

3GPP TSG RAN Meeting #97e
Electronic Meeting, September 12-16, 2022

RP-222454

Document for: Discussion and Decision
Agenda Item: 9.1
Source: Huawei, HiSilicon

Motivation for a study on x-IoT

Background

- **Moderator's conclusion on x-IoT from pre-RAN#94e discussions is copied as follows [1]**

There is interest in further discussions in 3GPP on the category of IoT referred to in this discussion as passive IoT, occupying a segment below NB-IoT/eMTC in metrics such as power consumption and cost.

Further discussions in 3GPP should address how a potential study is organized within 3GPP considering the following areas/objectives

- Precise definitions for the ultra-low power consumption and ultra-low cost IoT devices of interest, i.e., targets for power consumption and cost
- Use cases of interest not captured elsewhere in 3GPP, e.g., identification, tracking, monitoring, actuating and sensing for applications in sectors such as logistics, transportation, healthcare etc.
- Scenarios of interest including public/private network, indoor/outdoor environment, macro/micro/pico cells, connectivity to gNBs/UEs with/without relay/UE assistance, traffic models, TDD/FDD and frequency bands (including whether both licensed and unlicensed spectrum should be considered)
- Existing solutions that address the use cases of interest (e.g., RFID)
- Determination of feasibility of use cases and scenarios
- Design targets including link budget, data rate, power consumption, cost, supported energy sources or energy harvesting techniques, connectivity requirements (e.g., connection to gNBs/UEs with/without relays and the targeted range), positioning accuracy etc. considering trade-offs, e.g., between coverage and power consumption.
- Coexistence with UEs and infrastructure in frequency bands for current 3GPP technologies

Background (cont.)

- **SA1 SID: Study on Ambient power-enabled Internet of Things**

This study is to support ambient power-enabled Internet of Things. The energy is provided through the harvesting of radio waves, light, motion, heat, or any other power source that could be seen suitable.

The objectives include:

- Study use cases of ambient power-enabled Internet of Things and identify potential service requirements, including:
 - Security aspects, e.g., authentication and authorization, etc.
 - Network selection, access control, connection, mobility and identification management
 - Charging (e.g., per data volume, per message)
 - Aspects related to stakeholder models (e.g., involving interactions in PLMNs, NPNs or other parties)
 - Positioning
 - Aspects on device life cycle management related to 3GPP system.
- Study traffic scenarios, device constraints (e.g., power consumption) and identify potential performance requirements and KPIs
- Gap analysis between the identified requirements for ambient power-enabled Internet of Things and what is already defined by existing 3GPP requirements.

Note 1: Specifics of how the device performs energy harvesting are not in the scope of the study.

Considerations on why 3GPP needs to start work on x-IoT

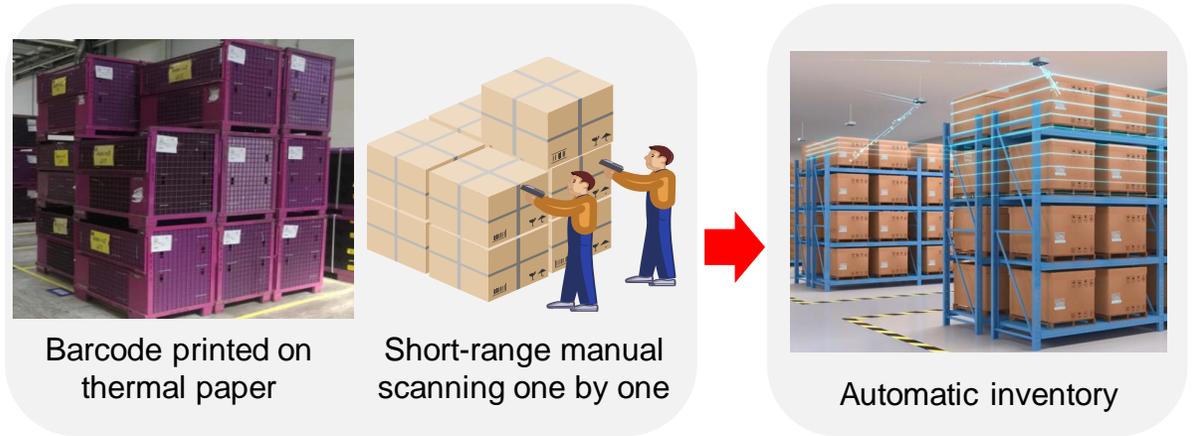
- Observations:
 - Asset tracking is a requirement in many industry sectors such as logistics and supply chain, manufacturing, agriculture, etc.
 - RFID is the primary technology on the market, and the number of RFID connections is expected to reach 49 billion by 2031
 - RFID has its merits (e.g. low cost, no need of battery) but also shortcomings (e.g. coverage, no operator control)
- Design targets for x-IoT :
 - Maintain the merits of existing RFID, i.e. the design of x-IoT shall enable extremely low complexity implementation and does not require battery for operation
 - Improve the link budget (coverage) compared to existing RFID technology, e.g. by exploiting features such as FEC, higher EIRP in operator licensed band compared to unlicensed ISM bands
 - Build up the intrinsic core network functions to manage and authenticate the x-IoT connections, enabling operators to build a business case out of it
- x-IoT is NOT to replace NB-IoT or eMTC
- x-IoT aims to enable massive numbers of connections – orders of magnitude higher than existing 3GPP IoT technologies

x-IoT targets at new low-end IoT markets requiring batteryless device

Typical use cases can be sorted into two categories, both of which require or prefer batteryless device.

Category 1: Pre-stored data report

- Information (e.g., identity) is pre-stored in a small size, ultra-low cost, and batteryless tag
- Typical use cases include object identification and tracking in industries such as logistics and supply chain, transportation, healthcare, etc.



Current: Barcode

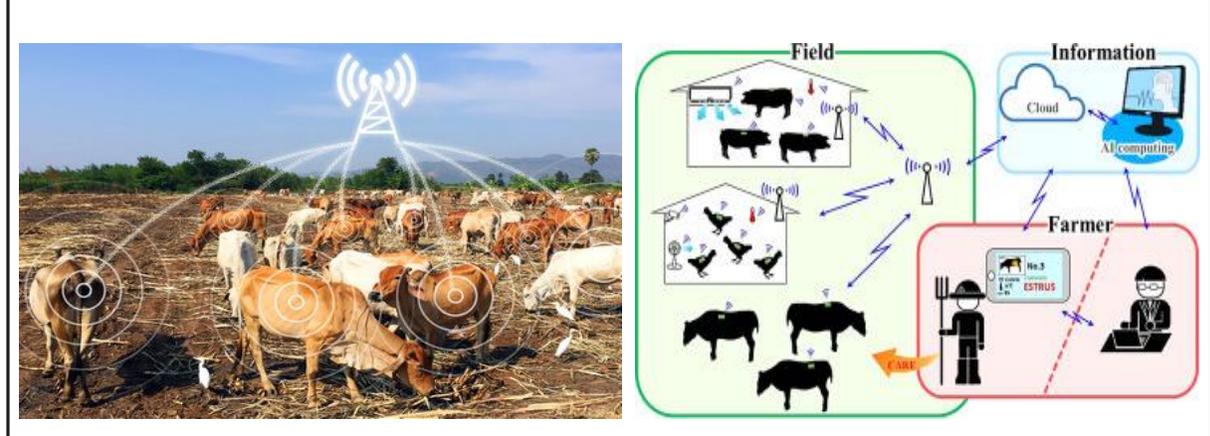
- No battery
- ultra-low cost & very small size
- Handheld LOS scanning (**labor intensive**)
- Slow one-by-one scanning (**time consuming**)

To be: x-IoT tag

- No battery
- ultra-low cost & very small size
- Automatic remote reading
- **Hundred times faster** reading

Category 2: Sensing data report

- Information (e.g., temperature) is generated and transmitted by wireless sensor without battery replacement during long lifetime
- Typical use cases include wireless sensor for environment, equipment, and living things monitoring in industries such as electric power, petroleum, livestock farming, manufacturing, etc.



Battery-operated device

- **Cost for batteries and replacement**
- **Increased device size**
- Infrequent transmissions for battery life
- Environmental issue (Lithium, lead, etc.)



Batteryless device

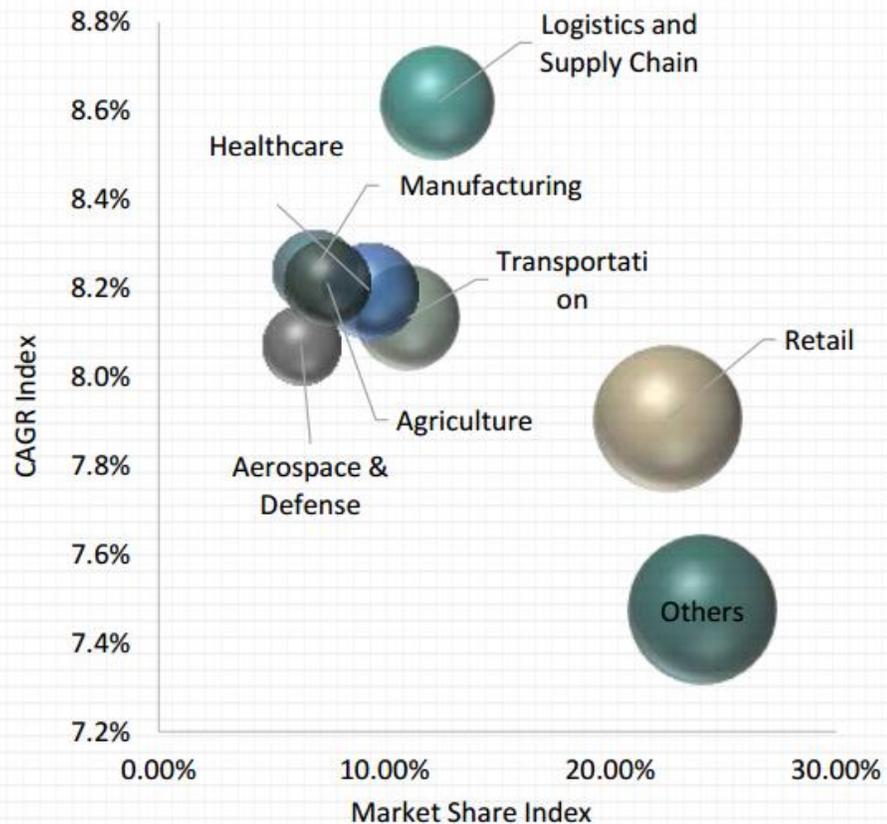
- Low maintenance cost
- Miniaturized device
- No limits on transmission period
- Environmental friendly



Different from all existing cellular technologies, x-IoT focuses on the support of ultra-low cost batteryless device.

Target Markets of x-IoT Requires Capabilities beyond RFID

Global RFID market analysis by end use industry



With **superior coverage** and **new functionalities**, such as sensing and positioning, x-IoT will be more attractive than RFID in the following markets

- Incremental market of some traditional industries
 - Logistics and supply chain, transportation, manufacturing, healthcare, agriculture, etc.
- New markets in industries requiring batteryless sensor urgently
 - energy (electricity/oil): battery-operated device are forbidden for safety reasons
 - livestock farming: low cost tag with thin and small form-factor

End User industry	Market volume in 2020 (Million unit)	Market volume in 2031 (Million unit)	CAGR (2021~2031)	Advantages of x-IoT			
				Coverage	Positioning	Sensing	Cost
Transportation	2042.3	5496.6	8.1%	✓	✓	✓	
Logistics and Supply Chain	2300.3	6501.9	8.6%	✓	✓		
Manufacturing	1276.7	3474	8.2%	✓	✓	✓	
Healthcare	1730.5	4687.8	8.2%	✓		✓	
Aerospace and Defense	1165.4	3115.7	8.1%				
Agriculture	1382.4	3750.9	8.2%	✓		✓	
Livestock farming	1281.3	3380.1	-	✓	✓	✓	
Energy (electricity/oil)	-	-	-	✓		✓	
Retail	4166.2	10956	7.9%				✓
Others(Sports, Advertisement, etc.)	4432.5	11155.7	7.5%				

- **Retail** gains the **largest share** in the global RFID market, which is cost sensitive
- Other industries enjoy **higher CAGR**, especially **logistics and supply chain**

[1] Global RFID Sensor Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2021-2031, Transparency Market Research, June 2021

Link Budget of UHF RFID is Insufficient for Practical Deployment

- **Theoretical link budget of commercial UHF RFID is as**
 - EIRP of signals should not exceed **36 dBm** in the ISM band for UHF RFID
 - The UHF RFID bands locate in 840~845 MHz or 865~869 MHz or 920-928 MHz in different countries and regions
 - Activation threshold of commercial passive RFID tag is mostly around **-20 dBm**
 - Optimal receiver sensitivity of existing commercial RFID reader is **-92 dBm** ^[1]
 - The receiver sensitivity is hard to be further improved due to the too simple transmission scheme defined by the protocol standardized in 2005

Downlink		Uplink		Unit
		Tag return loss	-8	dBc
<i>EIRP of downlink signal</i>	36			dBm
		<i>EIRP of reflected signal</i>	-28	dBm
		Reader antenna gain	6	dBi
Tag activation threshold	-20	Reader receiver sensitivity	-92	dBm
MCL	56	MCL	70	dB

Forward link MCL = Reader Tx EIRP - [Tag activation threshold](#)

Reverse Link MCL = [Tag activation threshold](#) + [Tag return Loss](#) + Reader antenna gain + Reader receiver sensitivity

- **In practice, coverage of a commercial RFID reader is less than 10 meters**
 - Some non-ideal issues will cause the loss of link budget
 - E.g., polarization mismatch between the antennas of reader and tag may cause 3 dB loss
 - **53 dB MCL** corresponds to a effective communication range of **<5 m** in InF-DL NLOS channel
- **Poor coverage of RFID leads to very dense deployment of readers**
 - As concluded in a GSMA report, “Implementation of the infrastructure requires significant disruption” for RFID trailed in a factory ^[2]

[1] IMPINJ R700 RAIN RFID READER DATASHEET

[2] 5G FOR SMART MANUFACTURING (GSMA report, April 2020)—INSIGHTS ON HOW 5G AND IOT CAN TRANSFORM INDUSTRY, PA Knowledge Limited, April 2020

x-IoT Network is controllable for MNO, while RFID is not

RFID architecture



EPC: Electronic Product Code

x-IoT architecture



EPCIS, RFID application layer

EPC Information service

x-IoT Service

x-IoT Service, application layer

Filtering & Collection

only simple operations, e.g. data management, Readers coordination

No Tag management!

Filtering & Collection

Tag management as 5GC function

- Tag authentication
- Tag billing and charging
- Support of mobility for outdoor usage

5GC

Reader, interacting with tag for Read/Write

Reader

NR, interacting with tag for Read/Write

NR

RFID Tag, containing EPC allocated by:

- EPC manager for global use case, or
- Vertical itself for local use case

EPC: 12345679ABCDEF
Tag

PIOT Tag, containing EPC allocated by:

- EPC manager for global use case, or
- Vertical itself for local use case

EPC: 12345679ABCDEF
Tag

RFID does NOT support tag management

x-IoT in 5G framework facilitates MNO management of tags

x-IoT Supports Low-Cost Batteryless Device with Proper Deployment

- **Ultra low power**

- Power consumption low enough to work with energy harvesting (**1~500 uW**)

- **Ultra low cost**

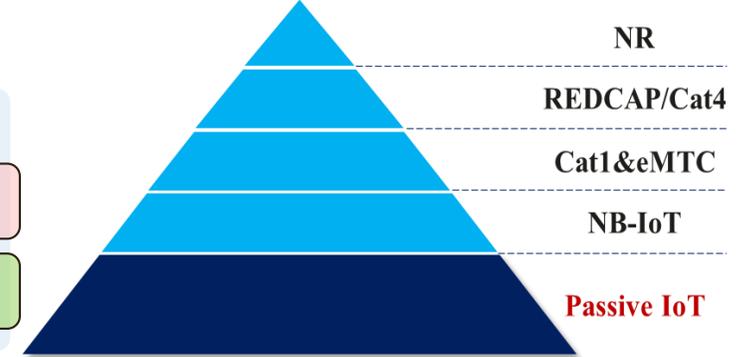
- For logistics management, no significant cost increase compared with barcode printed on heat sensitive paper (**0.01\$ level**)
- For wireless sensor, cost comparable with sensor itself (**0.1\$ level**)

- **Deployment: co-deployment with 5G network to achieve seamless coverage**

- Indoor small cell
 - **~30 m** between neighboring pico remote radio units
 - InF NLOS channel: ~70 dB
- Outdoor micro cell
 - **~200 m** between neighboring base stations
 - UMi NLOS channel: ~100 dB

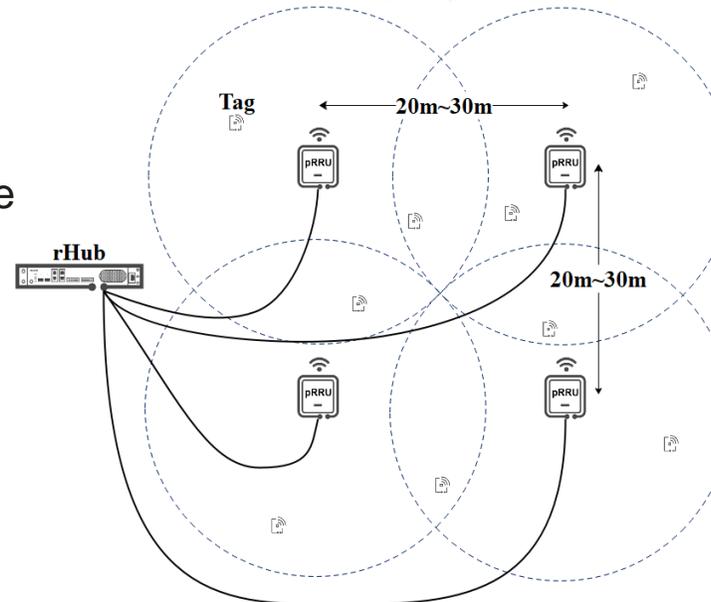
Targets on device

	Power	Cost
LPWAN	>10 mW	>1\$
x-IoT	1~500 uW	0.01~0.5\$

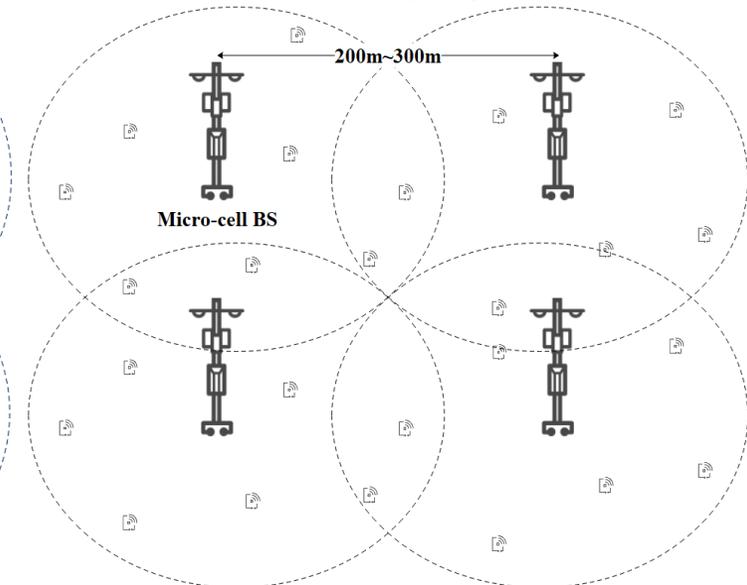


x-IoT targets at new IoT markets from all existing cellular technologies

Indoor deployment



Outdoor deployment



Proposal for the Study of x-IoT in Rel-18

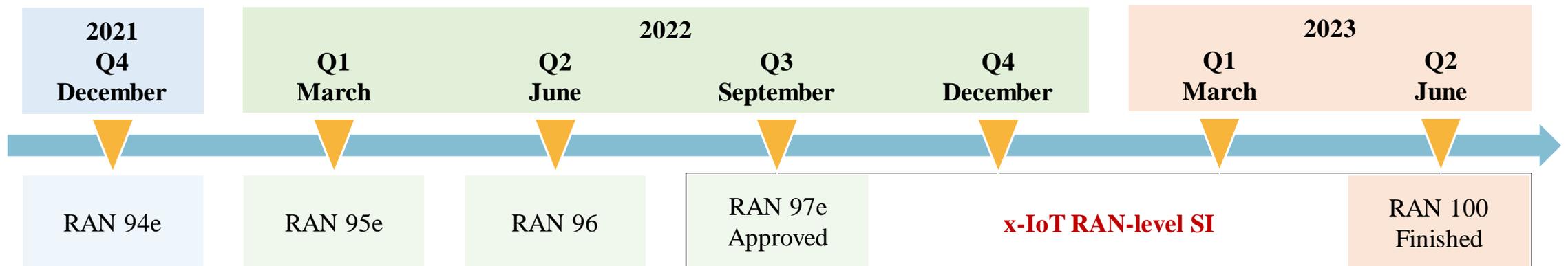
In the moderator summary of pre-meeting email discussion, it is proposed that “Further discussions in 3GPP should address how a potential study is organized within 3GPP”.

It is proposed to at least study x-IoT at RAN-level for Rel-18 and finish the design in Rel-19

- Urgent demand from the new IoT markets drives increasing research and investment of competitive non-3GPP technologies to supporting batteryless device.
- Once competing technologies grab the huge amount of connections, it will be difficult for cellular based technology (e.g. x-IoT) to regain the market share.
- Existing 3GPP technologies can hardly meet the requirements of ultra-low cost batteryless device.

Proposal: RAN#97e to discuss a timeline for establishing a x-IoT project, with a view to a Rel-18 SI based on the formulation identified in the pre-RAN#94-e email discussion final moderator’s summary.

Proposed timeline for the study of x-IoT in Rel-18



Proposed Objectives for the Study of x-IoT in Rel-18

This study targets at a new 3GPP IoT technology, suitable for cellular deployment, which relies on ultra-low complexity devices with ultra-low power consumption for the very-low end IoT applications. In terms of energy storage, the study will consider the following:

- Pure batteryless devices with no energy storage capability at all, and completely dependent on the availability of the ambient source of energy it is harvesting
- Devices with energy storage capability (e.g. up to that available from ambient sources via energy harvesting) that do not need to be replaced or recharged manually, and which can manage short periods of ambient energy unavailability.

Device characteristics other than energy storage are assumed to be investigated under the second objective below.

- Identify the suitable deployment scenarios and their characteristics, at least for the use cases/services agreed in SA1's "Study on Ambient power-enabled internet of Things", comprising among at least the following aspects
 - Indoor/outdoor environment
 - Basestation characteristics, e.g. macro/micro/pico cells-based deployments
 - Connectivity topologies, including which node(s) can be activator and/or reader, e.g. gNB, UE, relay, etc.
 - TDD/FDD, and frequency bands in licensed or unlicensed spectrum
 - Coexistence with UEs and infrastructure in frequency bands for existing 3GPP technologies
 - Mobile originated and/or mobile terminated traffic assumption

NOTE: There can be more than one deployment scenario identified for a use case, and a deployment scenario may be common to more than one use case.

NOTE: Where more than one deployment scenario is identified for a use case, the trade-offs between them should also be studied.

NOTE: The study shall not prioritize deployment aspects that should be coordinated with SA, e.g. public or private network, with or without CN connection.

- Formulate a set of RAN design targets based on the requirements from the relevant SA1's agreed use cases, at least including
 - Power consumption
 - Complexity
 - Coverage
 - Data rate
 - Positioning accuracy

NOTE: The study shall aim to provide better coverage compared to existing non-3GPP technologies for the relevant use cases.

- Compare and assess the feasibility of meeting the design targets for each agreed SA1 use case on the basis of the deployment scenario(s) appropriate to it, and identify assumptions on required functionality to be supported.

NOTE: This is not to require a detailed WG-level of analysis.

Note: This study shall target for an IoT segment well below the existing 3GPP IoT technologies, e.g. NB-IoT, eMTC, RedCap, etc. The study shall not aim to replace existing 3GPP LPWA technologies.

Thanks!