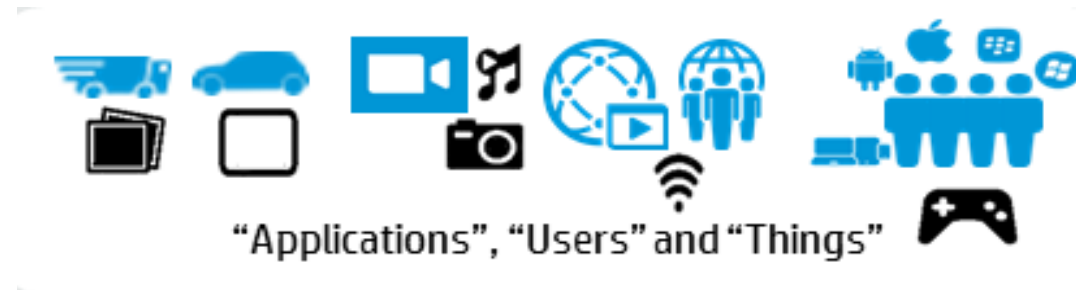


The Internet of Things in a Cellular World

“Everything is connected!!!”



John Bews

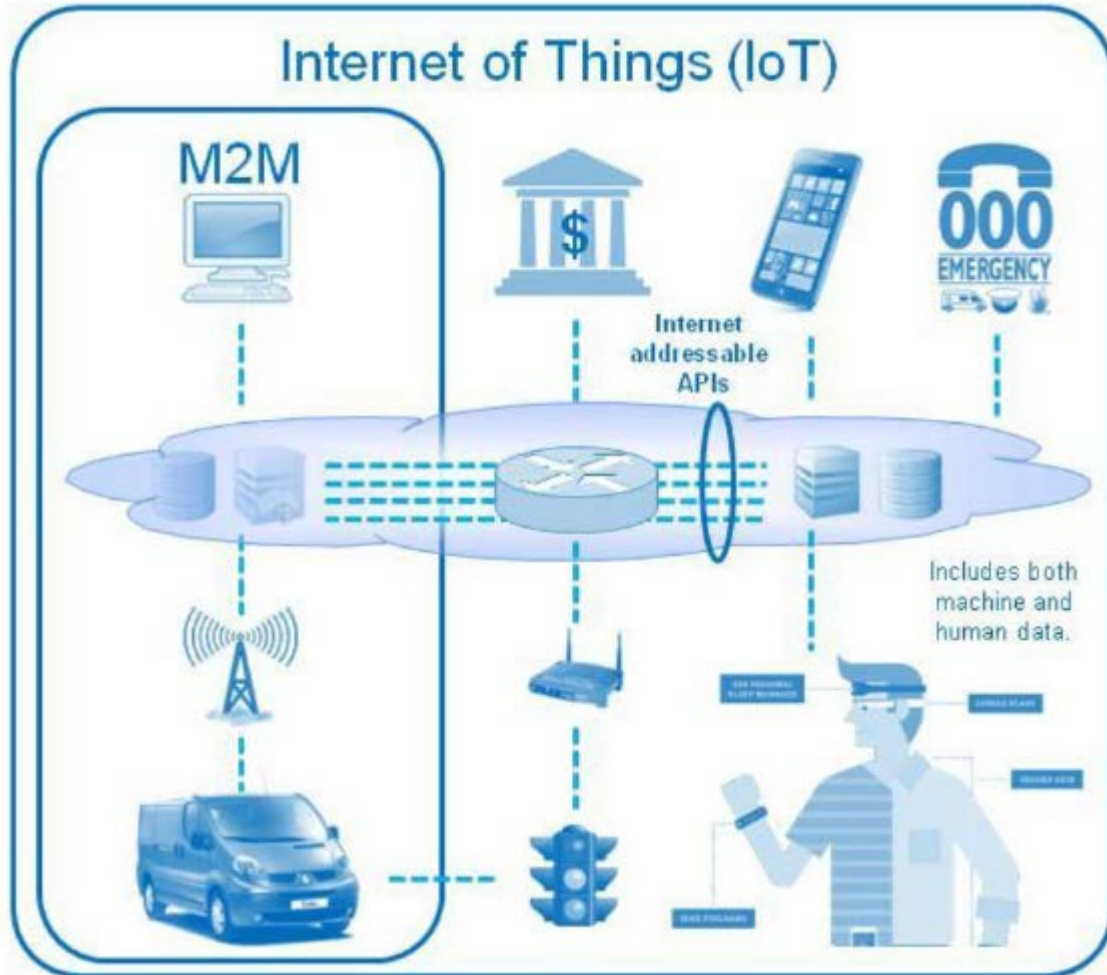
The Internet of Things in a Cellular World

Agenda

- *IoT Concept*
- *Cellular Networks and IoT*
- *LTE Refresher*
- *Reducing Cost and Complexity*
- *Improving Coverage*
- *Lowering Power Consumption*
- *Cellular IoT Gotcha's*
- *Summary*



What is the Internet of Things Concept?



If you can

- *identify the thing*
- *capture data from it*
- *send that data to a server*

Then you can

- *offer a range of services*
- *to all kinds of applications*
- *using that data*

Things include....

- *machines, people, animals, cars, etc....*
 - *Some Things have high data rate requirements....security systems, telemedicine*
 - *Some Things have low data rate requirements...telemetry*
 - *Some Things need real time feedback....smart cars*
 - *Some Things don't care about delays....smart meters*

So how do Cellular Networks do IoT?

Cellular Networks and IoT

Where does Cellular IoT sit in this range of services.....

- 4G LTE does M2M high speed data rates well – Cat-4 to Cat-16 – Upto 1Gbps DL.
- 4G LTE has wide area coverage – 700MHz, 850Mhz, 900MHz
- 4G LTE has good latency – less than 100ms

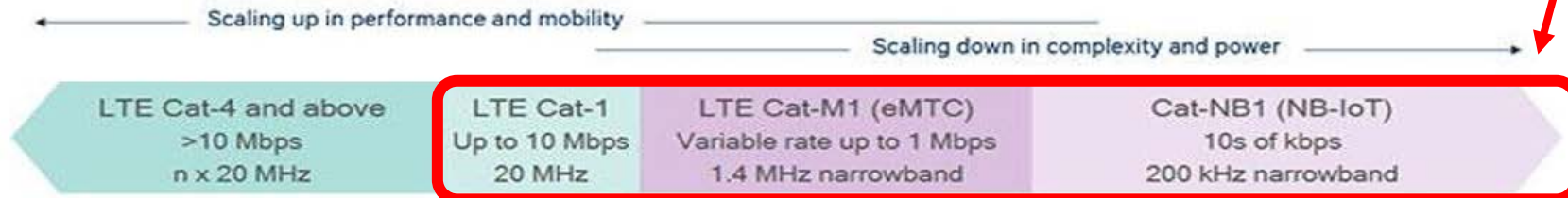
- Current LTE devices are costly for low speed data compared to Zigbee & LoRa.
- Zigbee & LoRa have limited coverage compared to LTE
 - LTE needs a cheap solution for low speed data applications.

3GPP is the standards body for LTE. - 3GPP have introduced new IoT features to the LTE standards.

- The IoT requirements were for:-
 - Low Cost/Low Complexity
 - Enhanced Coverage
 - Low Power Consumption

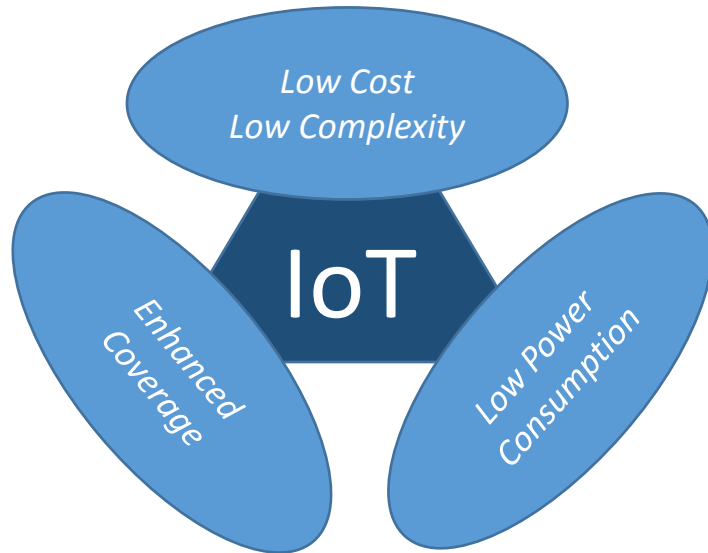
New 4G LTE IoT Standards & Devices

Fastest Network (M2M)



Slowest Network

Lets look at this in detail



- *How do we achieve Low Cost/Low Complexity?*
- *How do we achieve Enhanced Coverage?*
- *How do we achieve Low Power Consumption?*
- *What are the gotcha's?*

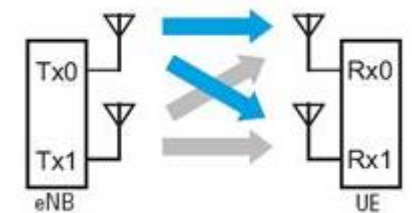
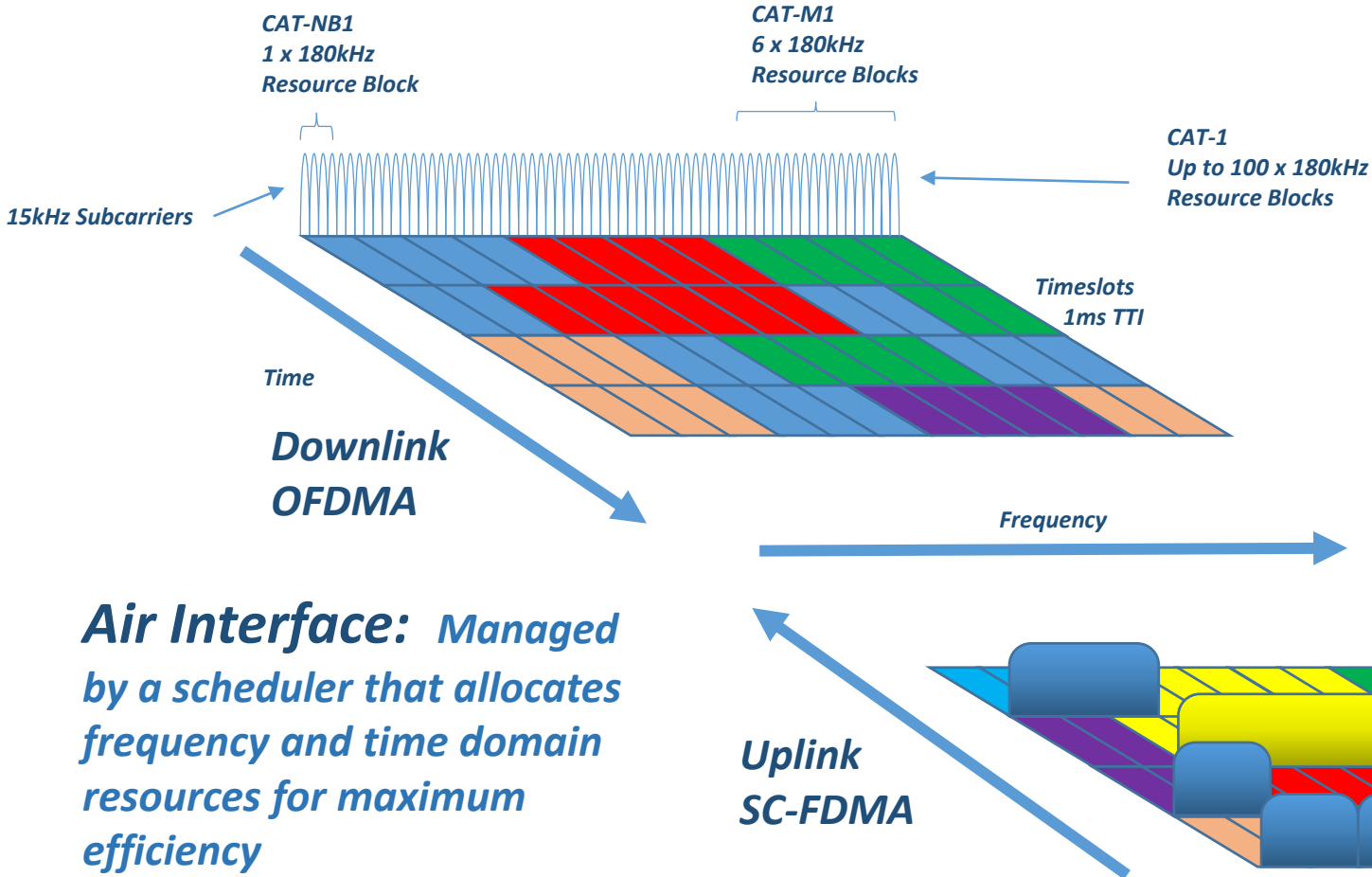
But first a LTE refresher!!!

A quick LTE Refresher

- **Bands:** 700, 850, 900, 1800, 2100, 2300, 2600MHz
- **Bandwidth:** 1.4MHz up to 20MHz
- **Channel Usage:**

- **Uses 12 x 15kHz subcarriers for a Resource Block**
- **Up to 100 Resource Blocks**
- **Transmits Data in 1ms Timeslots**

- **Modulation:** QPSK, 16QAM, 64QAM, 256QAM
- **Downlink:** OFDMA **Uplink:** SC-FDMA
- **Power:** +23dBm
- **Full Duplex on FDD**
- **DL MIMO:** Typically 4x2 MIMO or 2x2 MIMO
- **UL MIMO:** Typically 1x4 SIMO or 1x2 SIMO
- **Device Antennas:** Typically 2 Rx + 1 Tx



The IoT standard is going to modify many of these.....

How do we reduce cost and complexity?

- **Reduce Bands:** *Less switches and filters – Only do L700 or L700+L1800*
- **Reduce Bandwidth:** *Less compute power – Use 1.4MHz or 200kHz segment*
- **Reduce Modulation Complexity:** *Less compute power – QPSK or QPSK+16QAM*
- **Make Half Duplex:** *Less filters + less compute power – Full Duplex Optional*
- **Reduce Antennas:** *Less antennas are cheaper*

Reducing Complexity
Reduces Performance

| Feature | Cat-4 | Cat-1 | Cat-M1 | Cat-NB1 |
|-------------------------------------|----------|---------|-------------------|-------------------|
| Supported duplex modes | FD | FD | FD or HD | HD Only |
| UE bandwidth (inc guard band) [MHz] | 20 MHz | 20 MHz | 1.4 MHz (6 RB's) | 200 kHz (1 RB) |
| DL peak rate [Mbps] | 150 Mbps | 10 Mbps | 800kbps / 300kbps | 230kbps (~20kbps) |
| UL peak rate [Mbps] | 50 Mbps | 5 Mbps | 1 Mbps / 375 kbps | 250kbps (~60kbps) |
| Highest DL modulation scheme | 64QAM | 64QAM | 16QAM | QPSK |
| Highest UL modulation scheme | 16QAM | 16QAM | QPSK | QPSK |
| Maximum number of DL Spatial layers | 2 | 1 | 1 | 1 |
| Number of receive antennas | 2 | 2 | 2 or 1 | 1 |
| Maximum transmit power [dBm] | 23 dBm | 23 dBm | 23 dBm or 20 dBm | 23 dBm or 20 dBm |

Speed Impact

Coverage Impact

How do we achieve Enhanced Coverage

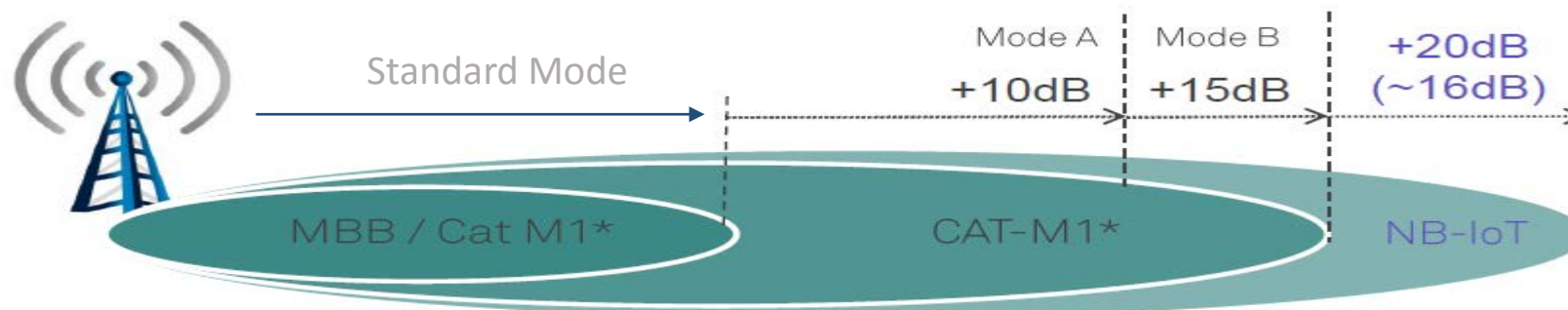
- **Concept:** *Introducing low data rate repetition of data blocks allows energy accumulation at UE.*
 - *Lower data rates give more sensitivity*
 - *More repetitions gives more sensitivity*
 - *Introduces inefficiency and increases latency*
- **Standard LTE:** *Most channels are intended for single transmission only*
 - *Maximises the efficiency and minimises latency*
- **IoT LTE:** *Most channels use repetitive transmissions to improve the sensitivity*
 - *This reduces efficiency and increases latency*
 - *Only do as much repetitions as necessary*
- *Cat-M1 has Standard Mode, Enhanced Mode A and Enhanced Mode B – 16QAM or QPSK*
- *Cat-NB1 uses even more enhancement + data rate limited to QPSK only*

Link Budget:

The IoT Link budget matches that for Zigbee and LoRa

Network Coverage:

LTE has a much bigger network coverage so you probably won't need all of it.



Cat-M1 device must support:-

- *2 x Rx antennas*
- *+23dBm Tx power....or get reduced coverage!!!!*
- *1 x Rx antenna reduces coverage by ~4dB*
- *+20dBm reduces coverage ~3dB*

How do we achieve Low Power Consumption?

Reduce Device Tx Power:

- **Standard LTE: +23dBm Max**
- **LTE IoT: Choice of +23dBm or +20dBm Max – Mainly set by the manufacturer**

- **LTE IoT: Introduces Power Saving Mode (PSM)**
 - **Standard LTE uses Discontinuous Rx but still Idle**
 - **Discontinuous Rxplus Power Saving Mode (PSM)**
 - **Device goes into deep sleep for periods**
 - **Extended Long Discontinuous Rx PSM**
 - **Devices goes into deep sleep for extended periods**

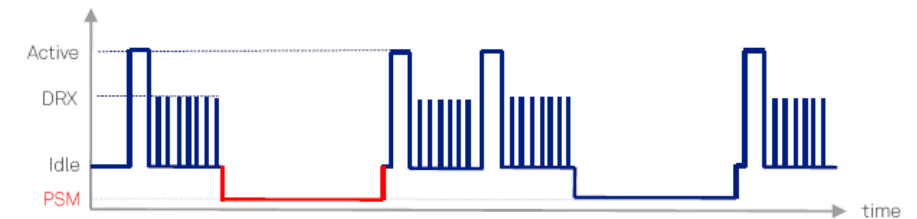
- **Battery Life: Target for Cat-NB1: 10+ years of battery life.**



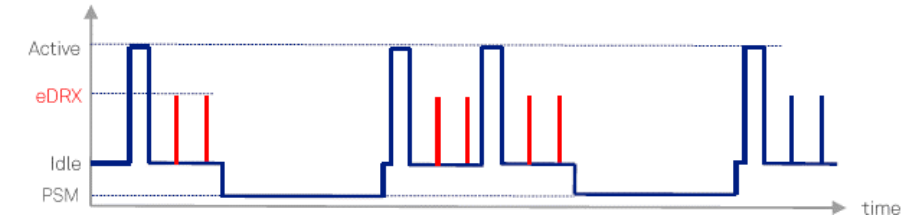
Today



R12 Power Save Mode



R13 Extended Long DRX



What are the Gotcha's

- **Reduced Bands:** Make sure your IoT device uses the band used by your carrier for IoT (700 or 900MHz)
- **Reduced Tx Power:** 20dBm reduces coverage by ~3dB.
 - Cat-M1 & Cat-NB1 could be 23 dBm or 20dBm – Make sure you get the right version.
- **Half Duplex:** Cat-M1 - Half duplex means reduced speed
 - If you want greater than 375kbps then you need full duplex or a Cat-1 device
- **Reduced Antennas:** Cat-M1 – 1 antenna reduces downlink coverage by 3-4dB...no impact on uplink
 - If you need better coverage get the 2 antenna device....or go to CAT-NB1
- **Stationary Fading Impact:** Devices may not move - Could be sitting in a null – reduced coverage
 - Multi band devices might be in a null on one band but ok in another band.



What are the Gotcha's

- **Poor Antennas:** Compact antennas in small devices will have reduced coverage
 - Some devices have external antenna option – something external will be a lot better than an integral antenna buried in the a device. Understand your environment.
- **Poorly Located Devices:** Make sure you understand your environment
 - Devices may be located deep inside building or even underground in a water meter –.
- **Battery Life:** If you transmit a lot of data you won't get 10 years of battery life.
 - Only Cat-NB1 low data rate devices are really suitable for battery operation.
 - Try and make them go into power saving mode for as long as possible.
- **IoT Device Modules:** Some modules are interchangeable.
 - Some module manufacturers use the same daughterboard for Cat-1, Cat-M1 & Cat-NB1
 - Note some chip manufactures use the same hardware for Cat-M1 & Cat-NB1
 - If you find you need more speed just change up a device category.



Cellular IoT Summary

- **Range of Devices:** *Cellular IoT offers a complete range of devices from ultra high speed to ultra low speed – not just low speed*
- **Coverage:** *Cellular IoT coverage is everywhere you have 4G coverage - and more!!!*
- **Operating Environment:** *Cellular IoT uses the extra sensitivity of the device to make up for the poor operating environment*
- **Cost:** *Cellular IoT devices will be cheap due to reduced complexity – effectively competing with Zigbee and LoRa*
- **Gotcha's:** *You need to understand the performance trade-offs*

Thank You

