3GPP TSG RAN Meeting #98e
Electronic Meeting, December 12-16, 2022

RP-222929

Agenda item : 9.2.3

Source : Samsung

Title : Discussion on Ambient IoT

Document for : Discussion

SAMSUNG

Background | Objectives

This study targets at a new 3GPP IoT technology, suitable for deployment in a 3GPP system, which relies on ultra-low complexity devices with ultra-low power consumption for the very-low end IoT applications. The study shall provide clear differentiation, i.e. addressing use cases and scenarios that cannot otherwise be fulfilled based on existing 3GPP LPWA IoT technology e.g. NB-IoT including with reduced peak Tx power.

In terms of energy storage, the study will consider the following device characteristics:

- *Pure batteryless devices with no energy storage capability at all, and completely dependent on the availability of an external source of energy*
- *Devices with limited energy storage capability that do not need to be replaced or recharged manually.*

Device categorization based on corresponding characteristics (e.g. energy source, energy storage capability, passive/active transmission, etc.) may be discussed during the study, in relation with the relevant use cases. The device's peak power consumption shall be limited by its practical form factor for the intended use cases, and shall consider its energy source.

- *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) , e.g. basestation, UE, relay, repeater, etc. can communicate with target devices*
  - *TDD/FDD, and frequency bands in licensed or unlicensed spectrum*
  - *Coexistence with UEs and infrastructure in frequency bands for existing 3GPP technologies*
  - *Device originated and/or device 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.*
- *NOTE: A representative use case can be studied for a group of use cases that have similar requirements.*

- *Formulate a set of RAN design targets based on the identified deployment scenarios and their characteristics for the relevant use cases, at least including*
  - *Power consumption*
  - *Complexity*
  - *Coverage*
  - *Data rate*
  - *Positioning accuracy*
- *NOTE: The requirements from SA1 on the relevant use cases shall be taken into consideration.*
- *NOTE: The study shall aim to provide better coverage compared to existing non-3GPP technologies for the relevant use cases.*
- *NOTE: Other RAN design targets in relation to connection density, mobility, security, latency, reliability etc. may be discussed, if necessary for the relevant use cases.*
- *NOTE: Detailed definitions of the RAN design targets should be discussed during the study.*

- *Compare and assess the feasibility of meeting the design targets for relevant 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.

Device Characteristics

- In terms of energy storage, the study will consider the following device characteristics:
  - Pure batteryless devices with no energy storage capability at all, and completely dependent on the availability of an external source of energy (TYPE I)
  - Devices with limited energy storage capability that do not need to be replaced or recharged manually. (TYPE II)

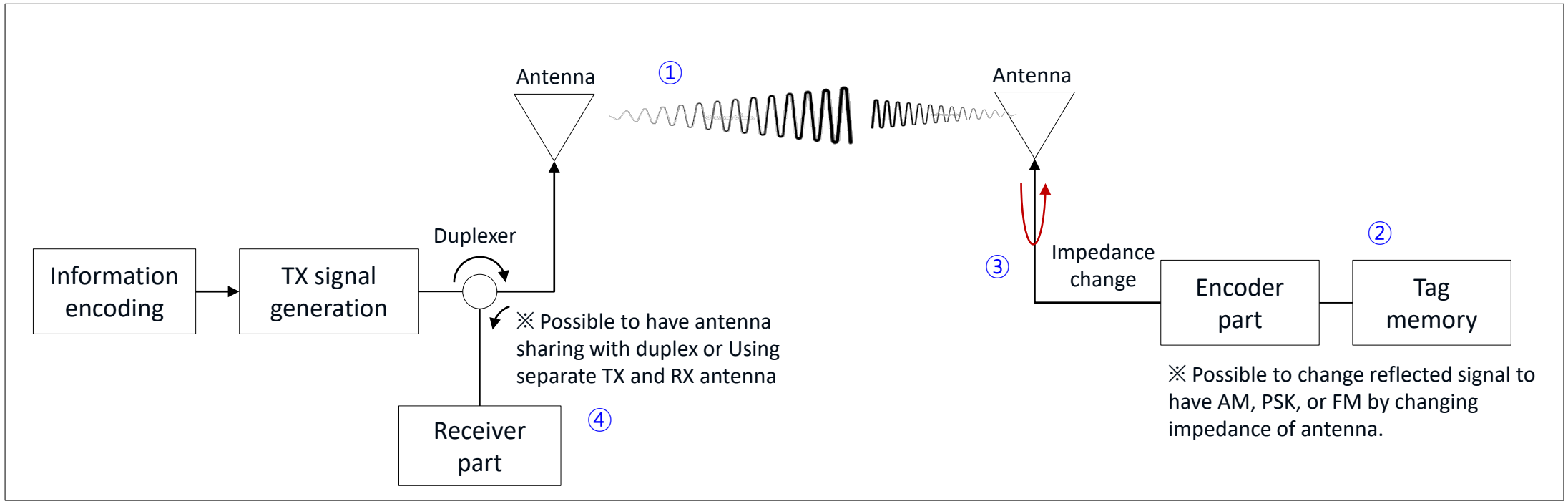
- Proposal 1: for device categorization including the corresponding characteristics (e.g., energy source, energy storage capability, passive/active transmission, etc.), the following two types should be included

AIoT device type	Energy source	Energy storage	Transmission	Available distance, use case	Packet size and contents	Latency	Capability
Type I	Reader TX power (Licensed)	No storage	Passive (backscatter)	[<10] m, indoor	Very small (<a few Bytes) and pre-defined information	Very short	RX/TX TX only
Type II	Reader TX power (licensed)+ other ambient power (unlicensed)	Super capacity or rechargeable battery	Active (low power TX)	[< 30 m, indoor] and [<100 m, outdoor]	Small (tens of Bytes) and sensor output	Long (1 sec – 2 mins per TX)	

  - FFS for transmission power, amount of storage, available distance

Device type | Type I

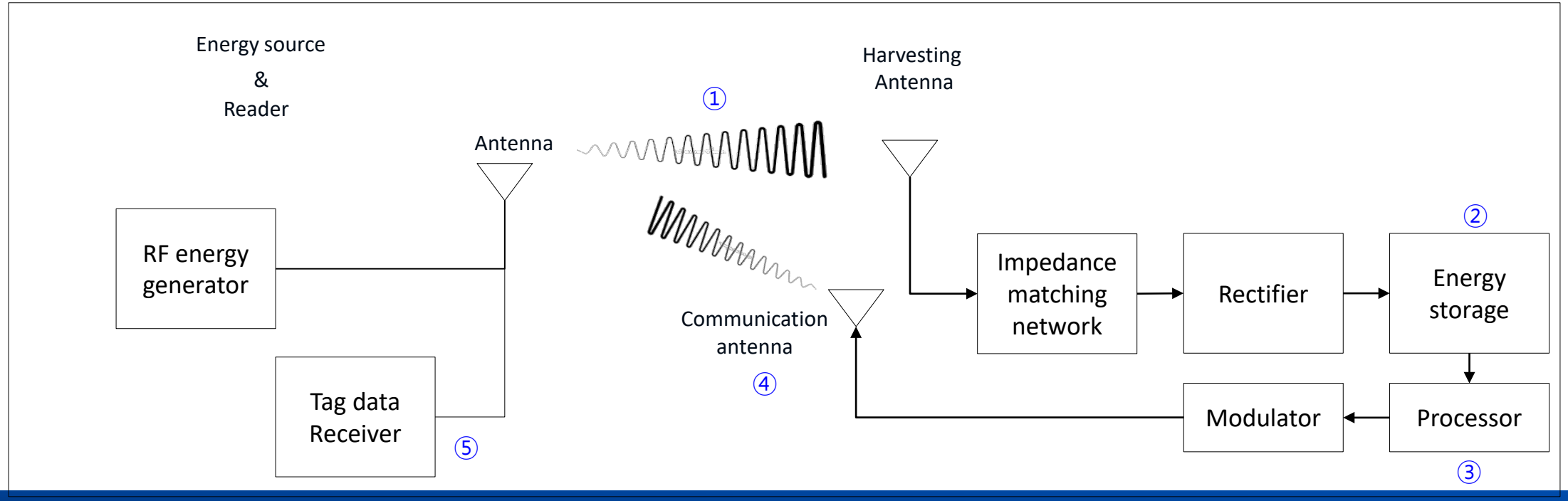
- Type I – passive type (Backscatter communications)
  - Tag wakes on reader's transmitting energy and tag reflects with information to the reader, for example
    - Step 1: from reader to Tag (send e.g., Pulse-Interval Encoded modulated signal)
    - Step 2: Tag wake up (use some of received power for wake)
    - Step 3: from Tag to reader (reflect energy by changing impedance of Tag antenna)
    - Step 4: reader received Tag data



Device type | Type II

Type II – Active type (RF energy harvesting based communications)

- Tag harvest RF energy and store in the tag until it has enough energy for wake up and send information when additional energy is charged for data transmission to reader, for example
  - Step 1: from reader to Tag (send harvest energy to readers or to everywhere)
  - Step 2: Tag harvest and charge e.g., super capacitor at tag until wake up
  - Step 3: Turn of processor at tag and generate Tx packet
  - Step 4: Send TX packet to reader and turn to sleep until enough energy is charged for the next packet
  - Step 5: Reader received tag data



Deployment scenarios

- Identify the suitable deployment scenarios and their characteristics,
  - For the use cases/services agreed in SA1's "Study on Ambient power-enabled internet of Things", for example

Use case for Ambient power enabled	Note
Automated warehousing	loading/unloading/inventory for moving objectives
Medical instrument inventory management and positioning	finding medical device
smart grids	Sensor report in factory
Non-public network for logistics	IoT in Private network
Intralogistics in automobile manufacturing	Logistic in car factory
IoT sensors in smart homes	Sensor report in smart home
Airport terminal / shipping port	Baggage tracking
Finding Remote Lost Item	Make other Ues to detect AIoT device

Use case for Ambient power enabled	Note
Ranging	Ranging
Online modification of medical instruments status	Update tag information
Personal belongings finding	Make gNB to find IoT device location
Base station machine room environment supervision	Sensor monitoring in machine room
Indoor positioning in shopping center	Indoor positioning
Smart Laundry	Auto inventory tracking
Automated supply distribution	Tracking mobility
Device activation and deactivation	Activate and deactive IoT device

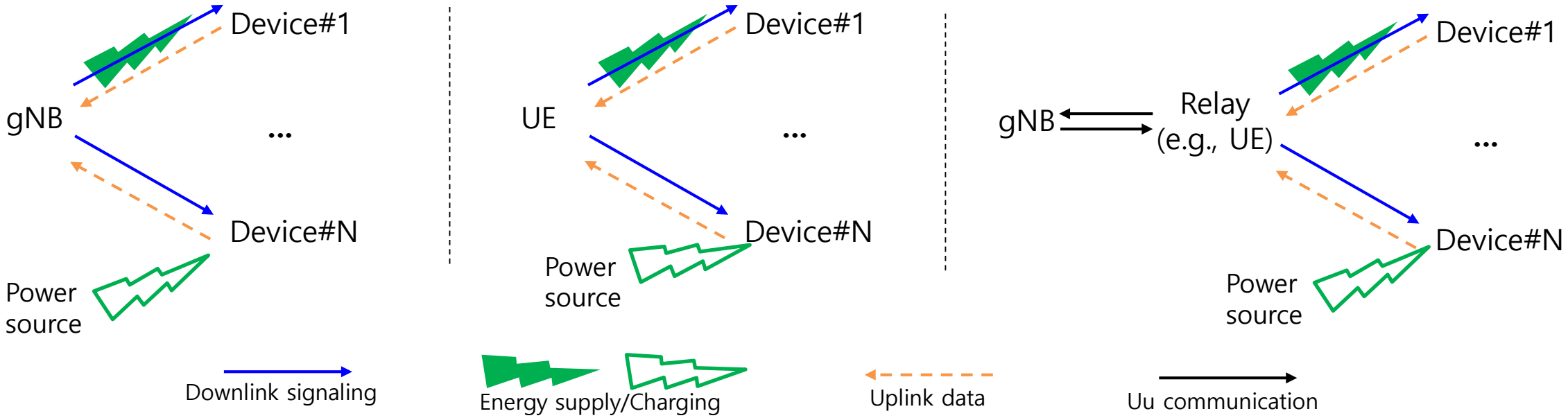
  - Based on use cases in SA1, general indoor and outdoor scenario can be considered with high priority
- Proposal 2: for deployment scenarios, both indoor and outdoor are included as follows

For both type I and II	Indoor/outdoor	Base station	Connectivity	Frequency band	Coexistence and interference	Traffic model	Topology
Deployment scenario A (indoor)	Indoor	Pico	sTRP, mTRP, UE (sidelink)	FDD (700 MHz, 2GHz) TDD (3.5 GHz, 28 GHz)	Inter UE-tag, inter-Tag	1 packet per sec/min/hour/day from tag or from NW to tag	gNB-tag gNB-UE-tag
Deployment scenario B (outdoor pico)	Outdoor						
Deployment scenario C (outdoor micro)		Micro					

  - FFS for more detailed sub-scenarios

Topology

- Consider topologies including gNB-Device, UE-Device, relay-based and hybrid types.



  - Energy supply can be embedded in gNB/UE/Relay respectively in above topologies, or it can be a separate node.
  - Hybrid type includes above three topology which can be deprioritized in this stage.
  - For better coverage, relay-based topology can be considered with high priority.
- Proposal 3: for topology, gNB-device, UE-device and relay-based types should be investigated.
  - FFS interference to downlink signaling caused by energy supply

RAN design targets

- From SI objectives
  - Formulate a set of RAN design targets based on the identified deployment scenarios and their characteristics for the relevant use cases, at least including
    - Power consumption
    - Complexity
    - Coverage
    - Data rate
    - Positioning accuracy
  - NOTE: The requirements from SA1 on the relevant use cases shall be taken into consideration.
  - NOTE: The study shall aim to provide better coverage compared to existing non-3GPP technologies for the relevant use cases.
  - NOTE: Other RAN design targets in relation to connection density, mobility, security, latency, reliability etc. may be discussed, if necessary for the relevant use cases.
  - NOTE: Detailed definitions of the RAN design targets should be discussed during the study.

- Observations
  - At least for type II device, most of performance matric should impact on latency requirement
  - Feasibility study should be required to identify a specific requirements such as power consumption and backscatter efficiency

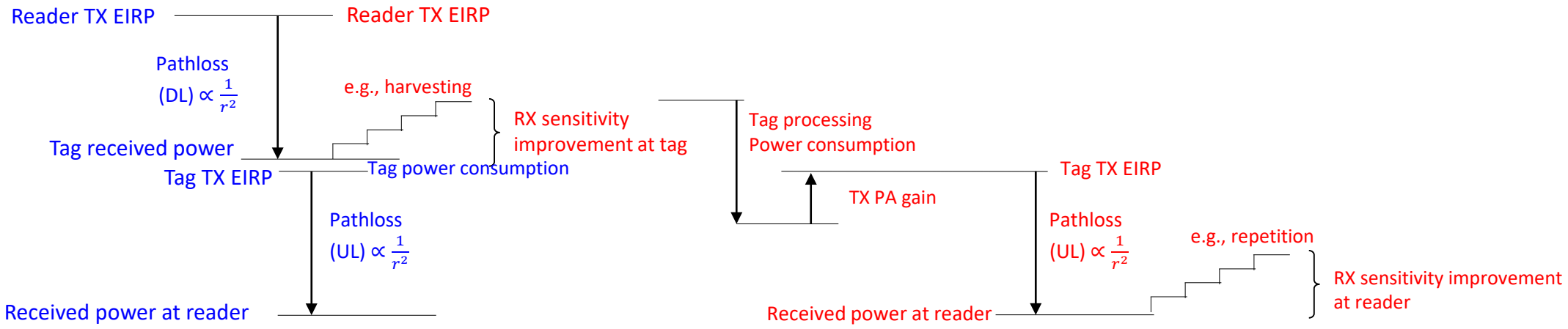
Coverage and latency

- Link budget

$$P_{rx,reader} = \sum_{TX=1}^{N} \eta(t) \frac{P_{tx,reader}}{r^4}$$

where r is distance from reader to tag
where N is the number of TX from reader

- For type 1: $\eta(t) = \eta < 1$ efficiency and latency is almost zero
- For type 2: $\eta(t) = \eta_0 + t\Delta\eta(t)$ and latency is $\eta(t_1) \geq \eta_{th}, \eta_0 = 0$ for the first packet, and $\eta_0 \neq 0$ for other packets



- To maximize the coverage
  - For type 1: (with limited TX power from reader) minimize processing power consumption and improve reflection efficiency
  - For type 2: (with required TX power and required latency) minimize processing power consumption, increase PA gain, and charging efficiency

Conclusion

- **Proposal 1: for device categorization including the corresponding characteristics (e.g., energy source, energy storage capability, passive/active transmission, etc.), the following two types should be included**

AIoT device type	Energy source	Energy storage	Transmission	Available distance, use case	Packet size and contents	Latency	Capability
Type I	Reader TX power (Licensed)	No storage	Passive (backscatter)	[<10] m, indoor	Very small (<a few Bytes) and pre-defined information	Very short	RX/TX TX only
Type II	Reader TX power (licensed)+ other ambient power (unlicensed)	Super capacity or rechargeable battery	Active (low power TX)	[< 30 m, indoor] and [<100 m, outdoor]	Small (tens of Bytes) and sensor output	Long (1 sec – 2 mins per TX)	

- **Proposal 2: for deployment scenarios, both indoor and outdoor are included as follows**

For both type I and II	Indoor/outdoor	Base station	Connectivity	Frequency band	Coexistence and interference	Traffic model	Topology
Deployment scenario A (indoor)	Indoor	Pico	sTRP, mTRP, UE (sidelink)	FDD (700 MHz, 2GHz) TDD (3.5 GHz, 28 GHz)	Inter UE-tag, inter-Tag	1 packet per sec/min/hour/day from tag or from NW to tag	gNB-tag gNB-UE-tag
Deployment scenario B (outdoor pico)	Outdoor						
Deployment scenario C (outdoor micro)		Micro					

- **Proposal 3: for topology, gNB-device, UE-device and relay-based types should be investigated.**
  - FFS interference to downlink signaling caused by energy supply
- **Observations**
  - At least for type II device, most of performance matric should impact on latency requirement
  - Feasibility study should be required to identify a specific requirements such as power consumption and backscatter efficiency