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RAN

3GPP TSG RAN#94e RP-212688

Electronic Meeting, December 06 - 17, 2021

Agenda Item: 8A.5

Source: Ericsson

Title: Moderator's summary of Discussion [RAN94e-R18Prep-28] Passive IoT

Document for: Information and Discussion

1 Introduction

This document covers the discussion in thread [RAN94e-R18Prep-28] on Passive IoT.

Deadlines and NWM organization is based on the guidelines provided by the RAN Chair in [1] and [2]. Specifically, the schedule for the different phases of the discussion is as follows.

- Initial email discussions: Wednesday, Oct. 20, 08:00 UTC - Friday, Oct. 22, 23:59 UTC
- Intermediate email discussions: Monday, Oct. 25 - Wednesday, Oct. 27, 12:00 UTC
- Final email discussions: Wednesday, Oct. 27, 16:00 UTC - Friday, Oct. 29, 12:00 UTC

The email discussion output from RAN#93e in [4] produced the following conclusion for this topic.

"There is interest among many companies for a study focusing on passive IoT, but there are also multiple companies that indicate that such a study in Rel-18 is premature. In case there is further discussion on a study for other IoT enhancements/types, the following objectives that were discussed as part of this discussion can be considered:

- Study of use cases and design targets for passive IoT for power consumption, complexity, link budget (RAN1/2/4, RAN)
- Identification of key areas to enhance to achieve design targets of passive IoT for power consumption, complexity, link budget (RAN1/2/4)"

The subsequent summary from the RAN Chair in [1] provided the following guidance for this email thread.

"An email thread is to be used to discuss passive IoT (based on [1][16]) for the purpose of better understanding."

After additional consultation with the RAN Chair, the goal of this discussion will be to discuss aspects that will lead to a better understanding of this topic and not necessarily to produce objectives or justifications for a study item description.

2 Initial Round

The initial round provides some questions that may serve as a starting point for discussion on the motivations for study of Passive IoT in 3GPP to facilitate a better understanding of the topic.

2.1 Use Cases and Scenarios

Please provide your views on the potential use cases and scenarios that may be of interest for Passive IoT in the form below.

Feedback Form 1: Use Cases and Scenarios

1 – VODAFONE Group Plc

NB-IoT/eMTC applications have shown many use cases for low data rate/small data volume sensors, and for device identification/tracking/monitoring. Many of these use cases do not require the extra cost/energy demands of the higher data rates and deep coverage extension that NB-IoT/eMTC provide.

RF-ID and barcodes similarly show many use cases for device identification and monitoring but these technologies have limited range.

In recent 3GPP releases (and in real world deployments) there has been substantial development in "Mobile Private Networks" and these would be a typical deployment/usage area for Passive IoT. Frequently these private networks have a rather dense base station layout and hence the range for Passive IoT need not be huge.

Customers expect the "devices" providing these services to have very long (e.g. >10 year) life and to be very low cost.

2 – Huawei Tech.(UK) Co.. Ltd

[Huawei]

Generally speaking, the target applications of Passive IoT can be sorted into two categories.

One is for ID identification, which plays an important role in various production activities. Some typical industries are given as examples in the following.

- Logistics and supply chain management: A large number of goods, materials, and assets all need to be labelled and tracked in many industries. For example, there are usually tens or hundreds of thousands of boxes filled with materials arriving at a factory every day. The ID and other information of those boxes has to be read and confirmed accurately. The materials and components involved in each production process within a factory also need to be inventoried and tracked.
- Transportation: In each year, more than one hundred billion parcels are transported all over the world [1]. Such a huge number of parcels require accurate sorting and tracking to avoid wrong delivery. Fast non-line-of-sight reading of the messages on each parcel will significantly promote the automaticity.
- Healthcare: Pharmaceuticals and medical equipment both need careful management. Inventory and tracking of them are required all around or even out of hospitals.

Currently, these industries have to resort mainly to barcode and RFID. The main advantage of the two technologies is their ultra-low cost small tag. However, the too-short reading range, and handheld scanning lead to labour intensive and time consuming operations. A wireless communication technology supporting automatic fast remote reading is strongly demanded by applications, especially for logistics management in

manufacturing industries. The challenge is to implement device of comparable cost and size with barcode and RFID tag.

The other category of applications for Passive IoT is to connect a huge amount of varied sensors, which collect information about environment, equipment, and living things for efficient production and life comfort. Since there will be hundreds of billion sensors all over the world, it is impossible to power all the sensors by battery, which leads to unacceptable cost, serious environmental issues, and safety hazards. Furthermore, a size limited device is required in many applications for proper installation. Some typical industries are given as examples in the following.

- Energy (e.g., electric power and petroleum industry): Environmental and equipment monitoring are important to avoid safety accident. For example, gas monitoring is required when highly toxic, flammable, or pyrophoric gas is produced, stored, or transported. Another example is equipment monitoring in converting stations, especially those located in remote rural areas. In those cases, battery-operated devices are forbidden for safety reasons.
- Manufacturing: Similar to energy industry, sensors are used to monitor environmental parameters, and status of equipment. Sensing reports with short periods are usually needed, which is unfriendly to battery operated devices. Some sensors are installed in places hard to reach. It will be very costly to replace battery for those sensors.
- Livestock farming: Biometric sensors are being used to monitor behavioural and physiological parameters of livestock, which allows farmers to evaluate an animal's health and welfare over time. Trajectory tracking of the animals is also needed in many cases for management. Since a sensor has to be placed on a particular part of and animal's body, both the size and weight of device should be strictly limited to avoid being damaged by the animal.
- Transportation: Cold-chain monitoring is required for food and pharmaceuticals in many countries by laws and regulations. For example, according to the regulations of some countries, the temperature during transportation shall be continuously monitored in real time, and the recording interval shall not exceed 10 minutes [2]. It is also desirable to keep such information available to consumers real-time. Sensors with limited size and cost are demanded.

In the above examples, it is seen that a small batteryless device is commonly required in many cases for economic or safety reasons. The scenarios include both indoor and outdoor. Proper deployment of network shall be considered, which requires proper communication range.

From the above two categories of use cases, it can be concluded that low cost, small, batteryless device is the common and essential requirement for the target applications of Passive IoT. The target markets are different from existing cellular technologies. Passive IoT will bring cellular network hundreds of billion new IoT connections in the future.

References

[1] Pitney Bowes Parcel Shipping Index Reports Continued Growth as Global Parcel Volume Exceeds 100 billion for First Time Ever (http://news.pb.com/article_display.cfm?article_id=5958), Pitney Bowes Inc., October 2020

[2] GB 31605-2020, China

3 – Motorola Mobility España SA

Lenovo/Motorola Mobility:

Present RFID solutions can be categorized into Passive RFID tags, active RFID tags and both have their own set of use cases inside the factory automation. RFID solutions are extensively used in the factories as part of asset tracking, logistics etc.,

4 – Nokia Corporation

The first element of discussing this area would be to understand what we are after, such as:

- Key use cases - we can identify transportation / logistics, possible manufacturing also, from the current RFID market
- What kind of link budget we are after? RFID has different variants.
- Do we want global usability, which is achieved in RFID with use of bands that are globally available (ISM etc), thus we should then target such a frequency bands as well. (ISM, unlicensed like 5 MHz etc.). For parcels this would seem like obvious requirement

5 – China Mobile Com. Corporation

Here we share two use cases from our vertical customers:

Use case 1: Bin management at the Gate of the warehouse

Scenario: unique identify the bins for logistic management. E.g., identify which bins move in or out of the warehouse, at the Gate of the warehouse, and identify the bins in a specific area inside the warehouse.

Currently, bins are manually managed via scanning the barcode attached on each bin. It causes: high OPEX and manual work often cause errors and many bins lost.

Use case 2: Bin management inside the warehouse

The traditional RFID was considered, but has the following 2 drawbacks:

Bad performance: Based on our test, RFID can only read labels in case the labels are not blocked. On the other words, in case the label attached on the bin is blocked, e.g. by another metal bin, RFID always fails to read it.

High Cost: The transmission distance for RFID readers is short, about 8 meters based on test. We need to deploy a lot of RFID readers to cover the whole warehouse(about 5000m2). Therefore, the cost to deploy the readers is very high.

6 – Shenzhen YZF Network Technolog

OPPO :

Use case and scenarios:

Massive MTC is one important use case for 5G. NB-IoT/MTC/RedCap have been specified in 3GPP to address the requirements from verticals. However, there are still many use cases not covered with these existing technologies:

- Under extreme conditions, e.g., high pressure, extremely high/low temperature, humid and other hazardous environments. For example, in some scenarios of IWSN (Industrial Wireless Sensor Network), such as product line monitoring/management in a manufactory, operating conditions or environment monitoring in a high voltage power station etc. It needs to support battery-less terminal to adapt to the extreme/hazardous working conditions or to realize maintenance-free (to save the labor cost). The life span of the terminal shall also be long enough (e.g., more than 10 years) to save the deployment cost.

- Ultra-low cost, very smaller form factor, maintenance-free and longer life cycle are required. For example, for the applications in smart logistics and smart warehousing, the cost of the terminals shall be comparable with barcodes. For wearables use cases, the terminal shall be thin and flexible enough and can be embedded into clothes. For smart home applications (e.g., for home asset management,

environment monitoring), the terminal shall be cheap enough, with small form factor and long life span.

Passive IoT utilizes back scattering and RF power harvesting thus it can realize battery-less, ultra-low cost, very small size and long-life span etc. Therefore, it is suitable to the above applications.

Passive-IoT is expected to extend the IoT applications of 3GPP ecosystem in both to-B and to-C area.

7 – Ericsson LM

We think any solution introduced in 3GPP should be generic and address as many use cases as possible (i.e. more than e.g. just 'barcode replacement'). Therefore, the study should to as large extent as possible be solution-agnostic, i.e. not limited to only backscattering solutions which may limit the coverage. Further, we think it is important that the solution targets the segment clearly below NB-IoT/LTE-M, which is associated with lower device complexity and lower energy consumption, and also relaxations in terms of the supported data rate and coverage.

8 – vivo Communication Technology

vivo We think the applications cited by Huawei is also interested from our side. In general, the passive IoT based on batteryless or energy harvesting operation largely extended NR application scenarios. We think it is one of the important enabler 5.5G technology.

We think the following scenarios is of interest for consideration

- **Scenario 1: base station and UE/tag direct communication**
- **Scenario 2: relay assisted base station and UE/tag communication**
- **Scenario 3: UE assisted base station and UE/tag communication**

Scenario 1 may be limited by coverage, scenario 2 and 3 should be of interests for considerations. For scenario 3, the main use case is that when the UE proximity communicates with the UE/tag and the ambient signal is from base station.

9 – InterDigital Communications

We agree with the use cases listed by Huawei. Massive IoT where batteryless, energy efficient devices should be supported.

10 – ZTE Corporation

For 3GPP, Passive IoT is a brand-new technology trend which aims to support a tremendous number of devices, including sensors/modules/tags/patches, with ultra-low power consumption, ultra-low device cost and maintenance-free requirements. Generally, such device may have very simple RF chains or may not be equipped with a battery at all (not only for cost/power consumption considerations, but also for human safety and environmental protection). The potential scenarios emerge from smart agriculture, industry, city and intelligent healthcare, etc. And typical use cases may include electronic tag for inventory management in logistics, warehousing, intelligent sensors/patches for human life, and comprehensive environmental monitoring in smart city/agriculture and so on.

11 – Philips International B.V.

We agree with Huawei use cases. Furthermore, we think that this new area of work should target use cases below LTE-M and NB-IoT in terms of battery life, size UE and complexity of the UE. Different techniques e.g. backscattering or energy harvesting solution can be studied as part of this item

12 – Classon Consulting

for FUTUREWEI

Passive IoT is an excellent new area to grow 3GPP, and we are supportive of the continued discussion or high level study. While there are clearly parallels with NB-IoT and expanding the 3GPP ecosystem into low end devices, passive IoT should not be viewed as a LPWA evolution. Power consumption and cost/size will be the biggest drivers for passive IoT, but wide area is not crucial.

13 – NOVAMINT

We appreciate the details of potential use cases brought by the proponents such as Vodafone, Huawei and others which are reflecting real needs as confirmed by many vertical industries we have consulted.

It shows there is a variety of use cases for which a new 3GPP innovative approach would be extremely beneficial and will allow 3GPP to provide a full spectrum of solutions for IoT to cover many and different use cases with always the right business models associated.

We agree with Ericsson that it is important that the solution targets the segment clearly below NB-IoT/LTE-M, which is clearly the case with the use cases brought forward.

14 – Samsung Research America

Cellular network may not be suitable for RF-ID like power-less device, considering the limited link budget without enough power source, ability to provide fundamental function like synchronization. Therefore, we suggest to focus on the use cases that can be benefit from cellular network, and separately discuss the use cases that may be SL based, or mesh network.

Overall we don't see big market opportunities for passive IoT in cellular network in 3GPP. We think some potential use cases may be overlapped with NB-IoT/eMTC, such as low-end wireless sensors or LPWA applications. It is not clear on what we can do for other use cases that may requires light weight/no protocol, ultra-simple hardware (e.g., no PA, no cell search/sync function).

15 – ROBERT BOSCH GmbH

We are supporting the topic. Many commercial and industrial devices, e.g., smart meters, sensors (fire, smoke), tags, etc. will benefit from being connected to the network with a very low power budget. We are interested in following two deployment scenario:

- UE based passive IoT reading, e.g., via PC5
- Network based IoT reading via Uu

16 – Sony Europe B.V.

Before discussing the use cases and scenarios are for Passive IoT, 3GPP needs to understand what "passive IoT" means. Our view is that passive IoT communication does not require battery replacement during the lifetime of the device and the power consumption of the device is low (i.e. passive IoT precludes devices with large batteries but includes devices with small batteries or supercapacitors). Communications can be either uplink or downlink for passive IoT and can be either mobile-originated or mobile-terminated.

Use cases and scenarios would be best studied in SA1 before being considered in RAN.

Subject to consideration in SA1, example use cases would include:

- Asset tracking

- Livestock / animal tracking
- Environmental monitoring (the natural environment, building temperature / air quality etc)
- Agricultural monitoring (crop health, soil characteristics etc)
- Monitoring of building / infrastructure state (stresses and strains in bridges/ roads etc)
- In-body sensors
- Etc

Scenarios. Other technologies, such as RFID, already enable some of the use cases of passive IoT. 3GPP should consider scenarios that are not covered by RFID. These tend to be longer range scenarios. Scenarios that are covered by other technologies, such as RFID, can be supported through interworking with those technologies.

However, 3GPP should consider in the SI whether 3GPP can better meet RFID-related RQs/KPIs, so we support also considering these "RFID-type" KPIs in the study.

In summary, we think that a 3GPP SI should not be limited to any particular set of use case and instead should be allowed to address any scenario/use case.

17 – Verizon UK Ltd

We are supportive of a SI on this. We see real market need too. We agree with Ericsson that the solution targets the segment below NB-IoT/LTE-M and should be treated accordingly.

18 – Intel Corporation (UK) Ltd

Intel

The possibility of cellular-based passive IoT devices needs careful study first to establish the feasibility and effectiveness in terms of achieving extremely low power consumption, size, and cost. These use-cases are characterized by extremely low power operations (few hundreds of uW) and very low cost (several orders of magnitude lower in cost compared to regular cellular devices), including, but not limited to, inventory management and asset tracking/sorting, personal IoT and healthcare, and various other possible use-cases similar to RF-ID tagging. Scenarios need to be carefully considered in appropriate context of the target technology used (including, e.g., energy harvesting with different energy storage capabilities, battery-less devices, etc.). For scenarios, in general, small cell-based networks can be expected to be more practical than macro deployments. High connection density for such devices would be of interest as well.

19 – Qualcomm Incorporated

We believe the following decisions should be made before considering detailed use cases and scenarios.

- A) Decide whether Passive IoT devices are to be supported in commercial cellular networks used by MNOs
- B) Decide whether connection to the core network by customary procedures, data rates, latencies and periodicities is a requirement, and if the answer is yes, decide whether achieving this goal is a realistic possibility
- C) Decide what distance / coupling loss is minimally required to make (A) realistic, in case the decision is in favor of (A)

20 – Apple Italia S.R.L.

The primary target use cases for passive IoT should be IoT devices that are very low cost/complexity and battery-less, with low data rate requirements. The applications can include industrial sensors, tags, asset tracking, healthcare, and wearables, etc.

From 3GPP perspective, we should also consider what kind of use cases 3GPP should be targeting at, because 3GPP-based solutions may not be suitable for all the use cases.

21 – China Unicom

Passive IoT is a very attractive new area for 3GPP to providing new type of IoT service for the new market, e.g. warehousing and logistics industry. Different from the LPWA solution, power consumption, cost, physical size, and relative smaller range of cell radius are need for further study. The use cases are clearly different from the NB-IoT/eMTC as well as other 3GPP IoT service. We support to have a study phase in RAN first.

22 – Telstra Corporation Limited

Passive IoT is potentially very interesting but must be clearly defined in terms of capability versus NB-IoT in particular. Moreover, any overlap with RFID in terms uses cases must also be better understood so we support a study phase first.

2.2 Existing Solutions and Motivation for Passive IoT in 3GPP

Please provide your views and any pertinent information on solutions based on existing technologies that may serve these use cases. Furthermore, please also provide your views on the need and opportunities for Passive IoT technology specified in 3GPP.

Feedback Form 2: Existing Solutions and Motivation for Passive IoT in 3GPP

1 – VODAFONE Group Plc

Existing solutions:

a) RF-ID and barcodes have limited range and seem unlikely to support sensors.

b) Multi-year battery life NB-IoT/eMTC devices tend to use expensive batteries.

Motivation

1) Customers expect the “devices” providing these services to have very long (e.g. >10 year) life and to be very low cost. However existing long-life battery technologies are expensive; use environmentally unfriendly components; and – if a discarded battery is eaten by children or animals – can be dangerous. Hence a Passive IoT solution that can work using low power energy harvesting would be valuable.

2) Market studies quoted in other documents (e.g. RP-212135) show substantial growth and value in the RF-ID area. Using 3GPP NR technology and NR base station sites to capture some of that revenue (and additional use cases) within the 3GPP eco-system is interesting.

2 – Huawei Tech.(UK) Co.. Ltd

[Huawei]

Existing 3GPP technologies cannot meet the requirement of ultra-low cost batteryless devices

According to the typical use cases introduced in the first question, it is seen that low-cost batteryless devices with small size is the common requirements. Unfortunately, existing cellular devices cannot meet this essential requirement. Taking NB-IoT module for example, the typical current absorption for receive processing is about 60mA with supply voltage higher than 3.1V, while 70mA for transmitting processing at 0dBm transmit power [1]. Considering the small size of a few square centimeters for practical devices, most environmental energy sources can only provide output power of less than 1 milliwatt, which cannot meet the high power consumption of NB-IoT module.

One possible solution is to integrate energy harvesting with rechargeable battery or supercapacitor. But these are not good solutions. Supercapacitors of sufficient size are too bulky (similar to the size of an NB-IoT module), and their lifetime too sensitive to environmental conditions such as temperature fluctuation. A button- or coin-cell battery providing a few tens of milliamps can be even larger than the module itself.

Both rechargeable batteries and supercapacitors can be more expensive than the module itself, especially for supercapacitors with rated voltage higher than 3V. Even purchased in large quantities, the cost of a suitable battery or supercapacitor may reach one or a few dollars, which is not acceptable for most of the target use cases of Passive IoT.

Existing non-3GPP technologies cannot meet the requirement of ultra-low cost batteryless devices

The devices of most non-3GPP technologies also consume power of tens of milliwatts during transceiving. RFID is the most well-known technology supporting batteryless tags (devices). However, RFID is designed for short-range communications, whose typical effective range is less than 10 meters. As the air interface of RFID almost remains unchanged since 2005, the too-simple transmission scheme becomes the obstacle of improving its link budget and capability of supporting scalable network. Currently, there is rarely successful commercial deployment of RFID network for the target use cases of Passive IoT.

Batteryless device is under investigation for various non-3GPP technologies

Attracted by the extremely low power consumption of backscatter communication, many non-3GPP technologies begin to put efforts into related researches, such as WiFi, Bluetooth, UWB, and LORA [2]-[5]. Various researches show that a few or tens of microwatts power consumption can be achieved for passive tags based on or with small modifications to the above air interfaces. A significant proportion of the studies are targeting at long range communication. The standardization of those technologies are agile and quick, as the industries usually follow some de facto standards.

Though the communication range of RFID makes it hard to be used in many use cases, the global RFID market volume is still predicted to be grow rapidly from 18.5 billion in 2020 to 49.1 billion in 2031 at a compound annual growth rate (CAGR) of 9.3% [6]. Solution providers will try their best efforts to seize the markets with technologies most likely to meet the requirements.

Consequently, it is necessary to start the study on passive IoT in 3GPP due to already-present demand from new IoT markets and increasing investment of competitive non-3GPP technologies in the area, especially considering existing 3GPP technologies cannot meet the requirements of the target markets. Once the huge amount of connections choose other technologies than those in 3GPP, it will not be easy to regain the market share.

References

[1] Quectel BC95-G datasheet, Quectel

[2] Battery-Less IoT Sensor Node with PLL-Less WiFi Backscattering Communications in a 2.5-μW Peak Power Envelope, 2021 Symposium on VLSI Circuits, June 2021

[3] Reliable and Practical Bluetooth Backscatter With Commodity Devices, IEEE/ACM Transactions on Networking, April 2021

[4] A UHF/UWB Hybrid RFID Tag With a 51-m Energy-Harvesting Sensitivity for Remote Vital-Sign Monitoring, IEEE Transactions on Microwave Theory and Techniques, Nov. 2020

[5] Self-sustainable Long Range Backscattering Communication Using RF Energy Harvesting, IEEE Internet of Things Journal, March 2021

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

3 – Motorola Mobility España SA

Lenovo/Motorola Mobility:

Ultra dense deployment of gNB inside the factory premises can help reduce the overall cost by not deploying standalone RFID readers by reusing the gNB functionality (e.g., higher Tx power compared to RFID reader) to the greater extent for connecting massive number of RFID tags.

Further, Energy harvesting can be considered for both active and passive RFID tags, and the requirement to support battery-less passive IoT RFID or low cost energy storage can be further discussed.

LPWAN solutions (e.g., Sigfox, LoRa, 3GPP NBIoT) provide sufficient coverage and throughput for IoT use case, however require battery as the power source and not sufficiently adapted for indoor factory scenarios.

Hence the motivation to study RFID solutions is long life (e.g., more than 20years), low cost/complexity (e.g., much smaller than NB-IOT) and medium coverage (e.g., at least tens of meters), finally the study detail use cases for the RFID and sufficiently differentiated with existing 3GPP solutions such as NB-IoT.

4 – Nokia Corporation

In general we would see need for high level discussion to build common understanding which segment to address, as RFID is widely use as of today, and where 3GPP based solution could create a clear advantage.

5 – China Mobile Com. Corporation

Share same view with Vodafone and Huawei on the existing solution and motivation. The performance for traditional RFID cannot meet the requirements from vertical industry.

Cost: The maximum transmission distance for traditional RFID labels is around 8 meters and suffered from high penetrate loss, which means to cover the 5000 m2 warehouse, the cost for deploying RFID reader is very high. By integrate Passive IoT into the NR gNB, the cost for deployment can be reduce.

Performance: High penetration loss for RFID makes it difficult to read labels inside bins. Besides, since RFID can only transmit around 8 meters, it can hardly meet the use case to work outdoor to cover large area.

Sensor data transmission: The traditional RFID can only transmit the RFID index. While there is the requirement from vertical customers to transmit some sensor data along with the index.

6 – Shenzhen YZF Network Technolog

OPPO :

1□ Our investigations on some of the existing solutions are listed in the following:

- RFID

RFID is battery-less and the tag has ultra-low cost and small size. But the coverage is very limited (less than 10 meters), system capacity is also limited and when the number of tags is large (more than 2000), the system efficiency and the reliability decrease obviously.

RFID is difficult to support sensors thus it restricts its application.

- Barcode

It has ultra-low cost and small size. But it relies on light condition and it requires the barcode to be placed facing the scanner.

- NB-IoT/MTC terminal needs a battery inside and the cost is not low enough for some verticals such as logistics, warehousing, asset inventory etc.

For some to-C applications such as wearables and smart home as mentioned in session 2.1, since the form factor is not thin enough and it is not foldable, it is not suitable for some of applications in these use cases. In addition, its limited battery life doesn't provide good enough user experience.

It gives opportunities for 3GPP ecosystem to provide competitive IoT schemes with passive IoT techniques to fulfill the requirements coming from the verticals and individual customers.

7 – Ericsson LM

To our knowledge there are proprietary solutions in the domain of battery-less wireless operation from e.g. Everactive, WilloT, Atmosic, etc., and in addition, there are initiatives to study this for WiFi, Bluetooth, LoRA etc., as mentioned by Huawei. It is of interest for 3GPP to be in the forefront of wireless communication, and we agree this is a new and interesting area. However, the technical solution would be quite different from existing 3GPP solutions and therefore it is important to allow sufficient time for study in 3GPP.

8 – vivo Communication Technology

vivo We think low power wake-up signal can benefit the passive IoT from power perspective. Currently 3GPP and non-3GPP technologies such as NB-IoT/eMTC/LoRa... can achieve very low power consumption by extending the receiving and transmitting to a very long period by e.g., eDRX. However, the service latency will be largely impacted.

9 – InterDigital Communications

Existing solutions include FRID and NB-IoT. The first has limited range and the second requires battery. A potential SI should investigate solutions to improve on the existing solutions. As other companies have mentioned, there is a growing market and potential non-3GPP solutions in the works.

10 – ZTE Corporation

As mentioned by some of the above companies, the existing 3GPP IoT technologies can promise wide-range and enhanced coverage and powerful multi-user access capability, but have not yet achieved the ultimate power saving. Meanwhile, some of the non-3GPP technologies, e.g., RFID, LoRa have been used in supporting miniature devices/tags, but limited transmission range, weak anti-interference ability and poor multi-user access capabilities are their common weakness.

Therefore, studying the scenarios and requirements of cellular-based passive IoT would be beneficial to expand passive IoT from traditional short-range applications to wider area cellular wireless networking applications. This can provide customers with convenient and standardized cellular network capabilities, and inspire novel applications and market directions.

However, we also realize that those non-3GPP technologies are still on their own evolution path, and some market requirements can be fulfilled through appropriate network deployment and technology combination. On the whole, at least for Release 18, the market demand for cellular-based passive IoT is still not particularly clear and seems not so urgent yet. It is more desirable to study the requirements, e.g. in SA, instead of starting the study in RAN.

11 – Philips International B.V.

We agree with Vodafone and Qualcomm. Whatever solution we come up with in 3GPP should go beyond existing solutions e.g. NB-IoT, LORA or RFID.

12 – Classon Consulting

for FUTUREWEI

RFID range is not sufficient

NB-IoT cost and power consumption for these applications is too high.

13 – Samsung Research America

Existing solutions

RF-ID, low/zero power device, supper low bit rate.

NB-IoT/eMTC, with 100kbps to Mbps bit rate, 10 years batter life, 20dB coverage extension.

Motivation:

For NR, it is attractive to support low-end IoT devices with features, e.g.,

- extremely low cost/complexity and power consumption, which similar or go beyond NB-IoT/eMTC/RedCap
- energy harvesting friendly protocol, or battery-less/super low power operations (if possible)

14 – ROBERT BOSCH GmbH

In our analysis, NB-IoT specifications do not meet our expected requirements. Additionally, RFID range and usability are not sufficient.

We believe that Passive IoT will extend 5G usability towards devices with very limited battery and extremely low cost.

15 – Sony Europe B.V.

Some of the use cases for passive IoT are already supported by other technologies, such as RFID or BLE with energy harvesting. There is no need for 3GPP to come up with an alternative solution to these solutions that already work. 3GPP can interwork with these existing solutions where necessary. We can still see whether it is possible to improve on those technologies.

Where 3GPP can provide differentiation is in longer range passive IoT. We would expect “longer range” to still fall under the umbrella of good coverage (we are not considering MCLs of 164dB, we are considering MCLs of less than 140dB). For example, 3GPP can support NB-IoT / eMTC devices operating on energy harvesting, although we should be looking at whether we can reduce the power consumption of these technologies. NB-IoT / eMTC devices operating on energy harvesting with lower power consumption do

not need large batteries, they just need sufficient energy storage to transmit / receive their data. 3GPP should also avoid plumping for a technology that can only support low data rates. Low data rates mean that the device is "on" for longer. Efficient transmission is associated with higher data rates (in the range of 1Mbps) where the device can transmit and go to sleep more quickly. We should be looking at data rates that are similar to those provided by BLE in order to provide power efficient communication. The combination of eMTC and energy harvesting is hence a good candidate for passive IoT.

16 – Intel Corporation (UK) Ltd

Intel

Subject to technical feasibility, support of high connection density, better coverage, and NLOS links could be the salient offerings from a 3GPP-based solution for passive IoT, targeting various use-cases currently addressed by RFID technology. The key to the success of cellular-based passive IoT would depend on achievability of competitive performance in terms of coverage, connection density, while getting to extremely low cost and power consumption.

17 – Qualcomm Incorporated

RFID based on EPC Gen2 can support 40 kbps – 640 kbps data rate from Tag to Reader with a sensitivity of -85dBm. Typical rates in the lab vary between 60-70 kbps using Miller (M=4) encoding.

For RFID, typical ranges of 3 m can be achieved using passive transponders and ranges up to 30 m can be achieved using active transponders. All long-range systems operate using UHF or microwave frequencies and use backscattered modulation to communicate with the reader.

It was observed that the range of the existing passive RFID system is limited mainly by the power-up link for powering the passive RF tag, not by the backscatter link for backscatter communication, and the range of the backscatter link for the antenna configuration of bistatic and dislocated case is only several dB better than the monostatic case [1].

At the same time, we also note that RFID communication range can be further improved by exploiting the quantum tunnelling effect via a high gain, low power reflection amplifier based on a tunnel diode [2].

Overall, we believe the existing RFID technology including its enhancements can meet requirement for traditional RFID uses. However, at least the provided range is insufficient to enable general operation in commercial cellular networks. It is unclear whether any enhancements would be able to achieve the latter goal.

[1] J. Griffin and G. Durgin, "Complete link budgets for backscatter-radio and RFID systems", Antennas and Propagation Magazine IEEE, vol. 51, no. 2, pp. 11-25, Apr. 2009

[2] F. Amato, C. W. Peterson, M. B. Akbar and G. D. Durgin, "Long range and low powered RFID tags with tunnel diode," 2015 IEEE International Conference on RFID Technology and Applications (RFID-TA), 2015, pp. 182-187, doi: 10.1109/RFID-TA.2015.7379815.

18 – Apple Italia S.R.L.

For battery-less operation, the most representative existing solution is RFID, which has a very limit transmission range. There is always motivation for better solutions to cover as many use cases as possible.

However, to be able to provide any competitive advantages over other technologies, we need to understand better in which aspects and/or in which use cases/scenarios 3GPP solutions may outperform other technologies.

2.3 Design Targets and Areas for Enhancement

Please provide our views on potential design targets (e.g., power consumption, complexity, link budget) for Passive IoT that may be needed for any use cases and scenarios mentioned in Section 2.1. Any preliminary views on potential areas for enhancements in current 3GPP technologies that may be needed to meet the design targets may also be provided.

Feedback Form 3: Design Targets and Areas for Enhancement

1 – VODAFONE Group Plc

a) Devices should be able to be extremely small size, thin, low complexity, very light-weight, and have a long life span

b) Devices should be able to operate with an energy harvesting source that produces around 200 micro Watts

c) Indoor range of around 30m and outdoor range of around 100m

d) For identification/tagging, payloads of e.g. 96 bits may be sufficient (e.g. Electronic Product Code standard).

e) For sensors, larger payloads of > 40 bytes would be useful.

f) A "cell capacity" of 10 kbit/s could be a target.

g) Reuse of existing remote radio head technology would be useful.

h) Bidirectional communication and MO and MT initiated communication should be supported.

2 – Huawei Tech.(UK) Co.. Ltd

[Huawei]

Target #1: Ultra-low power (e.g., 1 100uW) device supporting battery-free operations

In the use cases of both ID identification and sensing data report, it is desired that tags and sensors support no replacement of battery during their lifetime. Batteryless devices are always preferred, and even required in many cases. Energy harvesting is the most likely way to enable batteryless devices. To be powered by energy harvested from environment, the power consumed by all the hardware and software processing of a device should not exceed the output power of energy harvester too much. Considering that the size of a device is usually limited to a few square centimetres and the energy conversion efficiency may be as low as 10%, output power of most energy harvesting techniques is at the level of microwatts [1].

For example, according to our measurements, the output power of a thin-film solar panel is about 100uW/cm2 outdoor in a cloudy and cold day, while about 13uW/cm2 from indoor fluorescent lamp. Considering sufficient margin reserved to combat the instability of energy harvesting, the target should be to keep the power consumption of Passive IoT device at the same level as or even lower than the output power of energy harvester, which is mostly from 1uW to 100 uW.

Existing cellular devices usually consumes power of tens or hundreds of milliwatts for transceiving. It means that the power consumption of Passive IoT device shall be more than a hundred times lower than existing mMTC technologies in 3GPP.

Target #2: Ultra-low cost device with small size (e.g., thickness of a few millimeters)

According to the typical use cases described above, the target markets are more sensitive to device cost than those using existing mMTC technologies. For logistics, transportation, and healthcare industries, it is better that the cost of a tag for object identification reaches the level of 0.01$, which is comparable with the cost of thermal paper for barcode being used currently. For wireless sensors used in energy, manufacturing,

and livestock farming industries, the cost of a wireless module shall not exceed the sensor it attached to, which is predicted approaches 0.5$ by 2023 [2].

Generally speaking, the required device cost is more than 10 times lower than existing mMTC technologies in 3GPP.In livestock farming and manufacturing industries, device with limited size is usually required. For example, the temperature sensor placed on animals needs to be small and thin, while light-weight is also demanded to avoid making the animal uncomfortable.

Target #3: Proper communication range for practical deployment and seamless coverage

The short communication range of RFID leads to very high cost for deployment less than 10 meters between neighbouring readers, which prevents the application of RFID in many target use cases of Passive IoT.

Considering the capability of ultra-low power devices, the deployment of indoor small-cell or outdoor micro-cell can be referred for Passive IoT. For indoor small-cell deployed in factories, the distance between neighbouring pico remote radio units (pRRU) is usually a few tens of meters (e.g., around 20 meters). For outdoor pole base stations, the inter-site distance is usually 200 300 meters. Passive IoT needs to target sufficient link budget to meet the requirement.

Potential technical areas of Passive IoT

A new air interface needs to be studied to achieve the above three targets for Passive IoT. Some potential technical areas are listed in the following.

1. Techniques to enable microwatt-level power consumption and ultra-low complexity for Passive IoT devices, which includes

- *Modulation supporting ultra-low power RF frontend and digital signal processing*
  The essential issue for power saving of device is to avoid using the conventional radio architecture, which comprises power-hungry RF chains having oscillators, mixers and digital-to-analog converters [3]. Those components also take a large proportion in the cost of device. The key point is to design a proper modulation scheme to enable the lower power and low cost needed for Passive IoT.

- *Frame structure supporting synchronization with inaccurate and unstable reference clock*
  Fine synchronization in time domain and frequency domain are both infeasible for Passive IoT device. The frequency of reference clock is mostly like to be no higher than 1.92 MHz, while the stability of the clock may be as poor as one hundred PPM. Frame structure and synchronization scheme should take care of the very limited hardware capability of Passive IoT device.

- *Minimized protocol stack for ultra-low power logical processing*
  Protocol stack processing usually requires an MCU and some memories, which both take a large portion of overall power consumption of SOC. It is important to simplify the protocol stack of Passive IoT to minimum level to avoid high processing power and large die size. Take RFID for example, there are only 11 mandatory signaling in its protocol flow. The protocol stack of Passive IoT needs to target similar complexity to RFID.

2. Techniques for co-deployment with 5G network need to be studied, including:

- *Coverage enhancement techniques for proper communication range*
  Conventional techniques in 3GPP for link budget optimization may be referred to or reused, such as FEC code, repetitions, and narrowband transmission.
- *Interference management techniques for scalable adaptive networking*
  Interference measurement schemes and other interference suppression techniques already know in 3GPP may be referred to or reused.

References

[1] A survey of energy harvesting communications: models and offline optimal policies, IEEE Communications Magazine, June 2015

[2] Status of the MEMS industry 2018, YOLE, 2018

[3] Next Generation Backscatter Communication: Systems, Techniques and Applications, EURASIP Journal on Wireless Communications and Networking, March 2019

[4] A Survey of Low-Power Transceivers and Their Applications, IEEE Circuits and Systems Magazine (Volume: 15, Issue: 3), third quarter 2015

[5] A Battery-Free Tag for Wireless Monitoring of Heart Sounds, 2009 Sixth International Workshop on Wearable and Implantable Body Sensor Networks, June 2009

3 – Motorola Mobility España SA

Lenovo/Motorola Mobility:

Traffic, frequency band to be used, complexity of the receiver, link budget for coverage, power consumption, number of tags per Sq-mtr and type of waveform studied.

Coexistence with the NR-RAT should be considered by reusing much of the existing functionality of the NR-RAT as one of the key design target.

4 – Nokia Corporation

We see there would be first need to have common understanding what are the use cases to focus on and for which to optimize.

5 – China Mobile Com. Corporation

Here are the requirements from vertical industry, which can be taken as part of the design target:

Coverage capability: communication distance should be enhanced to 30 meters to construct a feasible network coverage in the 5000 m2 warehouse.

UE power consumption: <0.1mW to support working without battery.

UE cost: <0.1□(0.02$) to meet cost-sensitive applications.

Positioning accuracy□ 3 5m(Horizontal&Vertical) @ 90% for positioning .

6 – Shenzhen YZF Network Technolog

OPPO :

Our considerations on the design target include:

1) battery-less, ultra-low cost (e.g., less than 0.3 dollar), very small size (e.g., printable) and long-life span (e.g., more than 10 years).

2) Support ultra-low power operation (less than 1 mw) using harvested energy

3) support thousands of terminals to communicate at the same time (within seconds).

4) Date rate of 10 100kpbs.

5) Coverage: 100-200m for verticals.

10 20m for smart home.

Around 2 5m for wearables.

6) Support communication between gNB and passive IoT tags (mainly for vertical use cases),

and also support communication between UEs (smart phones) and passive IoT tags (mainly for to-C area, e.g., smart home and wearables).

7) Support working both in licensed frequency band or unlicensed frequency band
8) Support both standalone deployment and coexistence with NR.
9) Support FDD and TDD bands
10) Different categories of passive terminals can be considered (passive, semi-passive etc.)

Techniques shall be studied to support passive IoT include:

1) The waveform, modulation, coding, channelization etc. suitable for passive IoT
2) Simplified/light-weight protocol stack
3) Simplified/light-weight security management
4) Simplified network architecture

7 – Ericsson LM

We agree with the listed design targets on power consumption, complexity and link budget. Note however that these are inter-dependent; the better the coverage, the higher the power consumption and device complexity will be. Any study objective should therefore take this tradeoff into consideration.

8 – vivo Communication Technology

vivo Based on the power consumptions, sensitivity/coverage and design targets, the following types of passive IoT devices can be considered,

Type A (passive node)

- Power: depend on RF incident energy harvesting, the average power consumption is approximate 1uW.
- Sensitivity/coverage: typical passive RFID sensitivity is around -20dBm
- Design: can continuously Tx/Rx

Type B (Energy storage intermittent Passive node)

- Power: depend on ambient energy harvesting (e.g., solar, vibration), the average power consumption is approximate 1uW.
- Sensitivity/coverage: bursty Tx/Rx with an instantaneous high power so the sensitivity/coverage is better than Type A. Typical value can be -70 -100dBm
- Design: Intermittent communication, may introduce amplifier (e.g., LNA) for downlink/uplink

Type C (Semi-Passive node)

- Power: depend on ambient energy harvesting (e.g., solar, vibration) or button battery, the average power consumption is approximate 100uW.
- Sensitivity/coverage: Typical value can be -70 -100dBm
- Design: can continuously Tx/Rx, may introduce amplifier (e.g., LNA) for downlink/uplink

Type D (RF-front-end)

- Power: Good power supply for simple RF front end transceiver, the average power consumption is approximate 1mW
- Sensitivity/coverage: almost no sensitive/coverage degradation, same range as wide area coverage, e.g., more than -100dBm
- Design: can continuously Tx/Rx, may introduce amplifier (e.g., LNA) for downlink/uplink and simple RF-front-end transceiver with high accuracy crystal oscillator, mixer and etc.

9 – ZTE Corporation

Firstly, the typical scenarios/use cases with the corresponding KPIs, such as traffic pattern, coverage requirement, mobility, UE complexity, UE type (with simplified RF or totally passive) etc. should be clearly identified;

Secondly, radio technology needs to be studied, such as to support backscatter communication and energy harvesting; to extend the communication range of passive devices, to support efficient multi-user access, promising device security and a certain mobility etc.

Thirdly, networking technology study would also be involved, such as to study appropriate network architecture (e.g., integrated network or relays); to design efficient management for huge number of devices, and to provide appropriate QoS guarantee etc.

With the above preliminary considerations on the scope, we foresee a lot of study and specification work for supporting cellular-based passive IoT especially if the exact requirements are not clear. Given that there are already many other Rel-18 topics in RAN, it is more appropriate to start the work in future release in RAN with more focused study scope based on clearer requirements from SA.

10 – InterDigital Communications

We agree with the listed design targets. Low power and low complexity should be the main areas for enhancement.

11 – Philips International B.V.

- Size: devices may be foldable and very small
- Energy consumption:
  - Typical RF condition: <0.2mWh
  - Worst RF condition: <0.6mWh
- Data rate: <10Kbps
- Ultra low cost: agree with Huawei
- Coverage: study potential improvements due to the unavoidable reduced coverage these devices will have as suggested by Huawei.
- Positioning: room level accuracy
- Energy supply: the following devices shall be supported
  - Passive devices: use of backscattering techniques
  - Energy harvested devices
  - Semi-passive devices: devices with a very small battery <100mAh

12 – Classon Consulting

for FUTUREWEI

Primary focus should be on ultra-low power consumption, which can include energy harvesting / no battery solutions, waveform design, and protocol simplifications. It is possible that focusing on power consumption and the above will directly lead to much lower cost/size.

13 – Sony Europe B.V.

Design targets:

- No need for battery charging
- Device can have a battery or other energy storage device
- Device can harvest energy. Energy harvesting source produces around 200 microWatts
- Range = 10-100m
- Maximum coupling loss in the region of 130-140dB (i.e. good coverage)
- Low cost / complexity
- Packet sizes of around 100 bytes
- Minimise changes relative to existing eMTC / NB-IoT devices
- Mobile originated and mobile terminated data
-

Areas for enhancement:

- Operation with sporadically available energy
- Signalling enhancements to tolerate interrupted connections
- Power saving enhancement to reduce power consumption further

It would also be useful to investigate the feasibility and potential performance of a system that operates only on RF-incident energy (i.e. does not store harvested energy). Such a system can operate directly on continually harvested RF energy or on the basis of backscattering. This feasibility study would be useful as an input to SA1 (there is no point in SA1 defining requirements for a physical layer that may be unfeasible. We realise that there is a chicken and egg problem between SA1 and RAN in this area and we need to be realistic that both groups may need to work on potential requirements (SA1) and feasibility (RAN) in parallel).

14 – Intel Corporation (UK) Ltd

Intel

If a study is pursued in Rel-18 or beyond, the key objective would be to establish feasibility and efficiency of supporting passive IoT devices in context of cellular technologies.

Design targets include extremely low cost, power consumption, and form factors, relying on energy harvesting from environment. Devices with different levels of energy storage capacity, including battery less devices. This can be expected to necessitate study of suitable waveforms and modulation schemes for very low power transceiver architectures, and extremely simplified L1 procedures and higher layer protocols compared to regular NR operations.

Appropriate traffic models, corresponding to identified applications, need to be defined, including associated selection of deployment scenario and target coverage.

The study should also include considerations on coexistence with legacy and other UEs and inter-cell interference.

15 – Qualcomm Incorporated

In order to make operation in commercial cellular networks possible, communication range to closest base station should be at least in the order of 1 to 2 km.

Given that this range is unlikely to be achievable, secondary non-cellular uses can be further considered. However, the development of the relevant requirements for these might take longer time, starting with involving relevant new stakeholders.

If the achievable rates, packet sizes, latencies do not support connection to the core network with the existing procedures, significant amount of work in other TSGs would be also needed.

16 – Apple Italia S.R.L.

The design targets should at least include the following aspects:

- Battery-less/very low power consumption: the target depends on what can be achieved by energy harvesting today and in the future.

- Size/cost: very low cost (and very small size in typical scenarios)

- Very low data rate

- Communication range: to have advantage over RFID, the range should be at least tens of meters, which also makes a dense network deployment possible.

We think the establishment of the targeting use cases and the corresponding requirements needs careful study. The exact target values for each of the above aspects depend on the targeting use cases, which needs more discussions to achieve common understanding.

Whether/how it coexists with the legacy NR design should also be considered.

This will need a completely new system design to achieve the extremely low power consumption, including simplified PHY (frame structure, waveform, coding/modulation, etc.) and simplified protocol design. The target communication range is also critical to the design, and there are trade-offs between these design targets.

It may not be feasible/economic to support long range communication with coverage similar to the legacy cellular system. A private local area network may be more realistic.

2.4 Other Aspects

Any other views may be provided in the form below.

Feedback Form 4: Other Aspects

1 – VODAFONE Group Plc

Either as part of a study, or, before a study starts some decisions are needed on:

1) Whether or not the passive IoT device includes an energy storage device (e.g. capacitor), and if so, how much energy storage should be expected

2) What kind of duplex operation is supported.

2 – Motorola Mobility España SA

Lenovo/Motorola Mobility:

Passive RFID tags works on the principle of backscattering/reflecting the radio waves, hence does not decode radio signal while the active RFID tags can decode, modulate and transmit radio signal.

If the study is restricted only to the passive RFID tags, there is no or limited specification impact as the processing of the backscattered/reflected radio signals from tags is upto gNB implementation. However, Integrating the active RFID tags requires definition of the new UE type. Hence, we prefer prioritizing the study to integrate the existing RFID tags already deployed in the factory premises to gNB.

3 – Huawei Tech.(UK) Co.. Ltd

To give some points on the matters noted by Vodafone:

For a passive tag powered by energy harvested from RF signals, a capacitor can used to improve link budget. The power consumption of chipset is around 1uW (-30dBm) for passive tag. Considering the power conversion efficiency of around 10%, the received signal power should be around or higher than -20dBm. Otherwise, there will not be enough power to activate the chipset. To optimize the activation threshold, a small capacitor (e.g., a few tens of uF) can be integrated into the chipset. The harvested RF energy will be stored in the on-chip capacitor until it is sufficient for the chipset to work a while. By this means, the activation threshold can be optimized to about -30dBm. The passive tag with energy storage is one of the key techniques to improve link budget for passive tag.

For a semi-passive tag powered by other environmental energy sources, a capacitor is no longer used to optimize the activation threshold of tag chipset, but to enable stable continuous work for the device. Though some environmental energy source can provide much higher power than RF energy, one issue is that the energy supply is usually instable and uncontrollable. For example, the power provided by solar energy can be much higher than the power consumption of Passive tag in daytime, but almost no energy harvested at night. In this case, capacitor can be used to store extra harvested energy when the source is available. When no or little energy can be harvested, the stored energy will keep the tag working.

For passive tag of Passive IoT, the capacitor of 10uF level can even be integrated into the chipset.

For semi-passive tag of Passive IoT, supercapacitor with rate voltage of 2.5V or 3.3V and capacitance of around or less than 100mF can be used, whose cost is usually about or even lower than 0.5$.

Whereas by comparison, for an NB-IoT module, a supercapacitor with rated voltage of about or above 5V and capacitance of around of above 1F has to be used, whose cost is usually one or a few $.

4 – Ericsson LM

We think ‘battery-less IoT’ is a more descriptive notation that ‘Passive IoT’ since we do not want to rule out e.g. the use of super-capacitors before the start of any study.

‘Battery-less IoT’ would also, to an even greater extent than NB-IoT in LTE, be a new RAT. Therefore, the topic should be carefully studied in 3GPP before any normative work. Note that there would be considerable impact also to SA and CT WGs (given that ‘battery-less IoT’ will be more different than NB-IoT was when introduced, it can be assumed the impact would be at least as much as for NB-IoT).

If ‘battery-less IoT’ is introduced in the future, it would also be important to take “forward compatibility” into account to ensure the solution works also in the 6G era (to the extent possible).

5 – ROBERT BOSCH GmbH whether or not a UE supports two modes of operation: passive IoT and RedCap, if yes, if they are coordinated whether PC5 is used to connect to passive IoT
6 – Qualcomm Incorporated We believe broader preliminary discussion on whether or not the use of Passive IoT devices in commercial cellular network is the target is needed before considering any WG-level discussion/study. Such preliminary discussion could take place in a RAN Plenary level study, for example.
7 – Apple Italia S.R.L. Overall we feel this is an important area for 3GPP investigation in long term. But it is highly likely that low-power wake-up receiver/signal will be studied in R18, which is very much related to passive IoT. The two can have a lot of overlapping investigation in terms of techniques to reduce UE power consumption. From planning point of view, we think it is better that we focus on LP WUR study in R18, and then transition to passive IoT study in later releases, leveraging what we learn from LP WUR study. This avoids duplicated investigation in two closely related topics in the same release, and also allows progressive study for passive IoT.
8 – Nokia Corporation We agree with the point raised with Apple here, as (depending on the WUS study outcome) it could be a building block in ”passive IoT”. (We are open for better naming as well)

3 Intermediate Round

3.1 Moderator’s Summary

As brief distilled summary of the input provided in the initial rounds is given below. It should be noted that many details from the inputs are not captured here. All the inputs provided will be part of the final output document and will be available to the reader.

Scope

- Battery-less devices
  - Devices that have batteries but don’t need battery replacement over the lifetime of the device were also suggested to include in the scope.
- Lower complexity, data rate, coverage, cost and energy consumption than NB-IoT/eMTC

Use cases

- Functionality
  - Identification

    - Tracking
    - Monitoring
    - Sensing

- Target sectors

    - Logistics and supply chain management, transportation, manufacturing (factory automation), healthcare, wearables, smart home, energy, agriculture, transportation, smart cities, environment.

- Operating environments

    - Extreme conditions and hazardous environments in some use cases (environments where devices with batteries is not an option).

Scenarios

- Connected to operator network?
- Private network
- Small cell
- Indoor and outdoor
- Traffic models (need to be identified)
- Duplexing mode
- Connectivity (questions were raised on feasibility of some scenarios)

    - Base station and UE/tag direct communication
    - Relay assisted base station and UE/tag communication
    - UE assisted base station and UE/tag communication

Existing solutions

- Sensors, modules, tags, patches operating based on backscattering or energy harvesting

    - Passive RFID tags
        - Limited coverage and capacity
            - With EPC Gen 2, 40 – 640 kbps with a sensitivity of -85 dBm, range of 3 – 30 m
            - Range limited by power up link
    - Active RFID tags
    - Proprietary solutions from Everactive, Atmosic, WilloT

Motivation for passive/battery-less IoT in 3GPP

- 3GPP technologies cannot meet the combination of cost, longevity device footprint/form-factor requirements for the use cases of interest

- Current battery-less solutions like RFID do not meet all the requirements of use cases
    - Demand for improved coverage and device density with ultra-low cost and power consumption that is not addressed by existing solutions?
- Other technologies such as Wi-Fi, Bluetooth, UWB and LORA are investigating modifications to address use cases of interest
- Use of 3GPP ecosystem and networks

Design Targets

- Improved link budget compared to existing RFID solutions
- Frequency bands for global useability
    - Licensed and unlicensed?
- Ultra-low cost (e.g., $0.02 - $0.5)
- No need for battery charging or replacement (enabling low maintenance long life cycle operation)
- Ultra-low power (e.g., < 100 micro-Watts, to enable operation with back-scattering or energy harvesting)
- Small device size, form-factor
- Positioning accuracy (e.g., 3 – 5m)
- Data rate (e.g., 10 – 100 kbps)
- Energy source:
    - Passive devices: use of backscattering techniques
    - Semi-passive devices: Devices operating with energy harvesting or with a very small battery (e.g., <100mAh)?
- Mobile originated and mobile terminated data

Areas for enhancement (of 3GPP technologies)

- Light-weight protocol
    - Operation with intermittently available energy and interrupted connections
- Low-energy transmission
- Operation with inaccurate and unstable clock
- Device density
- Simplified security
- Simplified network architecture

Based on the input above from the initial round, some questions are posed below for discussion in the intermediate round with an intention to consolidate the areas/objectives that a potential study in 3GPP should cover.

3.2 Device Types

An important question to address is the type of devices that should be considered in any study. Some companies prefer to broaden the category to any battery-less device and one company would like to go further and include devices that have a battery but where recharging the battery is not needed during the lifetime of the device.

Question: Based on the discussion, it seems reasonable to include all use cases and scenarios where devices are battery-less in the scope of any study in 3GPP. Should devices that have a battery but where recharging the battery is not needed during the lifetime of the device also be included? Please provide your views on the above question or any other related views you may have below.

Feedback Form 5: Device types to be considered

1 – VODAFONE Group Plc

Although 'battery-less' seems an intuitive concept, we actually need to set power levels (as e.g. a large solar cell can produce enough power to run a smartphone continuously) and other KPIs on data volumes/rates (otherwise you could harvest microwatts for days and then drive a smartphone for seconds).

Hence our suggested KPIs in the previous round and in particular that "Devices should be able to operate with an energy harvesting source that produces around 200 micro Watts".

With regard to a battery that lasts the lifetime of the device: this is already achievable with NB-IoT, but the battery technologies that have shelf lives greater than a few years are not cheap and are not environmentally friendly. So we do NOT support that this is part of a Passive IoT study.

2 – Apple Italia S.R.L.

Which devices to consider basically impacts the UE power that can assumed for the study. It is not clear to us what power level is assumed for the devices with battery here. It is also not clear how such a device is different from e.g. NB-IoT devices that already has a battery and can last for many years.

3 – Motorola Mobility España SA

Lenovo/Motorola Mobility

The target is to identify the requirement to define a new UE type, after specifying the UE power class, we are open to define the UE with or without battery. So Apart from the battery-less devices the use cases should also look into device having low cost battery storage and as well extending the energy harvesting to recharge those battery.

4 – Classon Consulting

for FUTUREWEI Not in favor of adding a NB-IoT-like device type as a focus of the study.

5 – China Mobile Com. Corporation

We prefer to focus on the following 2 kinds of passive devices. And aim to serve both of them by one single radio framework.

- Passive devices: use of backscattering techniques
- Semi-passive devices: Devices operating with energy harvesting or with a very small battery (e.g., <100mAh)

6 – Intel Corporation (UK) Ltd

[Intel]

We agree with the moderator's observation that, at this stage, all relevant use-cases and scenarios, including different assumptions on energy source and storage, should be considered. However, the distinction from NB-IoT, as highlighted by other companies, needs to be addressed as well.

In addition, we suggest updating the list under identified "areas of enhancement (of 3GPP technologies)" to modify "Low-energy transmission" to "Low-energy transmission **and reception**".

Also, in the same list, it would be better to explicitly list "**Simplified L1/L2 design**" since "Light-weight protocol" may not sufficiently capture the criticality of a simplified L1/L2 design to enable cost/complexity and power consumption targets being considered in the current context of "passive IoT".

7 – LG Electronics France

We think it should be a very important initial objective of the SI (if agreed) to identify use cases and scenarios to be supported in 3GPP by passive IoT. Also, it should be a very important objective to identify demands on the new types of devices based on the identified use cases/scenarios since it seems that companies are having variety types of devices with different types of energy sources and energy consumption levels.

8 – Ericsson LM

We share QC's concerns on the coverage required to make the solution relevant for 3GPP and cellular networks. In our view, solutions should support devices connected to an operator network. Therefore, we agree it would be of interest to consider all relevant options in any study. I.e., also battery-operated with energy harvesting should be considered (at least as a baseline since in principle already now an off-the-shelf energy harvester could be combined with an existing 3GPP based IoT chipset). Therefore, a more descriptive notation could also be considered, e.g. 'Ultra-low-power IoT' or 'Self-sustained IoT'.

9 – InterDigital Communications

We agree with Apple that if devices with battery are also included, then distinction from IoT devices should be made clear. In that sense, battery operated device with energy harvesting (as Ericsson proposed) may be included.

10 – China Unicom

We are not in favor of adding NB-IoT/eMTC-like device type in the study.

11 – NOVAMINT

We are not in favour of adding NB-IoT/eMTC-like device type in the study.

We should focus on device with battery-operated with energy harvesting – KPIs proposed by Vodafone going in the right direction but may be improved as it may not cover all important aspects

We are fine also to consider the proposal from Ericsson to reflect these aspects by using the term "Self-sustained IoT"

12 – Shenzhen YZF Network Technolog

OPPO

Firstly, we share same with the moderator that all the potential use cases and scenarios shall be considered. Therefore, besides the use cases for vertical aera as listed, some use cases (e.g., smart home, smart wearables) in to-C area as we mentioned during the 1st round discussion shall be added. Passive IoT provides a promising solution in these areas due to its good characteristics such as ultra-low cost, ultra-low power consumption, battery-less, small form factor etc. So, we propose the following update on the target use cases.

− Target sectors

○ Logistics and supply chain management, transportation, manufacturing (factory automation), healthcare, **wearables, smart home**, energy, agriculture, transportation, smart cities, environment.

Secondly, for the device types need to be considered in the future study. We think it depends on the output of the identified use cases and its requirements. Also, it may depend on what we can provide to fulfill the target requirements in RAN study. Generally, passive IoT will use techniques such as RF power harvesting, back-scattering and ultra-low power receiver. For different use cases and application scenarios, different devices type that implement only some or all of the above techniques may be needed. Therefore, in the current stage, the following 3 types of devices shall all be considered in the future study.

- Purely battery-less passive IoT terminal

It uses RF power harvesting, back-scattering and ultra-low power receiver and can achieve the lowest cost, the smallest size etc. But the coverage may be limited. It may be applied in smart logistics, ware-housing, manufacturing, wearables etc.

- Semi-passive IoT terminal with an energy storage unit can store the harvested energy

It uses RF power harvesting, back-scattering and ultra-low power receiver and the terminal can store the harvested energy for future use. Its coverage can be extended. It may be applied in environment monitoring, live-stock farming, smart home etc.

- Passive IoT terminal with a battery

The terminal only uses back-scattering and/or RF power harvesting to keep it work with an ultra-low power sate, thus it can work for more than 10 years without replacing the battery. Please note that due to it is active with the battery, it has much better coverage than the above 2 device types and it also has clear gap with an NB-IoT terminal due to its ultra-low cost, ultra-low power (less than 100 microwatts, which is far below tens of hundreds of milliwatts of NB-IoT). Therefore, passive IoT terminal with a battery would be more compatible with the existing cellular network from the perspective of cell coverage while it has clear gap with current NB-IoT terminal.

13 – vivo Communication Technology

Refer to our previous comments. We think at least Type A, B and C can be considered for passive IoT device.

Based on the power consumptions, sensitivity/coverage and design targets, the following types of passive IoT devices can be considered,

- **Type A (passive node)**

o Power: depend on RF incident energy harvesting, the average power consumption is approximate 1uW.

o Sensitivity/coverage: typical passive RFID sensitivity is around -20dBm

o Design: can continuously Tx/Rx

- **Type B (Energy storage intermittent Passive node)**

o Power: depend on ambient energy harvesting (e.g., solar, vibration), the average power consumption is approximate 1uW.

o Sensitivity/coverage: bursty Tx/Rx with an instantaneous high power so the sensitivity/coverage is better than Type A. Typical value can be -70 -100dBm

o Design: Intermittent communication, may introduce amplifier (e.g., LNA) for downlink/uplink

- **Type C (Semi-Passive node)**

o Power: depend on ambient energy harvesting (e.g., solar, vibration) or button battery, the average power consumption is approximate 100uW.

o Sensitivity/coverage: Typical value can be -70 -100dBm

o Design: can continuously Tx/Rx, may introduce amplifier (e.g., LNA) for downlink/uplink

- **Type D (RF-front-end)**

o Power: Good power supply for simple RF front end transceiver, the average power consumption is approximate 1mW

o Sensitivity/coverage: almost no sensitive/coverage degradation, same range as wide area coverage, e.g., more than -100dBm

o Design: can continuously Tx/Rx, may introduce amplifier (e.g., LNA) for downlink/uplink and simple RF-front-end transceiver with high accuracy crystal oscillator, mixer and etc.

14 – Philips International B.V.

Yes, we should include devices that have a battery that is not recharged during the lifetime of the product

15 – ZTE Corporation

We should focus on the devices with battery-less. If devices with battery and devices with battery-less share the same solution, we can consider including devices with battery into this topic. However, we don't think we need to carry out technical research specific to devices with battery. If there is a strong motivation about specific enhancement for devices with a very small battery, we think it should be a separate discussion.

16 – Huawei Tech.(UK) Co.. Ltd

We agree with the summary of initial round discussions from moderator.

We also agree with the proposal from Vodafone that required power levels should be set regarding to the general concept of 'batteryless'. The corresponding KPI proposed by Vodafone is fine.

Once a device satisfies the proposed KPI, it certainly can work with battery for years, and may be a passive or semi-passive device. The implementation can be determined according to detailed scenarios and customer's preference. Consequently, it is unnecessary to treat device powered by battery specially in the study of Passive IoT.

17 – Sony Europe B.V.

Yes, the study should include devices that have a battery but where recharging is not needed during the lifetime of the device.

The study can compare the benefits and drawbacks of battery-less devices to devices that have a battery that does not need to be replaced. We also need to define what "battery-less" means. Does battery-less mean that the device has no energy storage capability at all. Is a device that stores energy in a capacitor / super-capacitor a battery-less device?

We should also avoid defining an implementation. We should not be defining whether the UE has a battery or whether it has a capacitor or some other specific energy storage device. If it is assumed that there is no energy storage whatsoever in the UE, then this assumption should be clearly stated.

Given the following questions on use cases and high-level feasibility, we wonder whether we need to consider the battery / battery-less issue at this stage or whether this issue would be addressed in the SA/RAN studies.

18 – Nokia Corporation

We need good understanding of the use cases and requirements before we can say that there is no battery in the device. This is not going to be such back and wait in any case as some sensor may need a battery for sensor itself while communication part would not necessary need that (if he required range is short enough).

3.3 Structure of a Potential Study in 3GPP

With respect to how a potential study in 3GPP should be structured, suggestions have been made that a TSG-level study in RAN and SA would be needed first to address some basic questions.

Question: A suggested approach for any study in 3GPP is to have a TSG-level study in SA and RAN first. SA can study use cases and scenarios and RAN can study feasibility of potential technical solutions. Please provide your views on this structure or any other related views you may have.

Feedback Form 6: Structure of a potential study in 3GPP

1 – VODAFONE Group Plc

We see that the market opportunity for the 3GPP eco-system will disappear if 3GPP does not move fast. Hence we would prefer Rel 18 activity with the working groups. However, we recognise that some other companies have different views, and a TSG led study could be one way to lead into normative specifications being delivered in Release 19.

Do we have previous (and good) experience of TSG led studies being shared between RAN and SA? If not, a TSG RAN led study would be better owing to Passive IoT's technical radio issues. Also, the SA requirements will either be limitless/impractical (while undoubtedly desirable), or, "whatever can be done with an interesting radio unit", so it is not clear to us that involving SA will help greatly.

2 – Apple Italia S.R.L.

We are generally supportive of having a TSG-level study in SA and RAN first, which can provide clearer guideline and more focused study in WGs.

3 – Motorola Mobility España SA

Lenovo/Motorola Mobility

Suggest to start with the SA1 use case and once the SA1 finished defining use cases then RAN can study feasibility of potential technical solutions based on well-targeted use case and scenarios, otherwise the work will get duplicated in both SA and RAN when the study is performed parallely.

4 – Classon Consulting

for FUTUREWEI Support RAN and SA level study.

5 – China Mobile Com. Corporation

Considering the urgent requirement from vertical customers, our first priority is to have a SI in RAN1 and RAN2. But if majority companies prefer to study at TSG level first, we are also fine.

6 – Intel Corporation (UK) Ltd

[Intel]

We agree with the moderator's suggestion to have a TSG-level study involving SA and RAN.

7 – LG Electronics France

If this item is to be in Rel-18, we agree SA should take the initial study of use cases/scenarios then RAN may proceed with feasibilities. This should be step-wise approach since RAN may not be able to progress efficiently without given use cases/scenarios.

We also stress that SA should identify use cases/scenarios which are "valid for support in 3GPP network" since the potential use cases/scenarios seems to be in a wide spectrum considering the comments so far.

8 – CAICT

If some techiques study is required for further WI in the next phase, a SI in RAN1 and RAN2 is a better choice. We are also fine to have some TSG level studies for deployment scenarios and use cases.

9 – Qualcomm Incorporated

We support the proposed approach. Whether the SA and RAN TSG-level studies should be sequential or parallel could be discussed further.

10 – Ericsson LM

We believe it would be beneficial to have clearer view on use cases, scenarios, and requirements from SA before defining a solution in RAN.

11 – China Unicom

Considering the urgent requirement from vertical customers, we propose to have a working group level study first, and then we can have a following work item and complete in Rel-18. Furthermore, we don't think TSG level will accelerate the discussion in 3GPP.

12 – InterDigital Communications

We prefer a study in working group level. But we are ok with Sa/RAN study if this cannot be agreed.

13 – vivo Communication Technology

vivo We agree that a SA/SA1 and RAN study item for better understanding the scenarios and feasibility of passive IoT in Rel-18 is necessary.

14 – Shenzhen YZF Network Technolog

We think both study in SA1 and RAN would be necessary.

SA1 can focus on the study of use cases and additional requirements from the network. The study in SA1 is important since its output would provide what 3GPP needs to provide for the identified use cases and

its impacts on other workgroup to fulfill the new requirements. Generally, we think passive IoI will has impact on the network architecture, security, L1/L2/L3 and even NAS and the discussion on these aspects may depend on the output from SA1. Therefore, the output from SA1 can provide a full picture on the potential impact and would facilitate the discussion in other working groups.

The study in RAN TSG-level can focus on the study feasibility and the potential technical solutions for the target use case and scenarios.

15 – Shenzhen YZF Network Technolog

OPPO Resend the reply with company name.

We think both study in SA1 and RAN would be necessary.

SA1 can focus on the study of use cases and additional requirements from the network. The study in SA1 is important since its output would provide what 3GPP needs to provide for the identified use cases and its impacts on other workgroup to fulfill the new requirements. Generally, we think passive IoI will has impact on the network architecture, security, L1/L2/L3 and even NAS and the discussion on these aspects may depend on the output from SA1. Therefore, the output from SA1 can provide a full picture on the potential impact and would facilitate the discussion in other working groups.

The study in RAN can focus on the study feasibility and the potential technical solutions for the target use case and scenarios.

16 – NOVAMINT

We would favour a study at the RAN working groups level. We believe as well that a first set of requirements and KPIs could be provided by SA1 to support this. But we are ok with SA/RAN study if this cannot be agreed.

17 – Philips International B.V.

We agree with having two parallel SI at TSG-level in SA and RAN.

18 – ZTE Corporation

We think it is necessary to identify use cases and corresponding requirements in SA1 and study how to support passive IoT by core network in SA2, then discuss the feasibility in RAN after SA1 and SA2 make some progress.

19 – Huawei Tech.(UK) Co.. Ltd

Our view is that it is urgent for 3GPP to start some activities in Rel-18 (e.g. a Rel-18 RAN1-led SI), and then complete the normative work in Rel-19. It is also noted that there is related discussion in SA ongoing.

20 – Nokia Corporation

Study in RAN plenary level would seem a good way forward. This study should ideally start when F2F meetings are possible, to ensure enough time for discussion is available.

21 – Sony Europe B.V.

We support a use case study in SA1 and a subsequent TSG-RAN level study of feasibility of potential technical solutions. The SA1 study should precede the TSG-RAN level study.

Once SA1 has studied a wide range of use cases and delivered normative system-wide RQs/KPIs on ”passive IoT”, then RAN can have a feasibility study to assess the potential performance of a system that operates only on RF-incident energy (i.e. does not store harvested energy). Such a system can operate directly on continually harvested RF energy or on the basis of backscattering. A RAN feasibility study will aim to identify limitations and pros vs. cons that will help to assess what is feasible to achieve with further standardization.

3.4 Areas/Objectives for a Potential Study in 3GPP

Based on the input in the initial round, a set of areas/objectives that need to be addressed by any potential study in 3GPP are listed below. At the end of each objective, whether the objective needs to be addressed in SA, RAN or both is noted. This is just for the purpose of this discussion here to understand how to structure any potential study in 3GPP.

Question: Please provide your views, suggestions or comments on the list of areas/objectives below that any study in 3GPP should address, including whether any particular objective should be addressed by SA, RAN or both.

Areas/objectives:

- Use cases of interest, e.g., identification, tracking, monitoring and sensing for applications in sectors such as logistics, transportation, healthcare etc. (SA)
    - Determine if there is a demand for improved coverage and device density with ultra-low cost and power consumption that is not addressed by existing solutions (e.g., RFID).
- Scenarios of interest including public/private network, indoor/outdoor environment, macro/micro/pico cells and traffic models, frequency bands (including whether both licensed and unlicensed spectrum should be considered) (SA, RAN)
- Existing solutions that address the use cases of interest (SA, RAN)
- Determination of feasibility of use cases and scenarios (RAN)
- Design targets including link budget, data rate, power consumption, cost, supported energy sources etc. (RAN)
- Identification of areas for enhancement including waveform, protocols and security (RAN, SA)

Feedback Form 7: Areas/Objectives for a potential study in 3GPP

1 – VODAFONE Group Plc

As stated in the previous answer, the desirable behaviour is ”to have everything” and the only way for SA to really restrict this is to base it on what they think the radio technology can/cannot achieve - which does

not seem a good use of SA or 3GPP time.

Hence I think it could be better to start with something like:

a) what can battery-less, very low cost technology do in terms of range/data rates (i.e. identification of Feasible use cases and scenarios by RAN)

(battery less meaning <less than [250] microwatts from energy harvesting; cost « 10% of NB-IoT cost)

b) how would it co-exist with 3GPP infrastructure/frequency bands?

c) how does it compare to existing non-3GPP technologies?

d) Design targets including link budget, data rate, power consumption, cost, supported energy sources etc. (RAN)

e) Identification of areas for enhancement including waveform (RAN), protocols (RAN, CT) and security (SA)

2 – Motorola Mobility España SA

Lenovo/Motorola Mobility

We prefer to first start analyzing the use case in SA1 before starting to do the feasibility study in RAN. Starting both at the same time is not desirable and may end up in discussions getting duplicated.

Also separate SA and RAN objectives are needed and not to mix them. Our preference is to work on RAN objectives only once the SA1 study objective is finalized and SA1 specification is stable detailing the use case and scenarios, otherwise RAN does not know how the radio needs to be designed and possible scenarios such as indoor/outdoor etc., to be considered.

There is no need for parallel work between SA and RAN to identify the use case and scenarios as mentioned in the above objectives.

Below is the revised objective with the corresponding SA working group, RAN objectives are removed as we prefer to start with the SA work first.

− Use cases of interest, e.g., identification, tracking, monitoring and sensing for applications in sectors such as logistics, transportation, healthcare etc. (SA)

○ Determine if there is a demand for improved coverage and device density with ultra-low cost and power consumption that is not addressed by existing solutions (e.g., RFID).

− Scenarios of interest including public/private network, indoor/outdoor environment, macro/micro/pico cells and traffic models(SA)

− Existing solutions that address the use cases of interest (SA)

− Identification of areas for enhancement including security (SA, SA3)

3 – Intel Corporation (UK) Ltd

[Intel]

The current list of objectives includes quite a bit of study on technical solutions and details that are better suited for WG-level study than at RAN or SA levels. At this point, we think that the first discussion should be at TSG-level as discussed in previous section, and consequently, we suggest to focus on the following objectives only.

Areas/objectives:

- ***Use cases of interest, e.g., identification, tracking, monitoring and sensing for applications in sectors such as logistics, transportation, healthcare etc. (SA)***
    - ***Determine if there is a demand for improved coverage and device density with ultra-low cost and power consumption that is not addressed by existing solutions (e.g., RFID).***
- ***Scenarios of interest including public/private network, indoor/outdoor environment, macro/micro/pico cells and traffic models, frequency bands (including whether both licensed and unlicensed spectrum should be considered) (SA, RAN)***
- ***Existing solutions that address the use cases of interest (SA, RAN)***
- ~~*Determination of feasibility of use cases and scenarios (RAN)*~~
- ~~*Design targets including link budget, data rate, power consumption, cost, supported energy sources etc. (RAN)*~~
- ~~*Identification of areas for enhancement including waveform, protocols and security (RAN, SA)*~~

4 – Apple Italia S.R.L.

It makes sense to start with SA1 study first to identify the potential use cases and the associated requirements, followed by RAN study to narrow down the use cases for further WG study. The feasibility study should belong to WG level, not RAN plenary level, because it requires discussions on the solutions.

5 – LG Electronics France

Regarding the first main bullet, use cases of interest, the sub-objective should not only be determining demand for improvement to existing solutions but also be suitability for support by 3GPP network. Secondly, the last subbullet, "identification of areas for enhancement…" seems to be too ambitious for the study scope and may not be suitable for RAN/SA study either. So we suggest removing it.

6 – China Mobile Com. Corporation

Considering the clear motivation and urgent requirement from vertical industry, it is unnecessary for RAN to wait for SA1's study on the use cases. We are supportive for the following SI objectives at RAN:

- Determination of feasibility of use cases and scenarios (RAN)
- Design targets including link budget, data rate, power consumption, cost, supported energy sources etc. (RAN)
- Identification of areas for enhancement including waveform, protocols and security (RAN, SA)

7 – Qualcomm Incorporated

We think it is an important decision point in both SA and RAN whether supporting operation in macro (and micro) cells is a requirement because it fundamentally impacts feasibility. Therefore, determining whether connecting to base stations and at what range is a requirement should be prioritized.

Regarding the SA design targets, determining whether connecting to the core network is a requirement should be with high priority.

Regarding the RAN design targets, we think coexistence with legacy UE and minimizing the impact on existing network performance should be also considered. A capacity in terms of the number of connected passive/battery-less IoT devices should be no worse than the existing RFID solutions.

We think it is premature to list the areas for enhancements at this moment before a feasibility study.

8 – Ericsson LM

Regarding the use cases, in our view it is important to support also actuators, and therefore support for 'mobile terminated data' should be included in the objectives (as stated in the summary above). In addition, the following should be clarified in the sub-bullet; "…that is not addressed by existing **non-3GPP** solutions".

Regarding the scenarios, we think TDD/FDD could be added to the list, this since it is not straight-forward to support backscattering in FDD bands.

Further, related to the 'Connectivity' options in the summary, we agree with Samsung's input to focus on use cases that benefit from a cellular network. That is, prioritizing Uu, over SL and mesh solutions, to leverage on 3GPP's competitive advantage (SL and mesh can be met by any other candidate technology).

It should also be captured in the objectives that both solutions with passive and active transmission are considered in the study (i.e. no down-selection before that).

9 – China Unicom

We share the same view it is unnecessary for RAN to wait for SA1's study on the use cases. We support to consider the following objectives in high priority:

- Study and determine the feasibility of use cases and scenarios;
- Design targets including link budget, data rate, power consumption, cost, supported energy sources etc.
- Identification of areas for enhancement including waveform, protocols and security.

10 – Shenzhen YZF Network Technolog

OPPO

The study in SA1 will includes the discussion of the details of different aspects (e.g., use cases and function requirements and KPI requirements of 5GS in SA side) of passive IoT. Therefore, it shall be a working group-level study in SA1. But anyway, the final decision would be made in SA groups.

For RAN side, since it is totally new technique for 3GPP and there is obvious difference between passive IoT and the existing 3GPP techniques. So, if it were to be done in RAN in Rel-18, we agree with a study in TSG-level to investigate the technical feasibility and the general technical framework.

For the scope of the study in RAN, since use cases in To-C area (e.g., smart home and wearables.) are important to extend passive IoT applications and passive IoT would provide a promising ultra-low cost and ultra-low power technique for short range communication. Therefore, we propose passive IoT using SL shall also be studied.

11 – vivo Communication Technology

vivo for scenarios of interests, we think the following should be considered in the scope for discussion,

- **Scenario 1**: base station and UE/tag direct communication
- **Scenario 2**: relay assisted base station and UE/tag communication
- **Scenario 3**: UE assisted base station and UE/tag communication

We think ambient backscatter is important to avoid very severe self-interference cancellation at reader side. For example, the incident signal is from gNB, Tag backscatters the signal to a UE. We think scenario 2 and 3 should be considered.

Suggest the following modifications,

l Scenarios of interest including public/private network, indoor/outdoor environment, macro/micro/pico cells and traffic models, frequency bands (including whether both licensed and unlicensed spectrum should be considered), **with or without relay/UE assistance** (SA, RAN)

12 – Philips International B.V.

We agree with the areas proposed by the moderator

13 – ZTE Corporation

We suggest to start the study of use cases and requirements in SA first, instead of having a comprehensive package of use cases, feasibility and enhancements, to avoid duplicated discussion in SA and RAN and make the best use of TU. Hence, our suggestion is as below.

- Use cases of interest, e.g., identification, tracking, monitoring and sensing for applications in sectors such as logistics, transportation, healthcare etc. (SA)

o ~~Determine if there is a demand for improved coverage and device density with ultra-low cost and power consumption that is not addressed by existing solutions (e.g., RFID).~~

- Scenarios of interest including public/private network, indoor/outdoor environment, macro/micro/pico cells and traffic models, frequency bands (including whether both licensed and unlicensed spectrum should be considered) (SA~~, RAN~~)

- ~~Existing solutions that address the use cases of interest (SA, RAN)~~

- ~~Determination of feasibility of use cases and scenarios (RAN)~~

- ~~Design targets including link budget, data rate, power consumption, cost, supported energy sources etc. (RAN)~~

- ~~Identification of areas for enhancement including waveform, protocols and security (RAN, SA)~~

14 – Huawei Tech.(UK) Co.. Ltd

These areas and objectives would be likely to form the framework of a study item, but there are a few points to adjust:

- 3GPP does not generally try to evaluate performance of non-3GPP technologies because it is hard or impractical for us to set evaluation methodologies, assumptions, etc. for them.
- 3GPP should want to introduce a cellular technology which offers a technically attractive alternative even when existing non-cellular solutions already exist in the same space.
- As per previous question, we don't need to decide the responsibility assignment of the study objectives right now.
- Structurally, some duplication between the bullets. The two bullets regarding "Determine if…" and "Determination of …" can be usefully combined.

Areas/objectives:

- Use cases of interest **not captured elsewhere in 3GPP**, e.g., identification, tracking, monitoring and sensing for applications in sectors such as logistics, transportation, healthcare etc. ~~**(SA)**~~

- ~~**Determine if there is a demand for improved coverage and device density with ultra-low cost and power consumption that is not addressed by existing solutions (e.g., RFID).**~~

- Scenarios of interest including public/private network, indoor/outdoor environment, macro/micro/pico cells and traffic models, frequency bands (including whether both licensed and unlicensed spectrum should be considered) ~~**(SA, RAN)**~~
- Existing solutions that address the use cases of interest ~~**(SA, RAN)**~~
- Determination of feasibility of use cases and scenarios**, together with feasible coverage improvement and device density assuming ultra-low cost and power consumption** ~~**(RAN)**~~
- Design targets including link budget, data rate, power consumption, cost, supported energy sources etc. ~~**(RAN)**~~
- Identification of areas for enhancement including waveform, protocols and security ~~**(RAN, SA)**~~

15 – Sony Europe B.V.

The areas / objectives look good. Is the proposal that these aspects are studied at TSG level or at WG level?

16 – Nokia Corporation

We see here indeed need to have understanding of the requirements (such as coverage, target frequency bands etc.) before concluding is there a battery in the UE or not and if mobile terminated data is in the scope or not. In RAN level discussions (suitable timing Ref SA related work needs to be discussed) we also see preference for the Uu solutions. As RAN plenary meetings are quite loaded in defining Release 18 content, this discussion should aim to start once Release 18 content is concluded.

4 Final Round

Based on the inputs in the intermediate round, the following general conclusions can be made

- There is general interest in discussing the category of IoT referred to in this discussion as passive IoT.
- There seems to be convergence on the idea that the devices to be considered should occupy a segment lower in capabilities than NB-IoT/eMTC while at the same time device types and implementations should have flexibility in terms of energy harvesting approaches. A possible approach to defining this category of IoT devices is to characterize the devices as having ultra-low power consumption and cost.
- There are divergent views on how to structure further discussions in 3GPP on many dimensions including TSG vs. WG level study, sequential vs. parallel discussions in RAN and SA, and involvement of SA. This aspect needs further discussion.
- While there is divergence on how to structure further discussions, there is a possibility of alignment on a general set of areas/objectives that can be the focus of further discussions in 3GPP, however they may be structured.

Based on the above, it seems best to conclude this thread with a set of areas/objectives that can be the focus of further discussions in 3GPP.

The proposal below aims to list all the objectives that have been brought up as interesting aspects that need to be studied. Note that there is no mention of where the study should be conducted (TSG, WG, SA, RAN etc.), in what sequence (e.g, SA first and then RAN, or in parallel etc.) and with what timing. All these aspects will also need to be further discussed as indicated in the main bullet of the proposal. Some notes are also provided by the moderator below to address some specific comments:

- The proposal is now only listing areas/objectives to focus on for further discussions on a potential study. Hence, no particular sequencing, timing or any organization of the work is proposed and these aspects are also listed as needing further discussion. Hopefully, this should address the concerns of companies that preferred a particular sequence in which the work is carried out and thought that some objectives that should come later are therefore premature as well as companies that had concerns on which group a particular area/objective should be studied in. The intention here is just to create a list of aspects that will eventually need to be studied.
- For the device types that should be included in the study, the first objective in the list characterizes the devices of interest as ultra-low power consumption and ultra-low cost and leaves the particular targets for these criteria as a point for further discussion. This approach should hopefully allow inclusion of all device types of interest while clearly differentiating these devices from NB-IOT/eMTC devices.
- For companies that had concerns that inclusion of areas for enhancements in the areas/objectives is premature, it is hoped that the removal of any sequencing/timing/organization of the work from the proposal can address the concern. Eventually, areas for enhancement have to be addressed in the study.
- For those that brought up prioritization of connectivity scenarios (e.g., prioritizing Uu interface or sidelink, with or without relay assistance), connectivity to gNBs/UEs with/without relays has been added as a point for discussion in both the scenarios of interest and design targets bullets
- For those that brought up inclusion of different device types, e.g., semi-passive, those with batteries etc., the intention now is to just focus on the key characteristics of low power consumption and cost in the hope that this can define the category below NB-IoT/eMTC that seems to be of common interest. This broader definition doesn't preclude any particular implementation.
- The sub-bullet under use cases of interest for determining demand for improved coverage and device density has been removed and folded into the design targets bullet to address a comment on the desirability of a 3GPP solution even in the presence of competing solutions from other technologies.

With the above in mind, feedback is solicited on the proposal below for inclusion in the Conclusions section of this document. Based on the feedback, areas/objectives will eventually be marked as controversial or not controversial in the final report from the moderator.

Proposal:

Include the following in the Conclusions section of the moderator report:

Further discussions on a potential study in 3GPP should focus on the following areas/objectives and how the study of these are organized within 3GPP, i.e., TSG/WGs where particular areas/objectives are studied and the timing and sequencing of the study of these 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 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
- Determination of feasibility of use cases and scenarios together with feasible coverage improvement and device density for devices with ultra-low power consumption and cost
- Design targets including link budget, data rate, power consumption, cost, supported energy sources, connectivity requirements (e.g., connection to gNBs/UEs with/without relays and the targeted range), positioning accuracy etc.
- Identification of areas for enhancement (following a feasibility study) of 3GPP technologies including waveform, protocols and security
- Coexistence with UEs, infrastructure and frequency bands for current 3GPP technologies

Feedback Form 8: Areas/Objectives for Further Discussions on a Potential Study in 3GPP

1 – Deutsche Telekom AG

We do not agree with any of this !

Currently there is discussion in SA1 to initiate a Rel-18 for the topic.

This will - if approved - discuss service requirements, deployment scenarios, technical requirements, use cases, parameters etc.

RAN should not spend any further discussion on the topic, before the SA1 study has come to a final conclusion and clearly defined requirements are available !

2 – VODAFONE Group Plc

We disagree with Deutsche Telekom. The SA1 meeting is not ongoing (it starts 8th November) and the document submission deadline for SA1 is after the closure of this RAN R18 email discussion. However, we are likely to submit some documents to SA1 because some companies have - i**n this RAN email discussion**, and in SA2 discussions on a Passive IoT SID - wanted to wait for SA(1) requirements. As the amount of RAN work is non-trivial, we cannot treat Passive IoT as ”alignment with SA” and hence proper discussion of the RAN tasks is needed here in this RAN email meeting.

3 – VODAFONE Group Plc

Thanks for the summary and proposals.

a) With regard to the moderator’s summary, we think that there should be some reporting that most (all?) companies seemed to be interested in starting work s*omewhere* in 3GPP.

b) From experience with several different technologies it is vital to not be late to a market opportunity. Hence, as this is clearly a radio technology, and in the same way that LTE, NB-IoT, eMTC, NR were created, it seems logical that this activity is led from a RAN area - either TSG or RAN 1. It would be logical to report this in the moderator’s summary.

4 – Classon Consulting

for FUTUREWEI The moderator conclusions look fine to be captured in the report. Two small points.

- It would be better to include somewhere the ”e.g. RFID” that was deleted in the first round so the ”coverage improvement” is not misunderstood to be an LPWA target. Adding ”(e.g RFID)” on the ”Existing solutions” bullet would suffice.
- The intent of the last bullet is not clear

5 – Apple Italia S.R.L.

The proposal basically captures all the points that have been raised by companies. We are generally fine with capturing it as the conclusion, with the understanding that this provides a list of issues to be discussed further.

6 – Intel Corporation (UK) Ltd

Intel

We think the summary from the moderator reflects the current situation and the identified discussion points rather accurately and are fine with the summary at this stage.

7 – Samsung Research America

It is not very clear for us on the potential next step with the proposed conclusion. We think it is premature to suggest a study in RAN level, while some further discussion in 3GPP on how to organize the study for passive IoT is required first. Therefore, we propose the following changes:

Further discussions ~~on a potential study~~ in 3GPP should focus on ~~the following areas/objectives and~~ how the study ~~of these~~ are organized within 3GPP, i.e., TSG/WGs ~~where particular areas/objectives are studied~~ and the timing and sequencing of the study considering the following ~~of these~~ areas/objectives

Moreover, on the areas/objectives part, we suggest to modify and combines some bullets, that is better to start later, as:

− Determination of feasibility of use cases and scenarios, and the corresponding ~~together with feasible coverage improvement and device density for devices with ultra-low power consumption and cost D~~design targets including link budget, data rate, power consumption, cost, ~~supported~~ energy sources or energy harvesting techniques to support battery-less devices, connectivity requirements (e.g., connection to gNBs/UEs with/without relays and the targeted range), positioning accuracy etc.

~~Identification of areas for enhancement (following a feasibility study) of 3GPP technologies including waveform, protocols and security~~

8 – Qualcomm Incorporated

One observation we can make is that there are two distinct and potentially incompatible outcomes that companies seem to have in mind:

- (1) A smaller/slower/lower complexity version of NB-IoT, capable of operating in traditional ways in a cellular network;
- (2) Next generation RFID, which could be able to communicate with base stations, but most of the time it would not communicate with base stations but rather with RFID readers, other devices, relays.

The two cases could be bridged, in theory, with a new type of Passive RFID device that is able to close the communication link at 1...2 km range with a reasonable minimum data rate. But based on the design targets presented in the email discussion, this type of device doesn't seem to be in the realm of possibilities. Therefore, it appears that we do not have a common target that the future work could converge on.

This means that significant further discussion is needed in order to converge on the characteristics of the target technology.

Based on that, a Plenary level study seems necessary. In order to avoid duplication work done by SA, close coordination with SA regarding the sequencing of the work is also needed. Conducting SA work first, before starting the RAN Plenary level study, would seem to make sense.

Our suggestion is to capture the latter part of the above in the moderato's summary as follows:

"Further discussions on a potential Plenary level study in 3GPP (SA first, RAN second) should focus on the following areas/objectives and how the study of these are organized within 3GPP~~, i.e., TSG/WGs where particular areas/objectives are studied and the timing and sequencing of the study of these areas/objectives~~

9 – Motorola Mobility España SA

Lenovo/Motorola Mobility:

The classification of the device type should be based on the data rate, ultra low power consumption, ultra low complexity/cost&form factor

while should not be based on whether the device supports battery source or not, and type & cost of battery source, such aspect can be used as evaluation criteria to design the system.

We prefer SA1 study for this item first before studying it in RAN plenary level and the scope should include use case and scenarios beyond passive RFID tags to define low power, low date rate, lower complexity devices compared to NB-IoT.

Also it is not clear whether defining a new RFID tags based on 3GPP tech would be useful as millions of existing/deployed RFID tags in factories also requires similar connectivity.

10 – Nokia Corporation

We see this as a topic that would benefit from F2F discussion as fully new area (for 3GPP) with very few inputs mentioning this in RAN Release 18 workshop. Perhaps the best would be to aim to have discussion on this once we have again F2F plenary meetings and we are past Release 18 package approval for RAN WGs. For this one could well assume we are not heading for approving any RAN WG level activity for this from RAN#94 (or RAN#95). Coming to common understanding of targets would be necessary before detailed technical discussion is sensible.

Topic wise items not foreseen to be covered elsewhere like energy harvesting would be good to have as part of the discussion scope listed in the moderator summary, whenever the discussion resumes.

11 – Ericsson LM

We are overall fine with the listed areas/objectives.

As earlier pointed out, we think it is important in any study to focus on the competitive advantage of 3GPP compared to competing technologies, and therefore 'connectivity to gNB' should be prioritized and 'relay' and 'UE assistance' omitted from the areas/objectives.

A key aspect of a study would be to better understand the tradeoff between coverage and power consumption of the devices. (In order to determine the most suitable device type, i.e. passive, semi-passive, battery-less, and which UE power class to target etc.). We propose to more clearly capture this among the listed areas/objectives, e.g. as a sub-bullet:

- *The device type should be selected based on a tradeoff between coverage and power consumption, for which the use cases, scenarios and requirements can be met.*

We propose to include 'actuators' in the example of use cases to emphasize that both UL data and DL data uses cases should be supported (currently only UL examples are listed).

12 – CAICT

We are fine with moderator's proposal. The urgence of introducing new IOT type is clear from previous discussions. Study item(s) in RAN in R18 is quite necessary.

13 – NOVAMINT

We are very supportive of this topic and we believe there is an urgency to address it in Release 18 but we should not confuse speed and haste.

We would agree that some further discussions in 3GPP are needed in order to converge on the characteristics of the target technology and how to organise the study for passive IoT.

So we would tend to agree with Qualcomm suggestion to have Plenary level study (conducting SA work first based likely on SA1 first inputs, before starting the RAN Plenary level study).

14 – InterDigital Communications

We are fine with this conclusion.

15 – China Mobile Com. Corporation

Thank you for moderator's hard work. The proposals look fine to us.

We share same view with Vodafone, CAICT and other proponents on the urgency of Passive IoT. The evaluation for introducing Passive IoT to 3GPP is mainly focus on the radio link, not core network nor service level. So it is more reasonable to have a study item in RAN rather than SA1.

16 – VODAFONE Group Plc

We see that RAN work is the essential part in order to establish what is technically feasible (and useful in a 3GPP eco-system) with a battery-less device. Hence we would not want this work to be delayed by having a preceeding SA study.

The rapid creation of a TSG-RAN led study would seem to be a natural compromise between an immediate RAN 1 SID and some SA led activity.

17 – Sony Europe B.V.

We basically agree with the moderator's conclusions.

There are comments in the feedback form above, many of which we agree with or have sympathy with, that propose detailed re-writing of the conclusion. Is this really necessary since this is just a conclusion and guidance for where we go next?

Having said that:

- we agree with Futurewei that it would be good to clarify that the coverage improvement is relative to existing technologies (e.g. RFID) and is not about LPWA

- we think it is good that the current conclusions don't talk about batteries. We think it is OK that the conclusions talk about "ultra low-power" etc. and that this is better than talking about batteries.

18 – China Unicom

Thanks for the good summary. We think there should be some reporting that a long list of companies shows the interest in starting work in 3GPP RAN. As a operator, we share the same view with other operators, the passive IoT solution is critical to explore new business opportunity. We strongly support to start a Rel-18 study item in RAN.

19 – Philips International B.V.

We agree with the proposed areas. We think this topic (28) will require further online discussion to try to converge in RP#94-e

We agree with Vodafone in that 3GPP should not start this work too late and miss the market opportunity and this discussion in RAN helps outlining the work ahead

20 – Shenzhen YZF Network Technolog

OPPO:

Generally, we are fine with the conclusion as the starting point for further discussion. In addition, we have following comments and suggestions.

Firstly, as we commented in previous rounds, besides the use cases for vertical aera as listed, some use cases (e.g., smart home, smart wearables) in to-C area shall be added for further study. Passive IoT provides a promising solution in these areas due to its good characteristics such as ultra-low cost, ultra-low power consumption, battery-less, small form factor etc. From this perspective, we would like to keep "connectivity to gNBs/UEs with/without relay/UE assistance" as it is.

Secondly, for the bullet "Determination of feasibility of use cases and scenarios together with feasible coverage improvement and device density for devices with ultra-low power consumption and cost", we understand the intention is to study the feasible coverage improvement and device density for devices with ultra-low power consumption and cost compared with the existing solution, e.g., RFID. Therefore, it shall be clarified as also suggested by other companies.

21 – Telstra Corporation Limited

Agree with China Unicom

22 – Huawei Tech.(UK) Co.. Ltd

The summary is a fair representation of the discussion this week.

There is a comment from Qualcomm relating to the range of the devices. In fact, passive IoT would sit between full macro cellular coverage, and the extremely limited range of RFID. The link budget of passive IoT suits indoor small cells with 20-30 m range, or micro-cell outdoor environments, on the order of 200-300 meters. It is feasible to achieve the requirement by referring to existing coverage enhancement techniques in 3GPP, while the power consumption of device is kept suitable to be powered by energy harvesting by careful design.

23 – ZTE Corporation

1) For the potential TSG,the following is suggested to be clearer:

Further discussions on a potential study in 3GPP should focus on the following areas/objectives and how the study of these are organized within 3GPP, i.e.,~~TSG/WGs~~ **SA/RAN** where particular areas/objectives are studied and the timing and sequencing of the study of these areas/objectives

2) Since waveform, protocols and security are not enhancements at the same level, and more enhamcements may be identified in the future study, the following update is proposed:

Identification of areas for enhancement (following a feasibility study) of 3GPP technologies in ~~**including**~~ **RAN and core network** ~~**waveform, protocols and security**~~

24 – Verizon UK Ltd

The summary seems to be fine. While we are interested in the potential new uses cases, we understand the reasons from both sides. The issues listed can be discussed further.

5 Summary

Section 2 contains the detailed inputs from companies on use cases and scenarios, existing solutions and design targets and areas for enhancement. Section 3.1 contains a distilled summary from the moderator of the company inputs on these and any other aspects raised. Section 3 and 4 contain further inputs from companies in response to the moderator's questions.

6 Conclusions

Moderator's Note: The conclusions below attempt to reflect all the inputs provided to this discussion. However, the conclusion may still be controversial.

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

7 References

[1] RP-212608, ”RAN Chair’s Summary for RAN Release 18”, RAN Chair

[2] RP-212657, ”Additional Guidance on RAN Rel-18 Email Discussion during October 20th to 29th”, RAN Chair

[3] RWS-210659, ”Summary of RAN Rel-18 Workshop”, RAN Chair

[4] RP-211665, ”Moderator’s summary for discussion [RAN93e-R18Prep-15] Additional RAN1/2/3 candidate topics, Set 2”, RAN1 Vice-Chair (Ericsson)