Survey of Localization Technologies

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***Abstract*— Localization Technologies is an important topic in the modern era. With the widely used mobile communication technology, Internet of things can be always on for every industry to adopt. Particularly, detecting the location of the device is an essential part of the system. In this paper, it introduces the background of the indoor and outdoor localization technologies and the theoretical measurement technique. Then, it will discuss the further prospect of the localization technologies**

Keywords—mobile, IoT, 5G, wireless, WIFI, RSSi, localization, trilateration, triangulation, fingerprint.

I. Introduction

Mobile computing is the famous technology in the modern era. It relates to smart phone, Internet of things (IOT), handheld device, smart watches etc. The communication method relies on mobile communication (4G,5G) and wireless connection (WIFI, WIMAX). Different than 90's, the current technique supports the high bandwidth, stable connection, roaming, location tracking. This paper is going to share about the mobile localization technique which is not limited to indoor and outdoor basis. The technical theory of trilateration, triangulation and fingerprint will also be introduced.

II. Localization

Internet of thing (IoT) applications are across the world nowadays. It has been applied to most of the current industry which does not limit to the Information technology firm. However, those IoT application devices operate in the field, service designer have to create an appropriate method to remote operate the device with the accurate identification technique such as how to recognize the right device you are looking for and system can support the precise location detection. It is what about "Localization".

A. What is Localization

Localization is a method to let you and your system to locate the device which you are looking for. Obviously, you and your system should have a concern of where the device installed or operating. The device may be installed indoor or outdoor and try to locate their position. There is various technique had been designed for this purpose.

It would be easily to identify that what IoT or mobile application require for an outdoor localization technique. In the modern era, the vehicle reservation needs to adopt localization technique to identify the customer and vehicle location. Such as traffic control and measurement system which may be based on Global Positioning System (GPS) to count the road occupation statistic. For the indoor localization, WIFI Signaling is the most common technique which is deployed widely at any inhouse or a place with a range of area due to the limited coverage.

There are the localization techniques has been introduced under the Low Power Wide-Area network (LPWAN) called Global Navigation Satellite Systems-Free IoT Localization Methods [1]. This solution is based on the modern mobile network technology interoperate to produce a hybrid location solution.

About the LPWAN, it includes the whole application architecture with LPWAN gateway, network gateway and backend application server. It relies on IoT or remote device transmit the location information under the IP/UDP traffic to the gateway. The transmit and storage data must follow the information security guidance. And based on the number of IoT device increase, the scalability is flexible that for expansion of IoT ecosystem [1].

There are 2 localization method categories introduced.

- Signal-Based
- Learning-Based

Signal Based Localization relates to the physical signaling operation to locate the device.

- Received Signal Strength Indicator (RSSI) [1,2]

  To measure the remote device received signal power level to determine the location.

- Time of Arrival or Time on Air (ToA) [1,2]

  Calculate the distance by sending signal to remote device. The data must have an accurate time stamp for the measurement.

- Time Difference of Arrival (TDoA) [1,2]

  Multiple gateways to consolidate the end node data and calculate the location distance.

- Angle of Arrival (AoA) [1,2]

  Various Antenna install at IoT device to estimate the angle between the device and gateway.

Learning Based Localization processed under machine learning based to overcome the cons of Signal Based Localization.

- Path Loss Modeling [1]

  Calculate the series of signal propagation loss and data set to determine the distance by experiment environment.

- Fingerprinting / Scene Analysis [1,2,6]

  Multiple gateways receive the signal dataset. Compare the set of signal data to determine the device location.

- Proximity Analysis [1,2]

  Measure the distance between 2 nodes point to point. No accurate location data need.

B. *Modern Outdoor Locaization Technique*

In the outdoor environment, the most common localization technique is mobile cellular network because the mobile cell-site has been deployed widely. The mobile network base station has been built in cell based to cover a long-range area [2,7].

5G cellular network operates with multiple base station nodes around the wide area range. The location measurement is working under the technique on ToA, TDoA and AoA [1,7]. The trilateration and triangulation method is used for the location calculation {Part III}. The specification of the 5G antenna support the precisely measurement of the device location with multiple high degree and half-power beamwidth supported [7].

Especially, 5G operation bandwidth is from 24.25GHz to 52.6GHz outdoor and IEEE 802.11 ad from 57GHz to 71GHz indoor, the accuracy of the location measurement enhanced due to the wide bandwidth support no matter outdoor and indoor.

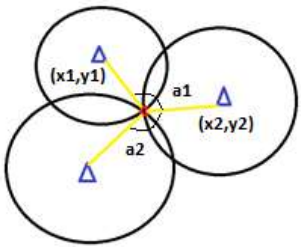

Fig. 1. Cellular network - Based Station and Mobile Node

In Fig. 1, the Blue Triangle refer to base station. Red for the mobile node. Yellow for the distance.

C. *3 Main Indoor Locaization Technique*

Under the Indoor environment, the signal would be in short-range with the limited coverage. For the most common used, Bluetooth, WIFI and Radio Frequency Identification (RFID) are the major techniques in indoor localization [2].

- Bluetooth

  It operates in the short-range area. Most popularly in handheld device. It uses 2.4GHz frequency. In Bluetooth version 5.1, it supports the angle direction measurement. The signal level can be measured by RSSI also. However, due to 2.4GHz channel overlap with WIFI signal, long-term localization broadcast measurement will affect the specific area's bandwidth performance [2].

- WIFI

  The most common technology adopted in the indoor environment. It operates in 2.4GHz and 5GHz with possibly multiple antennas and devices which can co-operation to support large-range coverage (indoor scale).

  WIFI access-point (AP) is possible to support the indoor localization function in fingerprint structure, RSSI measurement, TOA, TDOA, AOA [1,2] etc.

- RFID

  Radio Frequency Identification is based on a tag with active, passive frequency response. There are several types of frequency range used at RFID tag. However, the supporting distance is short. By using UHF which operate under 860 -960MHz, the RFID signal can operate up to 10 meters. The RFID solution will be based on a RFID tag and the detector for the localization identification.

III. TRILATERATION AND TRIANGULATION

For the fundamental of the localization techniques, it is used the signal strength, trilateration and triangulation which related to the mathematical calculation.

A. *Received Signal Strength Indicator - RSSI*

To further discuss with one localization technique. The RSSI would be the one most inexpensive technique for the localization [2]. However, there are some problems which the signal noise ratio will affect the accuracy.

RSSI based on measuring the device distance by signal ratio between the IoT nodes / mobile device and base station. The multiple base stations will be forming a trilateration [Fig.1] to measure the mobile device location [2].

$$RSSi = -10n\log10(d) + A \qquad \{1\}$$

If A for reference distance (1m), we can calculate the d (distance values). By Trilateration form, the accurate location could be obtained by calculation.

B. *Trilateration*

Trilateration is based on signal level by straight line distance calculation to estimate the location, it is related to the length / distance between base stations and mobile devices.

Referring to Fig.2, 3 base stations measure the signal level between mobile node. By calculate it, the Pythagoras theorem has been used [3].

$$Ri^2 = Xi^2 + Yi^2 \qquad \{2\}$$

The radius signal circle from base stations which is equal to the length between the base stations and remote nodes. As refer to RSSi formula {1}, the distance (Di) is calculated by the signal length. That is equivalent between the radius values of base station signal range. By multiple base stations signal calculation in signal range, the crossing point between 3 range will be the estimated location of the mobile node.

Mobile Node = (X,Y) = Unknown

Base station 1 = (X1,Y1)

Base station 2 = (X2,Y2)

Base station 3 = (X3,Y3)

RSSi distance from Base Station 1 to Mobile Node = D1

RSSi distance from Base Station 2 to Mobile Node = D2

RSSi distance from Base Station 3 to Mobile Node = D3

Under Pythagoras theorem, we could summarize as follow. [Fig. 2.]

$D1^2 = (X1-X)^2 + (Y1-Y)^2$

$D2^2 = (X2-X)^2 + (Y2-Y)^2$

$D3^2 = (X3-X)^2 + (Y3-Y)^2$

Then, It can extract the X,Y location value as all other values have been in known form. X,Y can be subtracted by 3 equations (with 3 base stations values) [4].

$D1^2 = X1^2-2X1X+X^2+Y1^2-2Y1Y+Y^2$

$D2^2 = X2^2-2X2X+X^2+Y2^2-2Y2Y+Y^2$

$D3^2 = X3^2-2X3X+X^2+Y3^2-2Y3Y+Y^2$

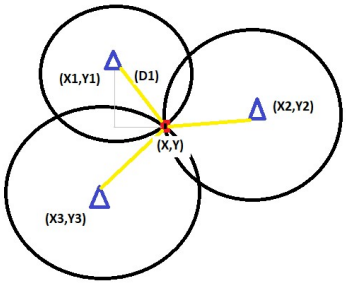

Fig. 2. Pythagoras theorem – Trilateration

C. *Triangulation*

It relates to the angle measurement between the base stations and mobile nodes [5]. It depends on 2 or more base stations – anchor nodes to measure the possible "Angle" pointing to the target node.

$$X2-X1 = Y/\tan(a1) + Y/\tan(a2) \quad \{3\}$$

$$X = Y / \tan(a1) \quad \{4\}$$

(X1, Y1) and (X2, Y2) are 2 base stations with well-known position. The angle (a1) and (a2) measured by multiple antenna [1,2] at base stations. We can find out the (X, Y) location by formula {3} and {4}.

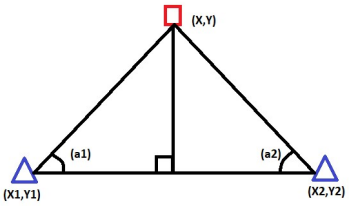

Fig. 3. Triangulation

IV. FINGERPRINT

Fingerprint is a learning base database to facilitate the range of area's characteristic. It is not limited to used the RSSi, trilateration and triangulation to measure the actual area's status. It records the location result between the access point / anchor nodes and mobile user by RSSi and Triangulation methods [6].

The measurement of RSSi would be the major method for building the database. There is an offline mode and online mode for the database creation [1]. For the offline mode, the multiple gateway/AP will measure the signal level and using the trilateration to calculate the location pointer in the range of area and then store to database [6]. For the online mode, the actual mobile node provides the active response for the location calculation. Fingerprint system will compare the database record and the least calculated record to adjust the location point difference. Each record will be stored with the timestamp, also, in WIFI Fingerprint database [6], SSID will also be recorded.

	RSSI1(X1,Y4)T1 RSSI2(X1,Y4)T2		AP LOCATION (X3,Y4)
		RSSI1(X2,Y2)T1 RSSI2(X2,Y2)T2	
AP LOCATION (X0,Y1)			
RSSI1(X0,Y0)T1			

Fig. 4. Fingerprint of localization database

In Fig 4, AP location in the range of area from X0-X3 to Y0-Y4. RSSI values will be recorded by Fingerprint database. And Xi,Yi depends for the location calculated by RSSi, trilateration and triangulation method. Ti refers to timestamp.

V. CONCLUSION

This paper shows the technical point of localization technique adopted recently. As the most widely used technique, it should be cellular network which operated by mobile service operator. The mobile network widely deployed in the regions. Particularly, the subscription fee is low. Compare with the operation perspective with other technique, cellular - 5G can support no matter in indoor or outdoor environment. It can be rapidly used at any IoT devices for precise location detection.

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