

The Discussion on the motivation of Passive IoT

China Mobile, Spreadtrum Communications, Huawei

Two Categories of Use Cases for Passive IoT

Pre-stored data report (e.g., Automated asset management)

Small size, ultra-low cost, and batteryless device is required in most cases for automated real-time inventory and tracking of objects for asset management. Typical industries include:

- Manufacturing
- Logistics and warehousing

Current practice: Barcode on paper for inventory and tracking



Printer



Printed barcode on various parcels



Barcode

Handheld LOS scanning (labor intensive)
Slow one-by-one scanning (time consuming)



Passive IoT tag

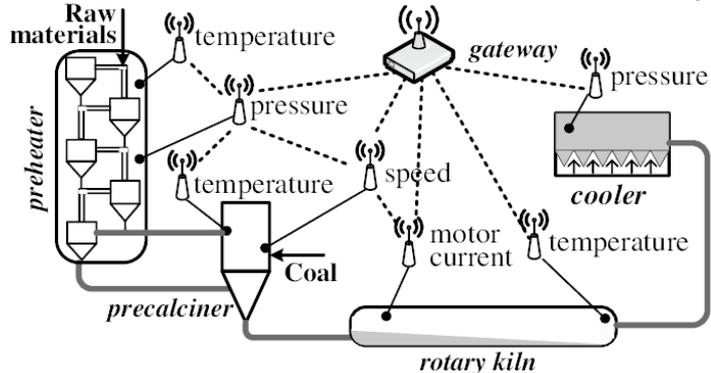
Automatic remote reading
Hundred times faster reading

Real-time data report (e.g., Sustainable sensor network)

Wireless sensor without battery during lifetime is required for remote environment and object status monitoring. Typical industries include:

- Manufacturing
- Agriculture and livestock farming

An industrial wireless sensor network in a cement factory



Battery-operated

Cost for batteries and replacement
Device size impacted by battery
Infrequent transmissions for battery life
Environmental issue (Lithium, lead, etc.)



Energy-harvesting

Self-sustainability
Miniaturized device
No limits on transmission period
Eco-friendly (Ambient energy)



Batteryless device during lifetime is the essential requirement.

Batteryless device market

- **RFID supports batteryless tag, predicted to have explosive market growth**
 - RFID tag is mainly used for identity detection, especially in retail and logistics industries
 - More R&D on applying RFID for sensing in recent years
 - With the acceleration of digitalization in various industries, global RFID market volume is predicted to exceed **49 billion** by 2031 at a compound annual growth rate (CAGR) of **9.3%** ^[1]
 - The market will grow more rapidly from 2026
- **Global sensor market is predicted to grow from \$193.9 billion in 2020 to \$332.8 billion in 2025, at a CAGR of 11.4%** ^[2]
 - Considering the average cost of 0.5\$ for sensors ^[3], there may be hundreds of billion connections in the near future
 - It is impractical to replace battery regularly for such a huge volume of sensors

Once competing technologies grab the huge amount of connections, it will be difficult for cellular based technology (e.g. Passive IoT) to regain the market share.

Passive IoT Advantage

- **Superior coverage** and **new functionalities**, such as sensing, will make Passive IoT more attractive than RFID in some traditional markets
 - Logistics and supply chain, manufacturing, agriculture, etc.
- Passive IoT can open new markets
 - Livestock farming, energy (electricity/oil)
- RFID may continue in cost sensitive markets without strong need of large communication range and new functionalities
 - Retail

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

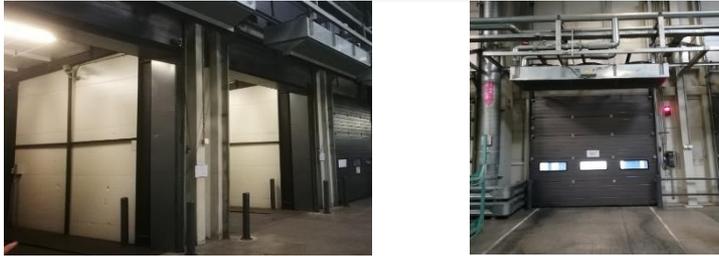
[2] Sensors: Technologies and Global Markets (<https://www.bccresearch.com/market-research/instrumentation-and-sensors/sensors-technologies-markets-report.html>), BCC Research

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

Use Cases #1: Automated Asset Management in Factories

unique identify the bins for logistic management.

Bin management at the Gate of the warehouse



Identify which bins move in or out of the warehouse, at the Gate of the warehouse.

Bin management inside the warehouse



RWS-210350 Requirements to URLLC, positioning and perception for automotive industry, China Mobile & BMW Brilliance Automotive, 3GPP R18 WS

Current Practice

Currently, bins are manually managed via scanning the barcode attached on each bin.

Problem:

- **High OPEX:** OPEX of warehouse management is very high for us
- **Manual error:** Manual work often cause errors and many bins lost

We are considering Automatic bin Management in the warehouse with a quite low cost.

Potential RFID technology

We have considered RFID technology, but RFID is not good.

- **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 fail 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) and the network cost is very high.

Key requirements :

1. **low cost batteryless device**
2. **sufficient link budget for appropriate deployment**

Use Cases #2: Automated Asset Management in Outdoor Warehouse

For power grid companies, there are plenty of equipment and cables stored in their outdoor warehouses (usually a few thousand square meters)

Equipment/Cables management outdoor



Identify the equipment/cables in outdoor warehouse

Current Practice

Currently, RFID tags are pasted on each equipment and cable for asset management

Problem: Inventory is done by scanning the RFID tags one by one within short range

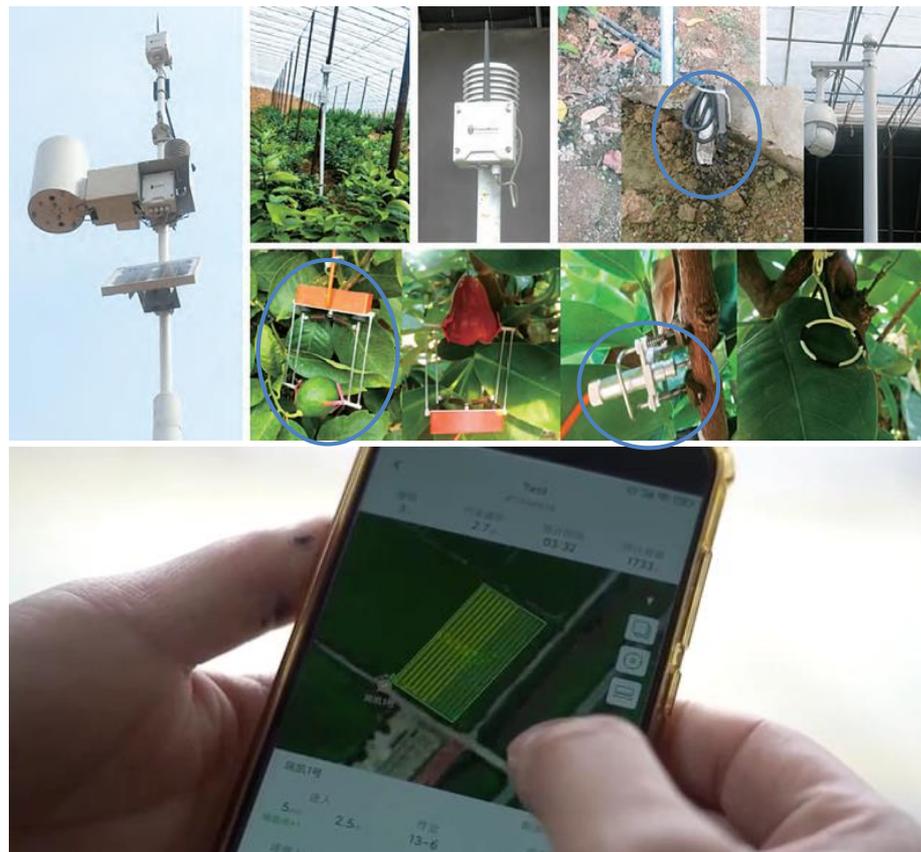
- **High OPEX:** OPEX is high for manual scanning is needed
- **Not realtime:** it takes long time to scanning the tags one by one. Additionally, as real time inventory is unable to be reached, asset lose cannot be warned in time

Key requirements:

1. low cost batteryless device to avoid high-voltage breakdown
2. sufficient link budget for outdoor deployment

Use Cases #3: Sustainable Sensor Network for Agriculture

- **Sensors are widely deployed in digital farm to monitor environments, crops state, and equipment state**
 - Environments
 - light intensity, CO² concentration
 - Crops state
 - size of fruit, temperature, humidity
 - Equipment state
 - working ours, power consumption
- **Real time information is important to adjust planting mode in time**
 - Existing cellular IoT devices will suffer from battery life of no larger than one year with reporting period of a few minutes
- **It is not realistic to replace batteries of thousands of sensors scattered throughout farms every year**
 - No battery is preferred



Key requirements for Passive IoT:

1. low cost batteryless device
2. sufficient link budget for outdoor deployment

Use Cases #4: Passive IoT Opens New Market of Livestock Monitoring

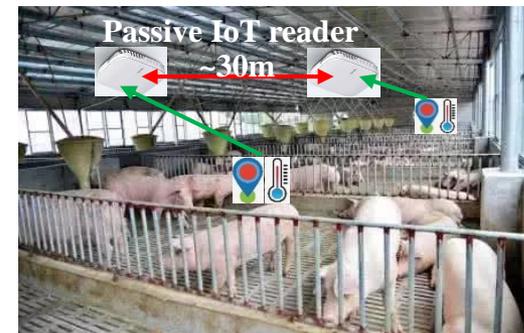
A GLOBAL INITIATIVE

- **Global livestock monitoring market size**
 - **4.1 billion \$ in 2020**
 - **13.5 billion \$ in 2028** with a CAGR of **16.56%** [1]
- **Requirements and current status**
 - **Periodical temperature monitoring**
 - Status: random sampling once for a long interval
 - **Periodical inventory**
 - Status: manual count and record

Inaccurate and insufficient manual operations reduce production capacity
- **RFID cannot work well**
 - Passive tag: short range of **a few meters** as harvested RF energy shared by sensor and transceiver
 - *Missing detections* caused by poor coverage
 - **Active tag with battery: large size, heavy weight** and **high cost**
 - Thick (e.g., >3cm) and heavy due to battery
 - At least several dollars per tag
- **Passive IoT provides optimal solution**
 - **Small size, light weight, low cost, and batteryless** tag
 - passive tags powered by energy harvesting (e.g., RF, illumination)
 - **Seamless coverage**
 - Larger communication range: indoor **>30m**, outdoor **>100m**



Small size and **light weight** are both critical for tags installed on animals

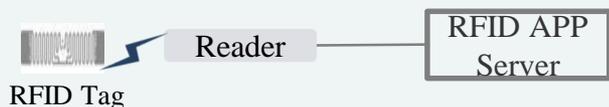


Passive IoT deployment: **~1 reader/1000m²**

[1] Livestock Monitoring Market Size, Share & Trends Analysis Report 2021-2028, Grand view research (<https://www.grandviewresearch.com/industry-analysis/livestock-monitoring-market>)

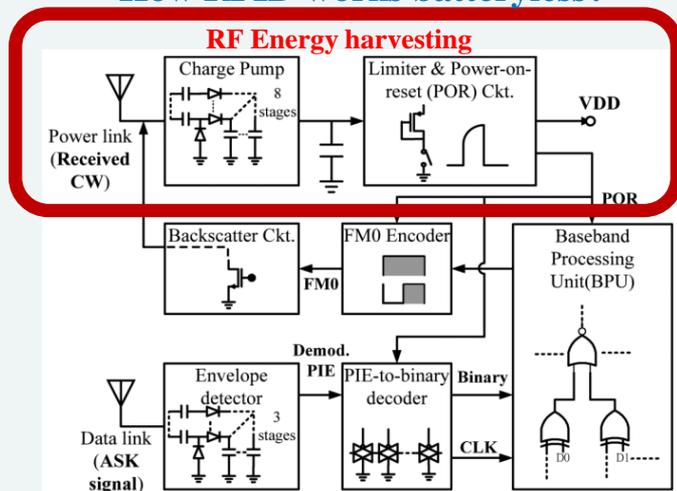
Existing batteryless technology-RFID

General architecture of RFID



Based on the order from RFID APP Server, a Reader wirelessly interacts with the RFID Tag to inventory/read/write the tag and return the information.

How RFID works batteryless?



[1] A -21.2dBm Dual-Channel UHF Passive CMOS RFID Tag Design

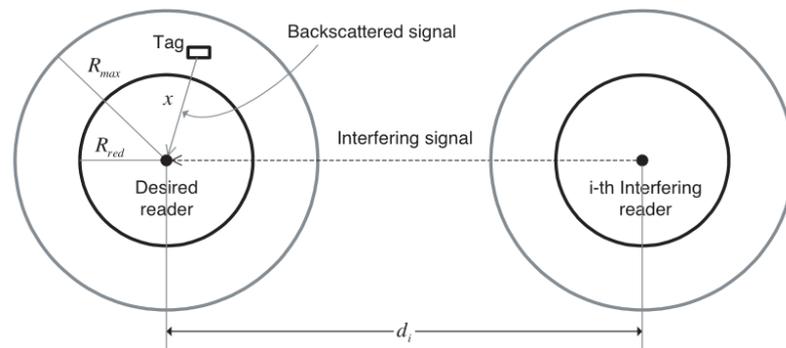
RFID tag is capable of harvesting energy for communication from RF(Radio Frequency) emitted by Reader

Problem of RFID

Coverage of a commercial RFID reader is only around or less than 10 meters in practical

Some of the reasons:

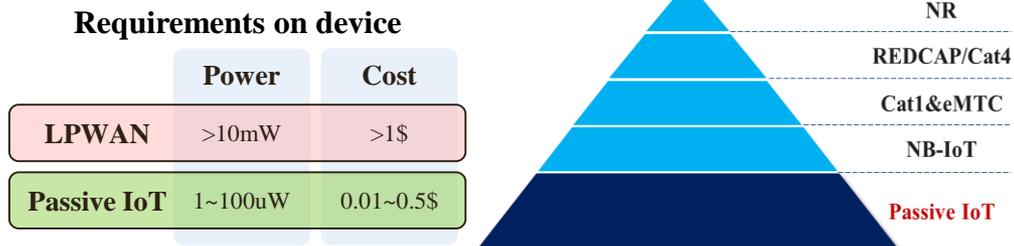
- ❑ **Power restriction:** according to the regulations of specific UHF band for RFID, EIRP of downlink signals should **not exceed 36dBm**
- ❑ **Interference between readers:** reduces the coverage of each reader significantly [1]



[1] INTERFERENCE ANALYSIS OF UHF RFID SYSTEMS, Progress In Electromagnetics Research B, Vol. 4, 2008

Requirements on Passive IoT for the Target Use Cases

- **Ultra low power device**
 - ❑ Power consumption low enough to work with energy harvesting (1~100uW)
 - ❑ Harvest energy from Radio frequency or Solar.
- **Ultra low cost device**
 - ❑ For automated asset management, cost no significant increase compared with barcode printed on heat sensitive paper (~0.01\$)
 - ❑ For sustainable sensor network, cost comparable with sensor (~0.5\$)
- **Coverage and networking match the deployed cellular network**
 - ❑ Indoor deployment: small cell with distance of 20~30 meters between neighboring pico remote radio units
 - ❑ Outdoor deployment: micro cell with distance of 200~300 meters between neighboring base stations
 - ❑ Interference management for adaptive networking
 - ❑ Network Architecture to manage the Passive IoT tags



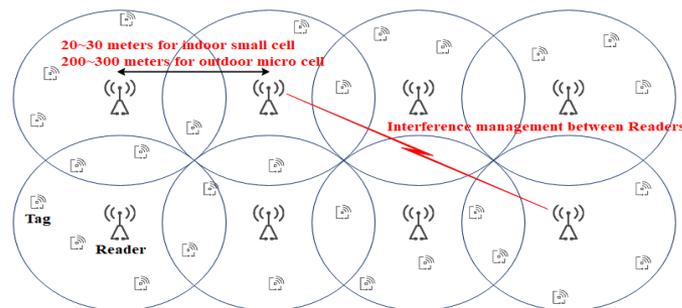
Passive IoT targets at new IoT markets lower-end than all the existing cellular technologies, which require batteryless device for low maintenance cost

Typical energy sources for energy harvesting [1][2]

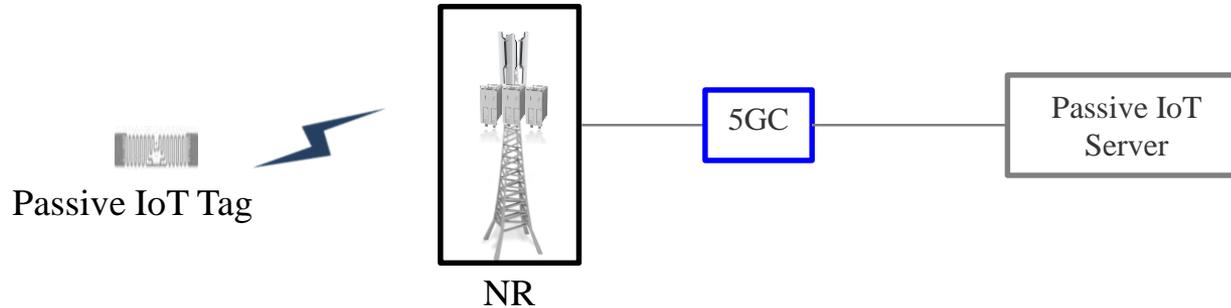
Energy source	Size	Availability	Power density	Conversion efficiency
Solar	Good	Fair	15~100mW/cm ²	10~20%
Artificial Light			10~100uW/cm ²	
Airflow	Poor	Good	100mW/cm ²	-
Motion	Fair	Fair	200uW/cm ²	~10%
Thermal	Good	Poor	~50uW/cm ²	3%
Radio frequency	Fair	Good	1~10uW/cm ²	< 20%

[1] Internet of Hybrid Energy Harvesting Things, IEEE INTERNET OF THINGS JOURNAL, VOL. 5, NO. 2, 2018

[2] Energy Harvesting Sensor Nodes - Survey and Implications, IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 13, NO. 3, 2011



Standard work on Passive IoT



• RAN Group

Motivation: develop the air technology to support the batteryless IoT device.

Work scope:

- ❑ Downlink coding and modulation
- ❑ Uplink coding and modulation scheme supporting backscatter transmission
- ❑ Frame structure and synchronization scheme
- ❑ Minimized protocol stack
- ❑ Coexistence with existing cellular technologies in licensed spectrum

• SA2 Group

Motivation: develop the network architecture to support batteryless IoT device and enable the business.

Work scope:

- ❑ Study the general architecture for supporting Passive IoT in 5G system
- ❑ Study how to manage the Passive IoT device
- ❑ Study how to manage the connectivity for the Passive IoT device
- ❑ Study how to support the mobility for Passive IoT device

Thanks!