COMPETENCE & RELIABILITY

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ČVUT FEL v Praze, 13.04.2018

U-BLOX IOT MODULES

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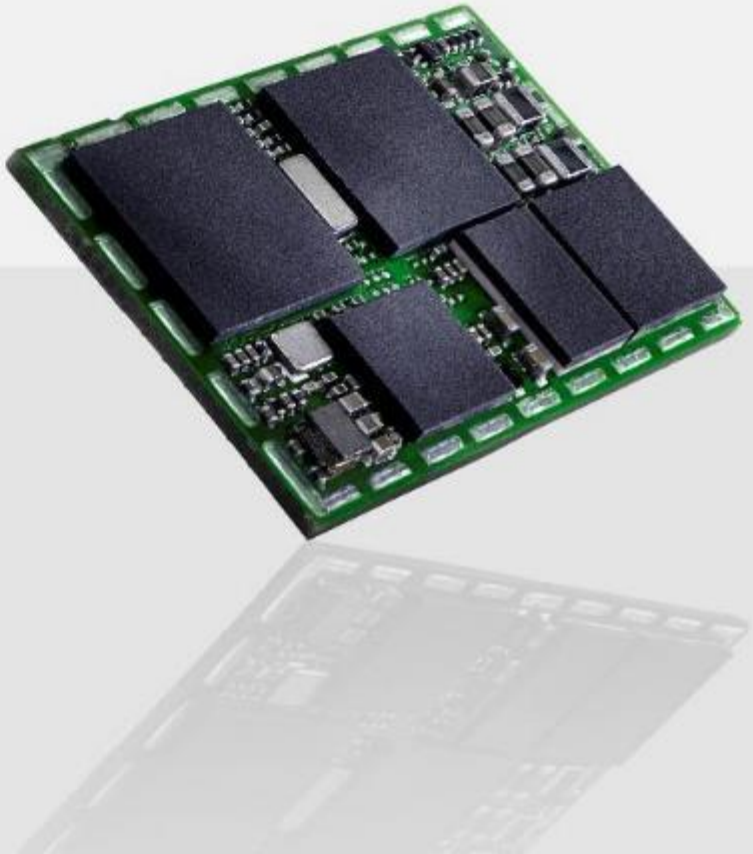
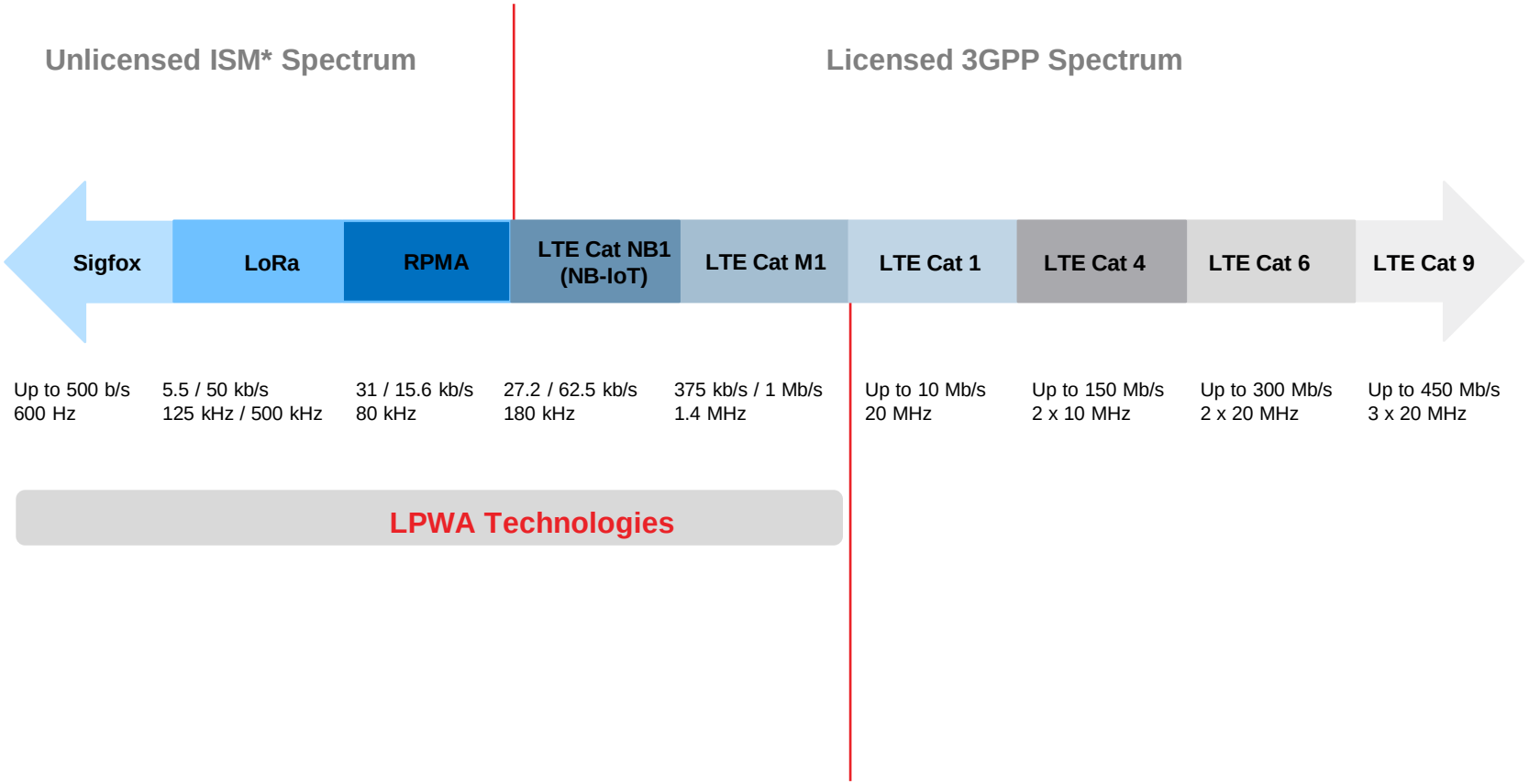
u-blox Cellular IoT Modules

April 2018, Prague

Mariusz Ciesielski, Microdis

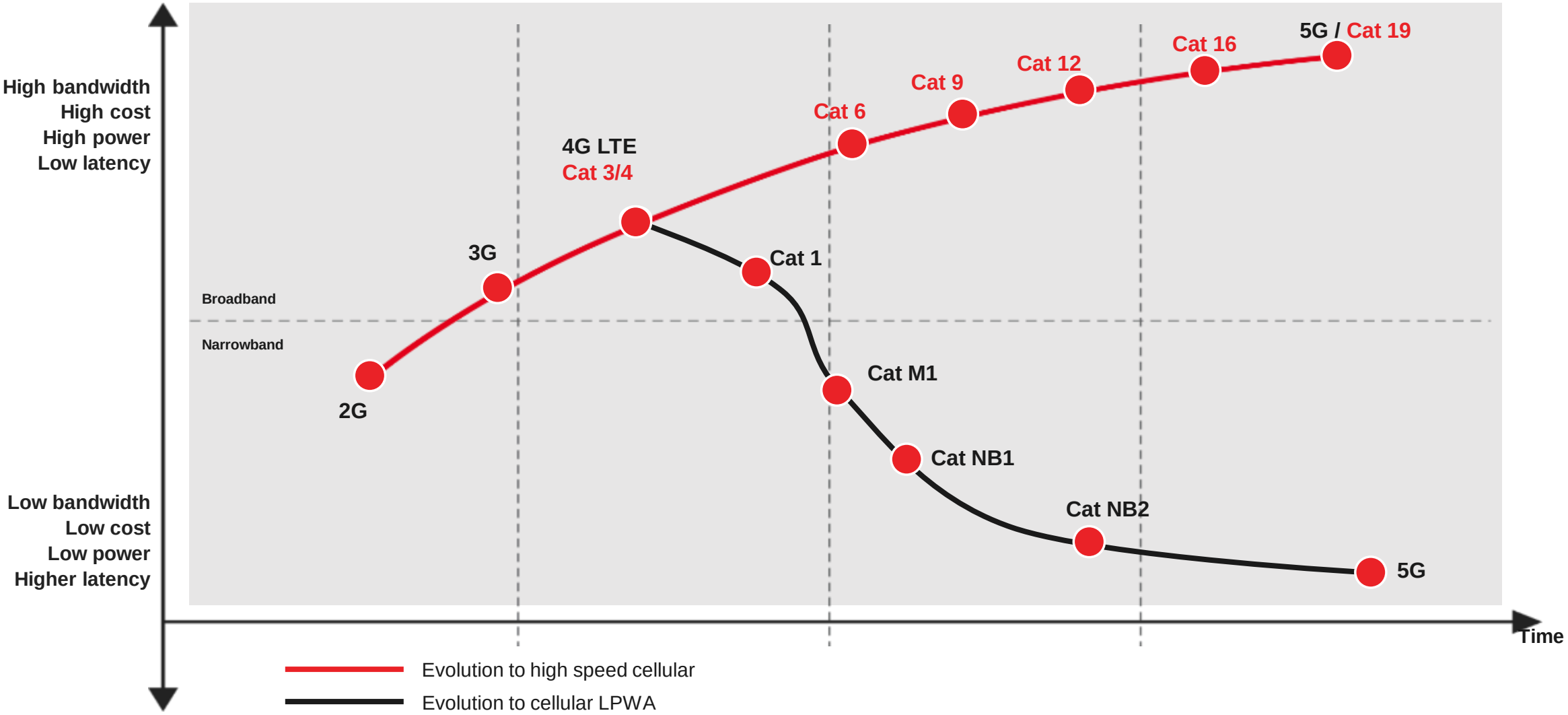


Global cellular technologies are evolving and multiplying…

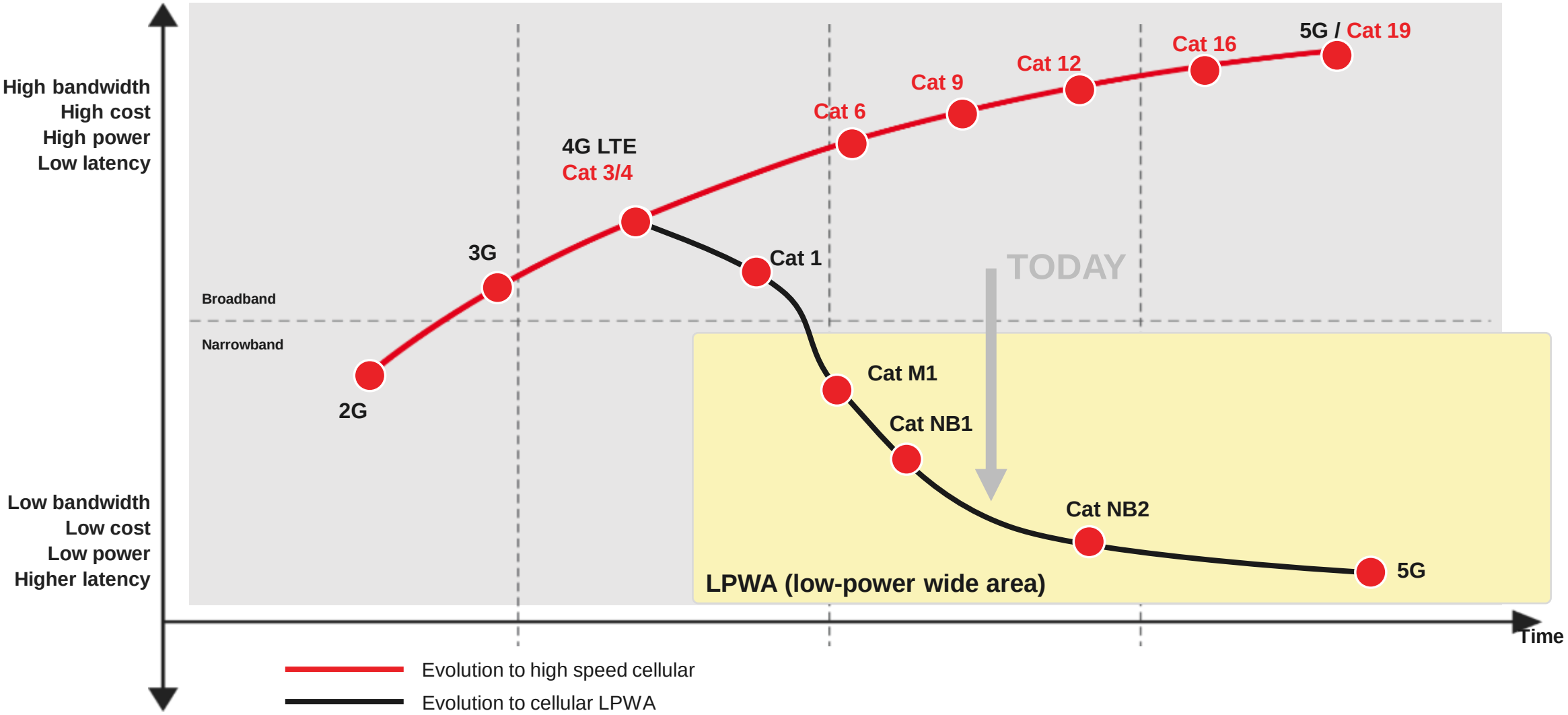


- *industrial, scientific, medical

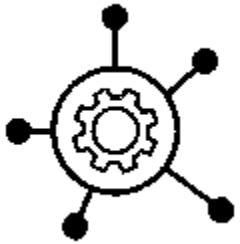
Global cellular technologies are evolving and multiplying…



…with a focus on LPWA technologies for the IoT



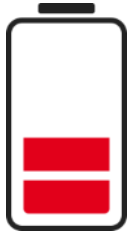
The cellular IoT promise:
Benefits of LTE Cat M1 and NB-IoT (LTE Cat NB1)



Large ecosystem

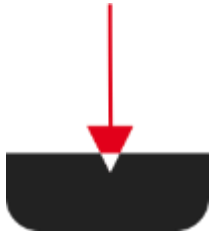
3GPP Release 13

Module certified in all major markets



Low power

Optimized for long battery life (in excess of 10 years depending on operating conditions)



Extended range

Enhanced coverage of 15-21dB* in buildings and basements (and underground with NB1)

Limited performance

M1 peak rates up to 375 kb/s DL / UL

NB1 peak rates up to 27.2kb/s DL / 62.5 kb/s UL

Reduced complexity

NB-IoT supports narrowband operation and reduced system complexity

*as compared to GSM, 15dB enhanced coverage with Cat M1, 21 dB with Cat NB1

Technology comparison

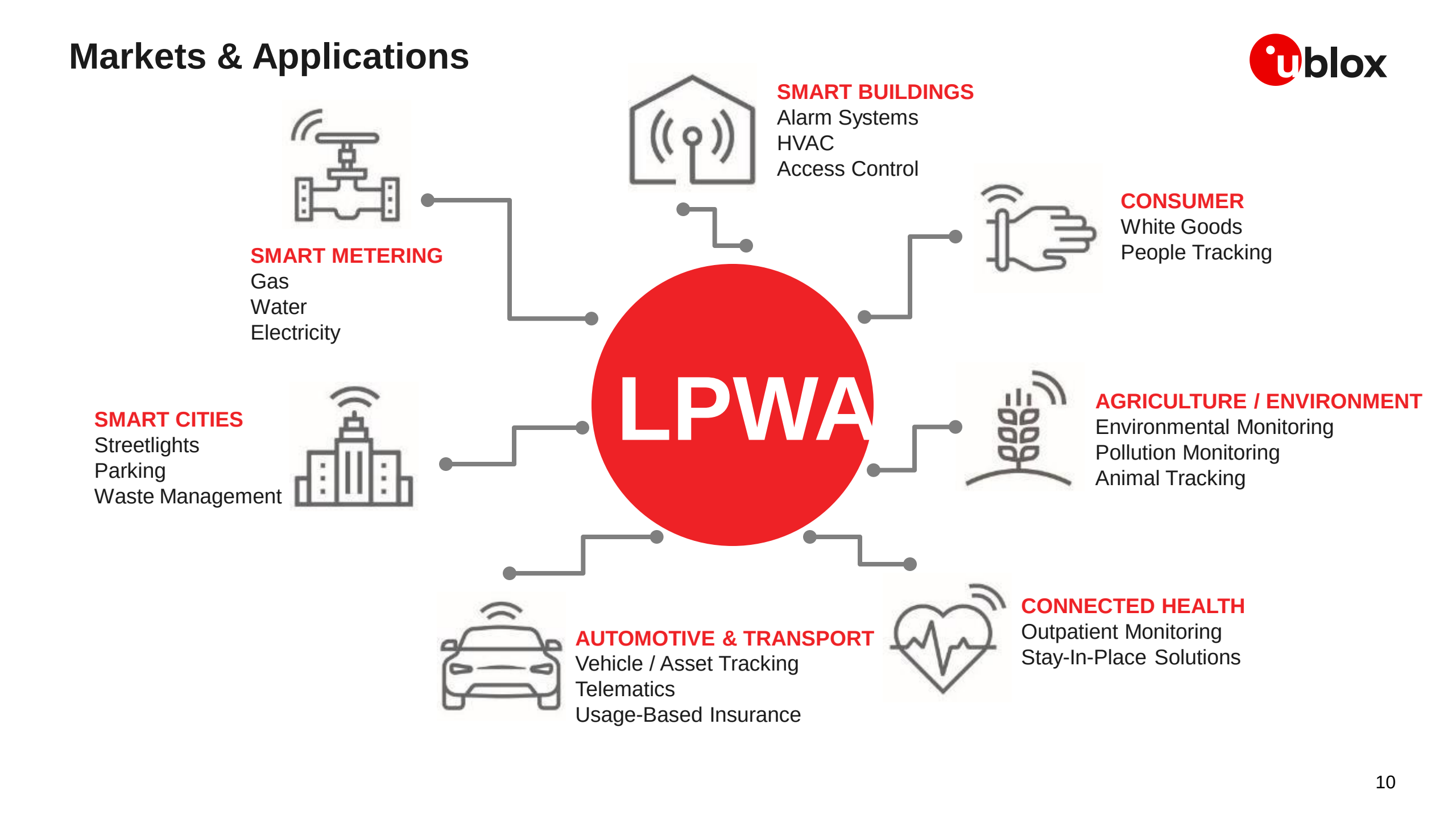
Feature	2G (GSM / GPRS)	Cat M1 (Full duplex)	Cat M1 (Half duplex)	Cat NB1 (NB-IoT)
Application focus	Mobile connectivity / M2M	Mobile connectivity / M2M		M2M
Radio Spectrum	200 kHz 3GPP Licensed [1]	1.4 MHz 3GPP Licensed [1]		180 kHz 3GPP Licensed [1]
Guaranteed Quality of Service (QoS)	Yes	Yes		Yes
Responsiveness	milliseconds => seconds	milliseconds	milliseconds => seconds	seconds => minutes
Roaming	Global	Global		Global
Peak Data Rate	Up to 85.6 kb/s (DL) Up to 42.8 kb/s (UL)	1 Mb/s (DL/UL)	375kb/s (DL/UL)	27.2 / 62.5 kb/s (DL/UL)
FOTA	No	Yes		Yes
Range / MCL [6]	Above ground / 139.4 / 144 dB [2]	Basement / 155.7 dB		Underground / 164 dB [3]
Mobility	Vehicular (300kmh) (full handover)	Vehicular (300kmh) (full handover) [4]		Vehicular (100kmh) (no handover)
Voice Support	Yes (GSM)	Yes (incl. VoLTE) [5]		No
Battery life	5-10yrs	5-10yrs		10yrs+
Cost (Module or eBoM)	$	$$	$	$

Supports use cases unique to LTE Cat M1

Notes:

1. 3GPP Licensed spectrum in 450MHz and 700MHz – 3.5GHz
2. GSM has MCL (maximum coupling loss) of 139.4 dB, GPRS of 144 dB
3. NB-IoT uses Single-Tone signalling in the UL to ensure reliable operation to the cell-edge
4. MNO support initially only in Idle Mode, will support Connected Mode in future FW rel.
5. Future FW release

Markets & Applications



Benefits of NB-IoT as compared to LoRa and Sigfox

More Secure & Reliable

- Industry-standards based (3GPP)
- Guaranteed Quality of Service
- Licensed spectrum controls interference
- 3GPP security (128-256 bit)

Easier Deployment

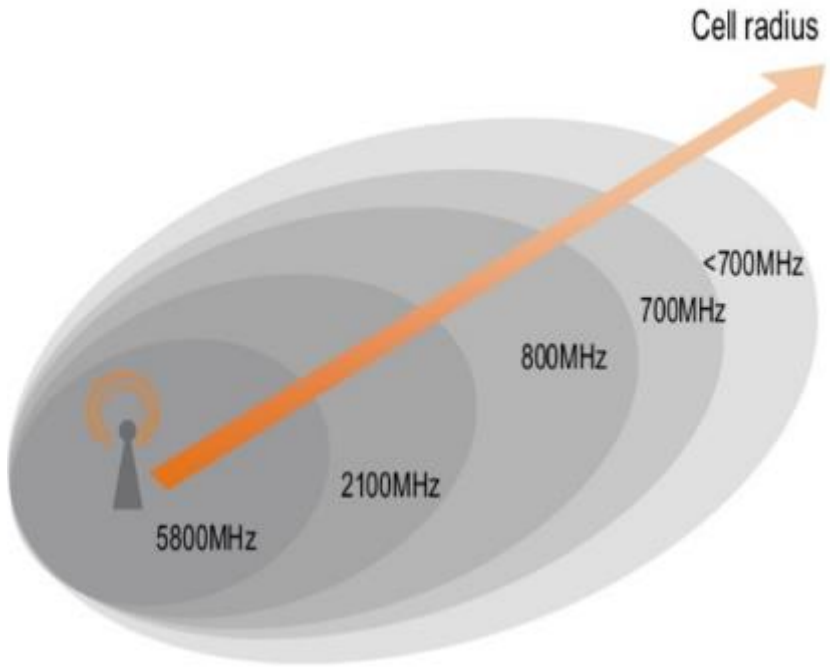
- Integrates into cellular system (i.e. existing 2G & LTE networks)
- Global roaming & availability
- Lower deployment costs, especially site costs

Higher Functionality

- System capacity supports 150k+ connections per cell
- Supports 2-way communication
- Allows for firmware-over-the-air updates

Sub-1GHz spectrum attractive for IoT

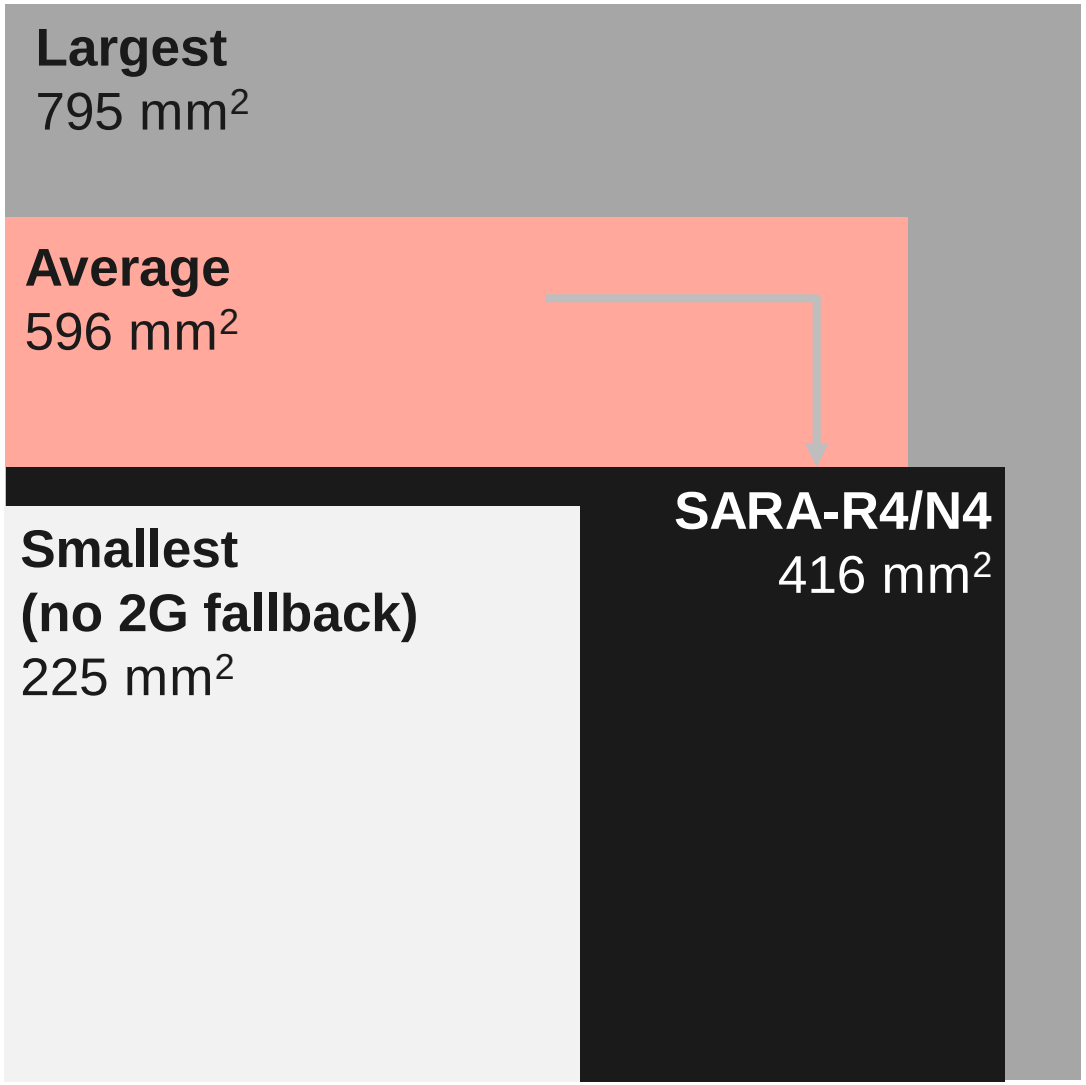
- Ideal to deploy mobile IoT over large areas – especially in rural areas
- Improved saturation in urban areas and better in-building penetration improves quality of service
- The digital dividend means more sub-1GHz spectrum is being made available for mobile broadband services around the world



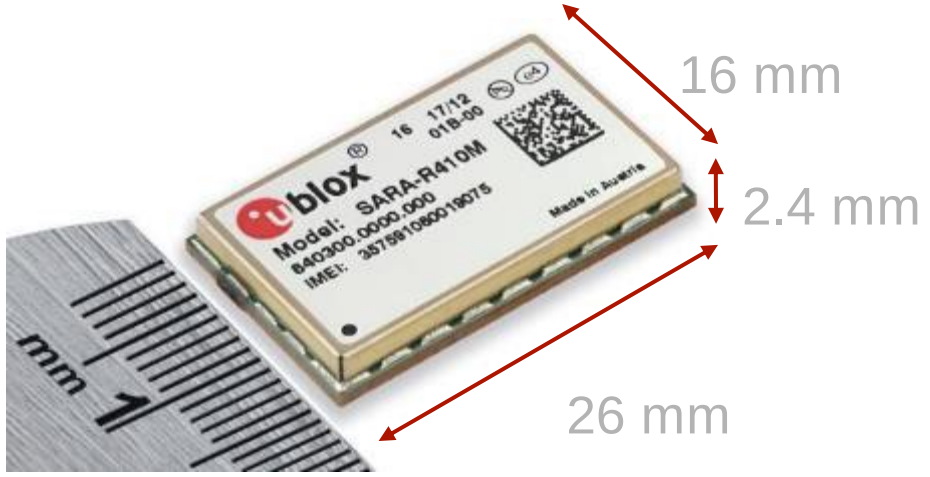
Benefits of sub-1GHz spectrum are crucial for high quality, cost effective deployments

Key Highlights

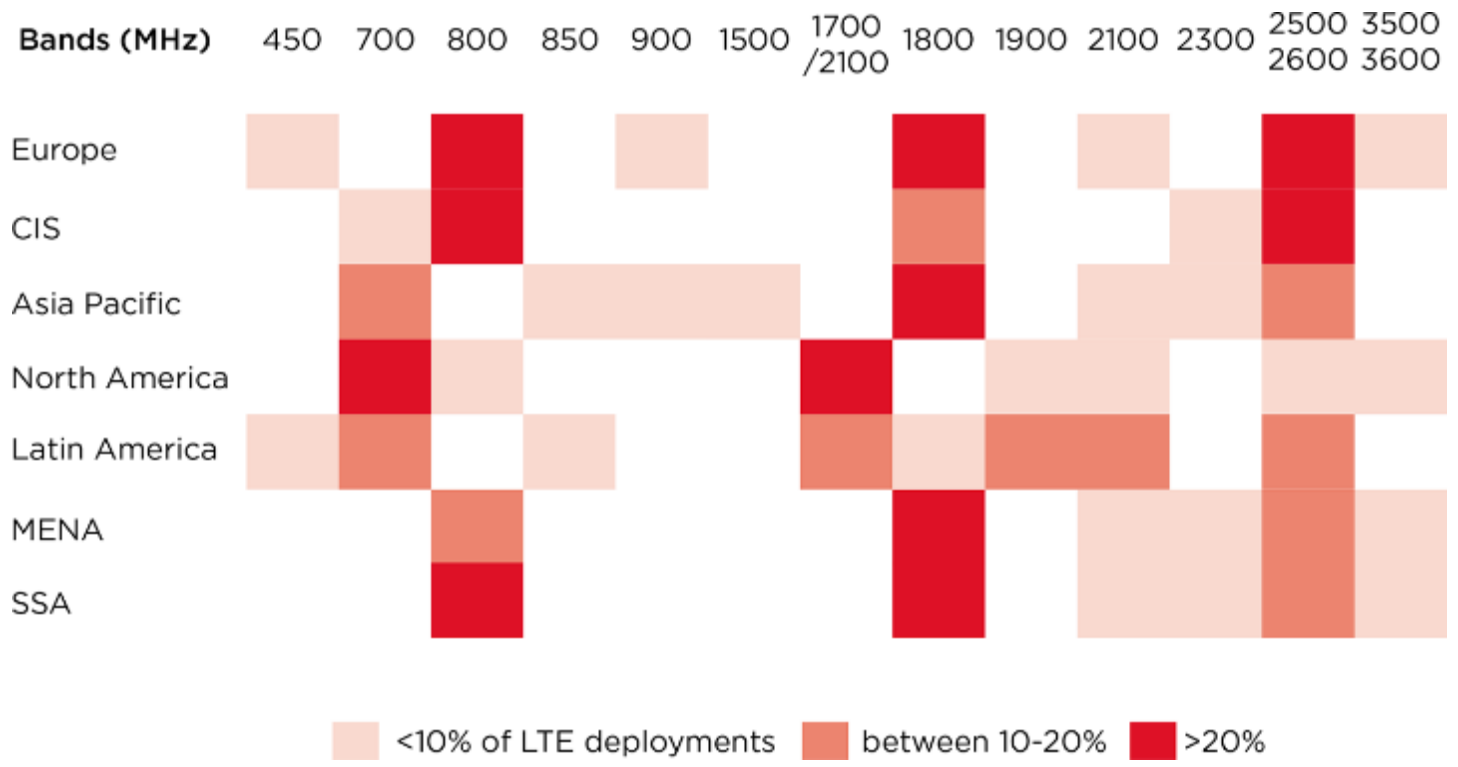
Ultra compact size for diverse applications



SARA-R/N is 30% smaller than the competition



LTE spectrum is very fragmented…

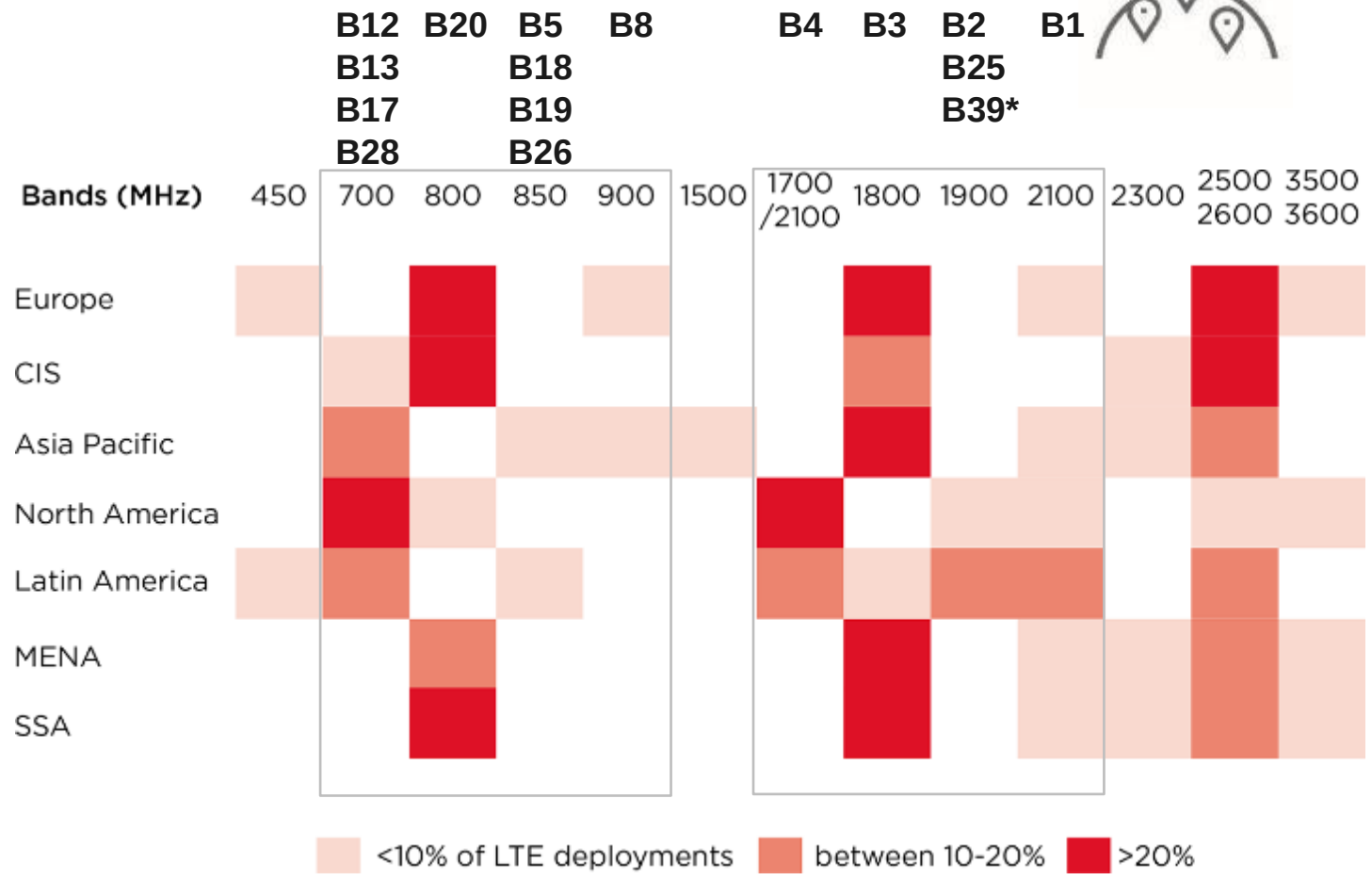


Source: GSMA

With SARA-R global hardware versions, configure any set of multiple bands

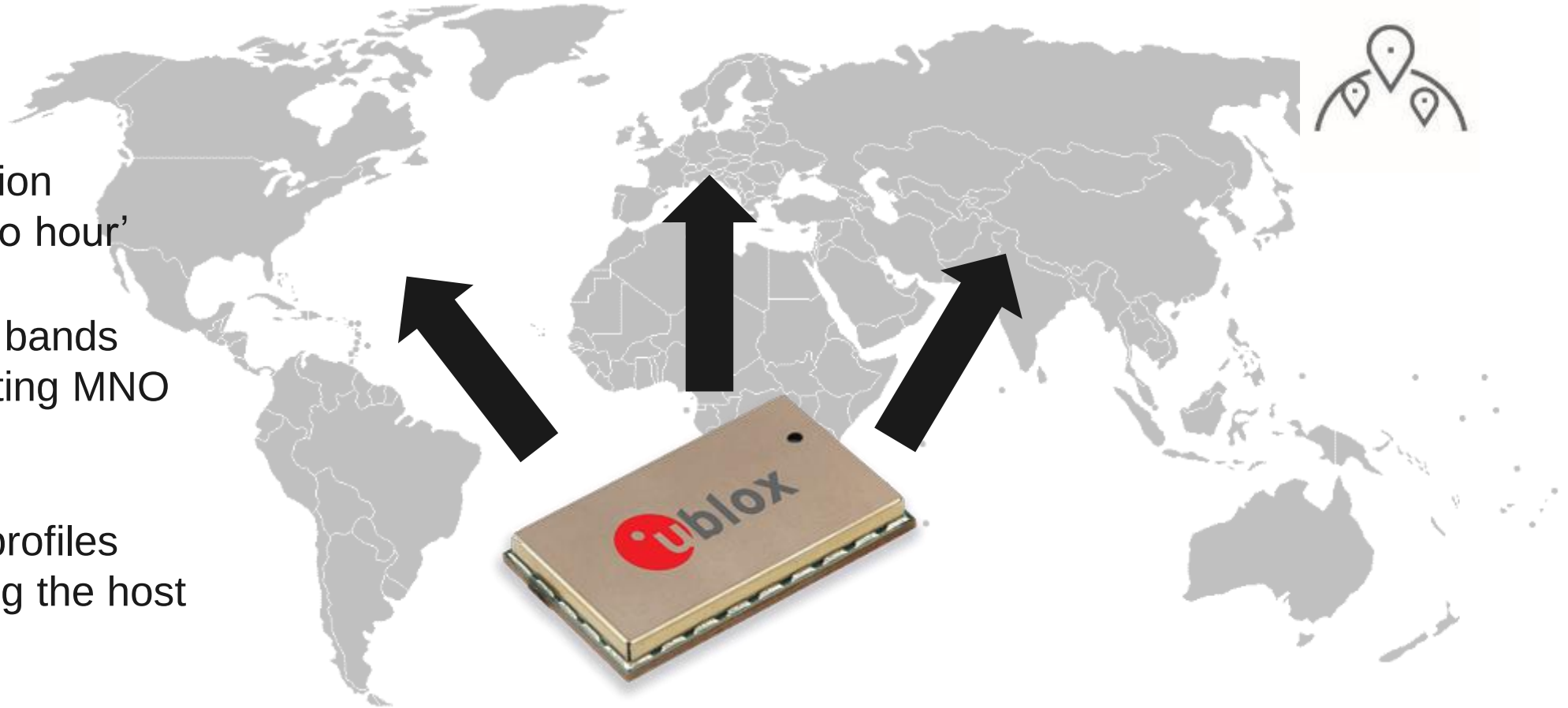
With SARA-R410M/R412M global hardware:

- Up to 16 allowable bands for LTE Cat M1 / NB1
- EGPRS quad band 850/900/1800/1900 (SARA-R412M only)



Source: GSMA

One world, one module

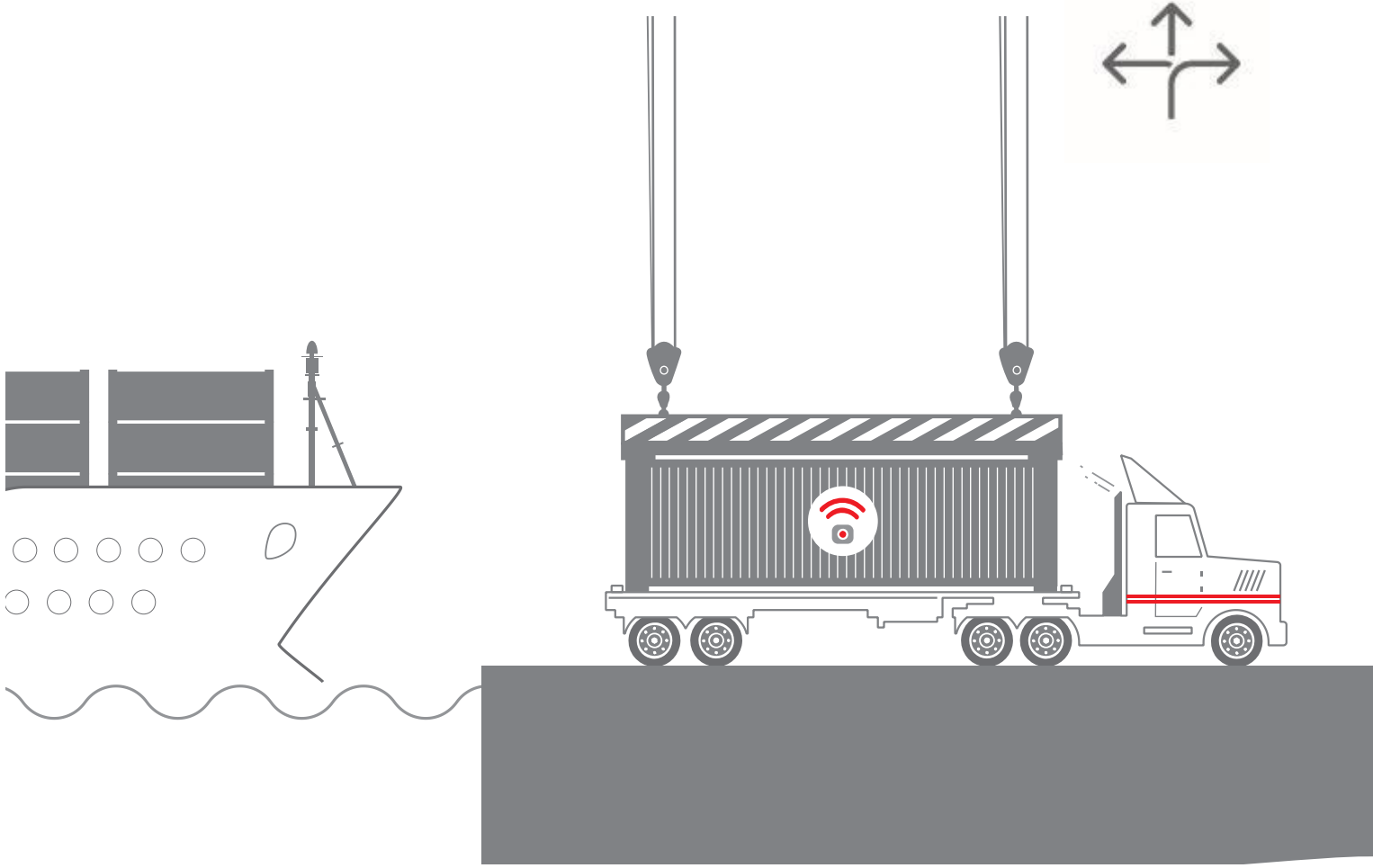


- Defer configuration decisions to ‘zero hour’
- Enable roaming bands beyond the existing MNO default profile
- Add new MNO profiles without changing the host software
- Continuously update fielded devices via uFOTA

NOTE: customer must comply with end device regulatory/certification restrictions

Connect your way with flexible system selection

- Dynamic selection as Cat M1, NB1, and EGPRS* in single mode or preferred connection
- At power up, the device searches for the preferred system and, if unavailable, for the next preferred system
- Perform periodic searches for the preferred system when connected to the non-preferred system
- Reboot not required to switch between modes



*EGPRS is only for SARA-R412M

SARA-R/N Series

Summary

Flexible Selection
LTE Cat M1, NB1, and EGPRS only or preferred modes

Ultra Compact
16.0 x 26.0 mm

Easy Migration
Between u-blox 2G, 3G and 4G modules

Voice Support
Via VoLTE on Cat M1 (future)

Global Configurability
With a single hardware version

uFOTA with LWM2M
Deliver critical firmware updates over the air

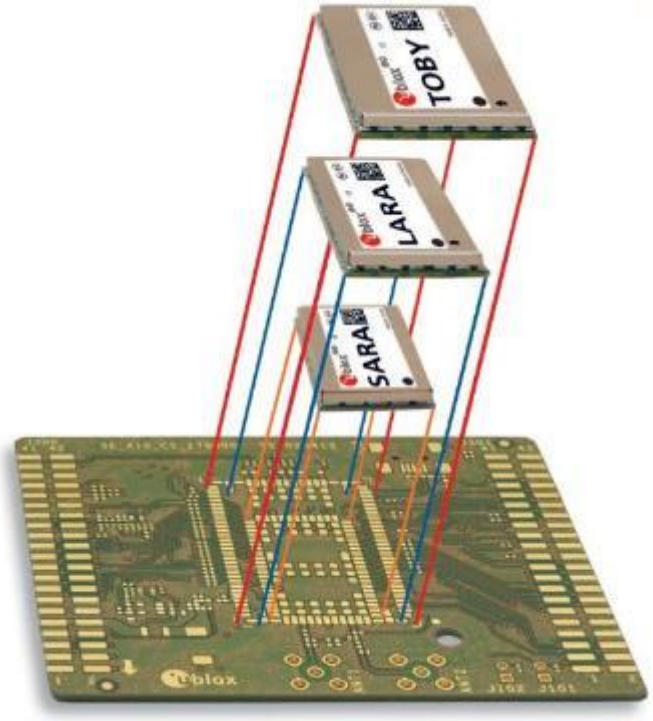
SARA form factor, ease of migration

Easy migration among u-blox SARA designs:

- SARA-G: 2G
- SARA-U: 3G
- SARA-R: LTE Cat M1, Cat NB1 and EGPRS
- SARA-N: LTE Cat NB1

Advantages

- Optimal solution for cost, size and wireless technology
- Easy migration between wireless technologies and module generations
- AT command compatibility to minimize software migration effort



LTE Cat NB1 (NB-IoT) modules, SARA-N2

Module	Form Factor	Bands				3GPP Rel.	Functions										Grade
		LoT NB	LTE Category M1	LTE Category NB1	GSM/GPRS/EDGE		Power Saving Mode	SARA-R4 Voice	UDP	TCP, HTTP, FTP	CoAP	LWM2M	Ext. GNSS interface	Assistnow client	CellLocate	Host Interfaces	
SARA-N200	LGA	8		NB1		R13	●	●		●		●				UART	Professional
SARA-N201	LGA	5		NB1		R13	●	●		●		●				UART	Professional
SARA-N210	LGA	20		NB1		R13	●	●		●		●				UART	Professional
SARA-N211 ATEX	LGA	8, 20		NB1		R13	●	●		●		●				UART	Professional
SARA-N280	LGA	28		NB1		R13	●	●		●		●				UART	Professional

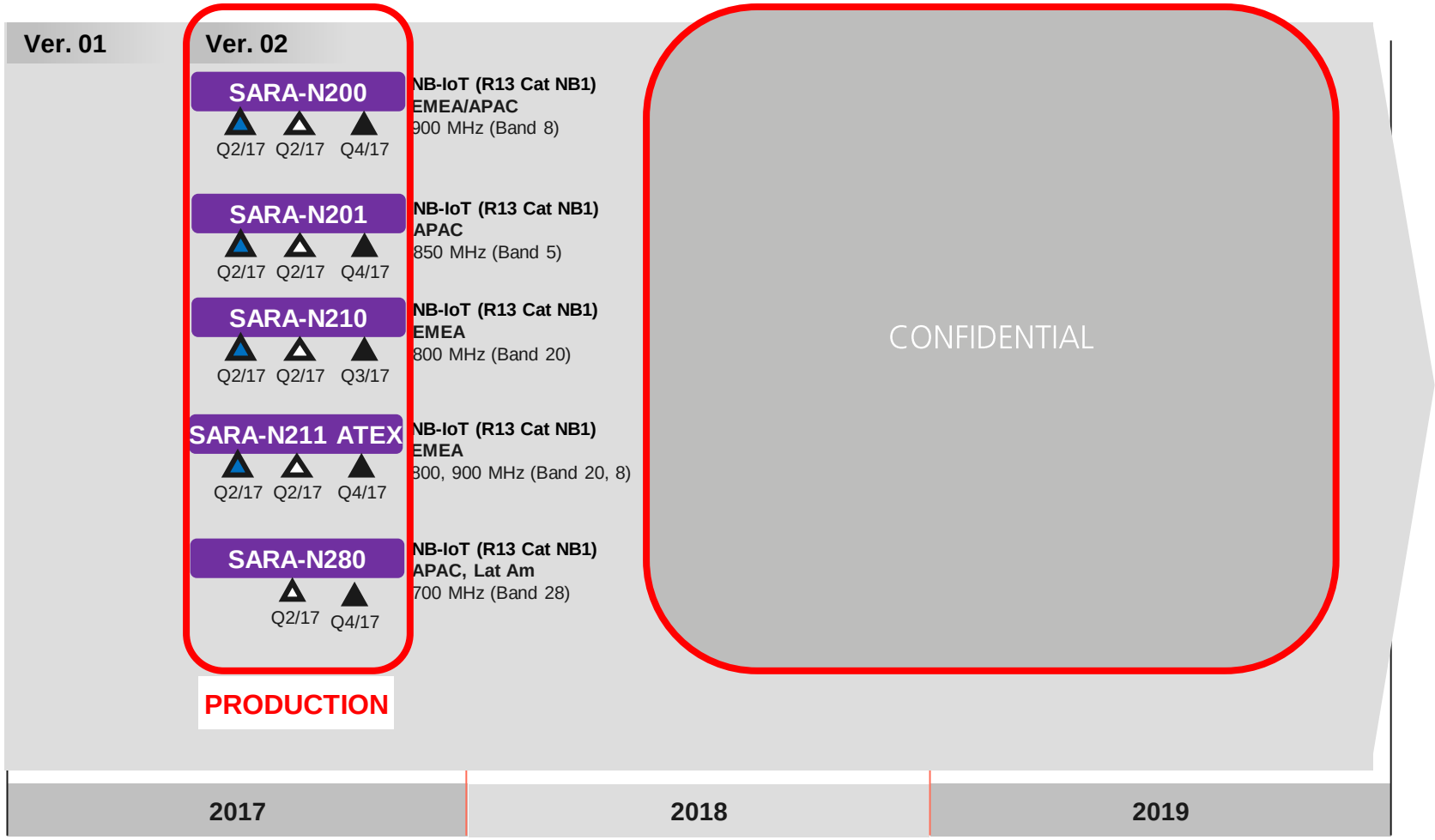
(1) Subsequent firmware version

Product Roadmap – LTE Cat NB1 (NB-IoT)
SARA-N2

Professional

SARA

16.0 x 26.0 mm



SARA-R4/N4 Series modules overview

Module	Form Factor	Bands				3GPP Rel.			Functions						Grade
		LTE FDD	LTE Category		GPRS quad band					HTTPS, FTPS, TLS	TCP/UDP, FTP, HTTP	Ext. GNSS interface Assistnow client		Host Interfaces	
SARA-R404M	LGA	13	M1			R13	●	(1)	(1)	(1)	●	(1)	(1)	USB, UART	Professional
SARA-R410M[2]	LGA	2, 4, 5, 12	M1			R13	●	(1)	(1)	●	●	(1)	(1)	USB, UART	Professional
SARA-R410M[2]	LGA	Configurable	M1, NB1			R13	●	●	(1)	●	●	●	(1)	USB, UART	Professional
SARA-R412M	LGA	Configurable	M1, NB1		●	R13	●	●	(1)	●	●	●	(1)	USB, UART	Professional
SARA-N410	LGA	2, 4, 5, 12	NB1			R13	●	●		●	●	●	(1)	USB, UART	Professional

(1): Subsequent firmware version
(2): ver. 01B: North America variant (2,4,5,12), LTE Cat M1 only
ver. 02B: Global (configurable LTE bands) variant, LTE Cat M1 and NB-IoT

NB-IoT communication architecture

NB-IoT and benefits of Release 13 network architecture for IoT / M2M

Efficient

Small, infrequent transmissions

- Highly optimized messaging
- Avoids unnecessary authentication exchanges
- >50% reduction in signaling

Secure

End-to-end security

- Payload secured within the cellular network
- End-to-end security may be implemented on top e.g. TLS/DTLS

Flexible

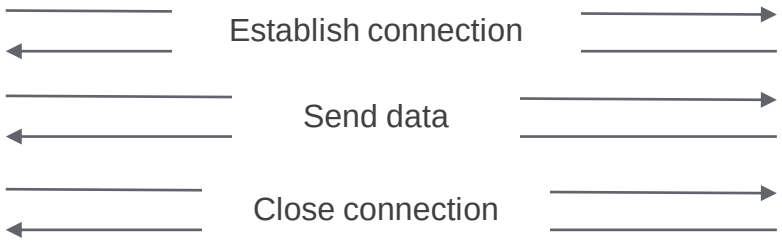
Data protocols

- 3 types of data transport supported
  - Non-IP
  - IP
  - SMS

NB-IoT connection and power mgmt differences to GPRS

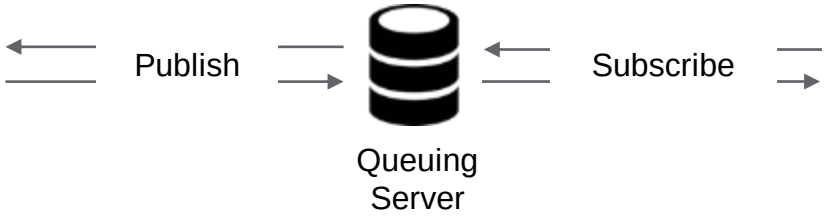
GPRS

- Many customers coming from GPRS expect a session-oriented, “IP Socket”-type connection
- To save power, network connection and device are forced to shut down
- Device needs to get woken up, which takes time and consumes power:



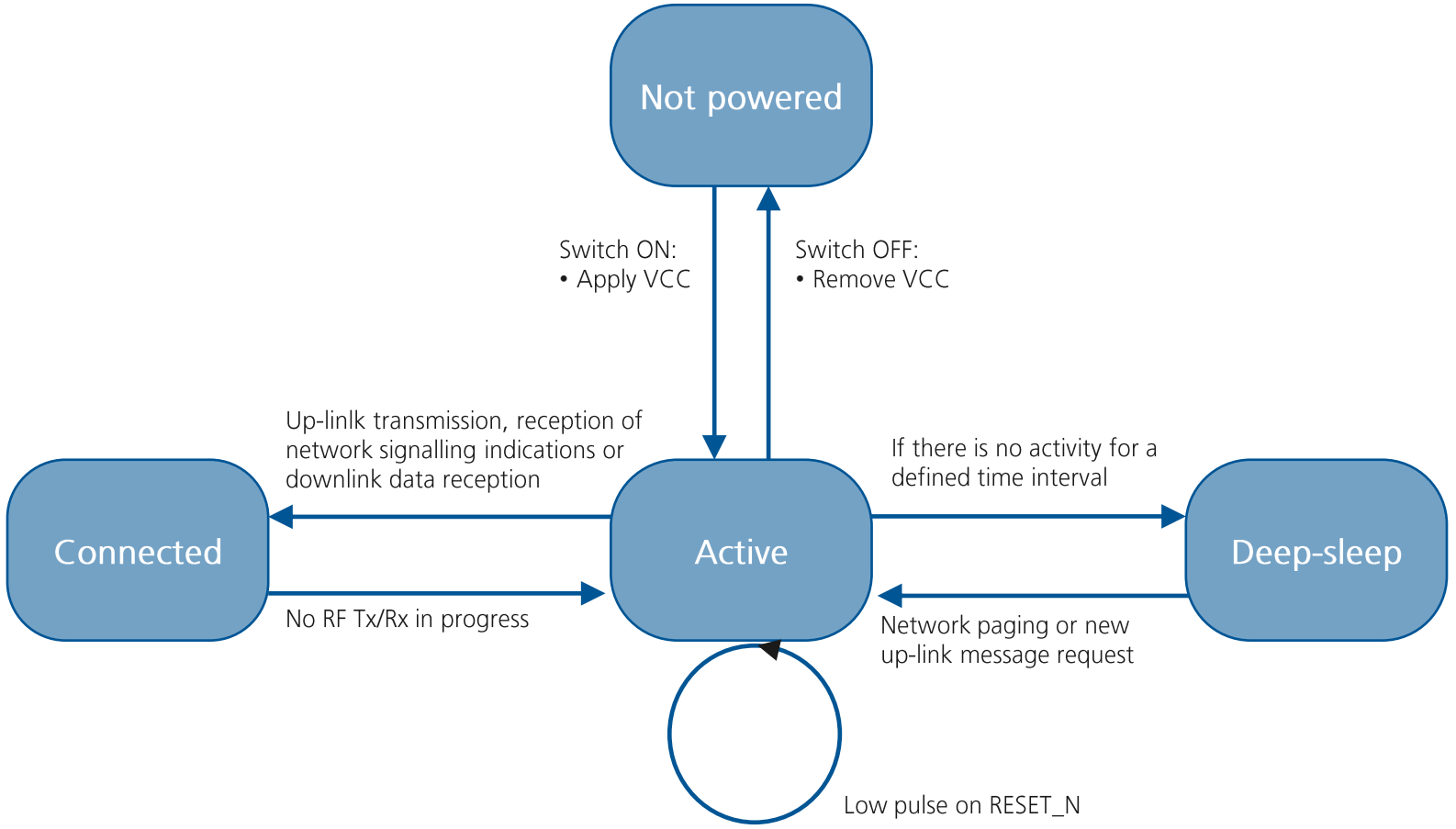
NB-IoT

- NB-IoT is not session-oriented
- The latencies between each packet and UL / DL are higher
- You want the device to sleep, rather than consume power waiting for a response
- An architecture that is much better suited to NB-IoT is this:

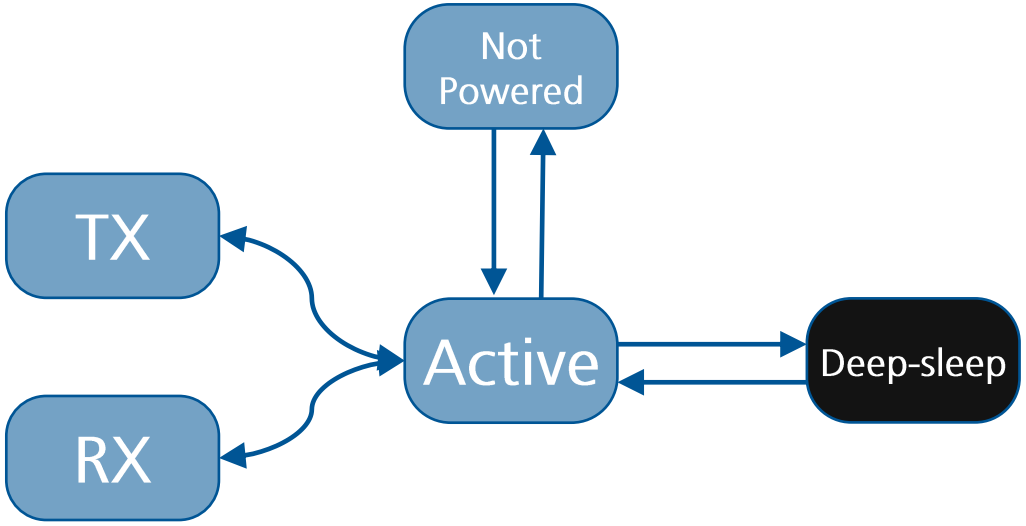


u-blox NB-IoT basics

SARA-N2 operating modes



Operating modes – Deep-sleep

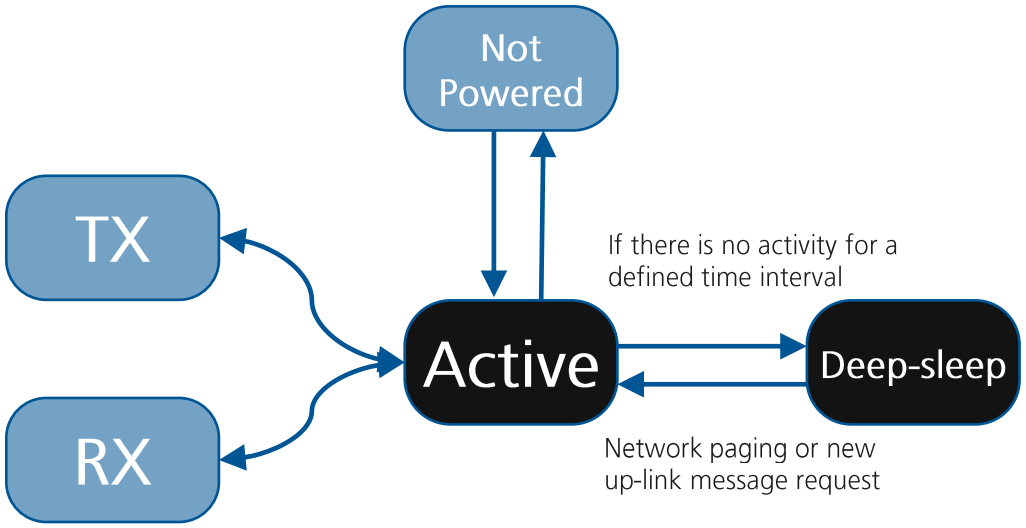


SARA-N2 goes in deep-sleep after a network-dependent time of inactivity on the radio side: no TX and no RX events

- In deep-sleep the RF is completely disabled
- **Lowest current consumption (~3 µA)**
- UART is still completely functional: AT commands can be sent
- All the other interfaces are disabled:

  V_INT goes "low" (i.e. 0V)
- How to monitor deep-sleep? Checking V_INT

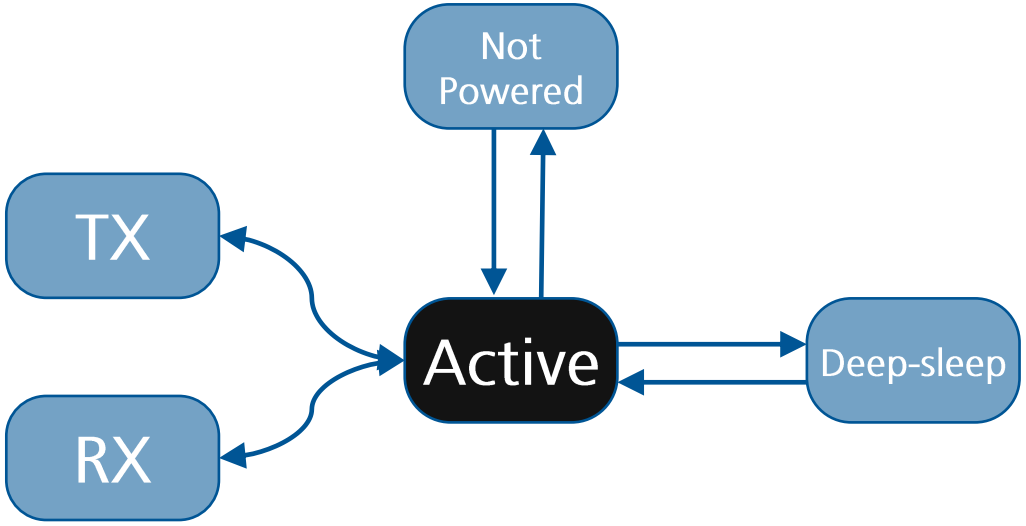
Operating modes – Transition deep-sleep / Active



Module exits deep-sleep mode if one of the following occurs:

- New data to be sent: triggered by user via AT commands
- **Paging event**

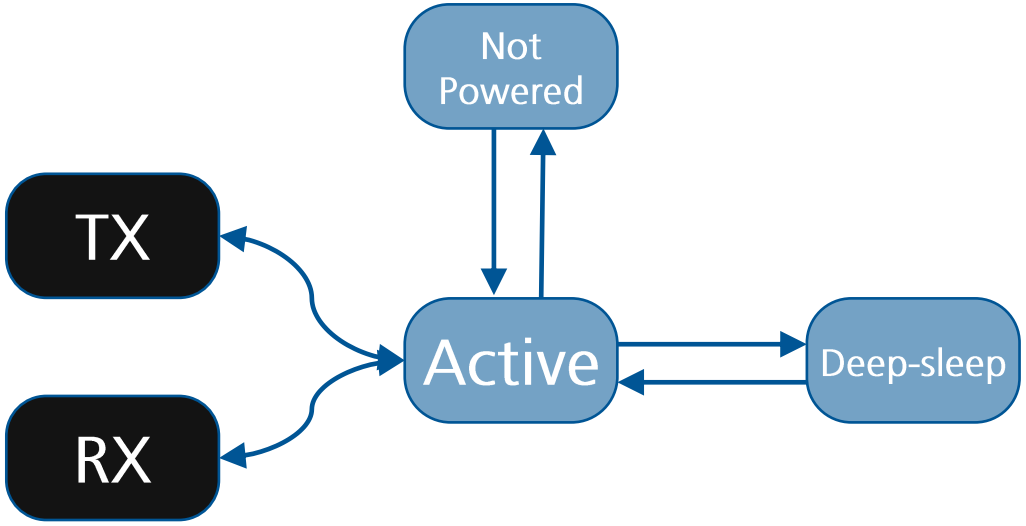
Operating modes – Active mode



Active means no TX and no RX events:

- Low current consumption (few mA)
- Active is a transition mode between TX/RX and Deep-sleep modes
- User has no control over the Active mode: no ways to monitor it; it's just a transition time mode
- Network dependent: module automatically enters this mode
- In this mode the module is fully functional
- All the interfaces are active

Operating modes – TX and RX modes



TX mode is triggered by a AT commands

- This mode also occurs during the registration phase

RX mode occurs in case of:

- Signalling indications (network/protocol dependent)
- Reception of downlink data
- Data is automatically received when the module is **out of the deep-sleep mode**

Working with High Latency transmissions

Application operation

Network connectivity

- Automatic
- Manual connection
- RRC Connection and Release

MO / MT Data

- Sending & Receiving
- Release Assistance

Power Save Mode

eDRX

Network Monitoring

- Coverage Classes
- Power consumption

Network connectivity – Automatic Connection

Make sure Autoconnect is turned **ON** (reboot to take effect)

- `AT+NCONFIG="AUTOCONNECT","TRUE"`
- `AT+NRB`

- After the module turns on it will read the SIM and start the process.

- With roaming (`+CEREG=<n>,5`) scanning and connecting to a network may take many minutes.

- Customers should understand what type of SIM they have been given and what network they are trying to connect to.

- APN will be set from the network

- If the module is not turned off, the previous base station will be scanned first when waking up – this should be fast.

Network connectivity – Manual Connection

Make sure Autoconnect is turned **OFF** (reboot to take effect)

- `AT+NCONFIG="AUTOCONNECT","FALSE"`
- `AT+NRB`

- When in manual mode you can specify APN and PLMN to search
- `AT+CDGCONT=…, "apn.default.com"`
- `AT+COPS=1,2,"plmn"`

- Do not use `AT+CGATT=1`, because this will use the default APN and PLMN and disregard your CDGCONT and COPS command.

- Default APN is set from the network.

Network connectivity - RRC Connection and Release

- When the module wakes from PSM it must first perform RACH procedure to attach to the network
- When the module connects to the eNodeB, the RRC connection can only be released by the eNodeB.
- After the module has sent its uplink messages, and finished with any downlink messages, an inactivity timer starts on the eNodeB. This is nominally 20 seconds. After this the RRC connection is released.
- The module will send an Acknowledgement back to the eNodeB for the RRC release.
- After RRC has been released the module starts the T3324 timer. When T3324 elapses the module goes into PSM.

Sending & Receiving Data

- SARA-N2xx-02B only supports UDP Sockets
- SendTo and ReceiveFrom commands are available
- NMGS and NMGR commands for Huawei IoT Platform are dedicated CoAP based commands which use UDP too
- Limited to 512 bytes for MO and MT data
- If more than 512 bytes is sent to the module in one message, it will be discarded

Release Assistance 1

- As noted in the previous RRC Connection slide, the module will keep connected to the eNodeB for at least 20 seconds of inactivity before the connection is released.
- Rx current in connected mode is about 50mA, so 20 seconds is 1mWh.
- The application has the option to terminate the RRC connection as soon as the uplink message is sent. This is called Release Assistance.
- Release Assistance is a flag the MME uses to send a message back to the eNodeB to release the RRC.
- This feature must be supported by the Network.

- AT+NSOSTF - “SendTo With Flags”
- With the flag set to ‘0x00’ this operates the same as +NSOST

Release Assistance 2

- For an application like Meter reading, where there is no need to acknowledge the message by the cloud server, Release Assistance should be considered. Use Flag 0x200.

- For application messages that require quick responses from the cloud server, don’t use Release Assistance.

- Using the 0x400 flag, the RRC connection is dropped after a short period (a few seconds). This could be used if the application only requires one response which is returned quickly.

- Consider Paging for downlink messages. Responses don’t have to be sent back while the module is in Connected mode if they have Paging.

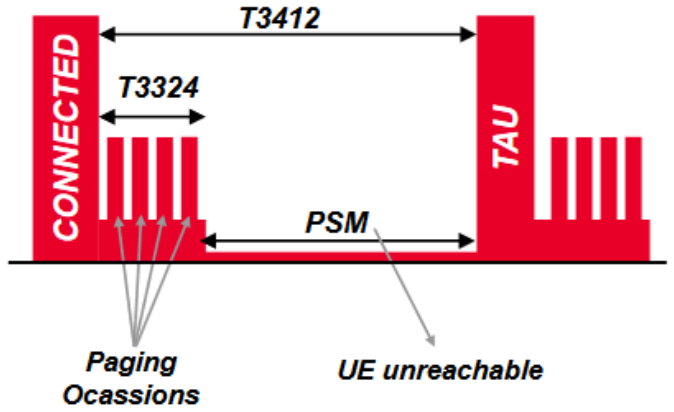
Power Save Mode

- Release 13 introduced Power Save Mode.
- This is described by the T3324 and T3412 timers.
- T3324 defines how long the module can be paging, until it goes into PSM.
- T3412 defines how long the module will be in Idle/PSM before it automatically sends a TAU (Tracking Area Update) message.

- AT+CPSMS configures these timers.
- AT+CEREG=4/5 queries what the timers have been set to by the network after registration is complete.

Power Save Mode

Rel-12 Power Saving Mode (PSM)



- T3324 determines for how long the UE will monitor paging beforing entering in PSM
- While in PSM, UE is not reachable by the Network and all circuitry is turned off
- UE exits PSM when T3412 expires (TAU) or with a Mobile Originated transfer

SOURCE: Keysight

eDRX

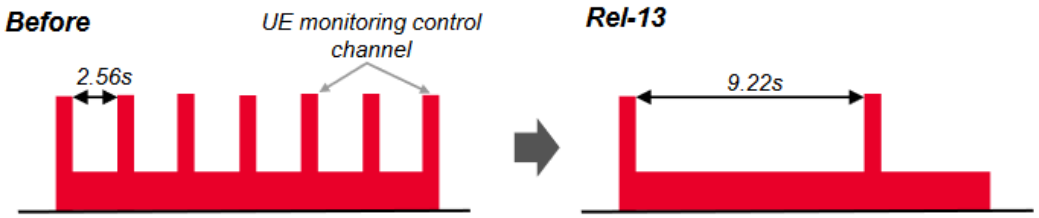
- Release 13 introduced eDRX
- eDRX is specified as a number of HyperFrames
- eDRX operates inside the T3324 period

- AT+CEDRX requests the value to the network.
- AT+CEDRXRDP returns the value set by the network
- AT+NPTWEDRXS returns the paging window and eDRX settings.

eDRX

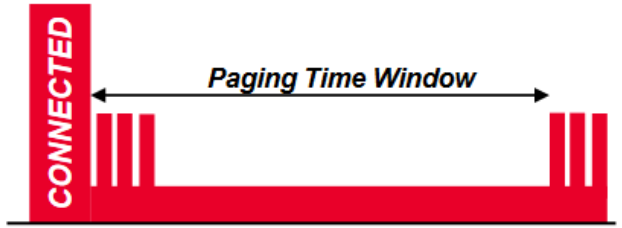
Rel-13 Enhanced DRX (eDRX)

CONNECTED eDRX



- DRX cycles extended from 2.56 seconds:
  - To 9.22 seconds in NB-IoT
  - To 10.24 seconds in Cat-M

IDLE eDRX



- New Paging Time Window which allows longer paging cycles:
  - 3 hours in NB-IoT
  - 44mis in Cat M

SOURCE: Keysight

Network Classes

NB-IoT defines three coverage classes

- AT+NUESTATS shows the coverage class last used (ECL)

- Coverage Class 0
  - Tx Power Control, from -40 dBm to +23 dBm
  - Power ramping for RACH procedure

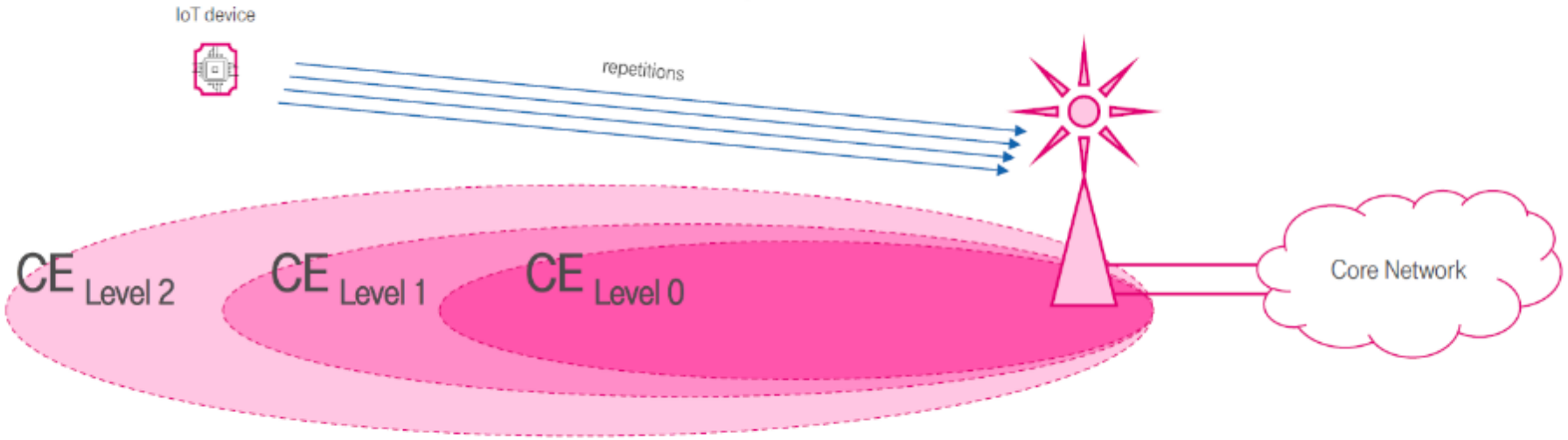
- Coverage Class 1
  - No Tx power control, always maximum +23 dBm
  - Small number of repetitions for RACH
  - eNodeB uses SNR to specify repetitions for data

- Coverage Class 2
  - No Tx power control, always maximum +23 dBm
  - Normally large number of repetitions for RACH
  - eNodeB uses SNR to specify repetitions for data

Network Classes

Coverage Extension

- Multiple repetitions to assure proper decoding of messages
  - NPDSCH maximum repetition factor up to 512
  - NPUSCH maximum repetition factor up to 128
- Device does not get disconnected



- Downlink data rage: Peak 226,7 kbps / Lowest 35 bps
- Uplink data rate: Peak 250 kbps / Lowest 20 bps

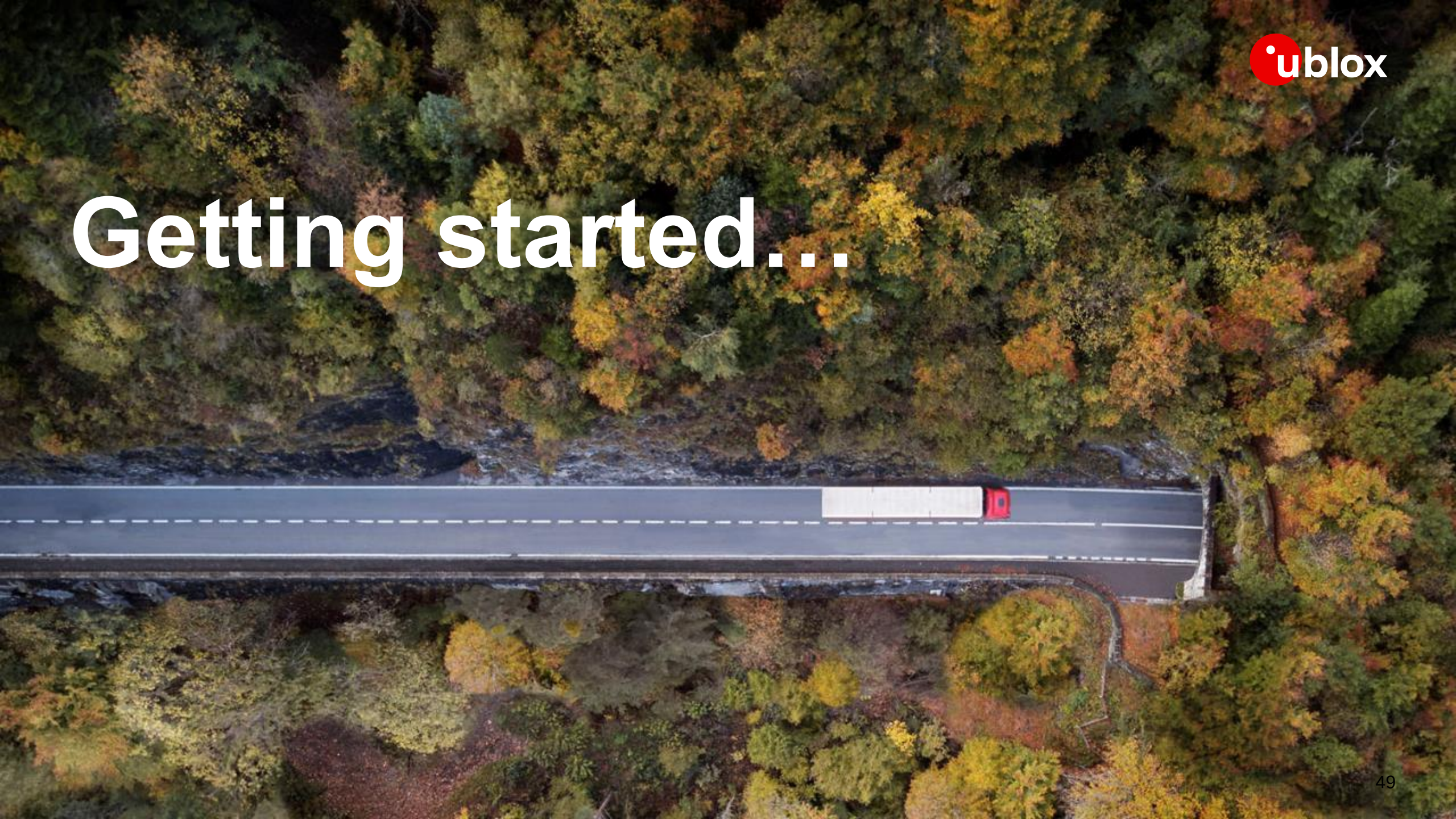
SOURCE: T-Mobile

Power consumption

Power Consumption

For information regarding the power consuption and battery life calculation it is necessary to sign a NDA agreement with u-blox.

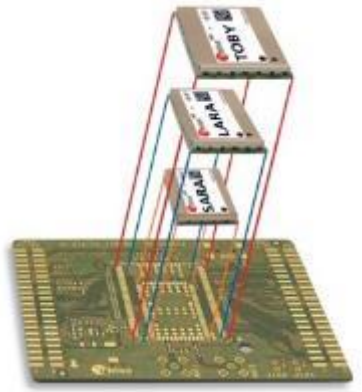
Contact Martin.Pflug@microdis.net for more details.


Getting started…

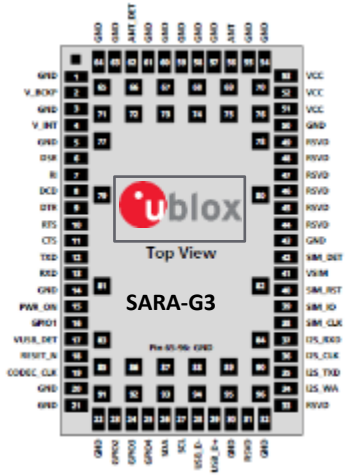
2G/3G to NB-IoT design migration with u-blox's nested design concept

MICRODIS
COMPETENCE & RELIABILITY

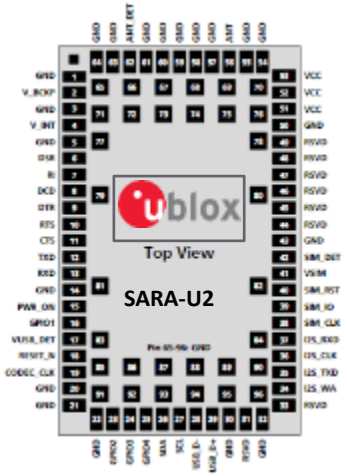
- Various modules can be **alternatively** mounted on **same board** space: **One board** for GSM, WCDMA, CDMA and LTE, NB-IoT
- AT **command compatibility** to minimize software migration effort



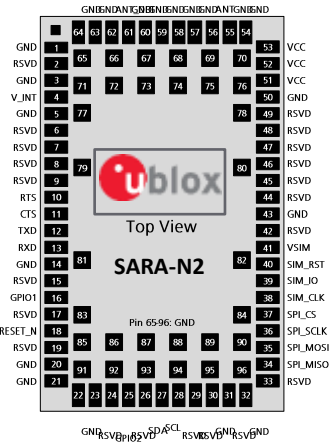
2G
Deployed: Now
SARA-G3



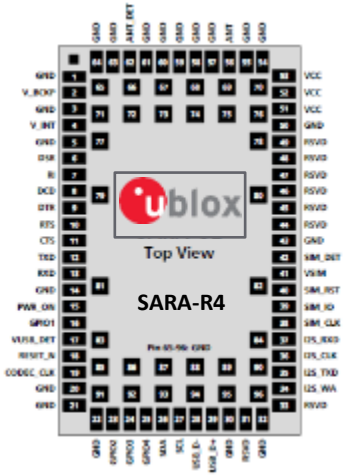
3G
Deployed: Now
SARA-U2



LTE Cat NB1 (NB-IoT)
Deployed: Now
SARA-N2



LTE Cat M1
Deployed: Now
SARA-R4



NB-IoT getting started - hardware

- NBIoT modules: SARA-N2xx
  - ✓ **available**
- SARA-N2xx evaluation kits
  - ✓ **available**
  - ✓ Microdis supports customers (lending)
- C030-N211 IoT starter kit (w/ SARA-N211)
  - ✓ Cortex-M4, GNSS module, antennas
  - ✓ ARM mbed envir., Arduino interface
  - ✓ **available**

SARA-N
NB-IoT modules

Evaluation kits

Mbed enabled IoT starter kit

M1 getting started - hardware

- M1/NB1 modules: SARA-R4xx
  - ✓ **available – ES samples**
- SARA-R4xx evaluation kits
  - ✓ **available – ES samples**
  - ✓ Microdis supports customers (lending)

SARA-R M1/NB1 modules

Evaluation kits

NB-IoT & M1 getting started - network

- Network service is **available**, contact Vodafone
  - ✓ arrange SIM card
  - ✓ agree access to network / BTS locations

- Contact Microdis to select the suitable module for selected market:
  - ✓ agree support of target market operator first
  - ✓ collect information about bands
  - ✓ Microdis keeps registered customers up to date

NB-IoT getting started – application support

- Dedicated application engineers in place:
  - ✓ ubloxFAE@microdis.net
- NB-IoT Application Note, System Integration Manual, information & support
- test & debug tools implemented in modules:
  - ✓ UTEST – AT command to control band and RF power, for antenna matching, power supply testing etc
  - ✓ TRACE – recording low level communication between module and network, for further investigation
- m-center – evaluation tool for PC
- estimate power consumption

m-center evaluation tool

NB-IoT getting started – purchase

- Microdis Electronics- distributor of electronic components in Eastern Europe
  - ✓ 2 offices in Czech republic
  - ✓ provides products and application support
  - ✓ **Czech@microdis.net**
- Microdis distributes:
  - ✓ u-blox modules, including NB-IoT
  - ✓ evaluation kits, application boards
  - ✓ antennas
  - ✓ SIMHolders, RF connectors
  - ✓ and other electronic components
  - ✓ **www.microdis.net**

THANK YOU FOR YOUR ATTENTION

2018