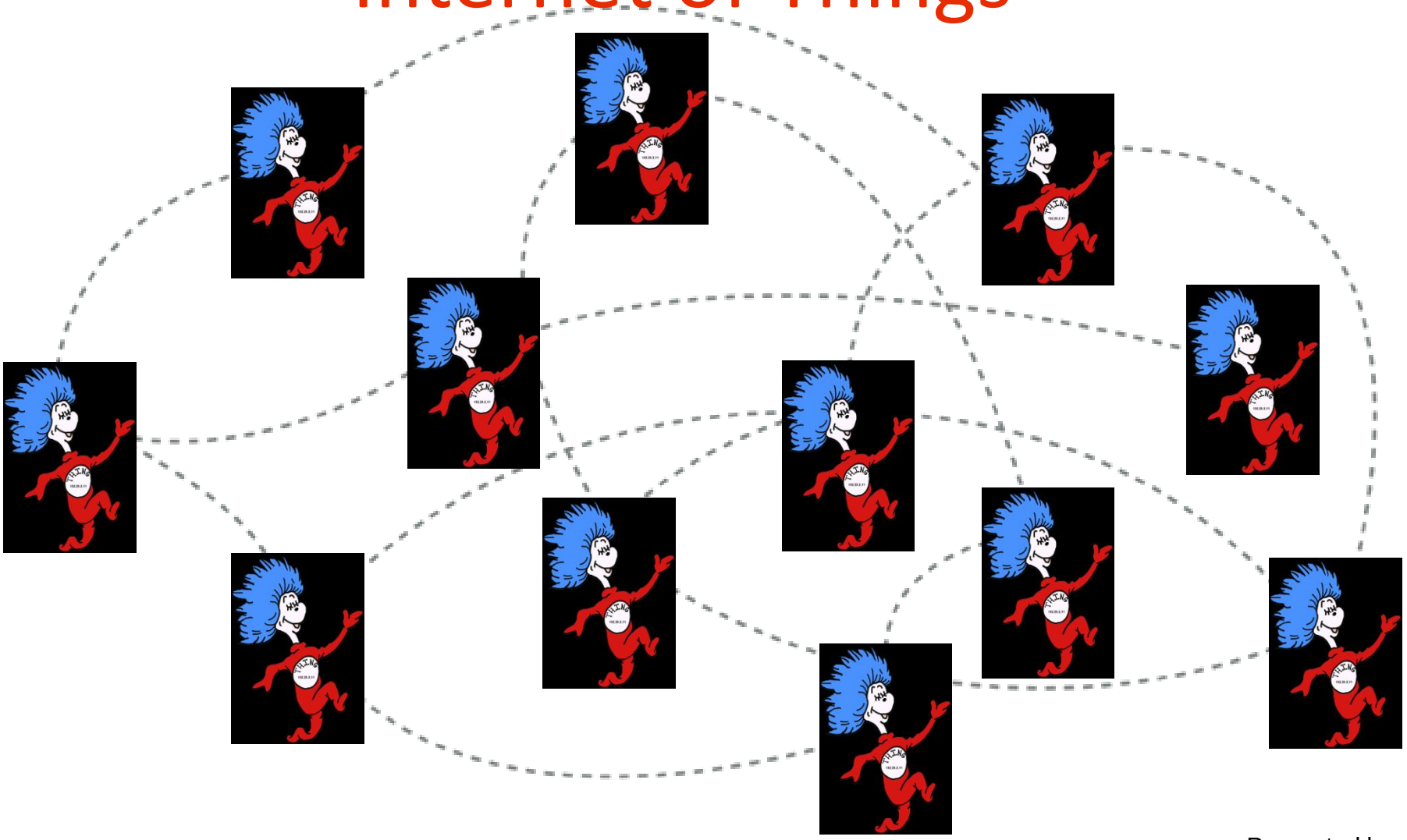
11/29 The design of a LoRaWAN node, hands-on

11/30 No Service? No Problem!

Building your own LoRaWAN server

12/1 Testing Our LoRaWAN design

Internet of Things



So What *IS* the Internet of Things

(From my October 2013 CEC – Hitchhikers Guide to the IoT)

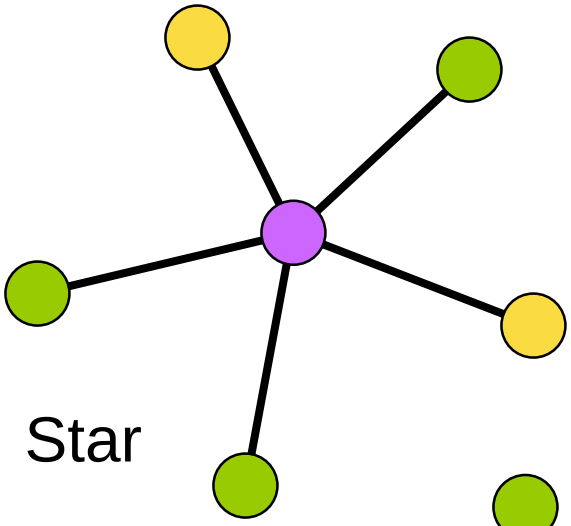
- A collection of unique objects gathered in an Internet**-like** structure
- Term coined by Kevin Ashton in 1999
  - Proctor and Gamble, later MIT
- Started primarily as tracking – was basis for RFID
- Outgrowth in tagging: bar codes, QR, digital watermarks, etc

My Conclusions in 2013

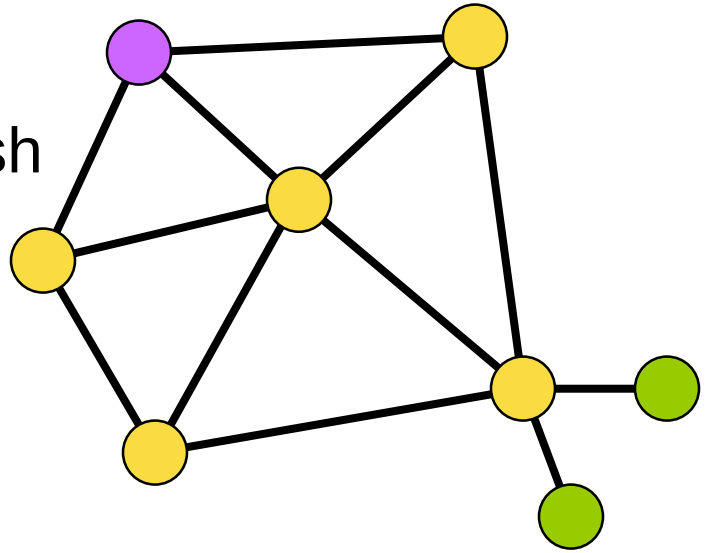
- The “Internet” in the IoT can be defined to whatever you considered your ‘universe’
  - True “IoT” (big-I) is the entire Internet
  - Many if not most “ioT” has a limited universe
- 2007 Automobile
- Most PAN solutions without gateways
- Networks behind NATs (192.168.0.xx)

Question 1 – What does NAT stand for and what does it do?

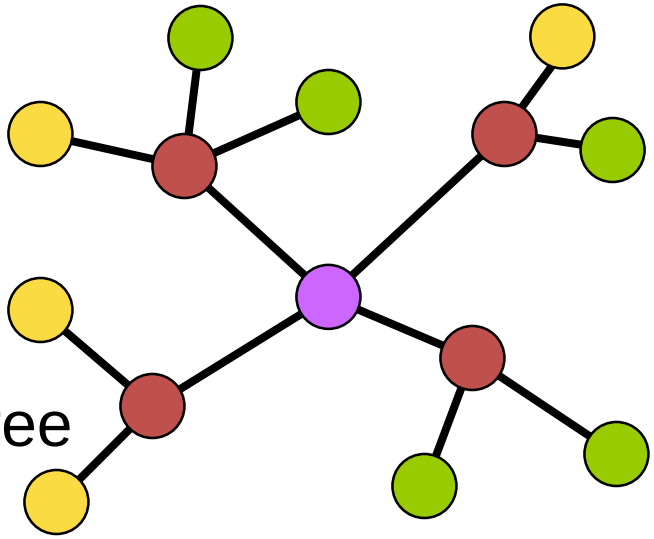
Topologies



Star

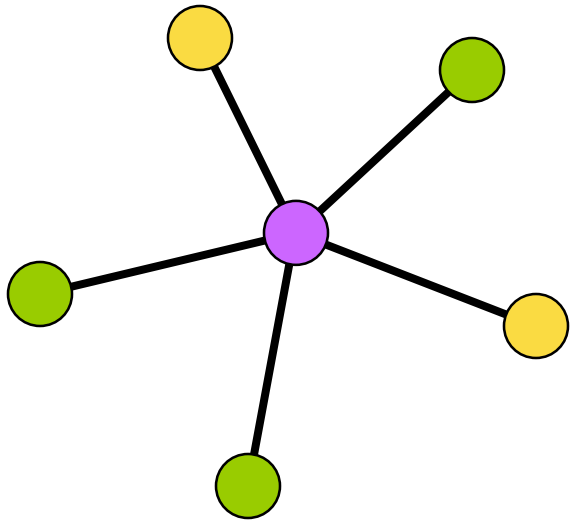


Mesh



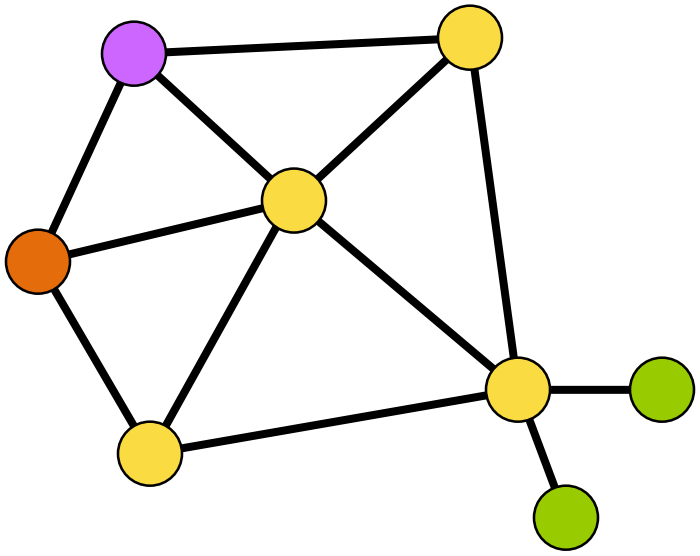
Cluster Tree

Star



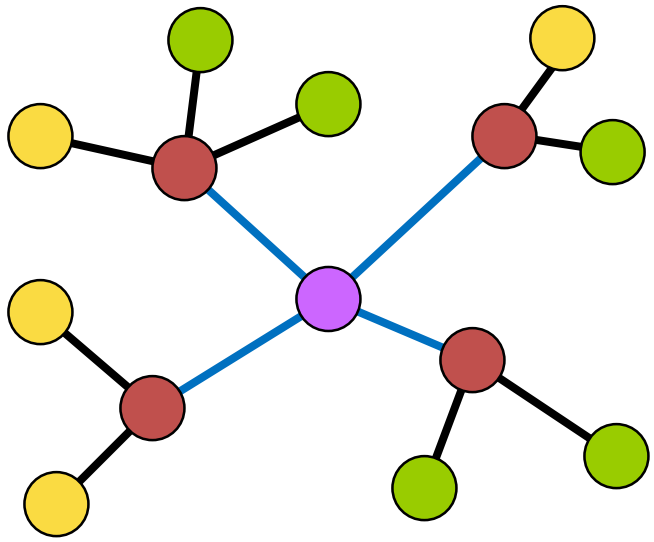
- Extension of point-to-point
- Center is only node that needs to communicate with more than one node
- Works well with extremely low latency
- Center is typically always listening and is mains powered
- Center can become a gateway to other networks

Mesh



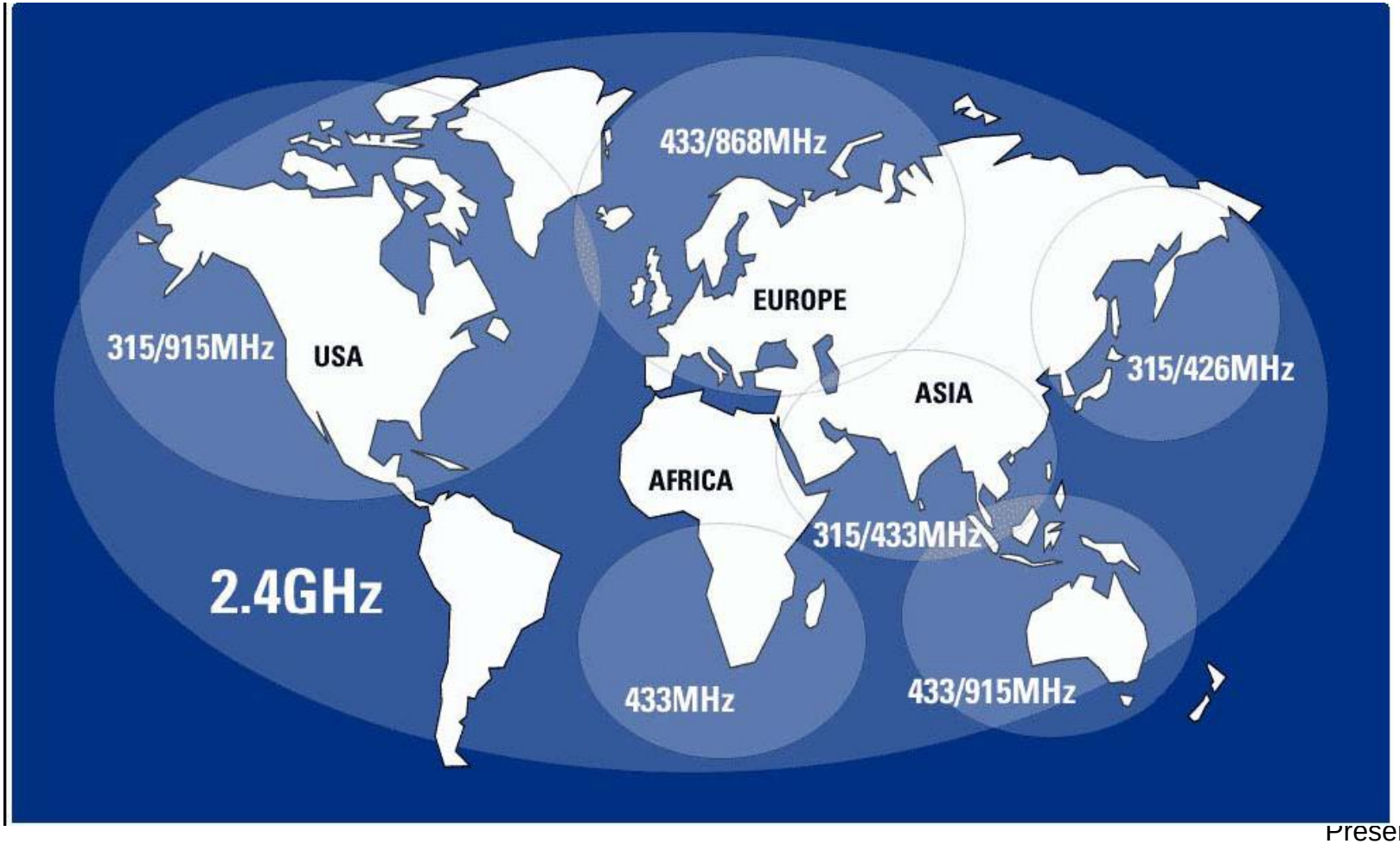
- Most resilient of networks – can support dynamic configuration
- Must have a control node in most protocols
- Most or all nodes are also routers
- Can also support end nodes
- Telephone network, ZigBee

Cluster Tree or Gateway



- Extension of Star
- The center of each ‘star’ can be either a router or a gateway
- The center node can be the cloud and the connections (blue) the Internet
- End nodes can still be very power efficient

Free Bands (ISM)



THE RF Protocol for the IoT

- Short answer – there isn't one
- Many contenders
- Sometimes depends on silicon availability or existing infrastructure
- Power consumption is often a major consideration – and occasional roadblock
- Let's look at some of the options

Wi-Fi (IEEE 802.11)

- Greatest strength – existing infrastructure, silicon and stack availability
- “Wi-Fi is EVERYWHERE!”
- Greatest weakness – high power consumption on transmit (sometimes 300-500mA @3.3V)
  - Can be offset in some cases by long latency
- Second greatest weakness – the existing infrastructure for public WiFi is mostly unprotected ‘open’ Wi-Fi
- Strength: it is a direct Internet connection – device-to-cloud
- Easy integration for general consumers – no special router or account

Cellular (4G/5G)

- Strength – general availability of cell networks
- Doesn't count on a local gateway or node
- Can support high data rates
- Weakness – can incur data charges
- Weakness – can be a power hog
- Strength – direct Internet connection
- Strength – not tied to geography as long as still in carrier (or roaming) range

Bluetooth (IEEE 802.15.1 etc)

- Short range
- Can support high data rates
- Strictly point-to-point
- Can tie into existing infrastructure (popular with phones and automotive)
- Power can be an issue (BTLE helps)
- Security issues

IEEE 802.15.4

- Low power, low data rate
- Foundation for ZigBee, Thread, many proprietary solutions
- Supports all topologies
  - ZigBee uses mesh
- With 6LowPAN supports full IPv6 addressing
- Supports “beacon mode” – star topology with full-time PAN controller.
  - Not in ZigBee
  - Potential for extremely low power on end nodes
- My personal ‘network of choice’ since 2004 for low-power

Question 2 – What other LP protocols are you using?

Lessons Learned in 10+ Years of 15.4

- Majority of silicon is at 2.4Ghz
  - Only worldwide ISM
  - Attenuation through materials or even fog/smoke
  - Small antennas great for PCB but easily masked
- Maximum data rate of 250Kbps
- Max usable range of 10M*
- Very low latency allows for great power efficiency when you can take advantage of it. Up to 245 seconds between comms
- Typical transceiver – receive is as high current as transmit. Works best with long sleep mode

$I_{RX} > I_{TX}$?

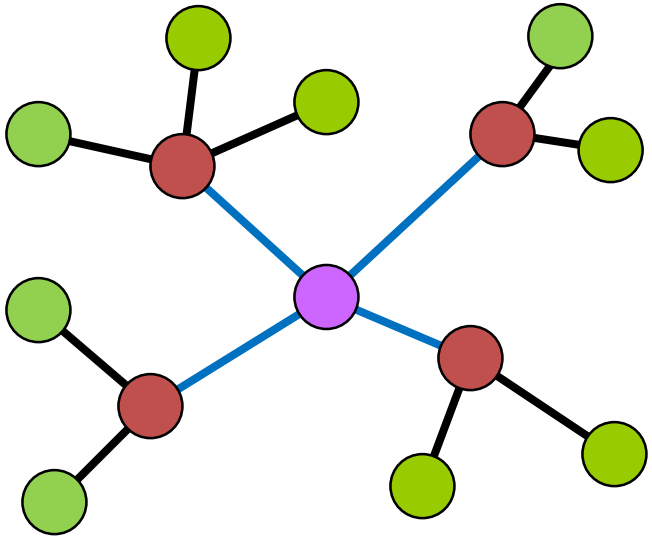
- NXP MC13202 802.15.4 transceiver @ 2.7V

Table 3. DC Electrical Characteristics

(V_{BATT}, V_{DDINT} = 2.7 V, T_A = 25 °C, unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Power Supply Current (V_{BATT} + V_{DDINT})					
Off[1]	$I_{leakage}$	-	0.2	1.0	µA
Hibernate[1]	I_{CCH}	-	1.0	6.0	µA
Doze (No CLKO)[1 2]	I_{CCD}	-	35	102	µA
Idle	I_{CCI}	-	500	800	µA
Transmit Mode (0 dBm nominal output power)	I_{CCT}	-	30	35	mA
Receive Mode	I_{CCR}	-	37	42	mA

802.15.4 Gateway



- Red nodes are combination of the beacon mode PAN and desired Internet (802.3 or 802.11, for example)
- Green nodes are typically battery powered

Disadvantages of the 15.4 Gateway

- Low data rate precludes OTA updates (security risk)
- 2.4Ghz attenuation
- Receive has to be timed
  (sleep – TX/RX – repeat)
- Range issues between gateway and nodes

New Protocols

There are a number of newer protocols that are proposed in an attempt to solve these issues:

- NB-IoT
- SigFox
- LoRa and LoRaWAN
- (there are others but outside the scope of this class)
- All are Wide Area Networks (WAN) that allow cellular-like coverage

NB-IoT

- Low power, low data rate cellular data
- Part of 3GPP (*3rd Generation Partnership Project*) spec for LTE-Advanced Pro

	LTE Cat 1	LTE Cat 0	LTE Cat M1 (eMTC)	LTE Cat NB1 (NB-IoT)	EC-GSM-IoT
3GPP Release	Release 8	Release 12	Release 13	Release 13	Release 13
Downlink Peak Rate	10 Mbit/s	1 Mbit/s	1 Mbit/s	250 kbit/s	474 kbit/s (EDGE) 2 Mbit/s (EGPRS2B)
Uplink Peak Rate	5 Mbit/s	1 Mbit/s	1 Mbit/s	250 kbit/s (multi-tone) 20 kbit/s (single-tone)	474 kbit/s (EDGE) 2 Mbit/s (EGPRS2B)
Latency	50-100ms	not deployed	10ms-15ms	1.6s-10s	700ms-2s
Number of Antennas	2	1	1	1	1-2
Duplex Mode	Full Duplex	Full or Half Duplex	Full or Half Duplex	Half Duplex	Half Duplex
Device Receive Bandwidth	1.08 - 18 MHz	1.08 - 18 MHz	1.08 MHz	180 kHz	200 kHz
Receiver Chains	2 (MIMO)	1 (SISO)	1 (SISO)	1 (SISO)	1-2
Device Transmit Power	23 dBm	23 dBm	20 / 23 dBm	20 / 23 dBm	23 / 33 dBm

Note – 1XRTT (2G) already shut down by ATT, Verizon is retiring in 2023

Question 3 – Are you using 1XRTT or other pre-4G data?

SigFox

- Proprietary standard – larger number of chip manufacturers licensed
- VERY slow data rate (remember 300 baud?)
- Licensing issues in US – part 15
- The owner of the technology owns the network
- BPSK on 868 (Europe) 915 (US)
- More power and tech in base unit.

LoRa and LoRaWAN

- LoRaWAN is a wide area network built on the LoRa protocol (open standard – LoRa Alliance)
- LoRa is a proprietary spread spectrum modulation scheme that is derivative of Chirp Spread Spectrum modulation
- Greater receiver sensitivity than SigFox
- Transceivers for base and end node are essentially the same
- Currently one manufacturer of RF silicon (SEMTECH) but working with other chip companies (ST Micro)

This Week's Agenda

11/27 An Overview of Low-Power IoT Technologies

11/28 Introduction to LoRa and LoRaWAN

11/29 The design of a LoRaWAN node, hands-on

11/30 No Service? No Problem!

Building your own LoRaWAN server

12/1 Testing Our LoRaWAN design

Please stick around as I answer your questions!

- Please give me a moment to scroll back through the chat window to find your questions
- I will stay on chat as long as it takes to answer!
- I am available to answer simple questions or to consult (or offer in-house training for your company)
  c.j.lord@ieee.org
  http://www.blueridgetechnc.com
  http://www.linkedin.com/in/charleslord
  Twitter: @charleslord
  https://www.github.com/bradatraining