DESIGNING EFFICIENT AND RELIABLE NB-IOT SOLUTIONS: BRIEFING

HANNOVERMESSE, 25 APRIL 2018

hosted by GSMA

LIFE IS FOR SHARING.

THE “DNA” OF NARROWBAND IOT

NB-IOT

Billions of devices

Up to 100x more devices
per cell (compared to GSM)

Low energy consumption

Up to 10 years
of battery-powered operation [1)]

Deep indoor penetration

+20dB link budget
(compared to GSM)

Low cost

Radio module <$5 (industry target)
Lower total cost of ownership

Low data volume

Bidirectional, infrequent transmission of low data volumes. Data rates 600b/s - 250kbit/s [2)]

Plug & Play

Direct connectivity of the sensor.
(No installation and maintenance of local networks/gateways required)

High security

Proven LTE-based security mechanisms

Worldwide standard

Worldwide 3GPP industry standard on operator-managed networks in licensed spectrum

3GPP
A GLOBAL INITIATIVE

1) Assuming equivalent of 2 AA batteries and typical traffic pattern

2) Dependent on network utilization and signal strength

SUITABLE USE CASES FOR NB-IOT

- ☑ High number of devices
- ☑ Low data rates
- ☑ Infrequent data transmission
- ☑ Latency is uncritical
- ☑ Deep indoor penetration
- ☑ Low power consumption/long battery lifetime
- ☑ No external wake-up function needed
- ☑ No voice or SMS needed

PART 01: BUILDING NB-IOT SOLUTIONS

The Technical DNA of NB-IoT

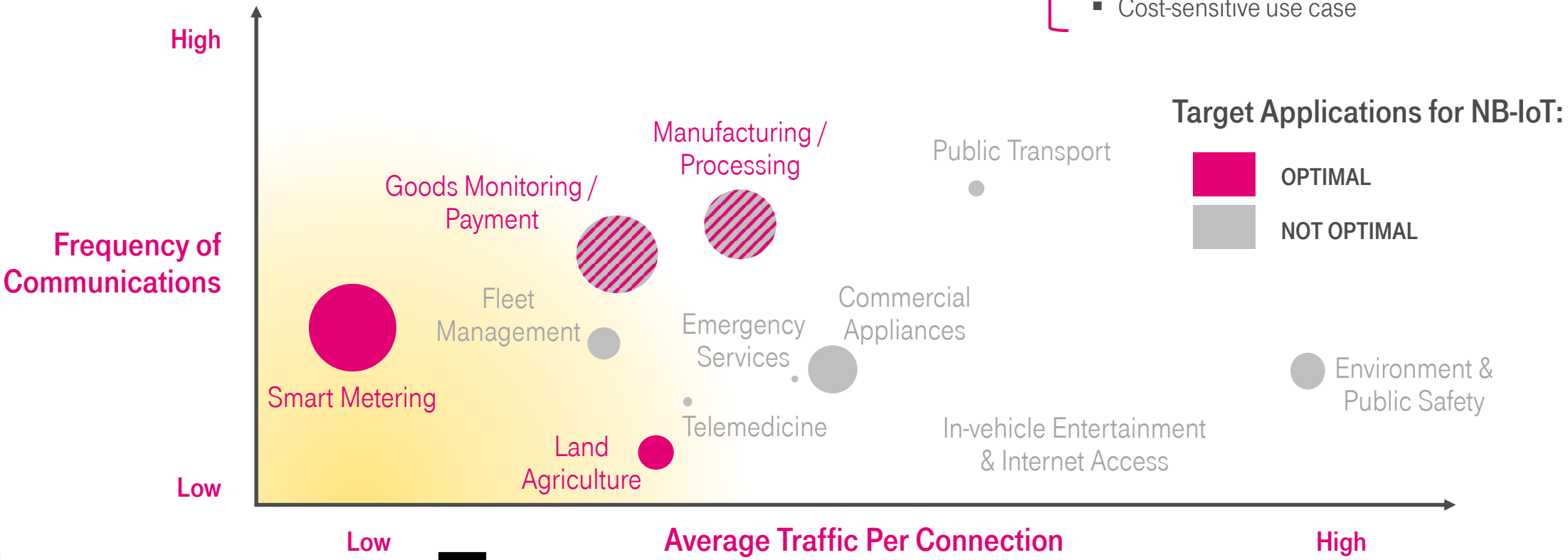
Validation & Certification

Design Optimization

SELECTING THE RIGHT TECHNOLOGY FOR YOUR NEEDS

NB-IoT has the right match of features & optimizations for Low-Power Wide-Area (LPWA)

- Low data rates
- Infrequent data transmission
- Latency is uncritical
- Deep indoor penetration
- Long battery lifetime
- Cost-sensitive use case



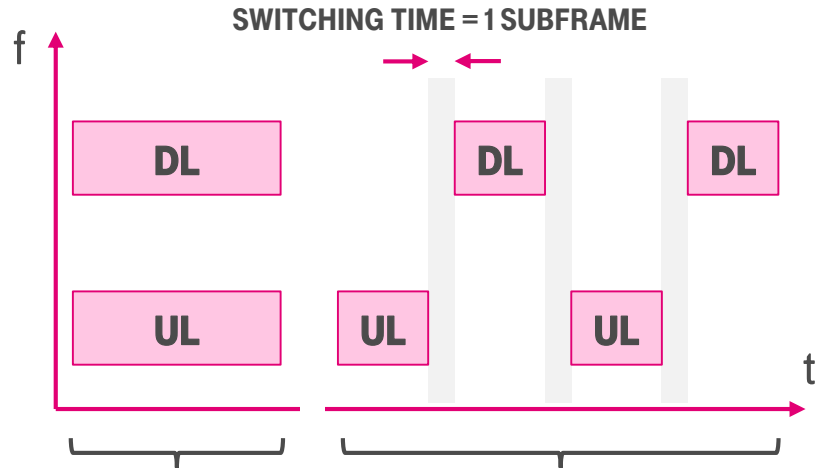
NB-IOT DUPLEX MODE

NB-IoT uses FDD Half-duplex Type-B for Uplink and Downlink communication

BAND NUMBER	UPLINK FREQUENCY RANGE (MHZ)	DOWNLINK FREQUENCY RANGE (MHZ)
1	1920 – 1980	2110 – 2170
2	1850 – 1910	1930 – 1990
3	1710 – 1785	1805 – 1880
...	...	...

UE TRANSMISSION ⟷ UE RECEPTION

SWITCHING TIME = 1 SUBFRAME



FDD Full-duplex vs. FDD Half-duplex

NB-IOT FREQUENCY BANDS

Telekom focuses on the lower frequency bands due to superior RF propagation

BAND NUMBER	UPLINK FREQUENCY RANGE (MHZ)	DOWNLINK FREQUENCY RANGE (MHZ)	REGION
1	1920 – 1980	2110 – 2170	Asia
2	1850 – 1910	1930 – 1990	PCS A-F: N./S. America
3	1710 – 1785	1805 – 1880	DCS Global exc. N. America
5	824 – 849	869 – 894	US, Asia, Australia
8	**880 – 915**	**925 – 960**	E-GSM: Europe, Asia
12	699 – 716	729 – 746	N. America, Oceania
13	777 – 787	746 – 756	N./S. America
17	704 – 716	734 – 746	N./S. America
18	815 – 830	860 – 875	Japan
19	830 – 845	875 – 890	Japan
20	**832 – 862**	**791 – 821**	Europe, Middle East
26	814 – 849	859 – 894	USA
28	703 – 748	758 – 803	Japan, Australia, Panama
66	1710 – 1780	2110 – 2200	N. America

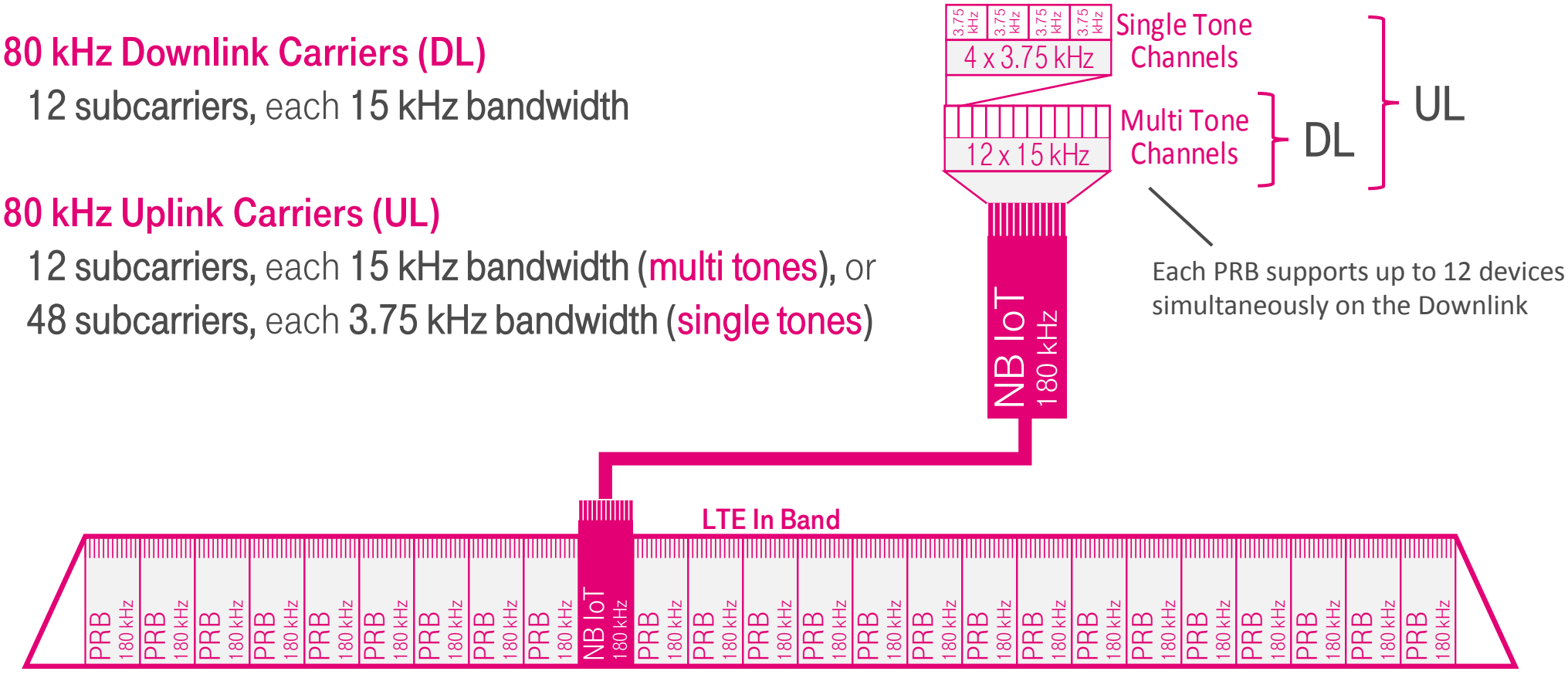
NB-IOT CARRIER STRUCTURE

180 kHz Downlink Carriers (DL)

- 12 subcarriers, each 15 kHz bandwidth

180 kHz Uplink Carriers (UL)

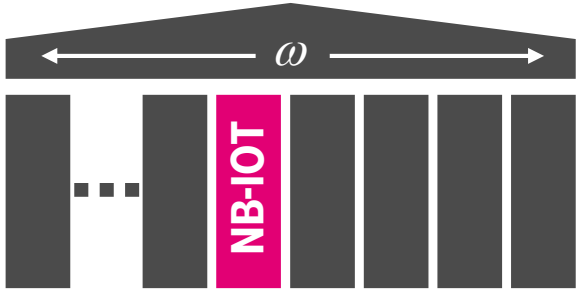
- 12 subcarriers, each 15 kHz bandwidth (multi tones), or
- 48 subcarriers, each 3.75 kHz bandwidth (single tones)



5 MHz-wide LTE channel, where one NB-IoT carrier replaces a standard LTE PRB

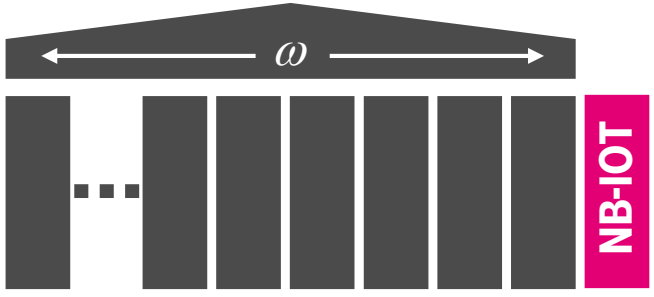
NB-IOT OPERATION MODES

LTE Carrier (ω = 3, 5, 10, 15, 20 MHz)
(No support for 1.4 MHz bandwidth)



In-Band Operation

LTE Carrier (ω = 10, 15, 20 MHz)
(No support for 1.4, 3, 5 MHz bandwidth)



Guardband Operation

Stand Alone Operation

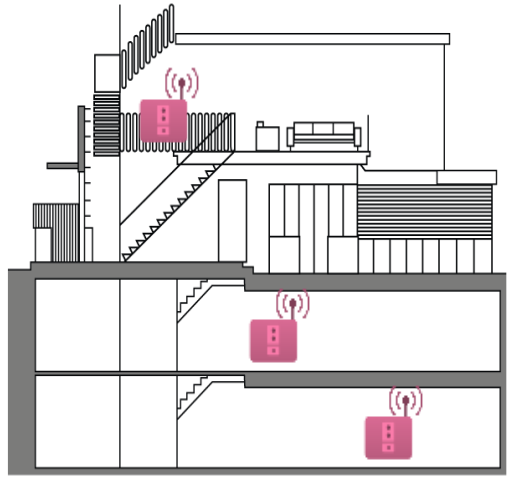
NB-IoT and LTE can share spectrum without causing mutual interference

NB-IoT carriers and LTE PRBs are orthogonal

COVERAGE ENHANCEMENT (CE)-LEVELS

NB-IoT has three Coverage Enhancement (CE)-Levels:

- CE-Level 0 → Equivalent to GSM Coverage (RSRP > -114 dBm)
- CE-Level 1 → Up to 10 dB gain vs. GSM (RSRP between -114 dBm and -124 dBm)
- CE-Level 2 → Up to 20 dB gain vs. GSM (RSRP < -124 dBm)



CE-Level 0 — Power-controlled Uplink Transmission

CE-Level 1, CE-Level 2 — Maximum Power Uplink Transmission (Power Class 3 = 23 dBm)

CE-Levels mainly determine number of times messages are repeated

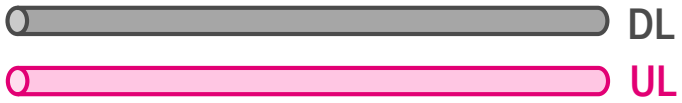
IMPACT ON BATTERY LIFETIME!

*RSRP = Reference Signal Received Power, measured at the device receiver

DATA RATES / THROUGHPUT

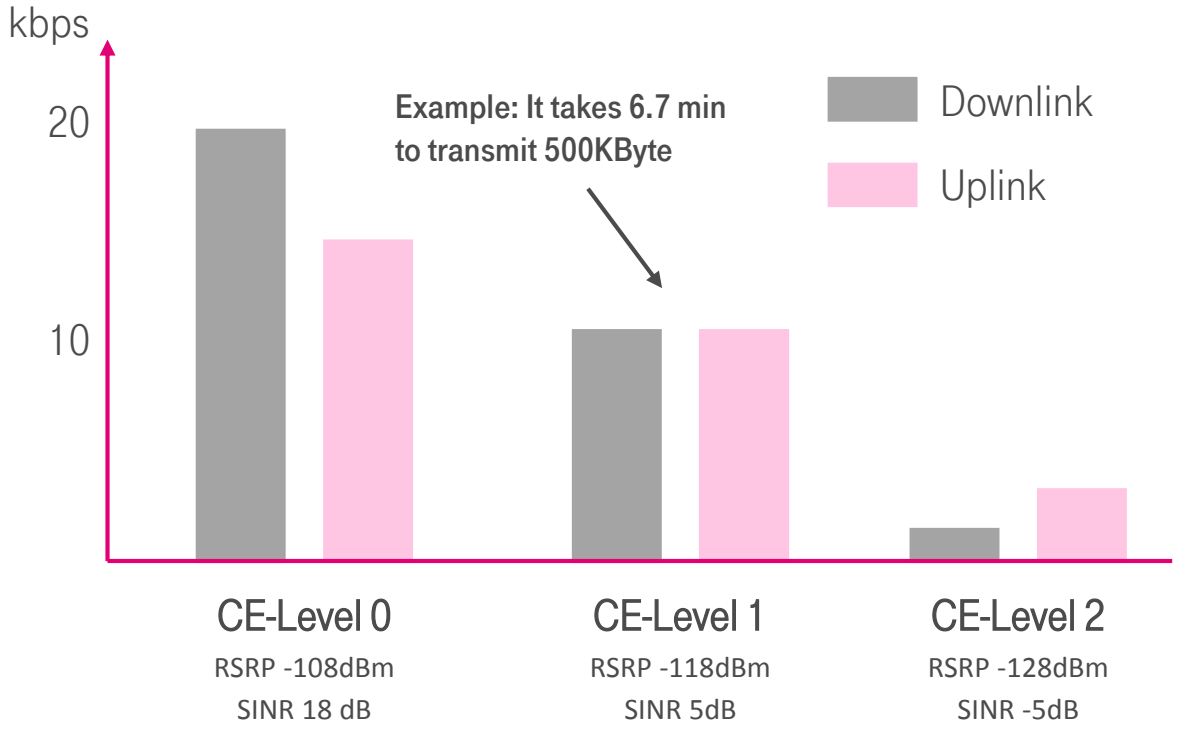
This performance is desired!

NB-IoT is intentionally a “thin pipe”



Downlink (NPDSCH)	Peak data rate → 250 kbps Lowest data rate → 20 bps
Uplink (NPUSCH)	Peak data rate → 226.7 kbps Lowest data rate → 35 bps

Average Uplink / Downlink Throughput is lower than in peak data rates, due to time-offsets between DCI, acknowledgements, as well as real-world interference.



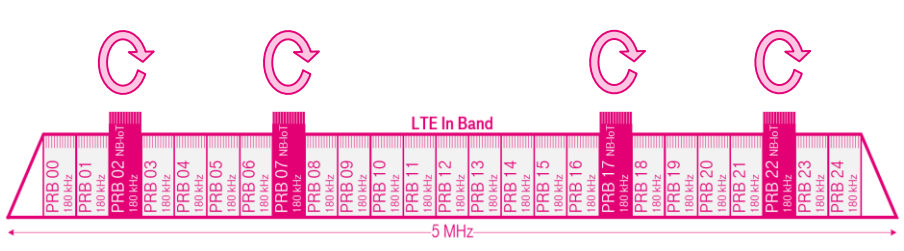
MOBILITY HANDLING VIA RESELECTION

NB-IoT is designed for infrequent / short message transfers between devices and network

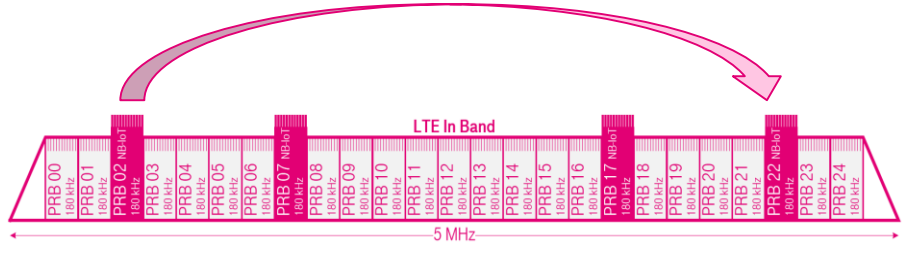
There is no need or support for handovers!

If cell change is required, device enters RRC_IDLE to re-select:

- Intra-frequency → Move to same 180 kHz carrier, implemented in different cell
- Inter-frequency → Move to another 180 kHz carrier, in/outside same LTE carrier

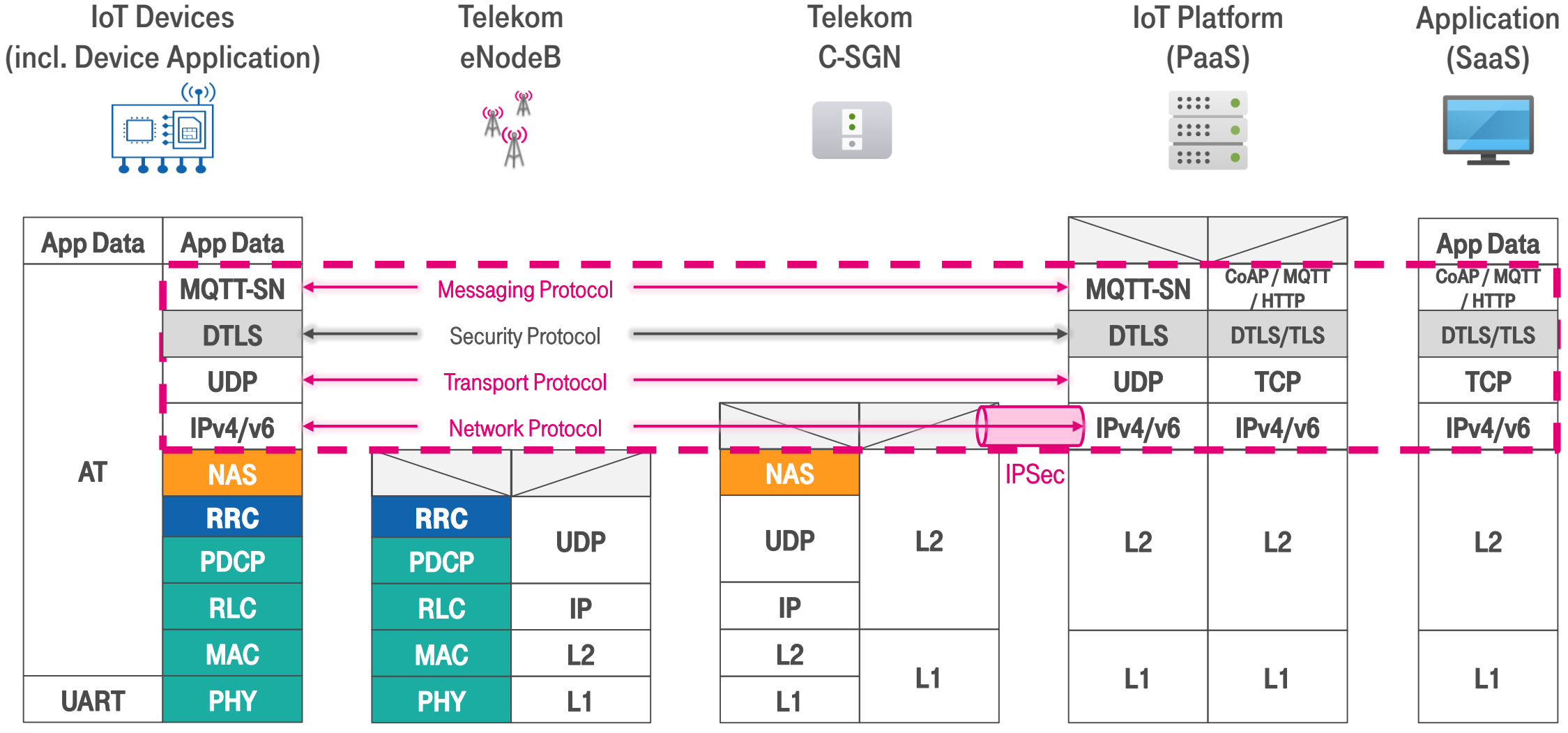


INTRA-FREQUENCY RESELECTION



INTER-FREQUENCY RESELECTION

PROTOCOL STACK: MQTT-SN/UDP/IP, OVER NAS

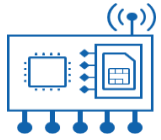


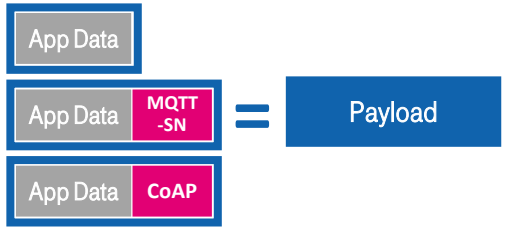
BENEFIT OF NON-IP DATA DELIVERY

IoT Devices (incl. Device Application)

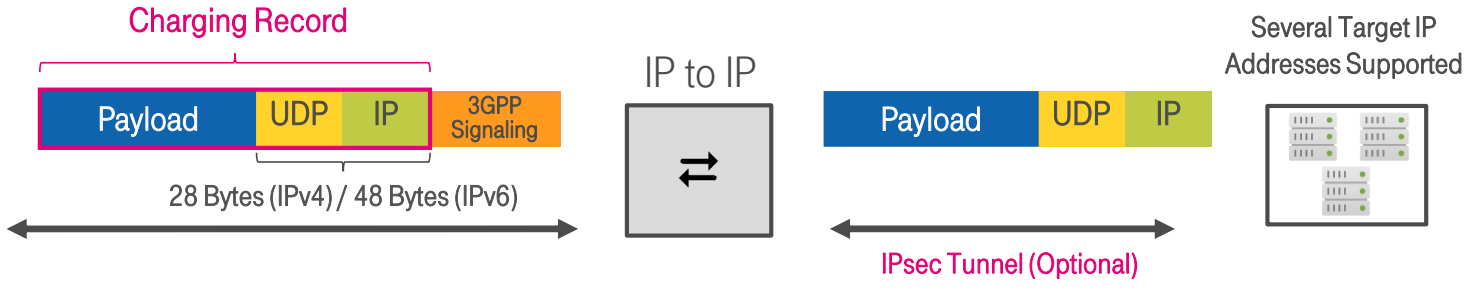
Telekom eNode B, C-SGN

IoT Application Platform / Server

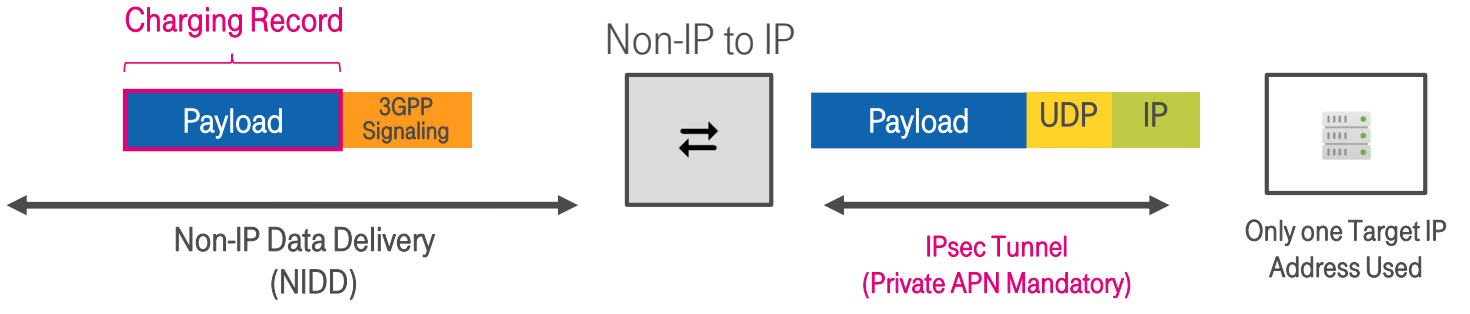




IP-based Data Delivery



Non-IP Data Delivery



Impacts:

- Reduced costs
- Improved battery life
- Maximum efficiency of payload vs. overhead

POWER SAVING FEATURES

Many options for best-fit!

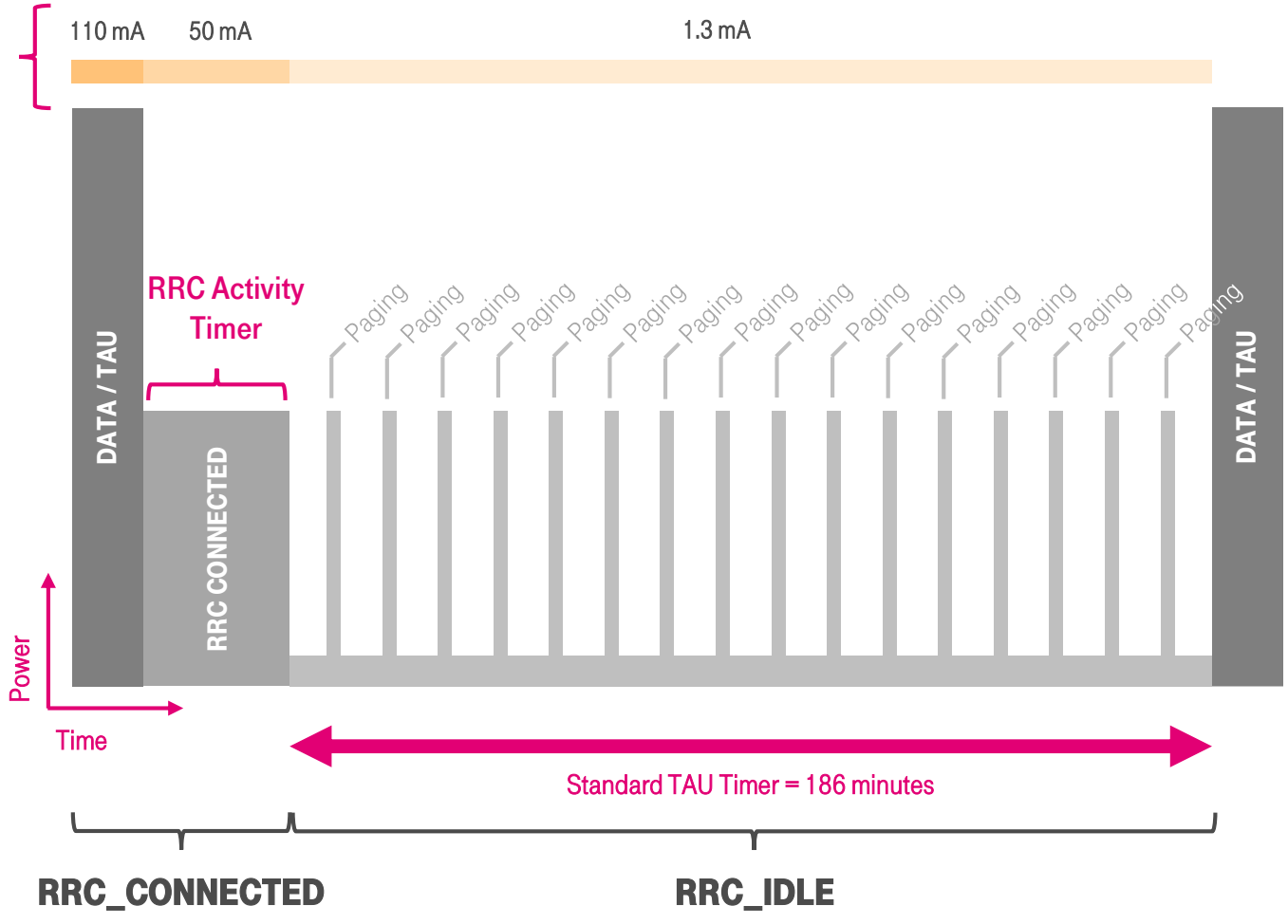
NB-IoT leverages 32 combinations of these power saving features:

- Long Periodic Tracking Area Update (TAU)
- Connected Discontinuous Reception (cDRX)
- Enhanced Discontinuous Reception (eDRX)
- Power Saving Mode (PSM)
- Rel.13 Early Release Indication

Periodic TAU	cDRX	eDRX	PSM	Early Rel. Indication	
Standard		X			
		X	X		
		X		X	
			X		
			X	X	
				X	
		X	X	X	
		X	X	X	
	X	X			
	X	X	X		
	X	X		X	
	X		X		
	X		X	X	
	X			X	
	X	X	X	X	
	X	X	X	X	
Long (T3412)		X			
		X	X		
		X		X	
			X		
			X	X	
				X	
		X	X	X	
		X	X	X	
	X	X			
	X	X	X		
	X	X		X	DL
	X		X		
	X		X	X	UL
	X			X	
	X	X	X	X	
	X	X	X	X	

ALL POWER SAVING FEATURES INACTIVE

Indicative avg. power consumption shown for CE-Level 0 (also in next slides)



TWO NB-IoT STATES:

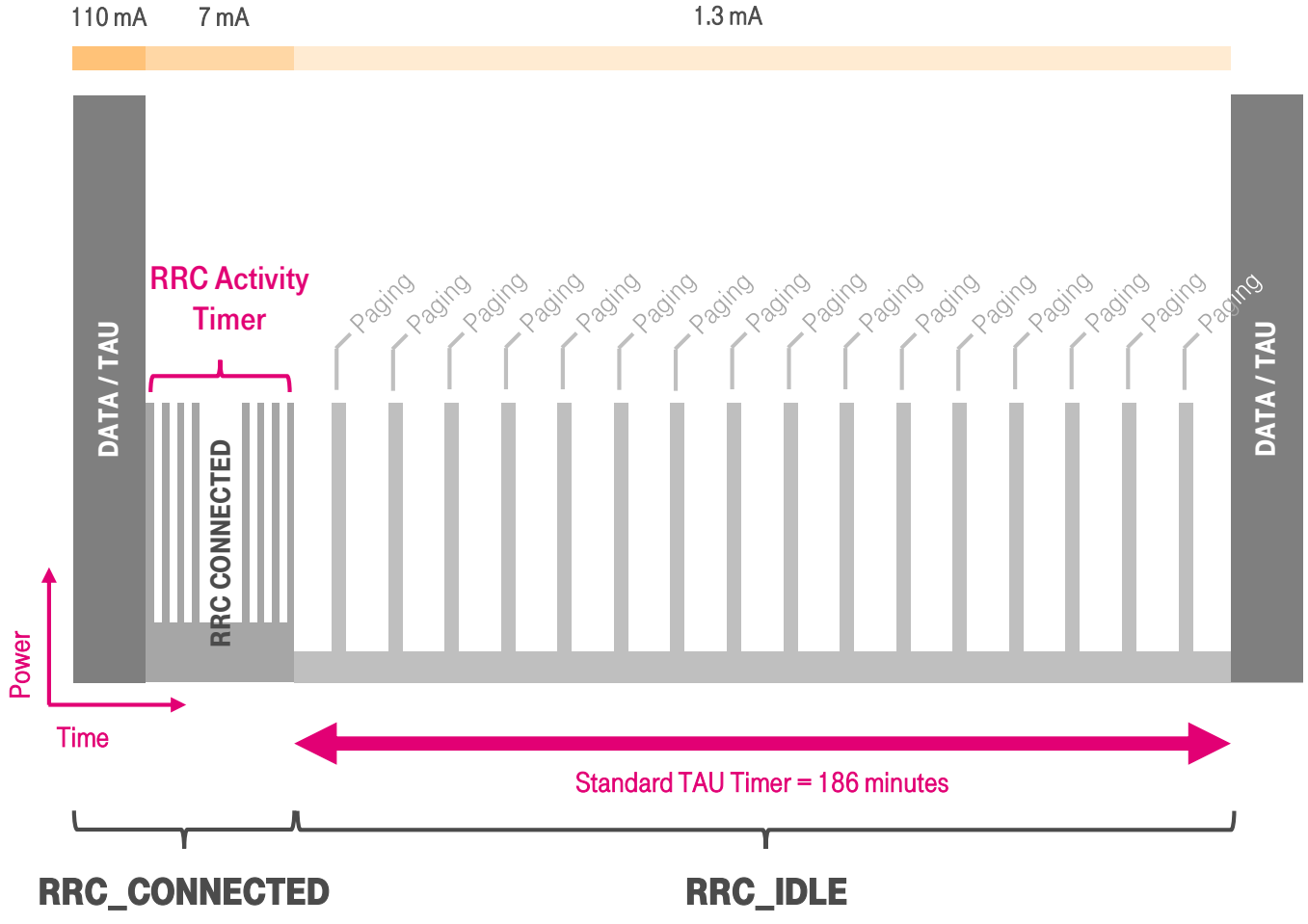
RRC_IDLE

RRC_CONNECTED

CONNECTED MODE DRX (CDRX)

Active Features:

- **cDRX**

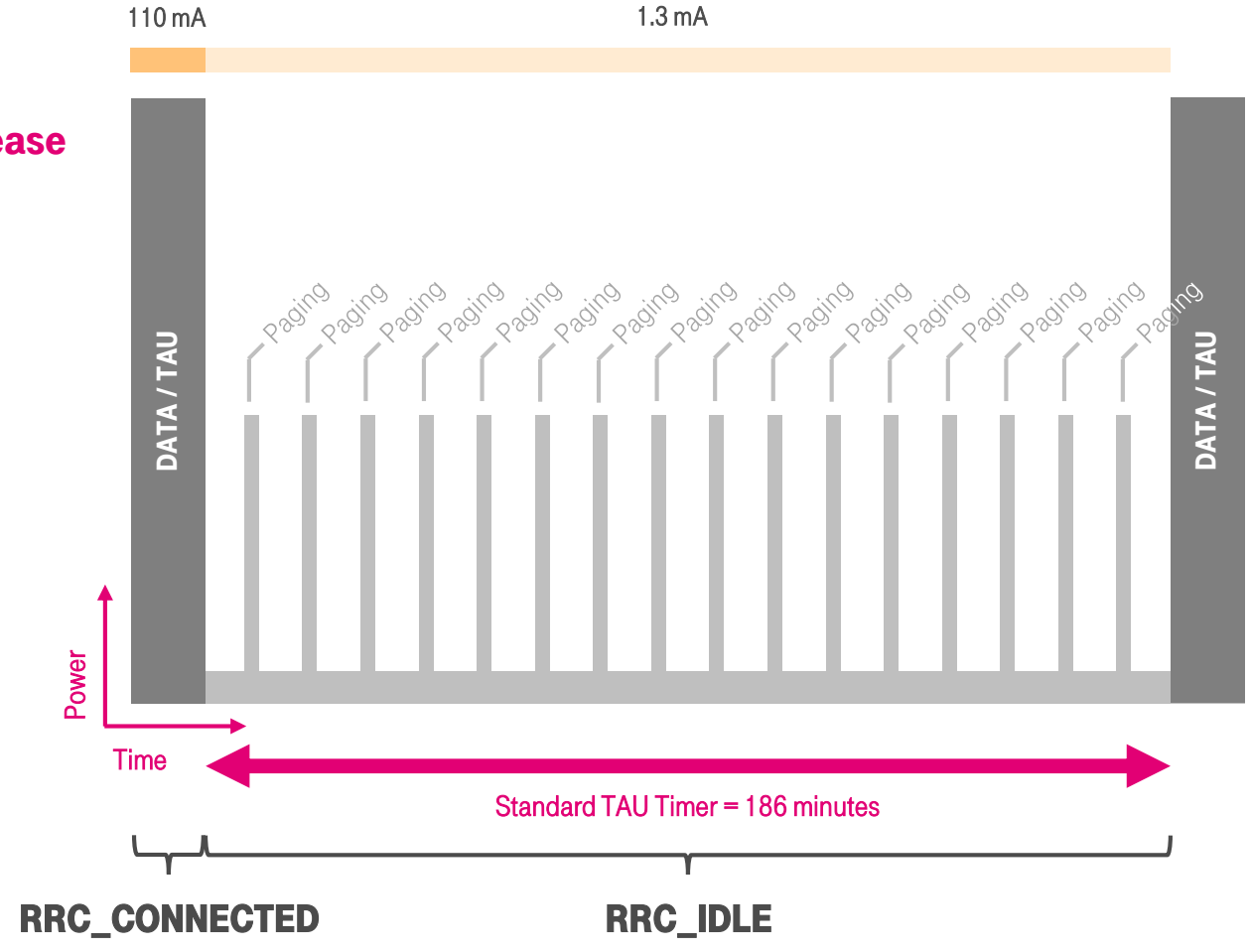


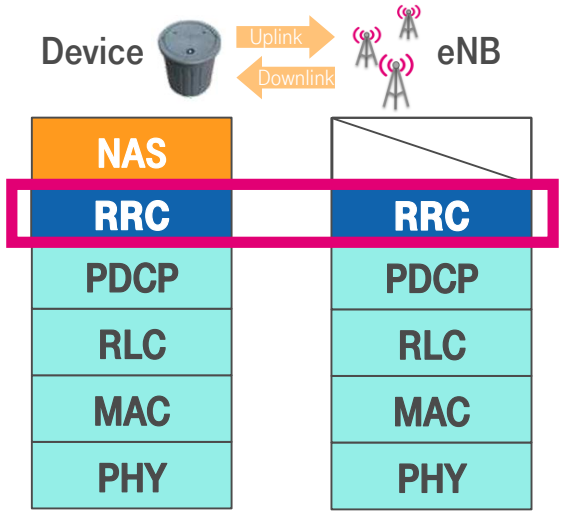
The cDRX feature is active by default on all Telekom NB-IoT networks

REL.13 EARLY RELEASE ASSISTANCE

Active Features:

- **Rel.13 Early Release**





Control Plane

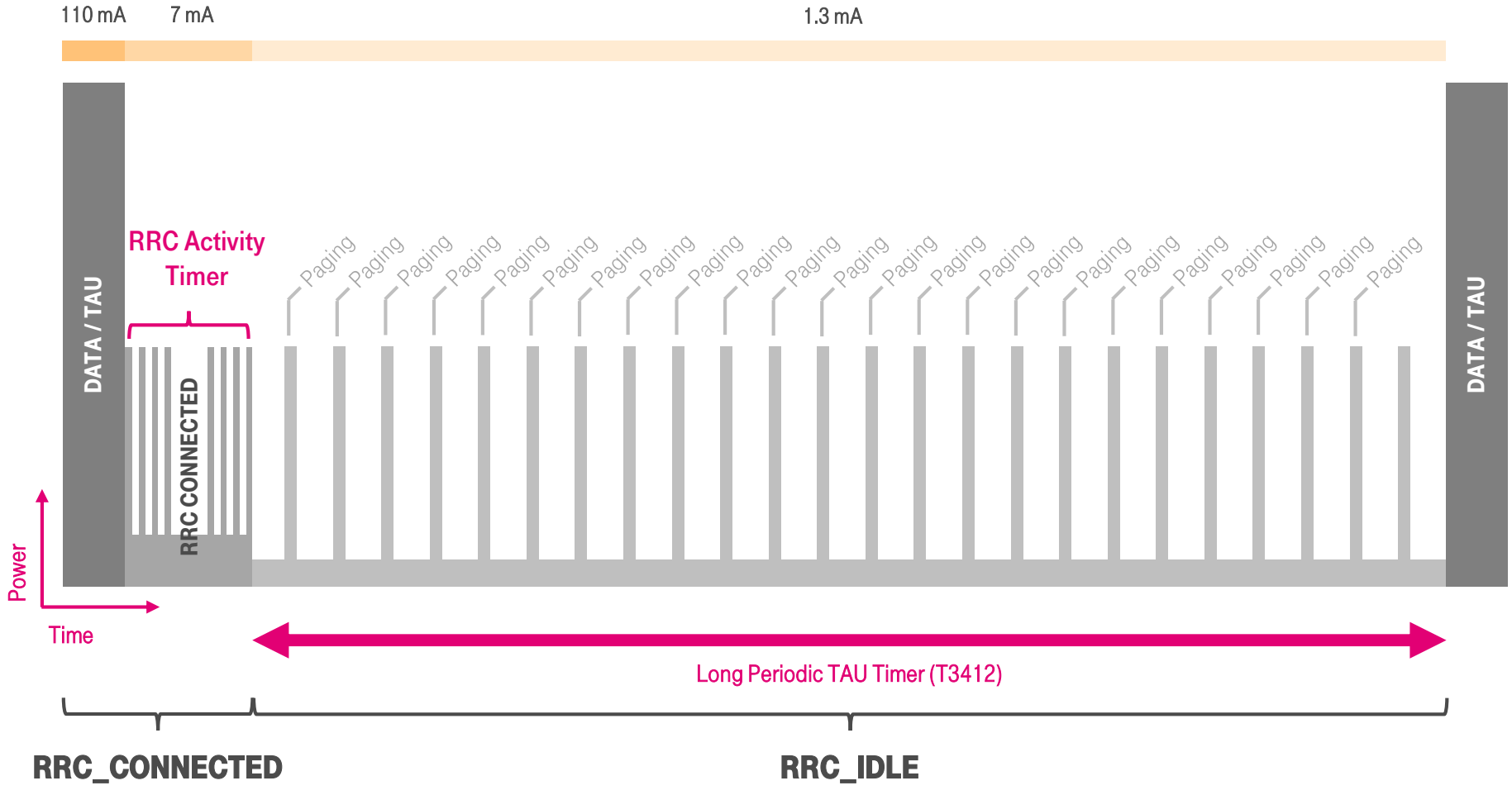
Early Release Assistance helps IoT Applications **further reduce device power consumption**

LONG PERIODIC TRACKING AREA UPDATE (TAU)

Active Features:

- **cDRX**
- **Long Periodic TAU**

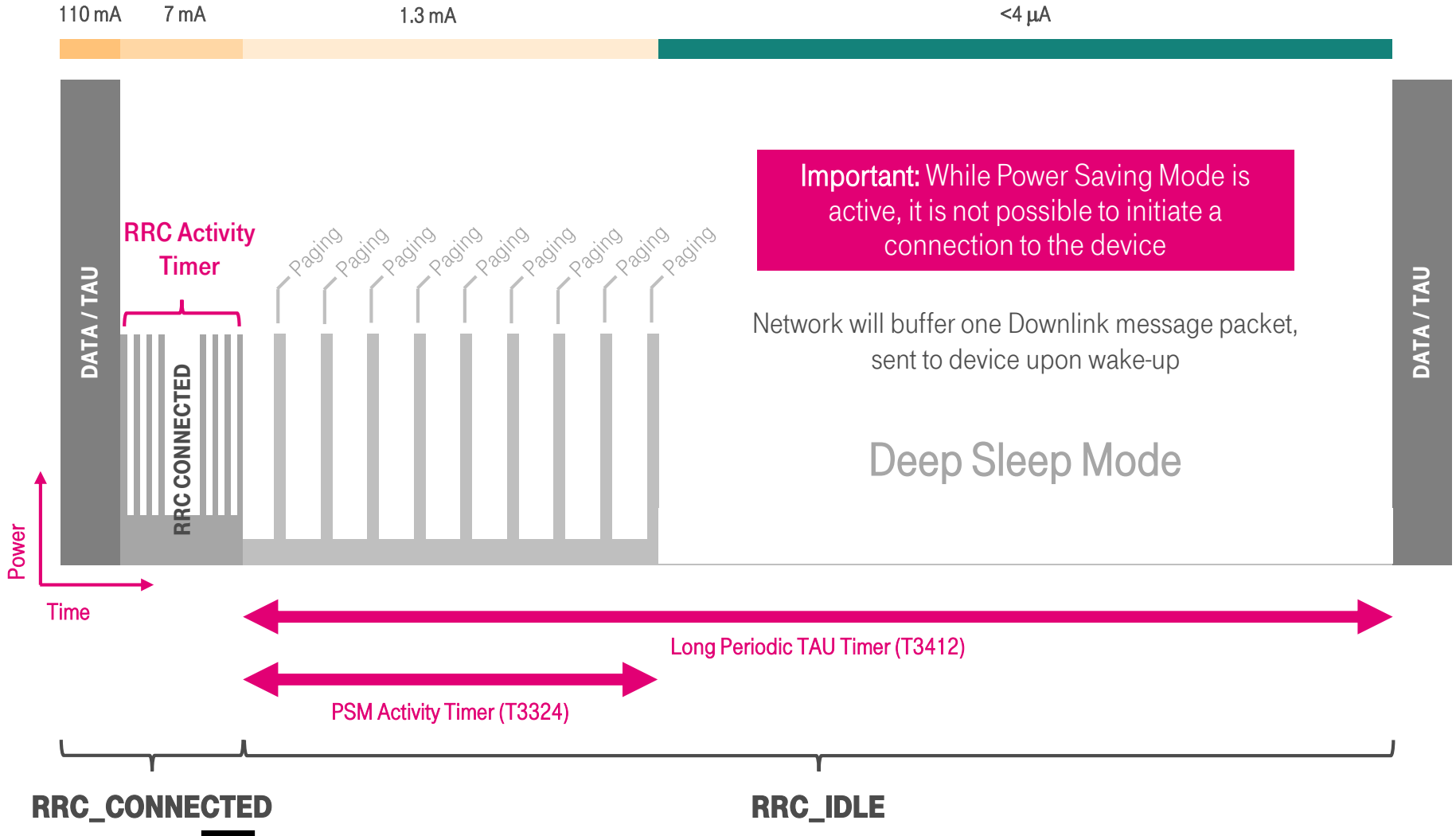
At a minimum, all NB-IoT devices must wake up to send a TAU at the expiration of the T3412 timer



POWER SAVING MODE (PSM)

Active Features:

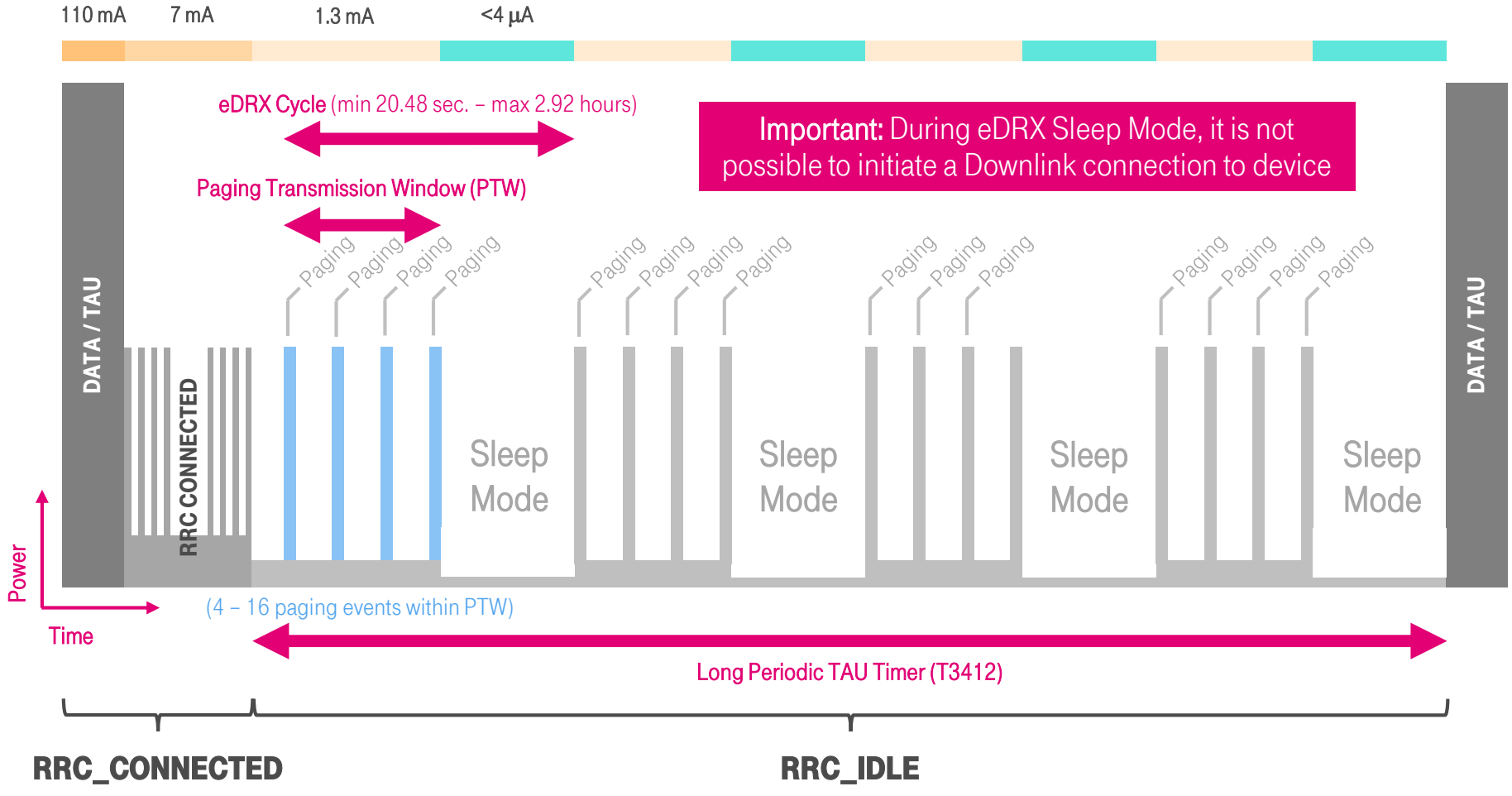
- **cDRX**
- **Long Periodic TAU**
- **PSM**



ENHANCED DRX (EDRX)

Active Features:

- **cDRX**
- **Long Periodic TAU**
- **eDRX**



NB-IOT DEVICE COMPONENTS

NB-IoT Application =
Connected Shopping Cart

Microcontroller (MCU)
(IoT Device Application, OS)

Sensor(s), Actuator(s)

SIM/UICC Holder

Batteries (Saft S.A., etc.)

External Interfaces
(e.g. USB)

Positioning
(e.g. GPS)

Antenna(e)

NB-IoT OEM Communication Module

- RFFE (Radio Frequency Front End)
- UICC software support
- Oscillators, filters, amplifiers
- Antenna connection
- Module is steered via AT commands
- **Vendors:** Fibocom, Foxconn, Gemalto, Murata, Neoway, Pycom, Quectel, Ruijie, Sercomm, Sierra Wireless, SIMCom, Telit, u-blox, etc.

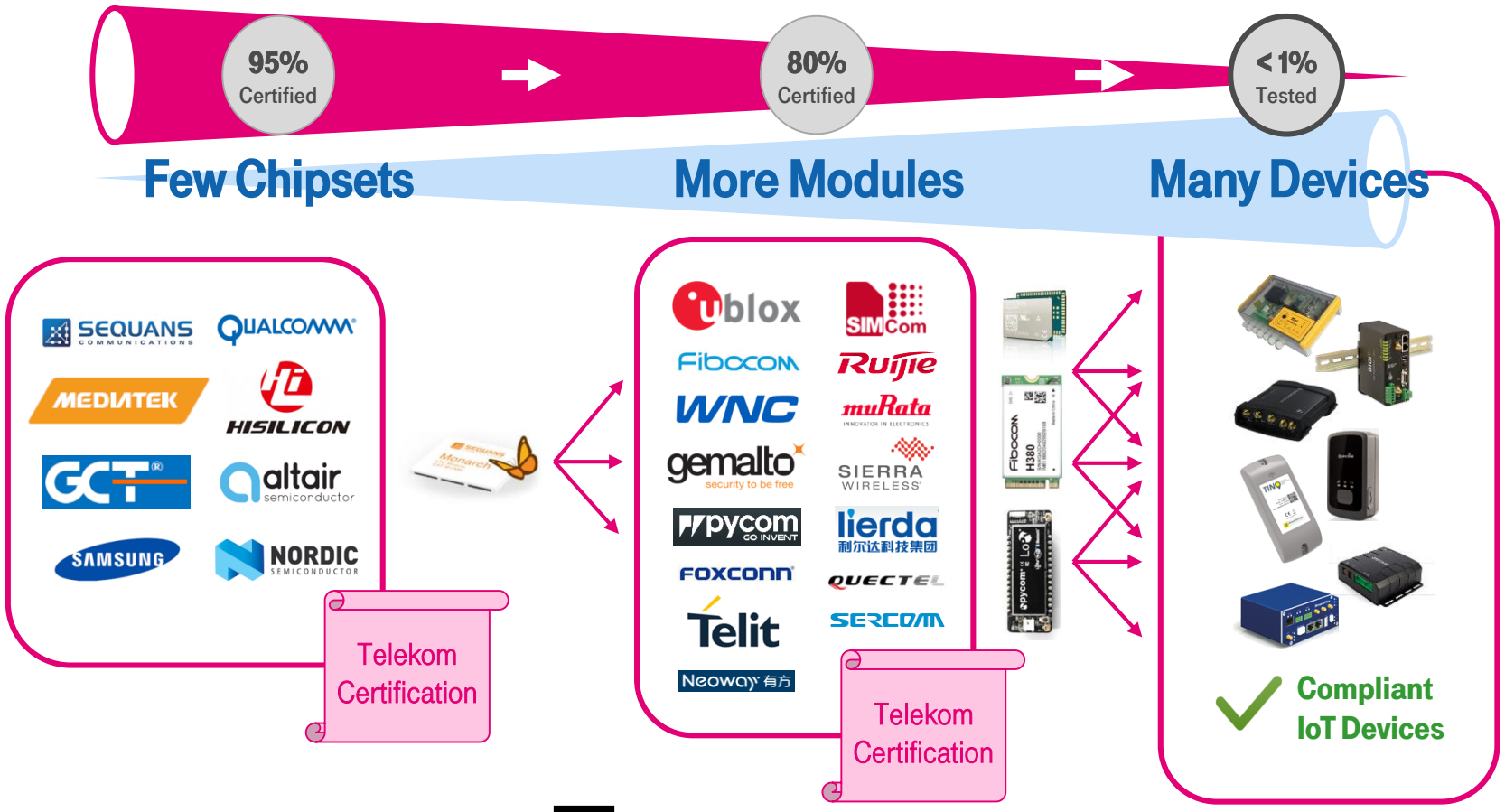
NB-IoT Chipset

- NB-IoT protocol stack
- Baseband chipset
- Frequency modulation
- **Vendors:** Altair, GCT, HiSilicon, MediaTek, Nordic Semiconductor, Qualcomm, Samsung, Sequans, etc.

CERTIFICATION HAS HALO EFFECT ACROSS VALUE CHAIN

Deutsche Telekom Certification Targets:

(IoT devices entering our networks)



Radio Access Interoperability Secured for most areas

Benefit of

TELEKOM IOT DEVICE CATALOG

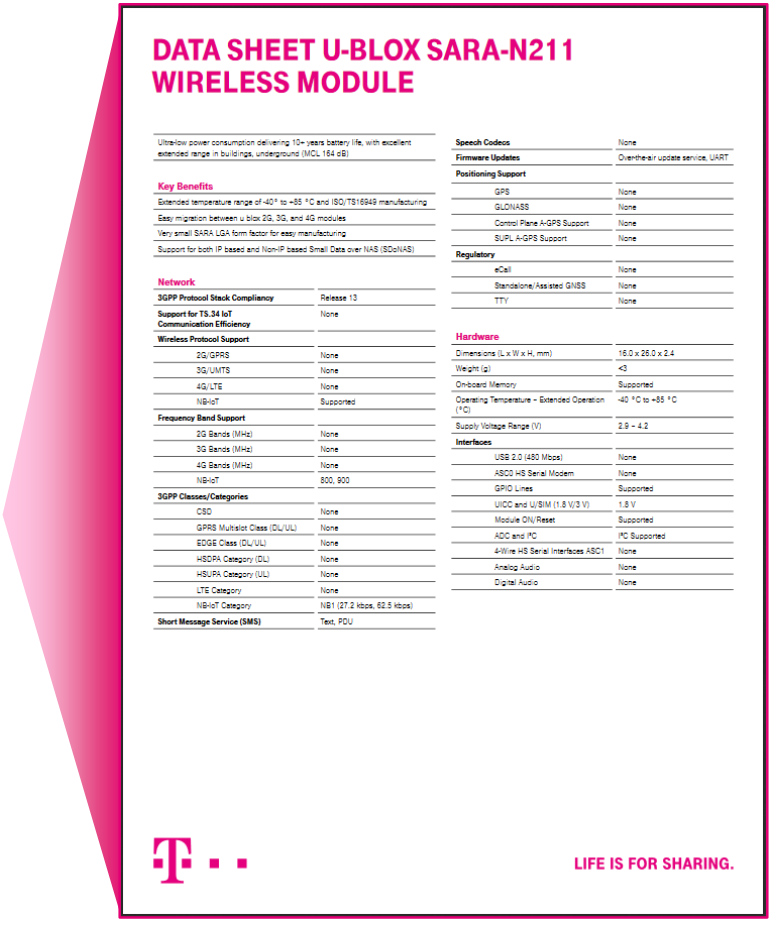
https://iot.telekom.com/produkte/hardware/

Product specifications and certification details shown for participating partners

Certified wireless modules

Always online: The certified modules from our best-of-breed partners can keep your vehicles and machinery constantly connected to the Internet of Things. We offer quality connections appropriate for any application, including 3G, LTE and innovative networking standards like NarrowBand IoT – or a combination of them!

- GEMALTO
- QUECTEL
- SIERRA WIRELESS
- TELIT
- U-BLOX
  - NarrowBand IoT:
    - SARA-N200
    - SARA-N210
    - SARA-N211
- SIMCOM



DATA SHEET U-BLOX SARA-N211
WIRELESS MODULE

Ultra-low power consumption delivering 10+ years battery life, with excellent extended range in buildings, underground (MCL 164 dB)

Key Benefits

- Extended temperature range of -40° to +85 °C and ISO/TS16949 manufacturing
- Easy migration between u-blox 2G, 3G, and 4G modules
- Very small SARA LGA form factor for easy manufacturing
- Support for both IP based and Non-IP based Small Data over NAS (SDoNAS)

Network

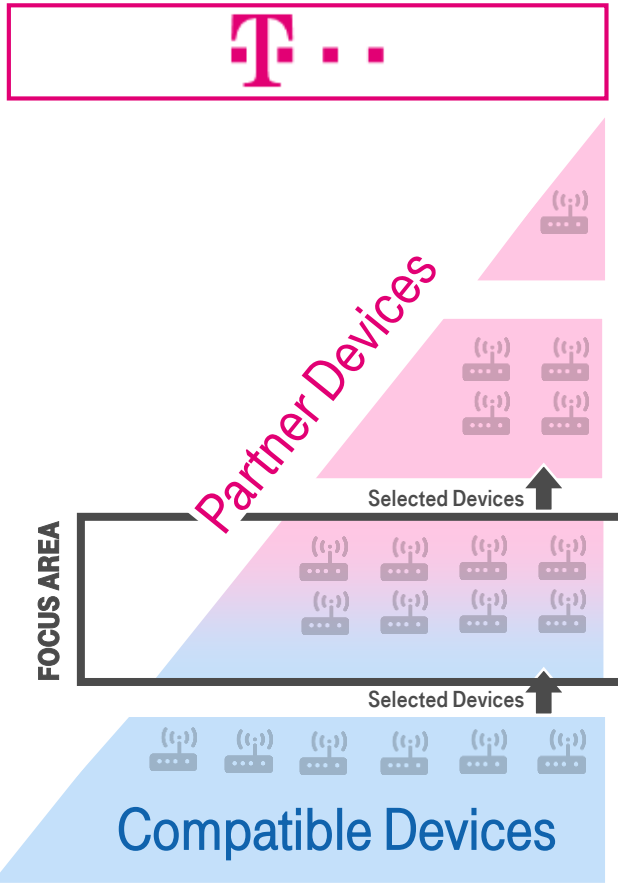
3GPP Protocol Stack Compliancy	Release 13
Support for TS.34 IoT Communication Efficiency	None
Wireless Protocol Support	
2G/GPRS	None
3G/UMTS	None
4G/LTE	None
NB-IoT	Supported
Frequency Band Support	
2G Bands (MHz)	None
3G Bands (MHz)	None
4G Bands (MHz)	None
NB-IoT	800, 900
3GPP Classes/Categories	
CSD	None
GPRS Multislot Class (DL/UL)	None
EDGE Class (DL/UL)	None
HSDPA Category (DL)	None
HSUPA Category (UL)	None
LTE Category	None
NB-IoT Category	NB1 (27.2 kbps, 62.5 kbps)
Short Message Service (SMS)	Text, PDU
Speech Codecs	None
Firmware Updates	Over-the-air update service, UART
Positioning Support	
GPS	None
GLONASS	None
Control Plane A-GPS Support	None
SUPL A-GPS Support	None
Regulatory	
eCall	None
Standalone/Assisted GNSS	None
TTY	None

Hardware

Dimensions (L x W x H, mm)	16.0 x 26.0 x 2.4
Weight (g)	<3
On-board Memory	Supported
Operating Temperature - Extended Operation (°C)	-40 °C to +85 °C
Supply Voltage Range (V)	2.9 – 4.2
Interfaces	
USB 2.0 (480 Mbps)	None
ASC0 HS Serial Modem	None
GPIO Lines	Supported
UICC and U/SIM (1.8 V/3 V)	1.8 V
Module ON/Reset	Supported
ADC and I²C	I²C Supported
4-Wire HS Serial Interfaces ASC1	None
Analog Audio	None
Digital Audio	None

LIFE IS FOR SHARING.

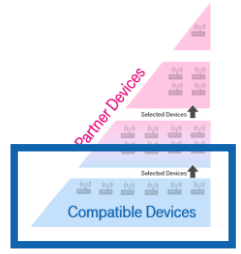
CLASSIFICATION OF IOT DEVICE SUPPLIERS IN FOUR PARTNERSHIP CATEGORIES



Partnership Level	Estimated Sales Volume / Device	Volume Commitment	Customization	Commission / Rebate	Integration Support	Service Level Agreement
★★★★ New Product Development	Very high	✓	✓	✓	✓	✓
★★★ Frame Contract	High	✓	✓ For strategic deals	✓	✓	✓
★★ Cooperation Agreement	Medium	–	✓ Possible, if needed	✓	✓	✓
★ Marketing Agreement	Small	–	–	–	✓	–

IOT DEVICE CATALOG QUALIFICATION PROCESS
- COMPATIBLE DEVICES -

Onboarding of new suppliers follows an agile, self-certification process



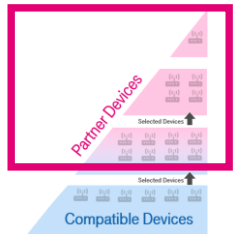
SUPPLIER

1. Download **Telekom IoT Platform API** and application document
2. Send application document to m2m-hardware-support@telekom.de
3. Check Application
   - OK → 4
4. Provide account, templates and test documentation
5. Implement API, provide test report and contract
6. Check Documentation
   - OK → 7
7. Add device to HW partner database (NEW)
8. Check Sales Potential
   - Low → ★ Marketing agreement
   - High → Next Slide

Use badge: "**Compatible with** Telekom Connected Things Management"

Lean Self-certification Process

IOT DEVICE CATALOG QUALIFICATION PROCESS
- PREFERRED DEVICES -



Certified chipsets and modules can be fast-tracked through “Preferred Devices” process

Interested?
iot-device-support@telekom.de

T - - Integration & Validation

Partner Device Validation

Chipset / Module

Telekom Certification

Hardware Verification

ok

Security & DM Verification

ok

No Critical Issues

High-volume products must enforce GSMA TS.34 “No Harm to Network”

GSMA

Previous Slide

T - -

High sales potential

Trigger **Partner Device Process**

★ ★
Cooperation agreement
Listing in device portfolio

★ ★ ★
Frame contract
Listing as “preferred device” in device portfolio

GSMA TS.34 BACKGROUND: NO HARM TO NETWORK

GSMA TS.34

IoT DEVICE CONNECTION EFFICIENCY GUIDELINES (v5)

SERVICE LAYER	**M2M SERVICE OPTIMIZATION** MSO (ANNEX G)
MODULE	**NETWORK FRIENDLY MODE** NFM (CHAPTER 7)
CHIPSET	**RADIO POLICY MANAGER** RPM (CHAPTER 8)

Many IoT Applications are inefficiently implemented, leading to poor communication patterns and signaling storms, threatening operator networks and partner service platforms

A repeat of the "Smartphone Challenge" must be avoided!

Operator Policy Controller on IoT Platform interacts with **OEM Module Policy Enforcement Engine** to define/adapt application communication pattern

Telekom trial with Sierra Wireless

(IoT "future-proof")

Module Vendor Application restricts mass-scale simultaneous registrations, PDP Context Activations, MO-SMS, re-attempts

Operator SIM-controlled feature limits signaling events per hour:

- Max. number of chipset resets
- Max. number of PDP Activation Requests
- Max. number of PDP (De-)activation Requests

Implemented by most chipset suppliers for 2G/3G/LTE

Enabled via TS.34 SIM Card fields or AT-commands

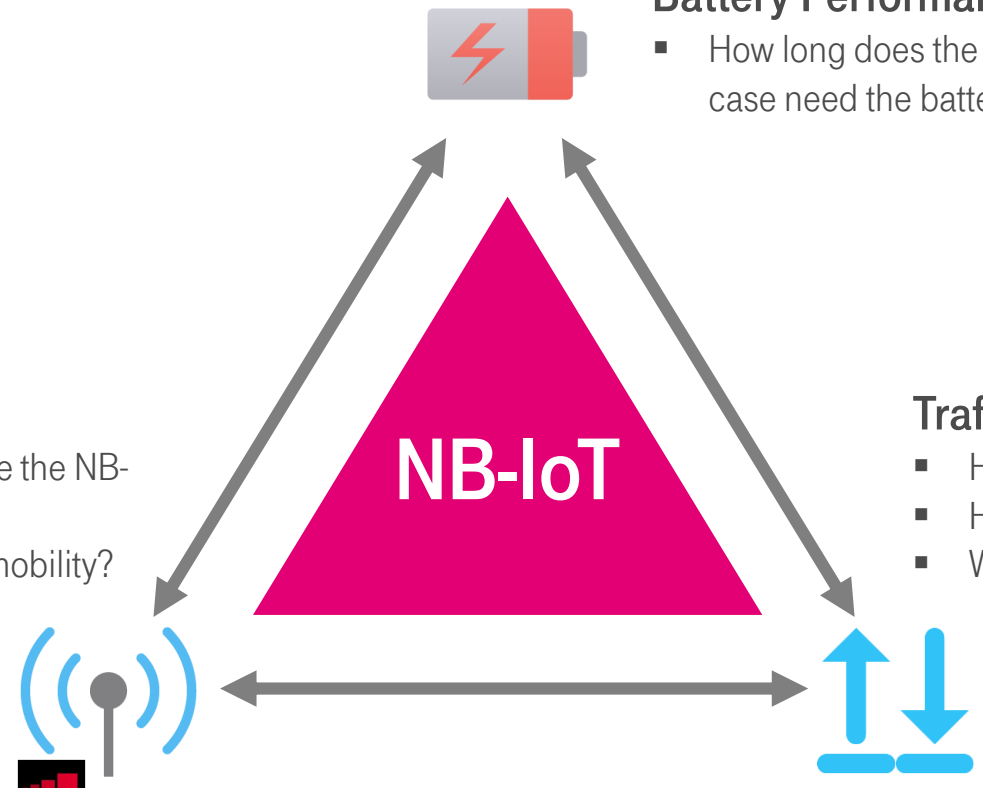
Telekom intro for NB-IoT underway

CUSTOM-TAILORED IOT APPLICATIONS NEEDED

NB-IoT applications must be optimized to secure or balance out your use-case needs

Example when10-year battery life is not possible:

- Medium-size battery
- Permanently in CE-Level 2
- Sending large payloads
- 100 messages per day



Battery Performance

- How long does the business case need the battery to last?

Coverage, Mobility

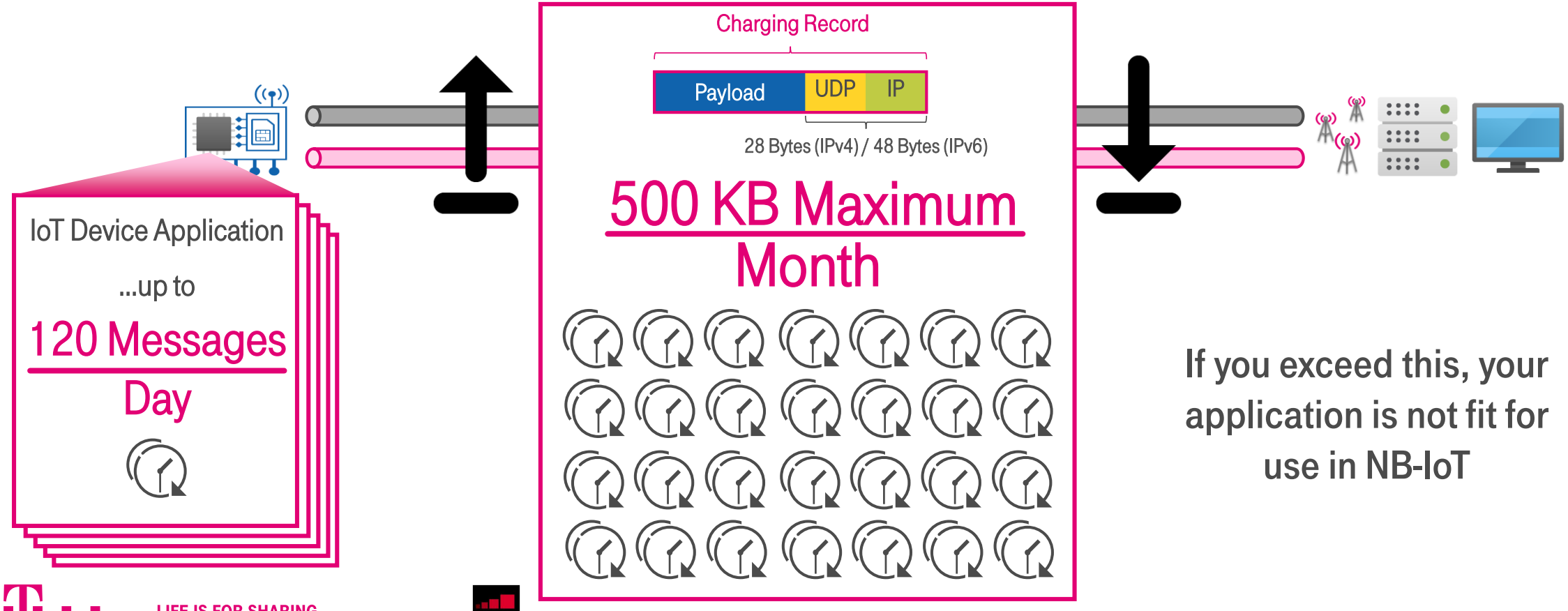
- What is the percentage of the time the NB-IoT device is in deep coverage?
- Is there a regular re-scan due to mobility?

Traffic Profile

- How often are Uplink reports sent?
- How large is the average payload?
- Will there be regular firmware updates?

TRAFFIC PROFILE “RULES OF THUMB”...

NB-IoT offers lean, optimized communication through a “thin pipe”...
Both technology and communication patterns must be dimensioned accordingly.



If you exceed this, your application is not fit for use in NB-IoT

POWER SAVING FEATURES USAGE

The more often IoT Applications interrupt power saving features, the less efficient they become...

Apply these features according to the specific use-case... more is not better!

	Long Periodic TAU	Enhanced DRX	Power Saving Mode	Early Release Assistance*
Uplink-Centric Application				
▪ **Very Regular Reporting** (e.g. Smart Parking)	Beneficial if reporting interval > 186 min	✗	✓	✓
▪ **Regular Reporting** (e.g. Hourly Climate Report)		✗	✓	✓
▪ **Irregular Reporting** (e.g. Smart Metering)		✗	✓	✓
Downlink-Centric Application				
▪ **Very Regular Reporting** (e.g. Access Control)	Beneficial if reporting interval > 186 min	✗	✗	✗
▪ **Regular Reporting** (e.g. Ventilation Actuator)		✓	✗	✓
▪ **Irregular Reporting** (e.g. Irrigation Actuator)		✓	✓	✓

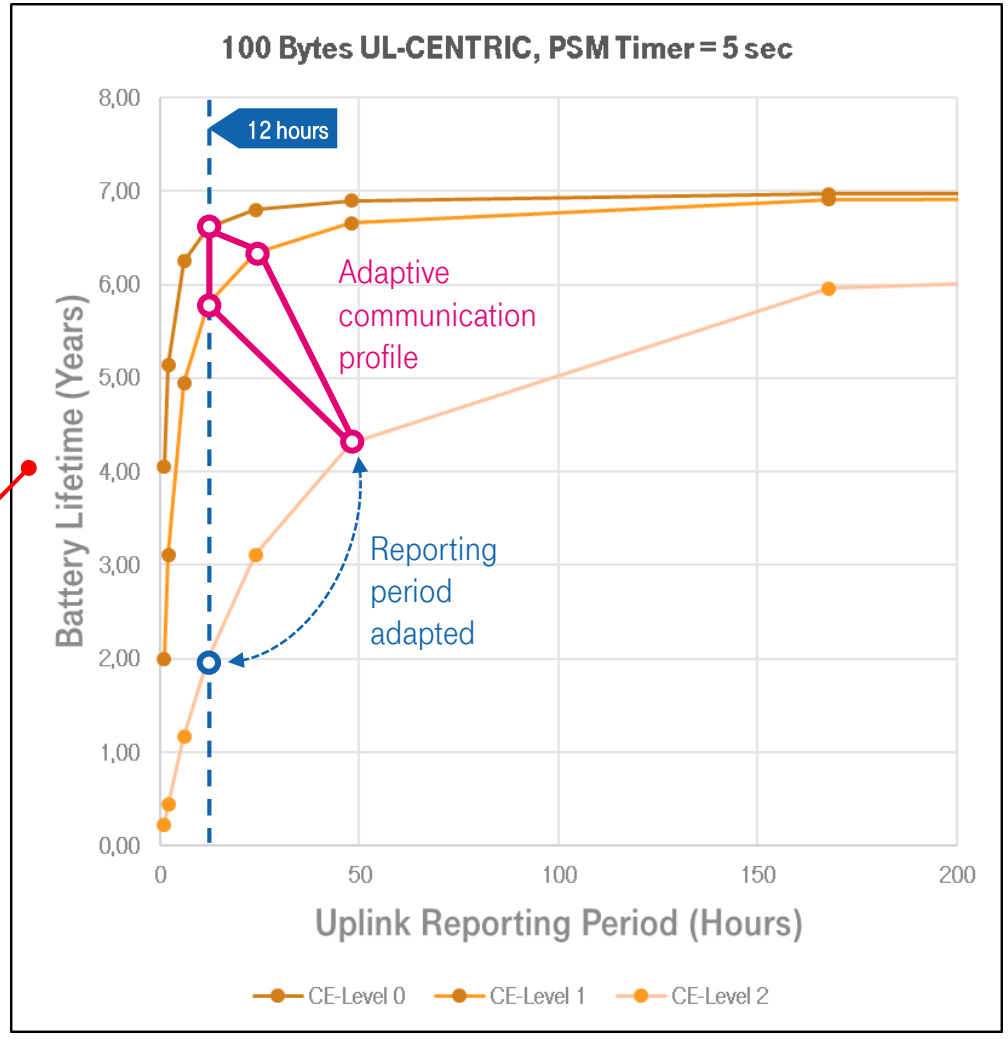
*Critical feature in case other operators' networks do not activate Connected Mode DRX

ADAPTIVE COMMUNICATION PROFILES

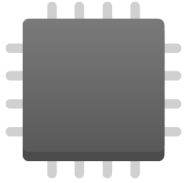
It is recommended to make the device application **adaptable**, extending or reducing uplink reporting periods based on measured coverage conditions

This extends battery life, improving business case

Example Project
(Battery lifetime depends on multiple factors not shown here)



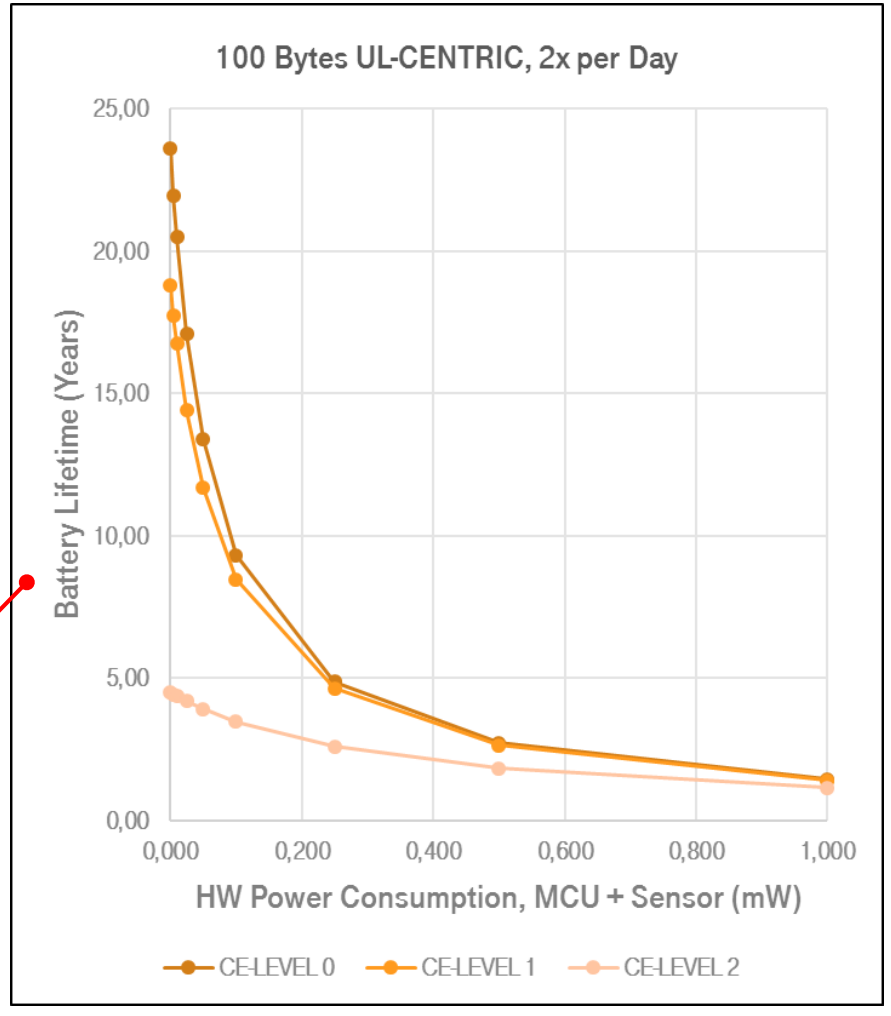
OPTIMIZING POWER LOSS: MCU, SENSORS, ACTUATORS



Even the average power consumption of MCU and sensor/actuator can impact battery lifetime...

Careful selection of suppliers and optimization of hardware design can result in a 20% efficiency gain in good coverage

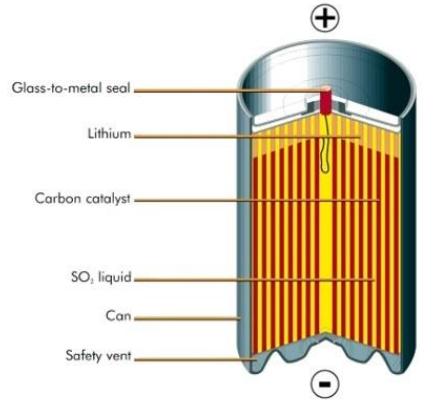
Example Project
(Battery lifetime depends on multiple factors not shown here)



*Non-IP Data Delivery, Uplink-centric

BATTERY SELECTION CAREFULLY MAPPED TO USE-CASE

Battery architecture and chemistry are critical to optimize for power...
Reliable battery suppliers can help you find the best-fitting battery technology



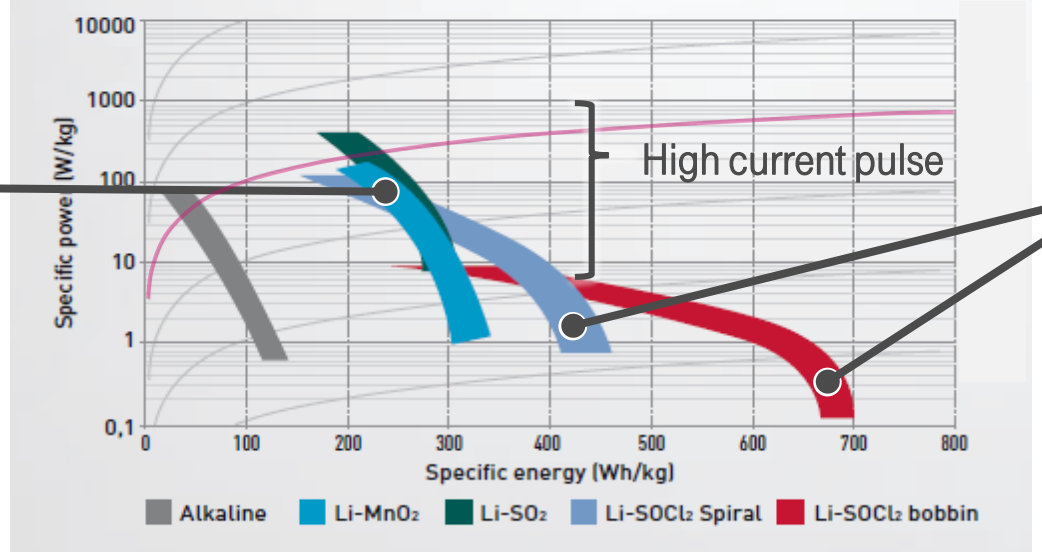
Spiral construction (LO, G)

Recommendation:
Spiral constructions deliver higher peak current, up to a few hundred mA

Saft Lithium Primary Technologies

www.saftbatteries.com

$Li\text{-}MnO_2$
Solid Cathode
3.0 V



$Li\text{-}SOCl_2$
Liquid Cathode
3.6 V

Lithium - Manganese Oxide

- Up to 15-year operating life
- -40°C to +70°C average
- Excellent voltage start-up from cold
- Optimized for 3.0V electronics

Spiral construction used:

- High current pulse (2 A to 12 A)

High energy density

Lithium - Thionyl Chloride

- Up to 20-year operating life (bobbin)
- -60°C to +85°C average
- High & low power applications
- Optimized for 3.6V electronics

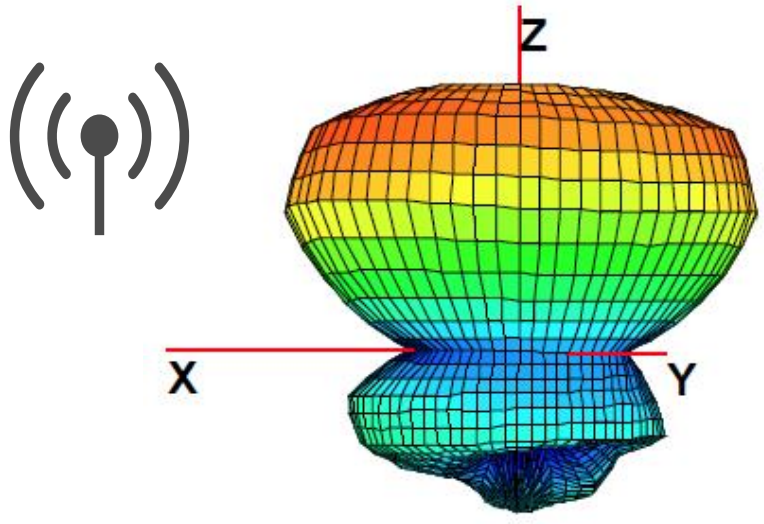
Two architectures available:

- Bobbin: current (0.1 A – 0.4 A)
- Spiral: current (2 A to 4 A)

AN OPTIMIZED ANTENNA DESIGN IS KEY

Antenna design is often underestimated; careful optimization is needed to secure optimal performance

Telekom is finalizing NB-IoT RF requirements & following industry standards for RF measurement definition



DESIGN TUNED TO FREQUENCY BANDS

PROPER RF DESIGN OF PCB (MATCHING)

ORIENTATION OF RADIATION PATTERN

BAND NUMBER	UPLINK FREQUENCY RANGE (MHZ)	DOWNLINK FREQUENCY RANGE (MHZ)	REGION
8	880 – 915	925 – 960	E-GSM: Europe, Asia
20	832 – 862	791 – 821	Europe, Middle East

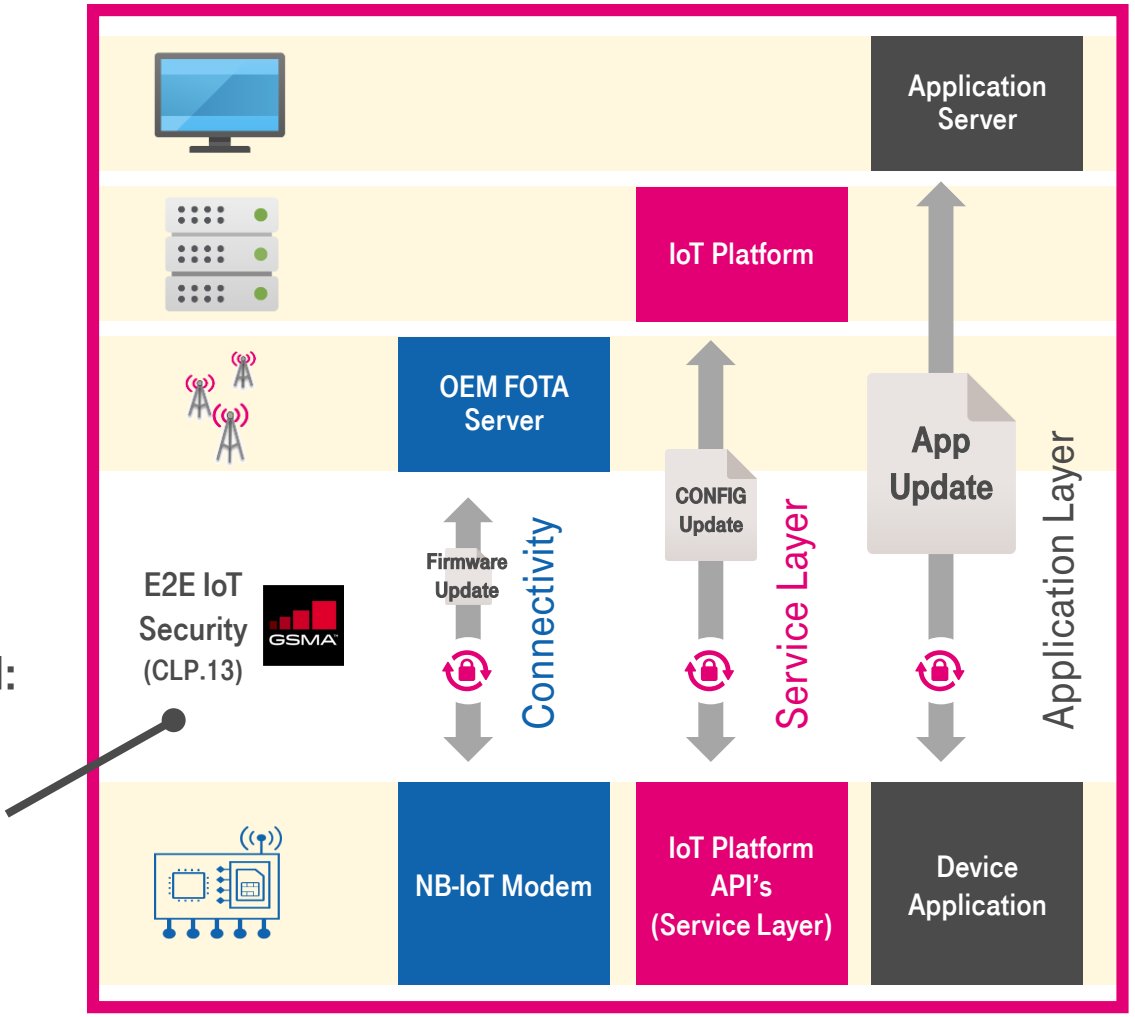
DEVICE MANAGEMENT (DM) KEEPS SOLUTIONS CURRENT

Solution layer updates are not monolithic:

- Interrupted updates can recover
- Avoid TCP/IP (due to overhead)

Implement best-practice DM:

- Secure transfer (DTLS or TLS)
- CRC check updates
- Verify cryptographic signature



Managing updates:

- Not pushed without Service Provider consent
- Devices updates throttled
- Maximum 2 yearly updates
- Leverage standardization: OMA LwM2M, oneM2M

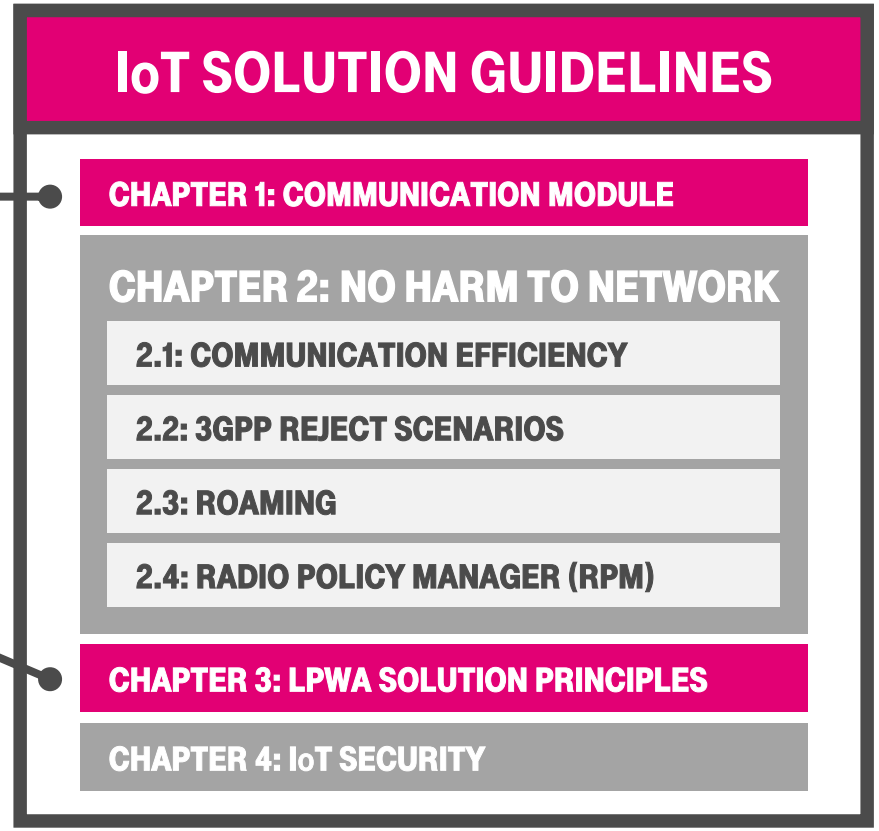
TELEKOM “IOT SOLUTION GUIDELINES”

We share our knowledge up-front, in the form of “best-practice” functional requirements...

Your success is our goal !

Communication Module
- Mobile Terminal Requirements (Technical)
- Chipset/Module Certification Requirements

NB-IoT Application Design Guidelines
- Interoperability (NB-IoT features)
- Power Consumption Optimization
- Special Consideration



TELEKOM “IOT SOLUTION GUIDELINES”

We share our knowledge up-front, in the form of “best-practice” functional requirements...

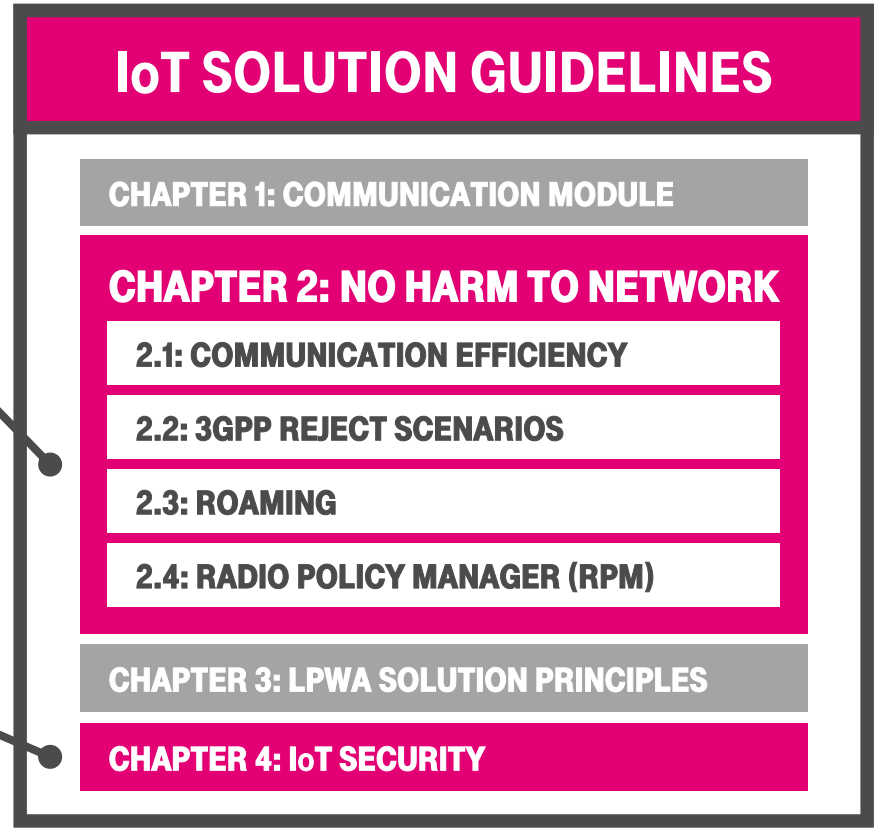
Your success is our goal !

GSMA TS.34 - IoT Connection Efficiency Guidelines

- Reviewed by Telekom core network experts vs. Telekom “lessons learned”
- Extended with Telekom-critical use cases

GSMA CLP.11 / CLP.13 - IoT Security Guidelines

- Reviewed by Telekom Device Security experts
- Added Telekom Embedded Security Requirements



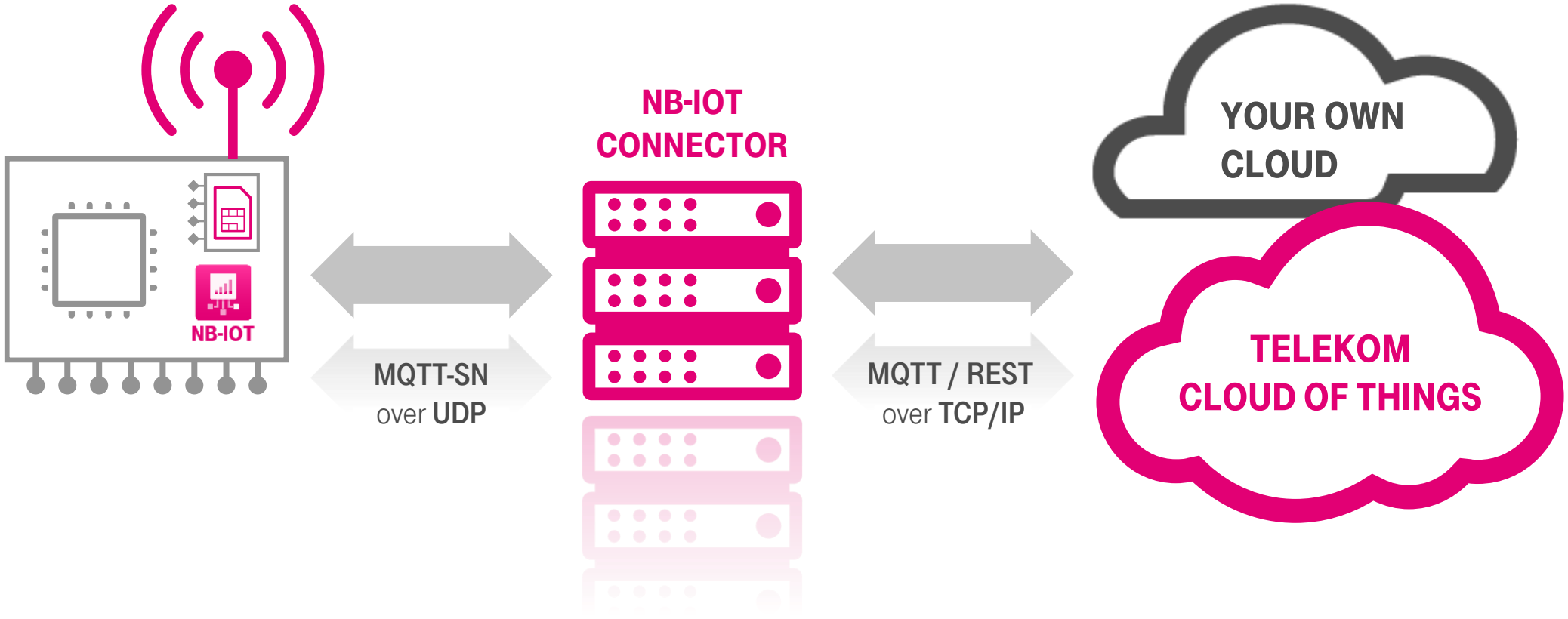
PART 02: DEPLOYING NB-IOT SOLUTIONS

Connecting to the Cloud

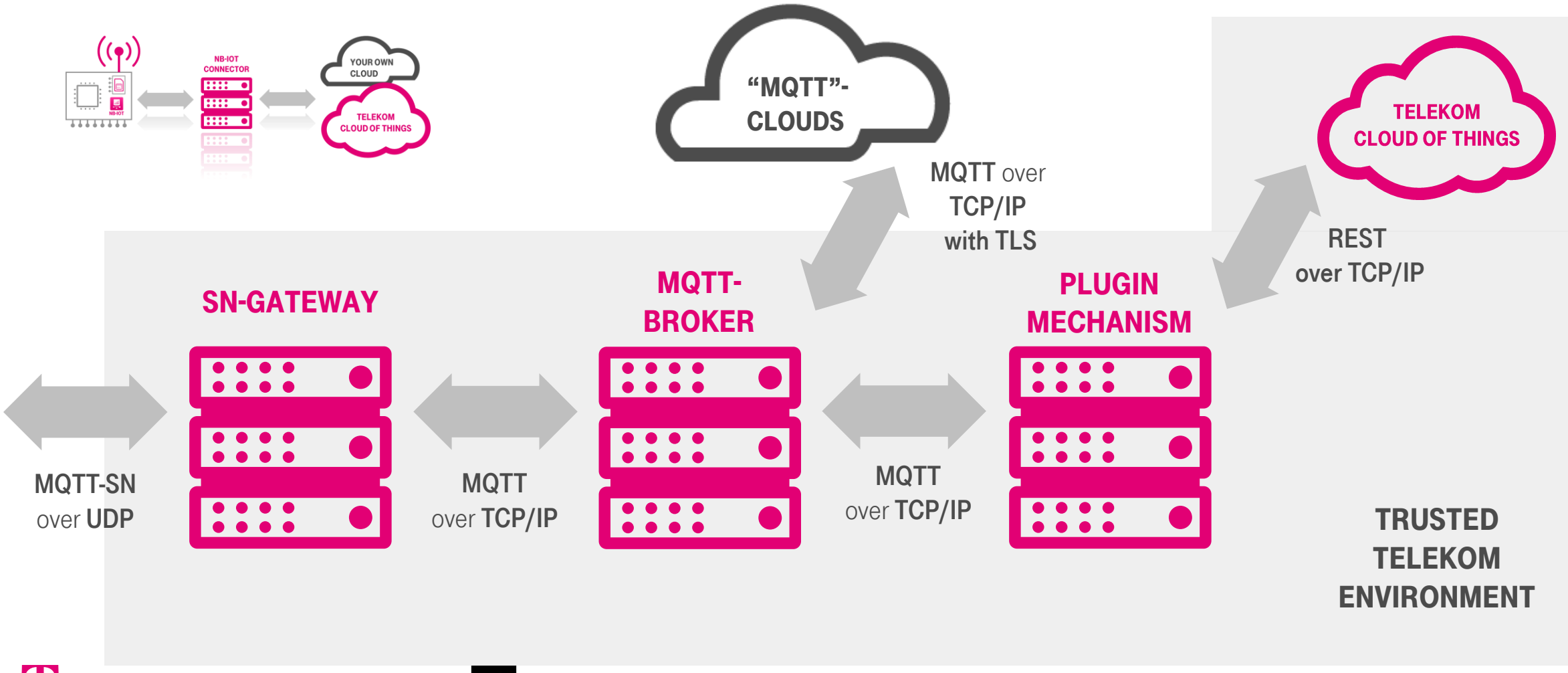
Protocol Aspects

Real World Examples

EDUCATED: ENVIRONMENT OF STANDARDS



NB-IOT CONNECTOR COMPONENTS



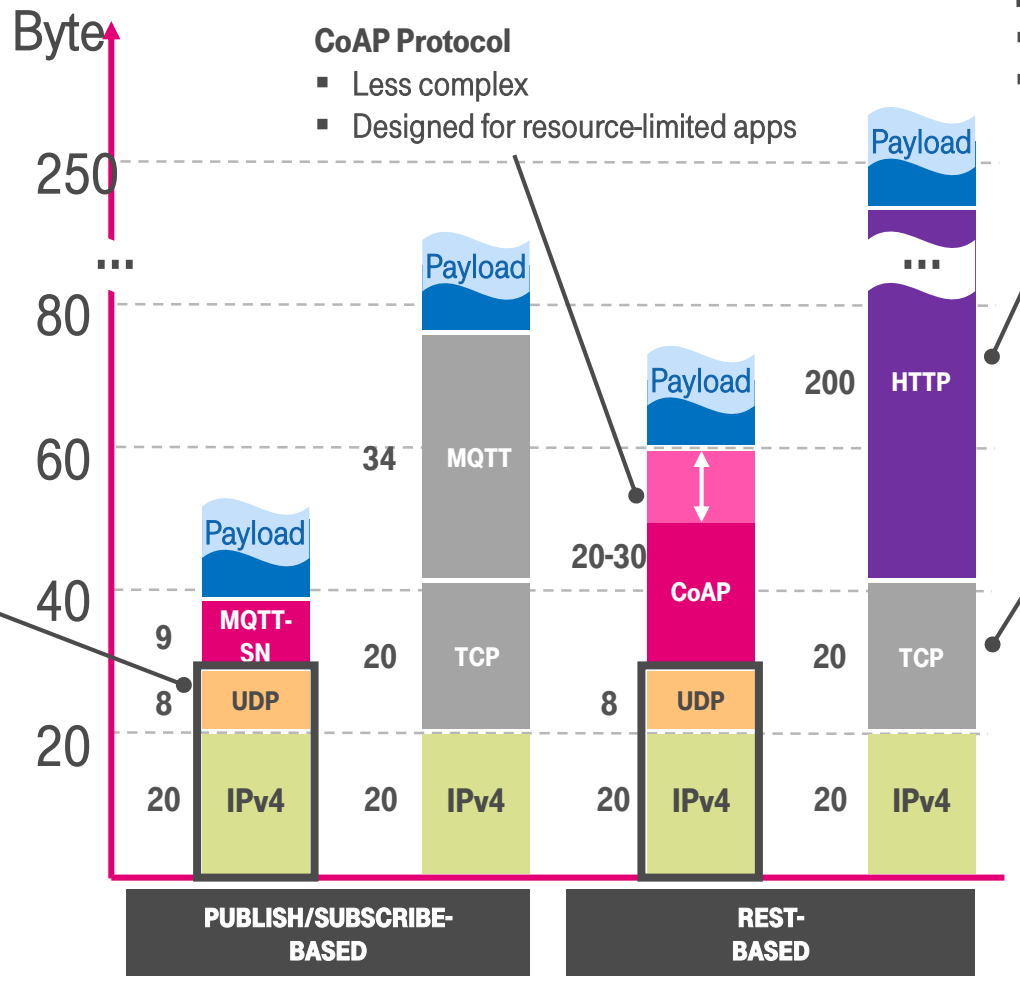
EXAMPLE PROTOCOL COMPARISONS

UDP Protocol
- Connectionless (no handshake)
- Lightweight transport layer design
- UDP/IP can be removed with NIDD

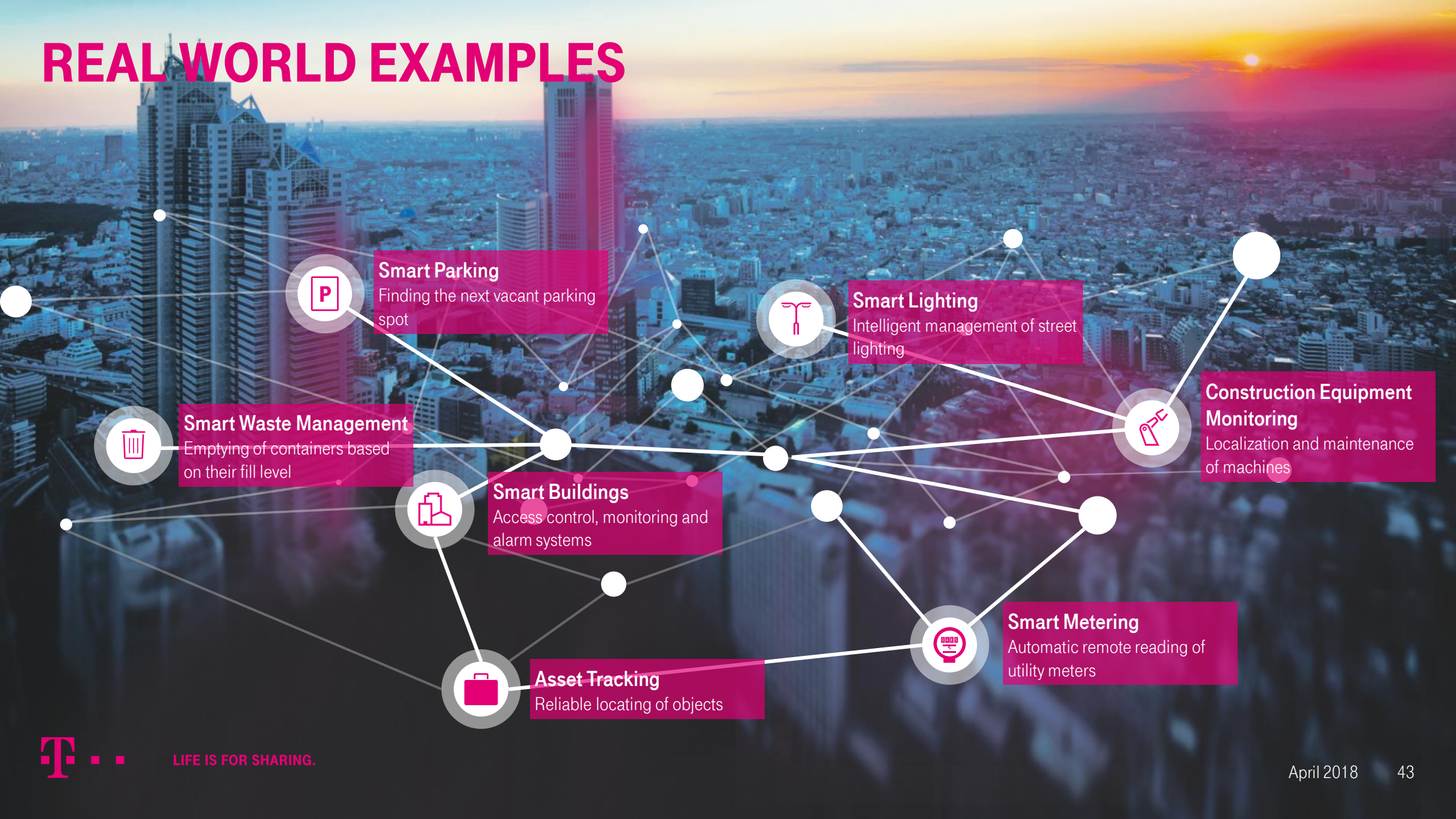
CoAP Protocol
- Less complex
- Designed for resource-limited apps

HTTP Protocol
- Synchronous communication
- More overhead & complexity

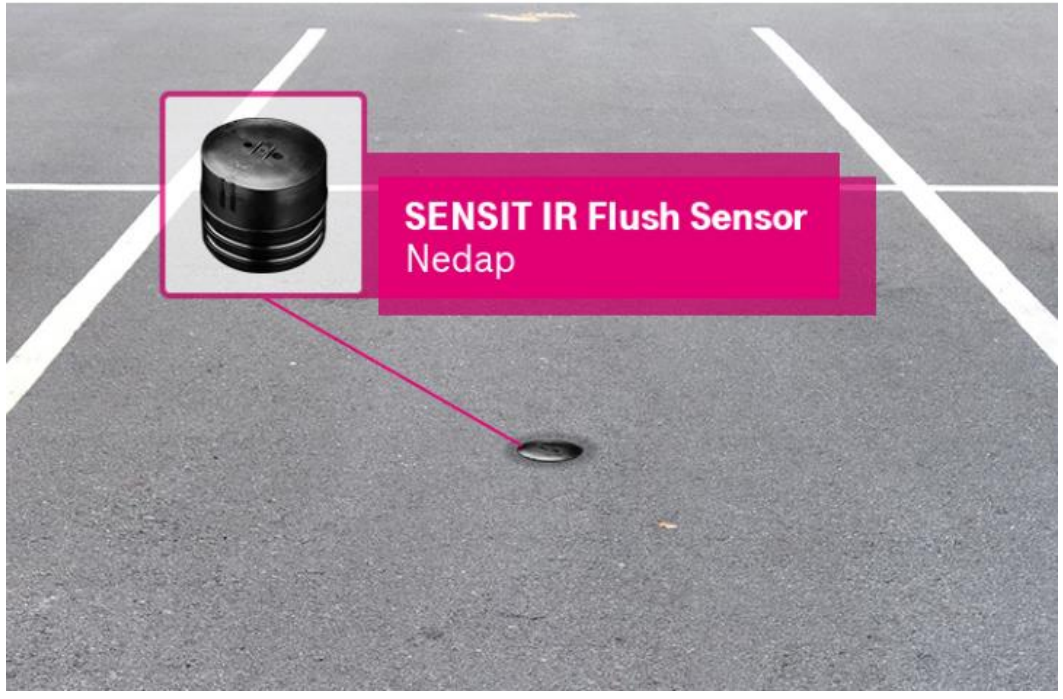
TCP Protocol
- Connection-oriented
- Heavyweight
- Several packets necessary for handshake

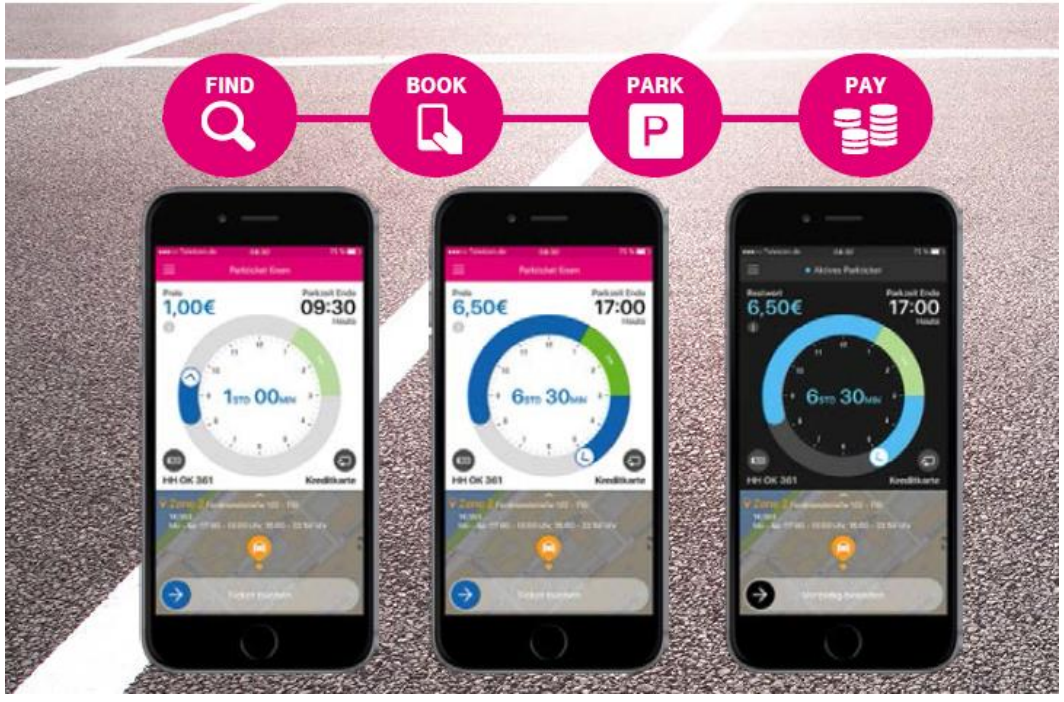


REAL WORLD EXAMPLES

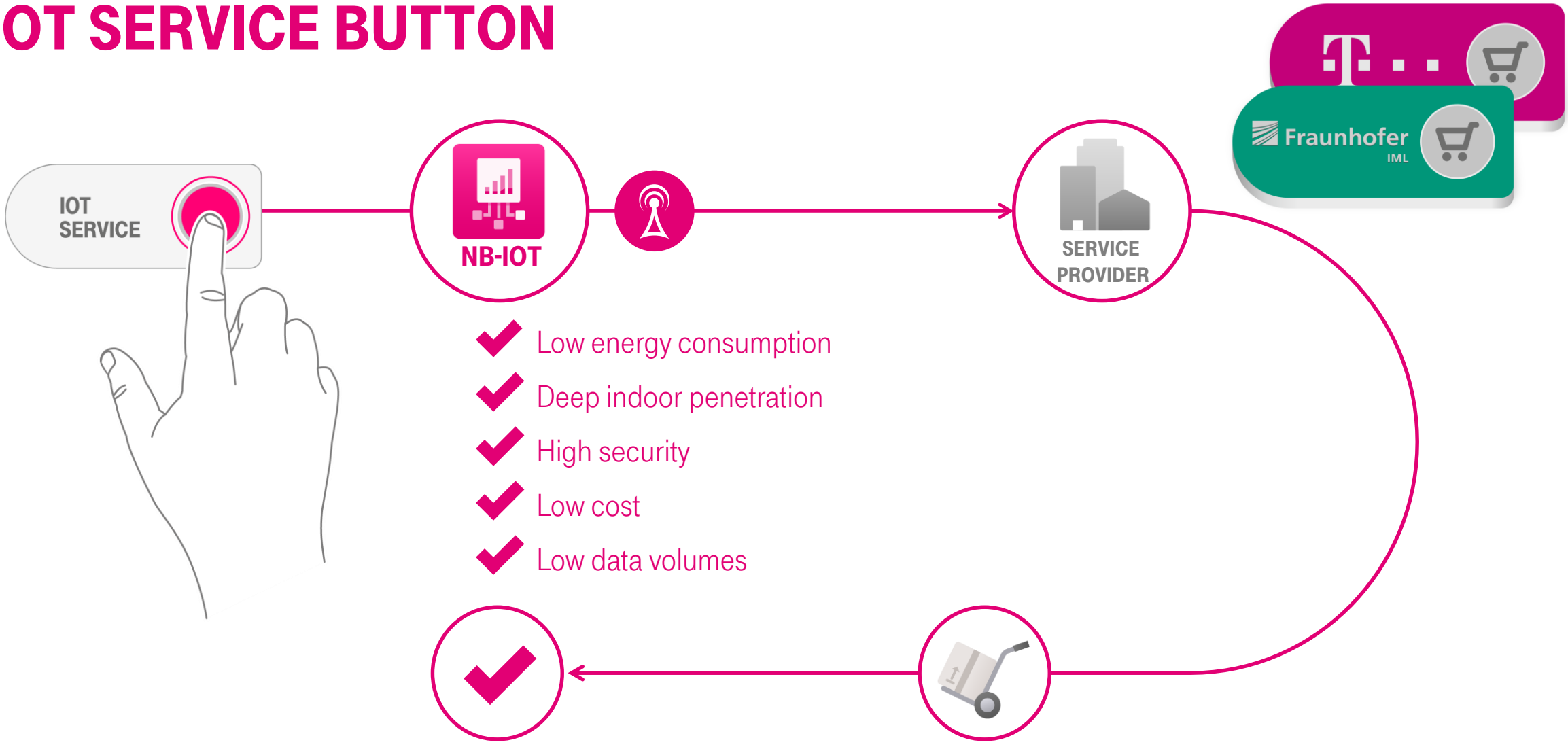


PARK & JOY


SENSIT IR Flush Sensor
Nedap


FIND
BOOK
PARK
PAY
1,00€
09:30
6,50€
17:00
6,50€
17:00

IOT SERVICE BUTTON



THANK YOU

ERLEBEN, WAS VERBINDET.