Ambient IoT positioning

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Abstract

- **Based on the discussion of the use cases and requirement, it can be seen that positioning/ranging is required in many of the Ambient IoT use cases[1][2][6] such as smart home, indoor positioning, intra-logistics and warehousing, smart manufacturing etc. The required positioning accuracy is 1~3m for indoor and 10m for outdoor.**
- **In this submission, the positioning technologies for Ambient IoT is discussed and a demo is also presented.**

Representative UC#1: Items tracking in Smart home scenario

- Ambient IoT can be used in the following applications:
  - Asset management: finding home belongings
  - Home environment monitoring: e.g., temperature, humidity, gas leakage etc.
  - Home security: intruder detection.

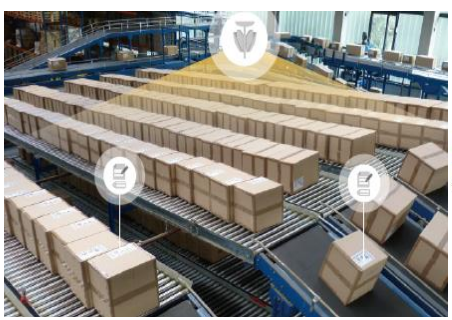
- Requirements
  - Low complexity and small size, e.g., thickness of 1mm and area of several cm2
  - Long service life., e.g., more than 10 years.
  - No need to replace/recharge a conventional battery, e.g. Maintenance-free for battery
  - Coverage up to 10m
  - Positioning accuracy of 1~3m

Representative UC#2: Indoor positioning

- ❑ Currently, there is no effective low-cost techniques for indoor positioning.
- ❑ Ambient IoT device can serve as anchors for indoor positioning.
  - For Car parking
  - Navigation in shopping centre
  - For manufacturing and logistics
- ❑ Requirements
  - Communication range: 10~30m
  - Positioning accuracy: 1~3 m horizontal accuracy

Representative UC#3: Intra-Logistics and warehousing

- ❑ Ambient IoT device can be attached on the packet for goods tracking when they are being transferred, stored, loaded/unloaded, and inventoried for logistics and warehousing.
- ❑ Requirements of the IoT devices:
  - Battery-less, thus no need to use a battery
  - Low complexity and small size
  - Coverage: up to 30m for indoor case, up to 100m for outdoor case
  - Processing (i.e., reading IDs) hundreds to thousands of devices per second.
  - Positioning requirement: 1-3m for indoor and 10m for outdoor

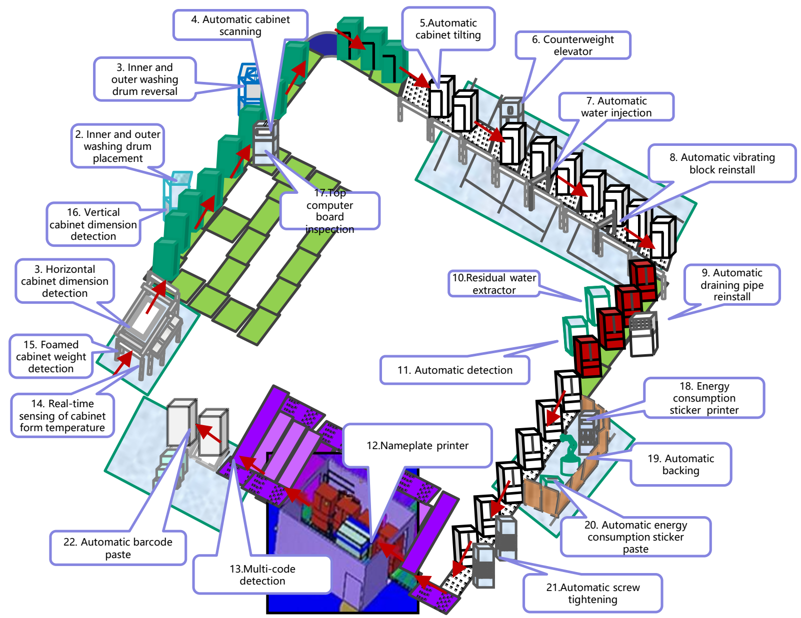


Representative UC#4: Smart manufacturing

- ❑ Ambient IoT tags attached on the product tray can be used to monitor the position of the product and its manufacturing Information.
- ❑ Real time quality inspection and tracing of the assembly line
  - The Product line occupies an area of 25 thousand m2 and it supports more than 20 process

❑ Potential Requirements

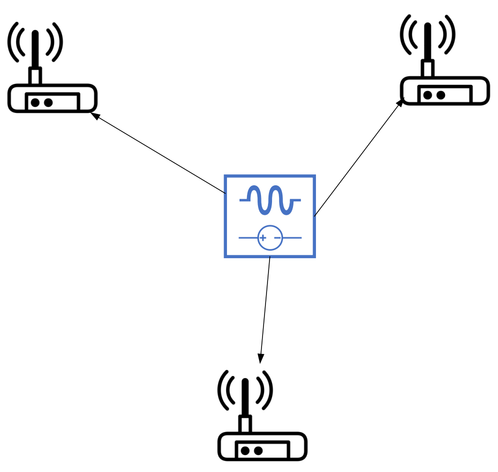
- Small size, maintenance-free, battery-free, and ultra-low-cost IoT devices
- Coverage: 10-30 meters for indoor
- Positioning accuracy: 1~3 m horizontal accuracy



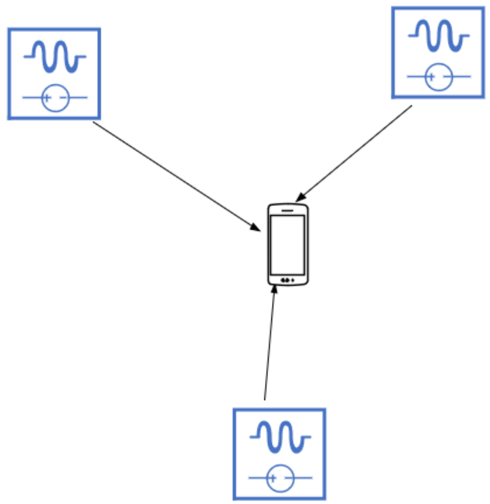
Role of AMP STA and the technique challenges

- It faces more challenges for AMP STA to support positioning due to its ultra-low complexity(e.g. narrow bandwidth, poor timing stability etc.) and its ultra-low power constraints.

- There are two possible roles for AMP STA:



(1) AMP STA to be positioned



(2) Anchors used to locate other devices

Timing based positioning

- AP: transmit PRS and measure the TOA of PRS signals from AMP STA, e.g. TOA, TDOA, RTT
- TOA → Propagation delay → Distance between AP and AMP STA
- The accuracy for TOA detection is highly dependent on bandwidth of the reference signal. If the bandwidth of the reference signal is small, there exists the ambiguity issue.

$$h(n) = a * \delta(n - n_\tau)$$

$$n_\tau = round(\frac{\tau}{Ts})$$

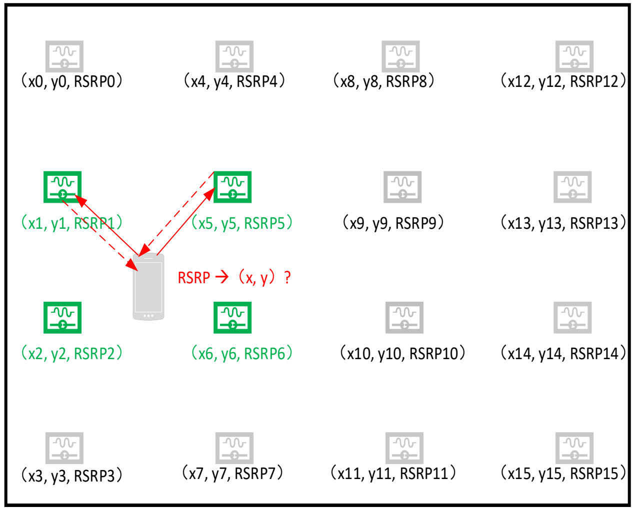
$$\mathrm{Ts} = \frac{1}{\Delta f * Nfft}$$

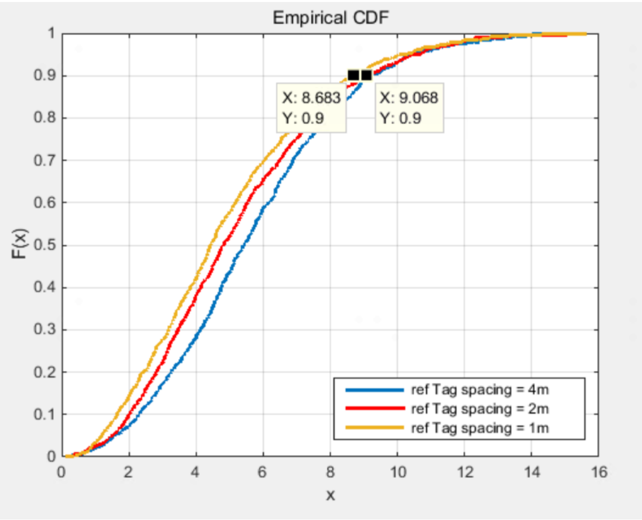
- It is infeasible to use timing based positioning for Ambient IoT due to its narrow bandwidth.

RSRP based positioning

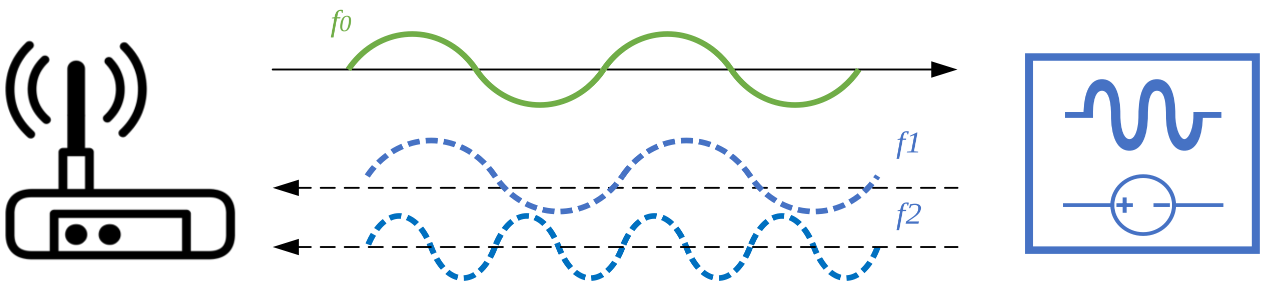
- ❑ RSRP based positioning will be limited by poor measurement accuracy of RSRP, non-ideal antenna pattern of the AMP STA etc.
- ❑ A system level simulation is performed for the indoor positioning case.
  - The indoor area is [20m * 20m] and the location of the smart phone AP is randomly generated within the area
  - RSRP value for each tag can be measured by the smart phone AP
  - The location of the reference tag is pre-known
  - Random LOS or NLOS for each STA
  - The location of the AP is weighted average of the reference STAs. The weight for a selected reference SAT, e.g.

$$w_{(i,k)} = \frac{RSRP_{(i,k)}}{\sum_{k=1}^{K} RSRP_{(i,k)}}$$





Positioning using Carrier Phase difference (1)



- Assuming two signals @f1/f2 are transmitted/backscattered by the AMP STA:

$$\text{signal 1} = \cos(w_1 t + \theta_1) = \cos(2\pi f_1 t + \theta_1)$$
$$\text{signal 2} = \cos(w_2 t + \theta_2) = \cos(2\pi f_2 t + \theta_2)$$

- Assuming t =0 when the signal departs from AMP STA and t=T when the AP receives the two signal @f1/f2

$$\begin{aligned}\mathrm{Phase}_{\mathrm{diff}} &= 2\pi f_2 t + \theta_2 - 2\pi f_1 t - \theta_1 = 2\pi(f_2 - f_1)t + \theta_{delta} \\ &= 2\pi(f_2 - f_1)\mathrm{T} + \theta_{delta} = 2\pi(f_2 - f_1) * \mathrm{d/c} + \theta_{delta}\end{aligned}$$

$Note\text{: } \theta_{delta}\ is\ \text{assumed}\ pre-known$

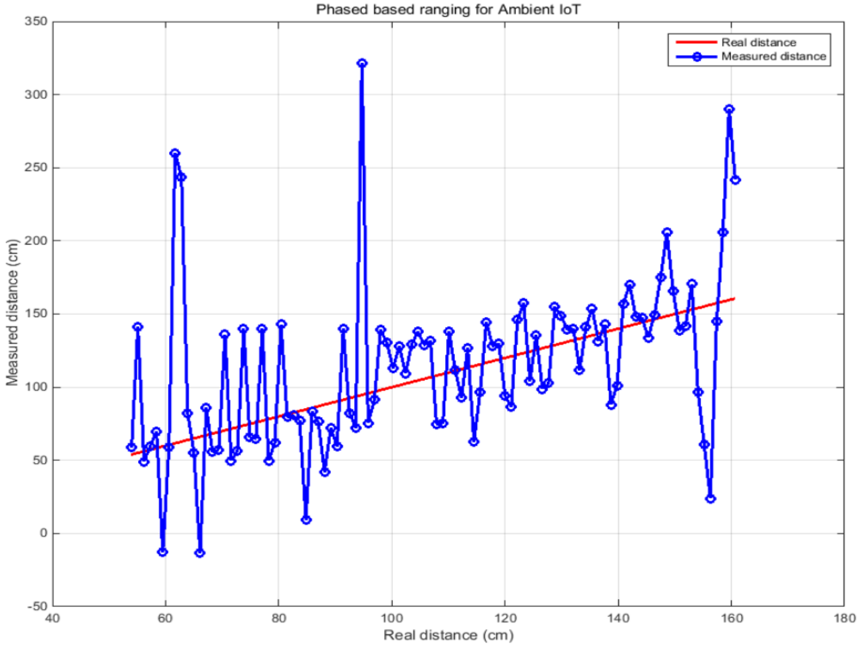
- Phase difference of two signals @f1/f2 can be measured at the AP side. Therefore, the distance d can be derived.

Positioning using Carrier Phase difference (2)

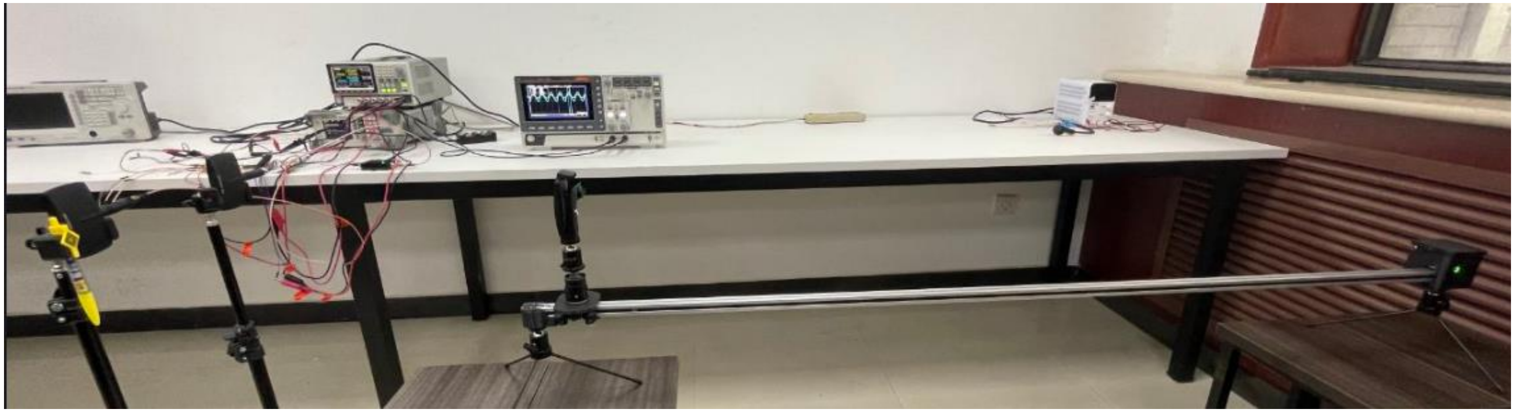
- A Simulation is performed for the proposed method.
  - $\mathrm{f}2 - f1 = 4.5MHz$,so the unambiguous positioning range is 3e8/0.9M/2=166m for backscattering and 333m for active transmission.
  - The distance between AP and AMP STA is randomly within [0, 30] indoor or [0, 100]m outdoor
  - $\mathrm{SNR_{dB}} = Tx_{power} - Noise - (PL - SF) - F_{BackScatter}$, where PL(pathloss)is dependent on distance
    - Noise Figure = 9dB (AP receiver)
    - SF: shadow fading =rand(0 4)dB
    - $F_{backscatter}$: backscattering loss =5dB

Simulation results to be added

Ambient IoT positioning Demo



- A demo (shown in below) is being developed to verify the proposed method. Some preliminary testing results are collected and shown in the right Figure.
- Based on the demo, it can be seen that it is possible to achieve the required performance with the proposed method.



Summary and proposal

- ❑ Positioning is one of the most important functions of ambient IoT and there are urgent needs from verticals.
- ❑ It faces more challenges for Ambient IoT device to support positioning due to its ultra-low device complexity(e.g. narrow bandwidth, poor timing stability etc.) and its ultra-low power constraints.
- ❑ Legacy TOA or TDOA methods may not be workable for ambient IoT, but it is still feasible to support positioning method using phase difference and achieve considerable performance based on the evaluations.

Based on the above observations:

- ❑ It is proposed to support and specify ambient IoT positioning in AMP TG.
- ❑ It is proposed to update the baseline PAR[4] for AMP TG as in the following.

This amendment defines:

- at least one mode of data communication in sub-1 GHz band
- at least one mode of data communication in 2.4 GHz band with [TBD restriction]
- at least one mode of RF energy harvesting [in TBD band]
- at least one mode of positioning protocol

Reference

1. IEEE 802.11-23/0436r0, Technical Report on support of AMP IoT devices in WLAN
2. IEEE 802.11-22/1960r6, Summary and recommendation for AMP IoT
3. IEEE 802.11-23/0835r1 "Use Cases and Requirements”
4. IEEE 802.11-23/1006r3, IEEE 802.11 AMP PAR Proposal