LINK LABS

LTE-M and NB-IoT

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VP, Strategic Partnerships

Welcome!

Here's the agenda for today...

- About Link Labs
- Cellular technology overview
- LTE Cat-M1 and NB1 (NB-IoT)
- Low power operations
- Design considerations
- Business considerations
- Q&A

What We Promise

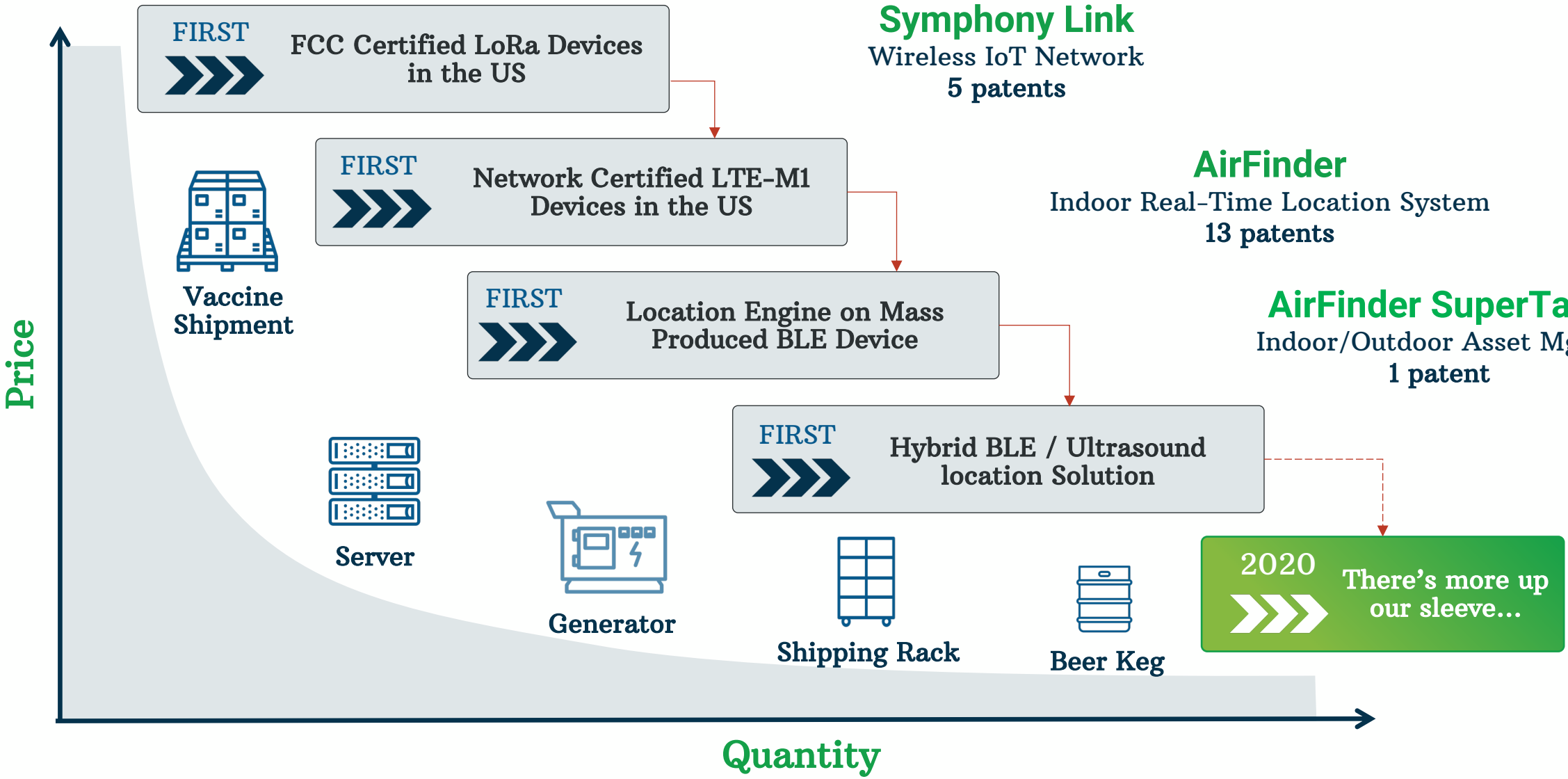
We believe unique solutions that **solve hard technical problems** transform businesses of any scale.

We build and deliver **easy, affordable,** and **impactful IoT.**

We **pursue answers** to hard technical challenges **without bias,** innovating and leveraging the innovations of others.

Link Labs Firsts

DRIVING DOWN THE COST CURVE



Technology Overview

2G

- GPRS
- EDGE
- CDMA2000 – 1xRTT

3G

- UMTS
- HSPA
- CDMA2000 – 1xEV-DO

4G

- HSPA+
- LTE-Advanced / E-UTRA
- WiMAX

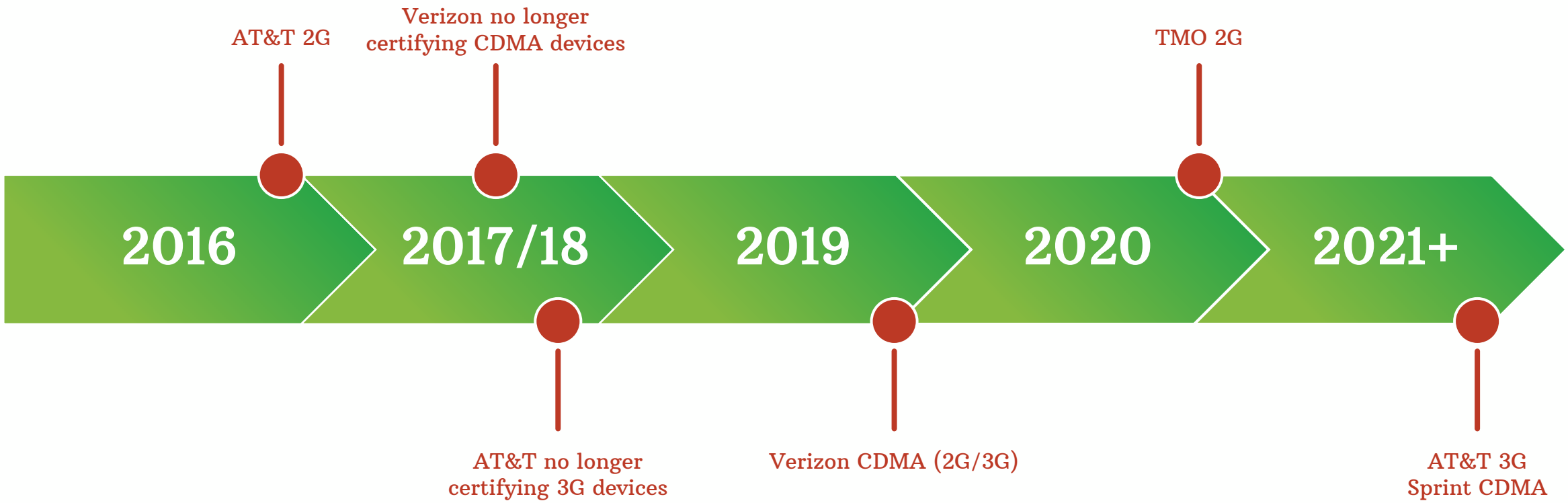
5G

- 5GTF
- 5G NR
- LTE-M (eMTC)
- NB-IoT

Technology Overview

Technology	Generation	Family	Typical DL data rates	Major US Carriers
GPRS	2G	GSM	85 Kbps	AT&T, T-Mobile
EDGE	2G	GSM	200 Kbps	AT&T, T-Mobile
1xRTT	2G	CDMA	150 Kbps	Verizon, Sprint, US Cellular
UMTS / HSPA	3G	GSM	1 Mbps	AT&T, T-Mobile
1xEV-DO	3G	CDMA	1 Mbps	Verizon, Sprint, US Cellular
HSPA+	3G	3GPP	5-20 Mbps	AT&T, T-Mobile
LTE	4G	3GPP	10 Mpbs	All
LTE-A	4G	3GPP	100 Mbps	All
WiMAX	4G	IEEE 802.16	100 Mbps?	Clearwire/Sprint (abandoned)
5G NR	5G	3GPP	0.5-2 Gbps?	All

Shutdown Dates



LTE-M vs. NB-IoT Summary

	LTE-M	NB-IoT
Receiver Bandwidth	1.2 MHz	200 kHz
Peak data rate – uplink	375 Kbps	20 Kbps (Single Tone)
Peak data rate – downlink	300 Kbps	250 Kbps
Typical UL/DL	50 Kbps	20 Kbps?
Frequency Deployment	In LTE Band	Flexible
Mobility	Yes	No
Base station SW upgrade	Yes*	No
Module Cost	<$10	~20% less than LTE-M

LTE-M

(LTE Cat-M1, eMTC)

- 1.4 MHz frontend (vs. 20 MHz) + 1 Antenna ⟶ Simplified design
- >300 Kbps half-duplex
- Can be deployed in existing LTE bands
- Compatible with existing LTE networks*
- Supports mobility
- VoLTE, FOTA, LTE LBS

NB-IoT

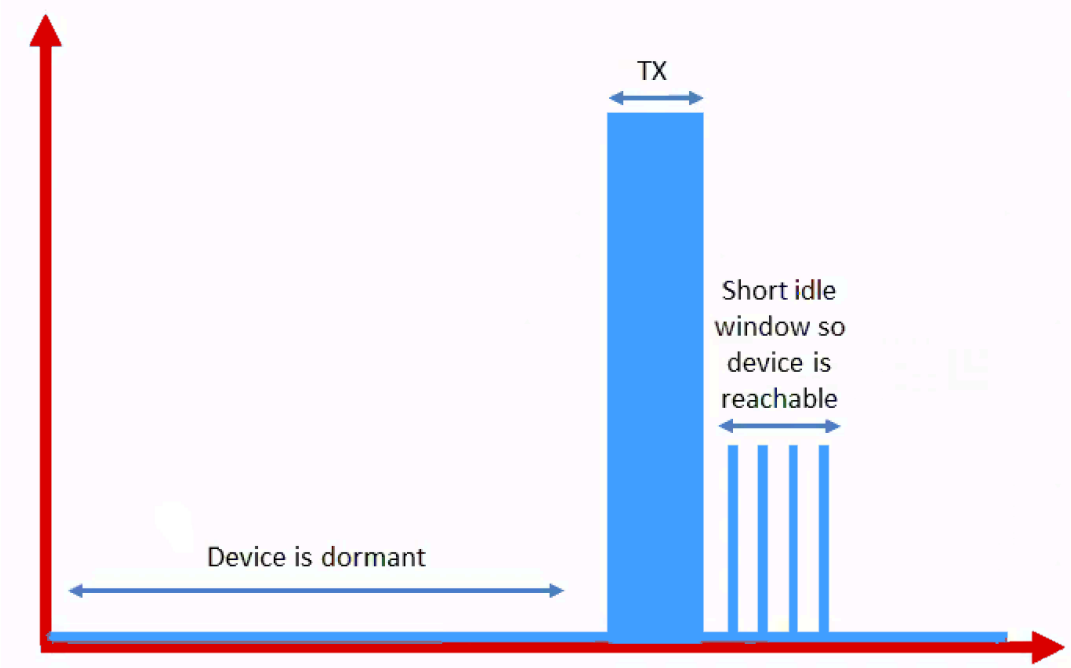
(LTE Cat-NB1)

- 200 kHz frontend ⟶ chipsets could be less expensive than Cat-M1
- <250 Kbps half-duplex (multi-tone uplink), <20 Kbps uplink (single tone)
- Can be deployed in existing LTE bands, in guard bands, re-farmed spectrum, or other standalone bands
- Requires new base station hardware
- Does not currently support mobility

Efficient Operation with LTE-M/NB-IoT

POWER SAVINGS MODE (PSM)

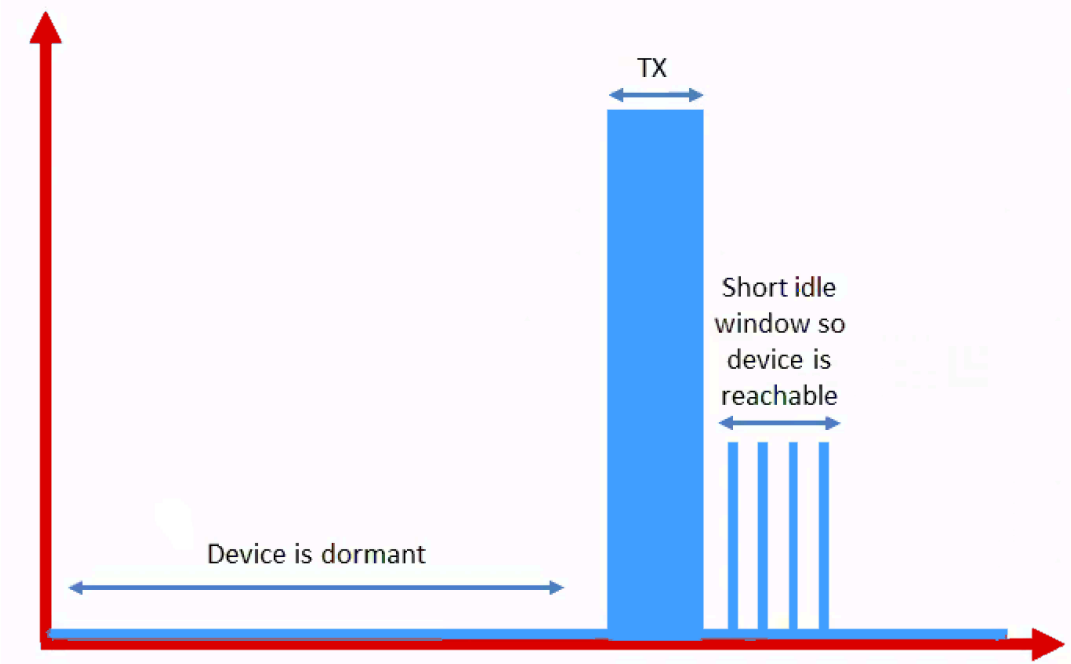
- Device remains attached to network, but is not reachable during sleep
- User can send messages to device during idle windows after transmissions
- Sleep period between hours and days (defined by network operator)
- Good for applications with event or timer driven uplink



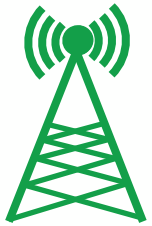
Efficient Operation with LTE-M/NB-IoT

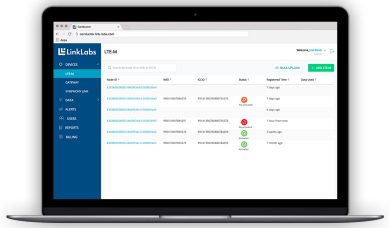
EXTENDED DISCONTINUOUS RECEIVE (eDRX) MODE

- Extended windows of sleep between LTE paging cycles
- eDRX cycles can be up to ~44 min for LTE-M and ~3 hours for NB-IoT
- Good alternative to extend battery life for “always on” devices



Typical Cellular IoT System

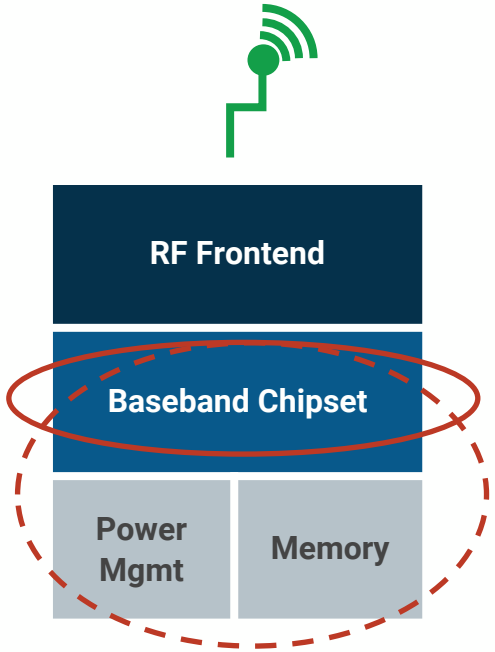




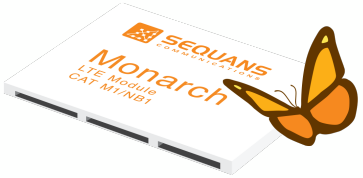
Sensor(s) / Actuator(s)	Other I/Os / Peripherals	RF Frontend	eNodeB	Managed Services	Application
Host Application Processor		Baseband Chipset	EPC	Device Management	U/I
			PDN	SIM Management	Rules / Alerts
Battery / Power	Memory	Power Mgmt	Memory	IMS / Gateway / VPN	Application Enablement	Reports
				Power and data management	Billing
				Billing	
				FOTA	

SIM/UICC

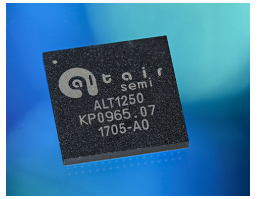
Baseband Chipset



SEQUANS COMMUNICATIONS



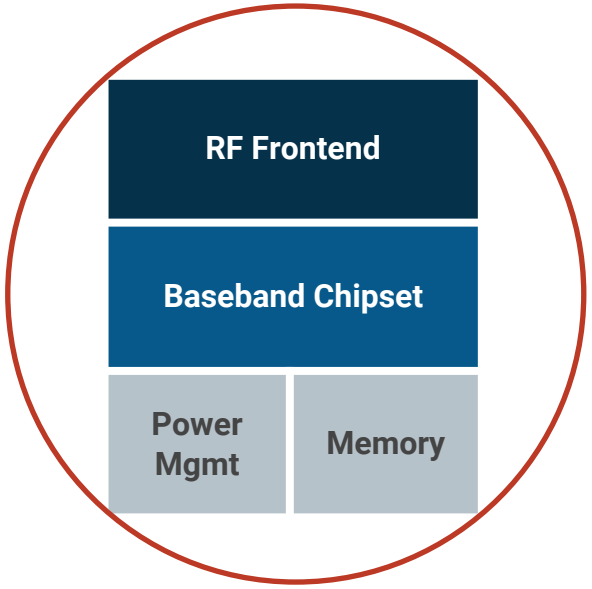
altair semiconductor



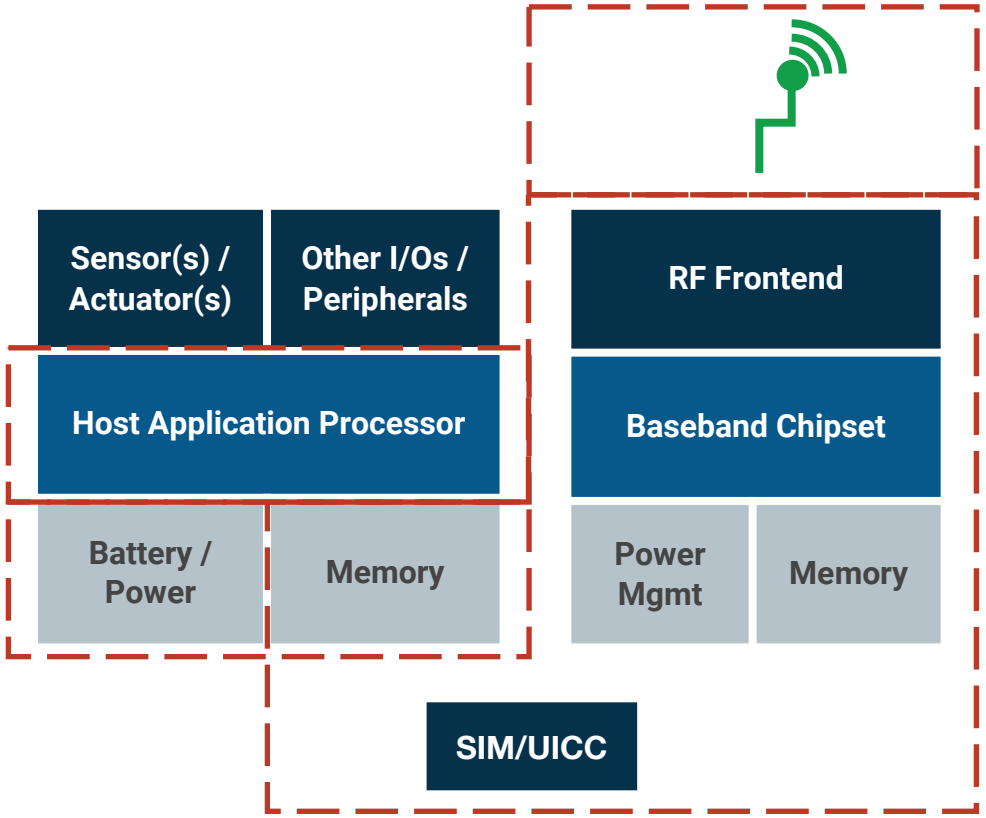
QUALCOMM®

intel®

Cellular Module



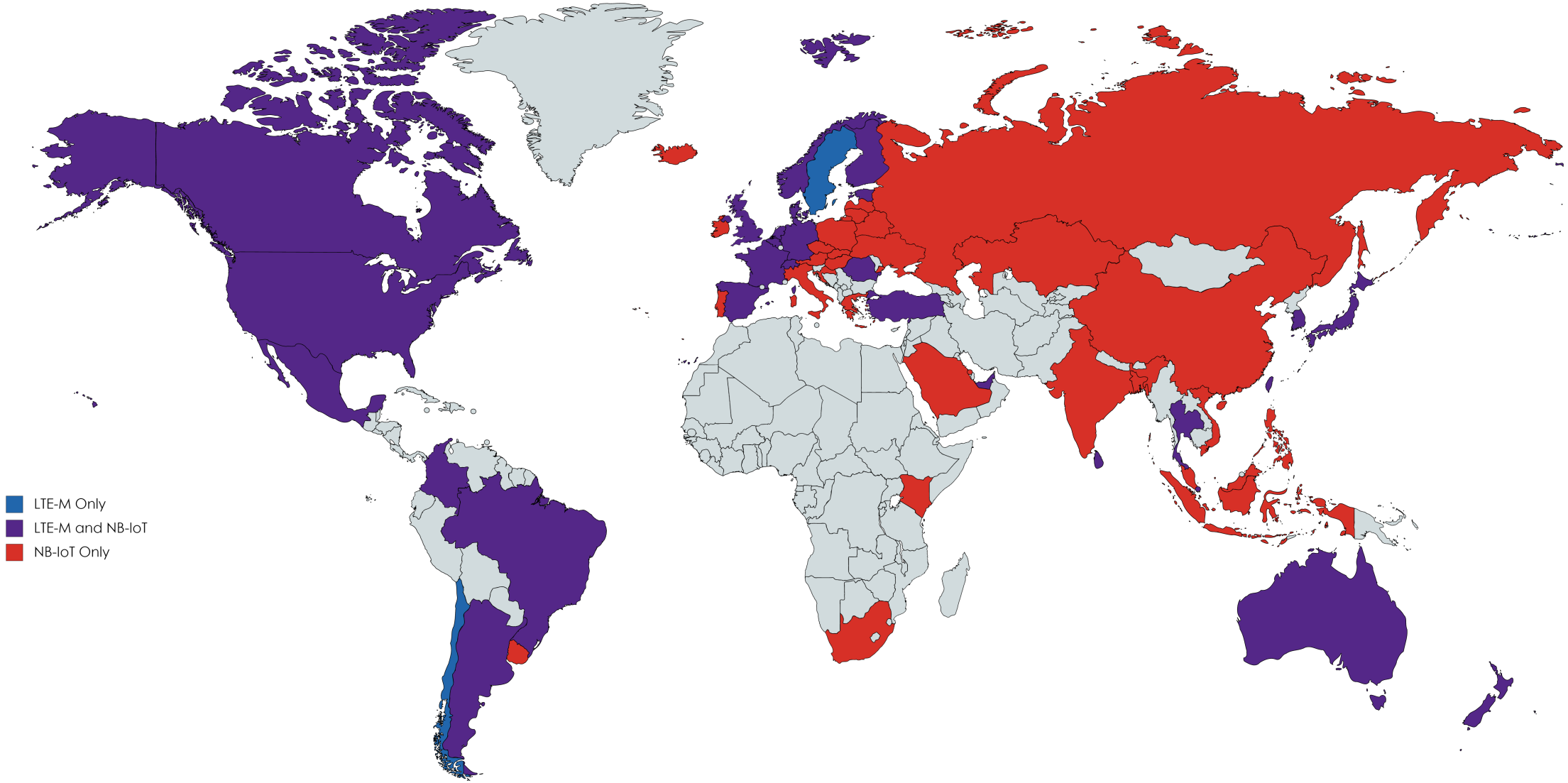
Hardware Platform



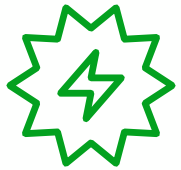
- Some vendors incorporate a module into a "platform," "system," "modem," etc.
- Incorporates other features, such as simple HW interfaces, proprietary SW stacks, SIMs, power management, cloud platforms, etc.
- Some of these are "pre-certified" on various carriers or give customers more certainty or ease of carrier certification

Network Availability

TRUST WHAT YOU CAN TEST



LTE-M Battery Considerations



Chemistry,
Chemistry,
Chemistry

Cost

Test,
Test,
Test

Example LTE-M Battery Calculation

CONSUMER GPS TRACKER (450 mAh LiPO battery)

Fix / Transmission Interval	Operating Mode	Estimated Battery Life
5 minutes	Normal	17 hours
5 minutes	PSM	~2 days
5 minutes	eDRX (10 s latency)	~2 days
1 hour	PSM	22.5 days
1 hour	eDRX (3 min latency)	19.8 days
4 hours	PSM	73 days
12 hours	PSM	152 days
1 day	PSM	209 days
1 day	Toggle On / Off	129 days

Example LTE-M Battery Calculation

CONSUMER GPS TRACKER (450 mAh battery)

Transmission Interval	Operating Mode	Estimated Battery Life
1 hour	PSM	5.7 years
4 hours	PSM	10.7 years
12 hours	PSM	14.4 years
1 day	PSM	15.8 years
1 day	Toggle On / Off	8.3 years

Cost Considerations

1
Design

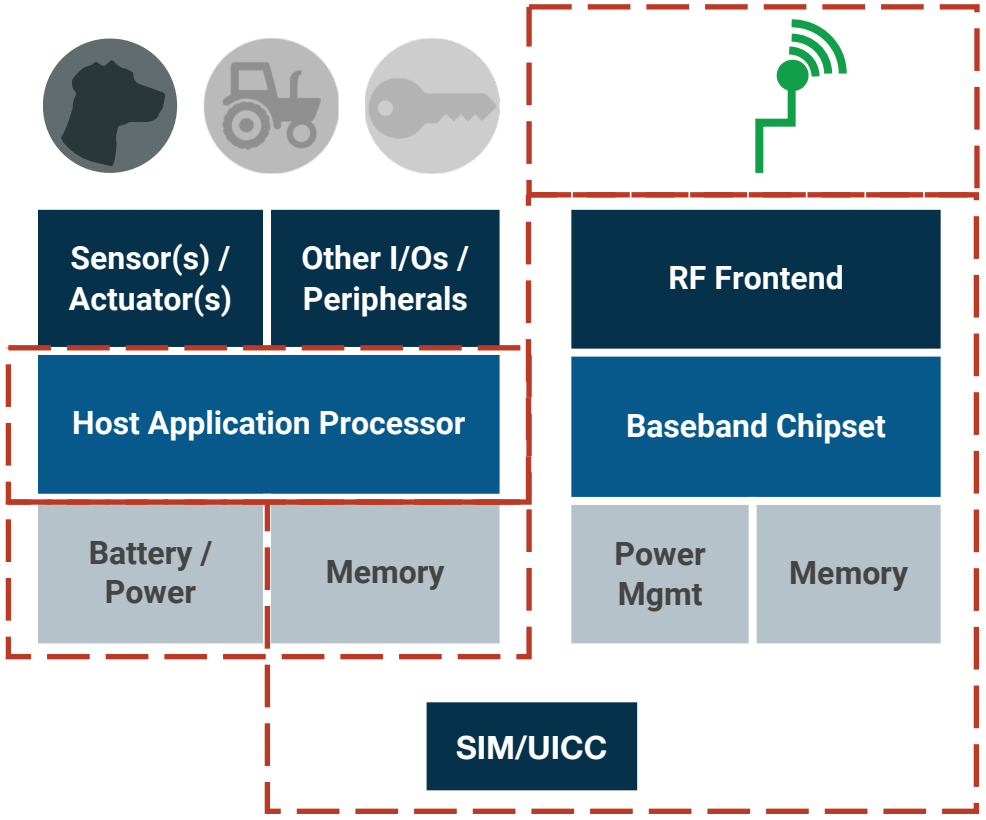
2
Components

3
Certification
& Testing

4
Cellular
Service

5
Managed
Service

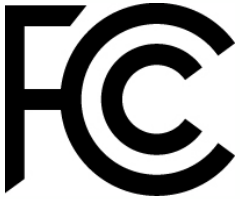
Design and Components



- Assume 5-10K units per year
- Sensor, Host MCU, Memory, PCB, connectors, other application-specific components – $10-30
- Cellular Module, SIM, SIM holder, level shifter(s), connectors – $15-30
- Antenna – $2-10
- Battery – $2-10
- Enclosure – $2-10

Certification and testing

- PTCRB / GCF / Other carrier certifications
- FCC / IC / Other government regulatory agencies



Cellular Service

COSTS ARE DRIVEN BY THE *AMOUNT OF TRANSMITTED DATA*

	Traditional Cellular	MNO Low-Power IoT (LTE-M, NB-IOT)
Connectivity Cost / Metering	Low ~ $1/(100 MB) per month	High ~ $1/(MB) per month

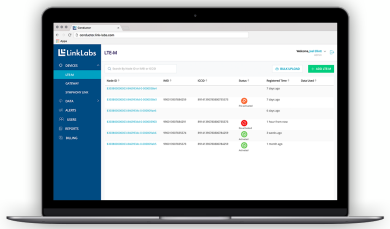
!

100x more expensive per byte!

Un-pooled Network Operator Rate Plan Example

	If average device transmits 0.95 MB of data per month	If average device transmits 1.05 MB of data per month
Cost per device	$1	$2
Number of devices	1,000,000	1,000,000
Operating cost	$1,000,000 per month	$2,000,000 per month

IoT Platform / Managed services



Managed Services

Device Management

SIM Management

Application Enablement

Power and data management

Billing

FOTA

Other Risks and Challenges

- Business Case???
- Component Availability
- Network Availability
- Roaming / “Global” Coverage
- Data usage and exposure
- “True” Low Power Operation
- Battery chemistry
- Uncertain battery performance