RWS-210453

3GPP TSG RAN Rel-18 workshop
Electronic Meeting, June 28th – July 2nd, 2021

Agenda Item: 4.2

5G evolution support of NR passive IoT

Huawei, HiSilicon

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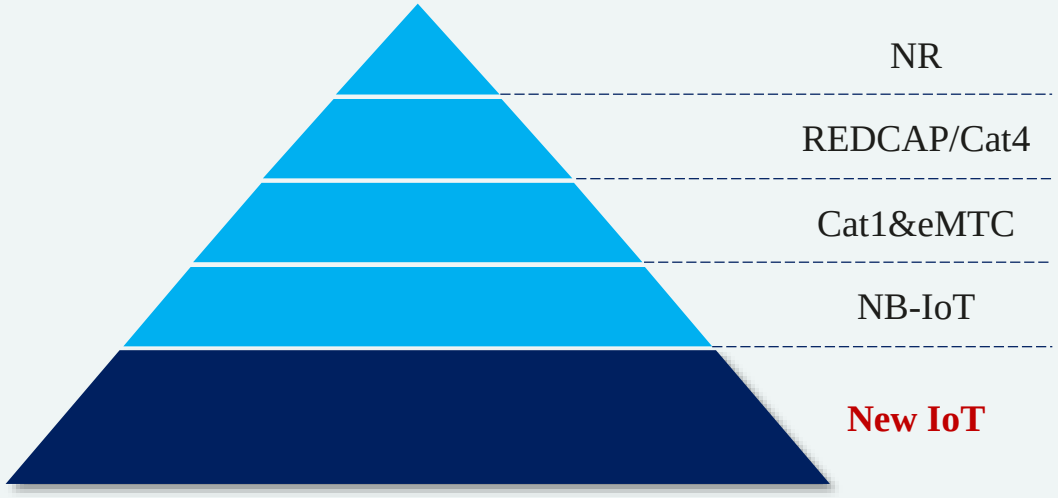
New IoT Technology Is Needed for Connections of Everything

Hierarchy of future IoT world



Essential requirements on new IoT technology

	Power consumption	Cost
LPWAN	>10mW	>1$
New IoT	E.g., 1~100uW	E.g., 0.01~0.1$

Proposal 1: Study and specify new IoT techniques to reduce device cost by more than 10 times and power consumption by more than 1000 times compared with existing mMTC technologies in 3GPP.

Typical applications for new IoT technology

Logistics and Warehousing

- Automatic inventory and tracking of goods, with **ultra-low cost and batteryless** tags for identity inquiry
- Temperature and humidity sensing for goods, with **ultra-low cost and power** sensors preferred

Manufacturing

- Automatic inventory and tracking of materials and assets, with **ultra-low cost and batteryless** tags for identity inquiry
- Environment and equipment status sensing **without replacing battery** during sensor's lifetime

Electrical power and energy industry

- Environment and equipment status sensing in power grid, coal mine and etc., with **batteryless** sensors for production safety

Example of potential markets: the express industry

- Parcel volume is forecasted to reach 163.4 billion by 2025 in china [1] and 220-262 billion by 2026 globally [2].
- Automatic inventory and tracking of parcels requires **ultra-low cost and batteryless** tags

[1] Research on logistics industry trend and key manufacturers, Deloitte Consulting, 2019
[2] http://news.pb.com/article_display.cfm?article_id=5958, Pitney Bowes Inc., October 2020

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Use case (1): Inventory Management

- **In logistics, warehousing and manufacturing industries, it is important to maintain an accurate and up-to-date database for goods, materials and assets**
  - Barcode is used nowadays, which is hard to realize real-time inventory and tracking
    - Scan at a short range with a direct line of sight to the barcode
    - Manually scan one by one
    - Not able to be rewritten to keep a record of current status, quality, process progress and etc.
    - More easily to be damaged as barcode has to be exposed for scanning

- **Automatic inventory improve productivity by reducing labor costs, promoting throughput of warehouse, and providing real-time accurate data and quality control**
  - Replace barcode with an electronic tag wirelessly communicating through radio frequency (RF) signals
    - Remote reading with no need of line of sight
    - Automatic scanning at a rate of more than one hundred tags per second
    - Rewritable to record various information during the process
    - Positioning for tracking

  - Ultra-low cost and power consumption for the tag, where batteryless tag preferred or even desired for a self-sustaining and maintenance-free network

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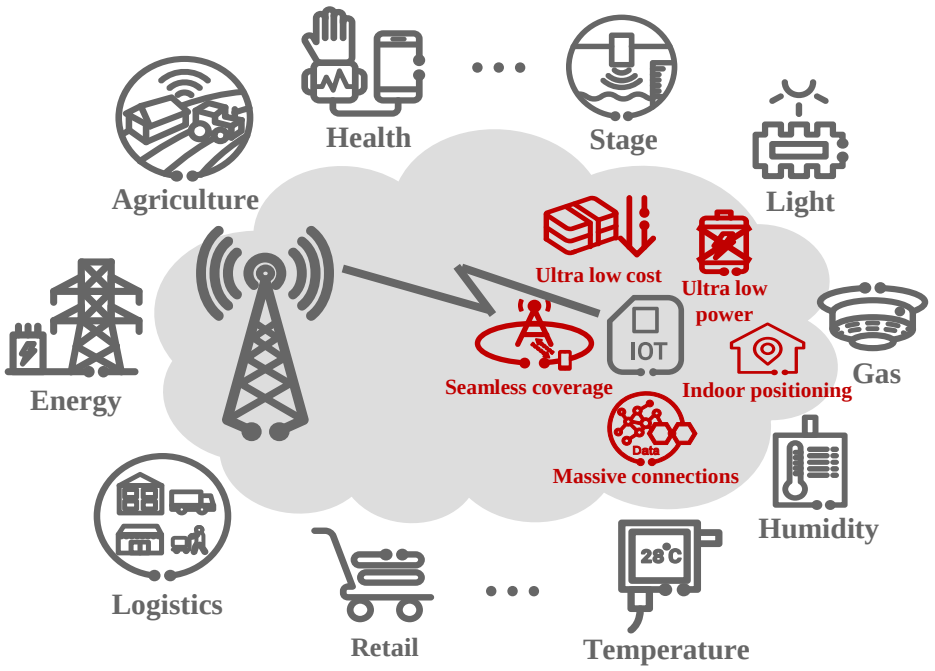
Use Case (2): Wireless Sensor Network

- **Build a world with sensors and actuators ubiquitously distributed and conveniently interconnected**
  - In smart agriculture, sensors are used to monitor temperature, humidity and pH of soil for harvesting more crops per area and yielding higher quality products
  - In industrial automation, sensors are used to monitor environments and status of equipment for prediction and planning to avoid failure, ensure safety and increase efficiency
- **One critical challenge is to build sensors to be easily deployed and run autonomously during lifetime**
  - Large area deployed with lots of sensors randomly located, which makes the replacement of sensor batteries expensive or impossible



Connecting everything

- **With the development of microelectromechanical system (MEMS) techniques, sensors become tiny size, low cost and high performance**
  - The power consumption of MEMS sensor can be as low as the level of microwatts
  - Wireless communication devices are expected to share the same level of power consumption

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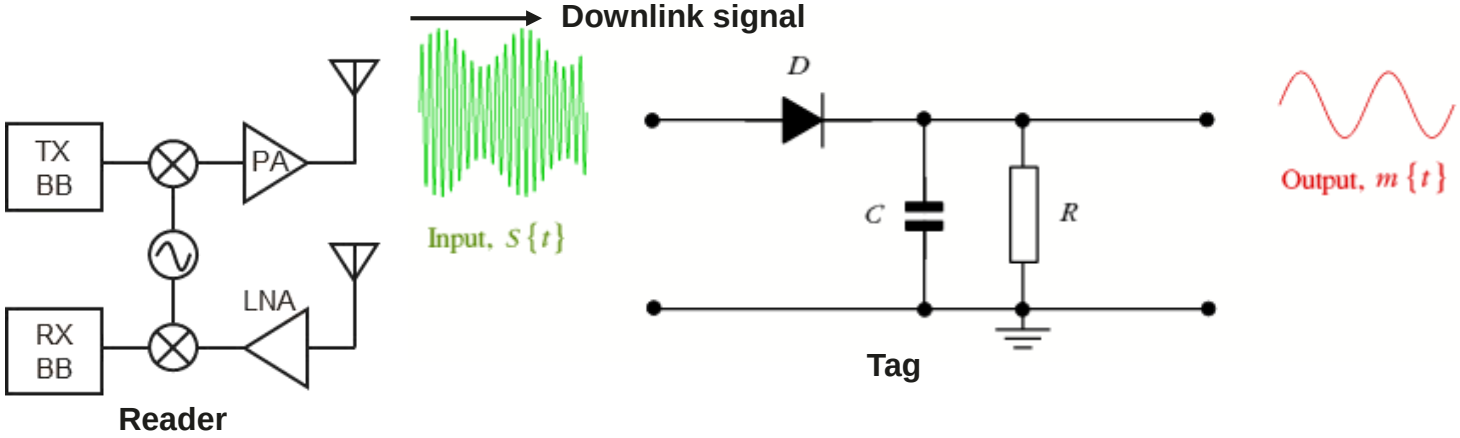
Technical Approaches (1): Envelope Detection for Downlink

- **Envelope detection is a kind of non-coherent demodulation method**
  - Ultra-simple hardware without the need of mixing received RF signal with locally generated carrier waves
    - High power RF chains can be saved, which comprises oscillators, mixers and digital-to-analog converters
  - Proper modulation scheme supporting envelope detection shall be used for downlink
    - For example, a detector for on-off keying (OOK) can easily be implemented by using a diode and a resistor-capacitor oscillator circuit as a bandpass filter
    - Power consumption as low as 1uW can be achieved for envelope detection of OOK [1]



Envelope Detector for OOK [2]

Observation 1: Downlink receiving with envelope detection can achieve power consumption as low as 1uW.

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

[2] http://www.winlab.rutgers.edu/~crose/322_html/envelope_detector.html

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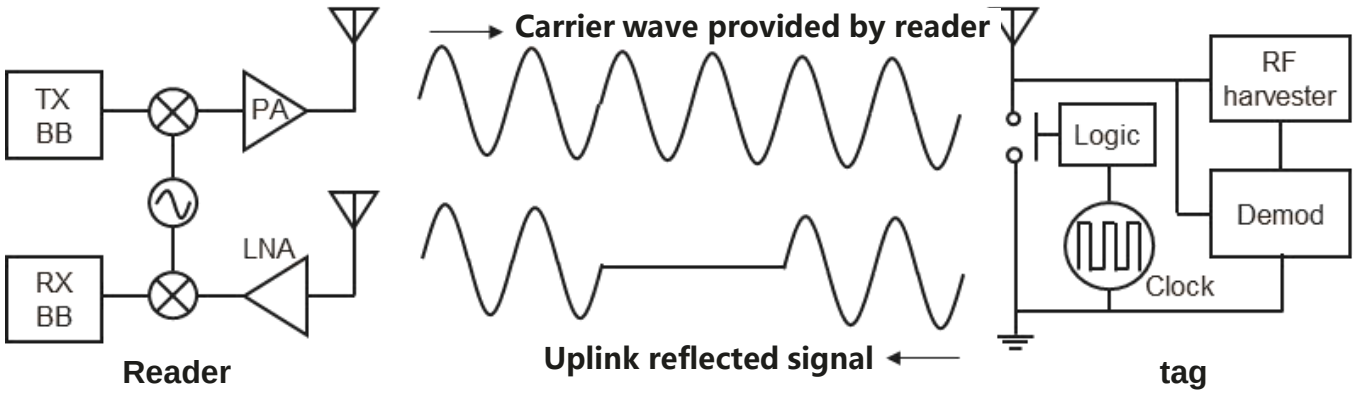
Technical Approaches (2): Backscatter Communication for Uplink

- **Backscatter transmitter transmits data without generating carrier wave by itself**
  - Reader sends carrier wave to a backscatter tag
  - Tag modulates and reflects received carrier wave to transmit data
- **Power consumption of a backscatter transmitter can be as low as 1uW [1]**
  - As a reference, traditional transceiver with RF carrier generation usually consumes power of tens of milliwatts [2]
- **The RF frontend of tag is reduced to a single transistor switch, which minimizes manufacturing costs as well**



Demonstration of backscatter communication

Observation 2: Uplink backscatter transmitter can achieve power consumption as low as 1uW.

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

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

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New 5G IoT paradigm: Passive IoT

- **For ultra-low power consumption device, envelope detection for downlink receiving and backscatter modulation for uplink transmission shall be used**
- **Passive IoT device with ultra-low cost power consumption will have strongly restricted hardware capability**
  - Inaccurate and unstable reference clock
  - Unable to support complex protocol stack
- **The following basic aspects have to be studied for Passive IoT**
  - Downlink coding and modulation scheme supporting envelope detection
  - Uplink coding and modulation scheme supporting backscatter transmission
  - Frame structure and synchronization scheme supporting inaccurate and unstable reference clock for low-end device
  - Minimized protocol stack supporting necessary functionalities and proper performance (e.g., radio resource efficiency)
  - Coexistence with existing cellular technologies

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Thank you.

Energy Harvesting

- **Energy harvesting**
  - Collecting energy from environment or energy sources other than battery or grid
  - Output power is usually around or less than 1mW for devices with limited size
    - Many typical applications require devices with limited size
    - Energy conversion efficiency is usually not high (e.g., ~15% for solar energy)

Typical energy sources for energy harvesting [1]

Energy source	Power density	Advantages	Disadvantages
Solar	15mW/cm^3	Sufficient energy in the daytime, high output voltage	Disappear at night
Vibration (piezoelectric)	200uW/cm^3	Without voltage source	Brittle materials
Thermoelectric	40uW/cm^2	Long life, reliable with low maintenance	Low energy conversion efficiency
Acoustic noise	960nW/cm^3	High energy conversion efficiency	Rare environments with high acoustic noise value
Airflow	1mW/cm^2	Sufficient in certain place and time	Big Size
Radio frequency	1uW/cm^2	Sufficient in urban areas	Few in suburbs

- **Wireless power transmission**
  - Radio waves can be used to carry energy as well as information
    - Far-filed energy transfer with signal strength attenuated by about 20 dB per decade of the transmission distance
    - Suitable for simultaneously powering a larger number of devices distributed in effective area

[1] A survey of energy harvesting communications: models and offline optimal policies, IEEE Communications Magazine (Volume: 13, Issue: 3), June 2015

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