


Introduction to IoT

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Chapter Four

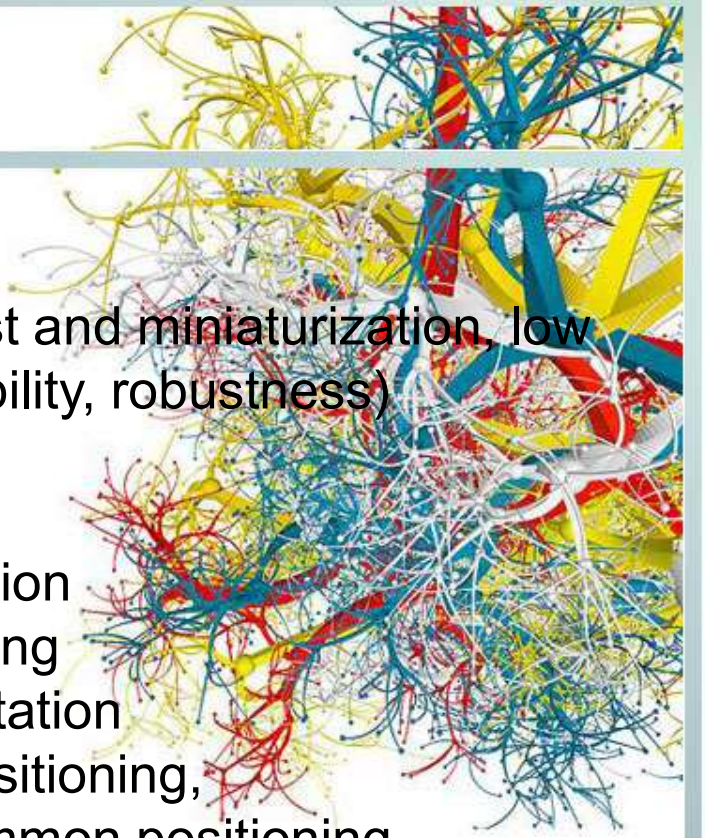
Positioning system

Obtaining location information through **Positioning System** is an important research topic in the era of Internet of things.

This chapter will describe typical location systems and location techniques.

内容提要

Review



Chapter 3 introduces sensor technology

- Design requirements of sensors (low cost and miniaturization, low power consumption, flexibility and scalability, robustness)
- Sensor hardware and software platform

This chapter introduces the concept of location information, focusing on the typical positioning system (satellite positioning, cellular base station positioning, wireless indoor environment positioning, emerging positioning system) and three common positioning technology.

Content

4.1 The Location information

4.2 Positioning system

4.3 Positioning technology

4.4 New challenges of the Internet of things to positioning technology

What are the three elements of location information?

Why should we need position?

Location-based services

- ✓ Automatic navigation
- ✓ Search for peripheral services
- ✓ Location-based social networking: Four square

Location information is closely related to our life

Location information is not just "location"

- Geographical location (spatial coordinates)
- Time at that position (time coordinate)
- Objects in that location (identity information)

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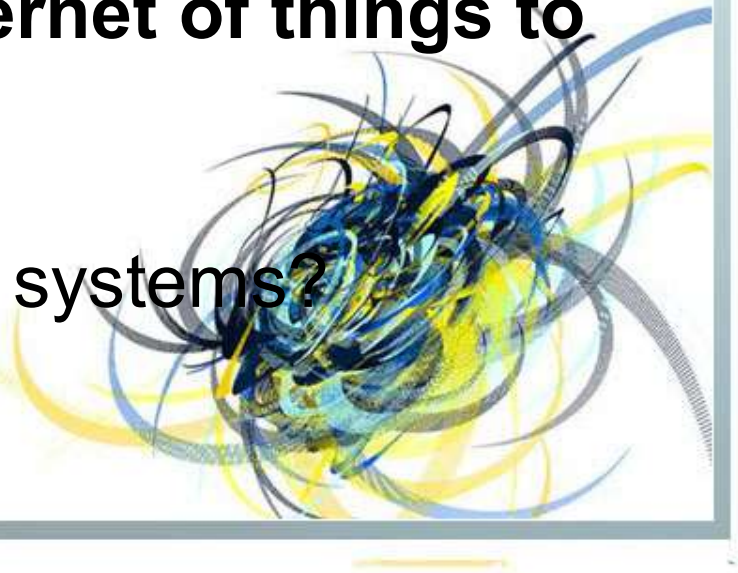
4.1 The Location information

4.2 Positioning system

4.3 Positioning technology

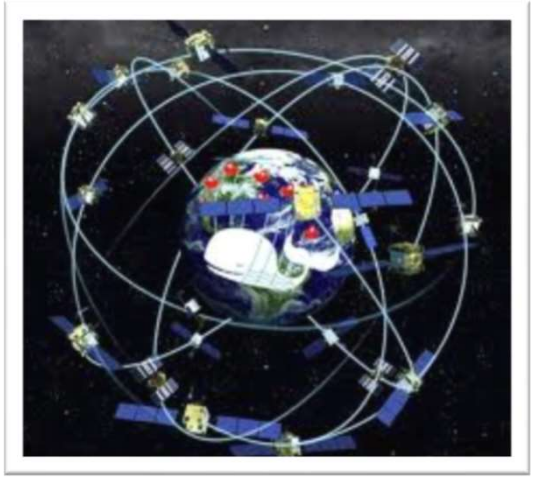
4.4 New challenges of the Internet of things to positioning technology

What are the typical positioning systems?
What are their characteristics?



Existing mainstream positioning system

Satellite positioning: GPS
Cellular base station positioning
Wireless indoor environment positioning
Emerging positioning system: A-GPS, network positioning



Satellite positioning

Satellite positioning systems of various countries

- The United States: GPS
- Russia: GLONASS
- Eu: Galileo
- China: bds-1 (regional), bds-2 (global)

GPS is the most commonly used satellite navigation system in the world.

GPS: The development history

- 1973, the U.S. department of defense began its GPS program
- 1983, Reagan promised to open it to private use in the future
- 1989, GPS working satellites were officially launched
- 1994, the satellite constellation network was completed and put into use
- 2000, Clinton ordered the elimination of precision discrimination for military/civilian signals

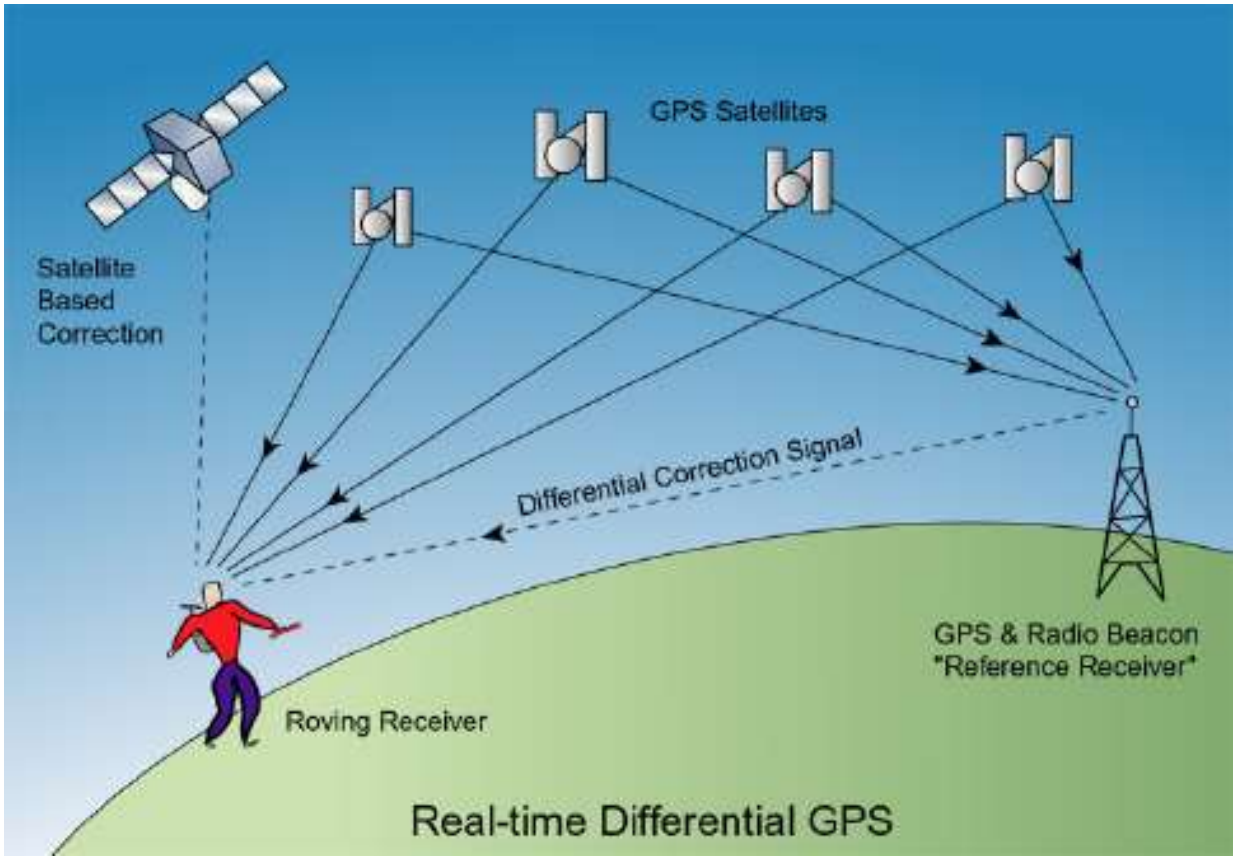
Satellite positioning

GPS: The system structure

- Space segment
  - ✓ 24 working satellites
- Ground surveillance (all in the us)
  - ✓ 1 main control center (another standby)
  - ✓ Four dedicated ground antennas
  - ✓ 6 dedicated monitoring stations
- User equipment section
  - ✓ GPS receiver

Satellite positioning

GPS: Positioning principle



Satellite positioning

GPS: Main advantages and disadvantages

- Advantages
  - ✓ High precision
  - ✓ Global coverage can be used in hostile environments
- Disadvantages
  - ✓ Long startup time
  - ✓ Indoor signal difference
  - ✓ Need GPS receiver

Satellite positioning

Typical application of GPS: Car navigation

- Initially only location and perimeter maps are available
- The second generation of car navigation system can automatically calculate the "shortest" route according to the destination
- In the Internet age, car navigation can obtain road condition consultation from traffic management department, optimize the route and find out the "fastest" route

Satellite positioning

Typical application of GPS: Car navigation

In the era of Internet of things, the perception is more thorough

- ✓ Find the "best" route by combining road conditions, pollution index, weather conditions, distribution of gas stations, driver's physical condition and other factors
- ✓ From "road-based" to "people-oriented"

Satellite positioning

Cellular base station positioning

GSM cellular network

- ✓ The communication area is divided into cellular cells
- ✓ Each cell corresponds to a communication base station
- ✓ Communication equipment connects cell base station for communication

Based on the known location of the base station, the communication equipment can be located

Cellular base station positioning

Single base station positioning

COO location (Cell of Origin)

- ✓ Consider the location of the base station belonging to the mobile device as the location of the mobile device
- ✓ The accuracy depends directly on the coverage of the base station
- ✓ Base stations are distributed in loose areas, and the radius of coverage of a base station can reach several kilometers, with huge errors

Advantages: simple, fast, suitable for emergency situations

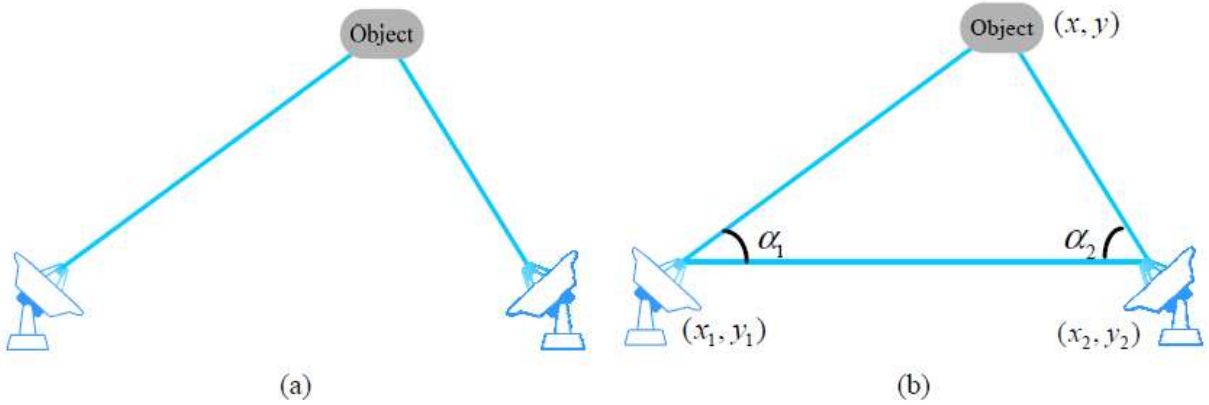
Cellular base station positioning

Multiple base station positioning

ToA/TDoA location method

- ✓ Three base stations are needed to locate it
- ✓ Sparse areas may only receive signals from two base stations, not applicable

AoA location method



Cellular base station positioning

Cellular base station location: major advantages and disadvantages

Advantages

- ✓ No need for GPS receiver, can communicate to locate
- ✓ Slow starting speed
- ✓ Strong signal penetration, indoor can also be received

Disadvantages

- ✓ The positioning accuracy is relatively low
- ✓ Base stations require specialized hardware, which is expensive

Cellular base station positioning

Typical application: emergency telephone location

American e-911 system

- Call the police, according to the location of the cell phone base station, automatically received the nearest police station
- Integrated various positioning systems, including ToA, TDoA, AoA, RSS, A-GPS
- Try a variety of positioning methods when using, choose the best and use

Cellular base station positioning

Wireless indoor environment positioning :

The complexity of the indoor environment

- The multipath effect
  - ✓ Reason: obstacles reflect electromagnetic waves, reflected waves and original waves at the receiving end of aliasing
  - ✓ Indoor obstacles are numerous and multipath effect is obvious
- Obstruction to electromagnetic waves
  - ✓ Long wave signal (GPS) transmission ability is strong, penetration ability is weak
  - ✓ Short wave signal should be used indoors for positioning

Wireless indoor environment positioning

Wireless indoor environment positioning :

The demand is mainly from businesses and individuals: it is difficult to purchase the expensive hardware needed for ToA, TDoA, AoA and other technologies

RSS positioning technology

- Use signal strength to locate
- Use existing wireless network (Bluetooth, wi-fi, ZigBee)
- Infrared, ultrasonic, Bluetooth, RFID, UWB...

Wireless indoor environment positioning

Typical applications of RFID positioning

Asset management

- Attach RFID tags to devices
- When it needs to be used, the location of the tag can be found through RFID positioning, so as to locate the location of the device
- Combined with sensing technology, it can also monitor the condition of the device
  - ✓ Whether free
  - ✓ Whether the fault
  - ✓ Whether the aging

Wireless indoor environment positioning

New positioning system

A - GPS

- A combination of GPS and cellular location
- Use base station location to determine the approximate range
- Connect to the network to query the current location of the visible satellite
- Greatly reducing the time it takes to search for satellites

New positioning system

New positioning system

Wireless AP location

- Locate using a visible wi-fi access point
- In large cities, the number of wireless AP is large and the location is very accurate
- Mature application in iPhone

The network location

- For wireless sensor network, self-organizing network
- The location of all network nodes is located by a small number of known nodes

New positioning system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4.1 The Location information

4.2 Positioning system

4.3 Positioning technology

4.4 New challenges of the Internet of things to positioning technology

Besides distance, which spatial information can also be used for positioning technology?

4.3 Location technique

Key to positioning technology:

- A reference point with one or more known coordinates
- The spatial relationship between the object to be determined and the known reference point is obtained

The positioning technique consists of two steps:

Measuring the physical quantity and then **determining** the target position according to the physical quantity

Common positioning techniques:

- ✓ Range-based positioning (ToA)
- ✓ Distance difference based positioning (TDoA)
- ✓ Location based on signal characteristics (RSS)

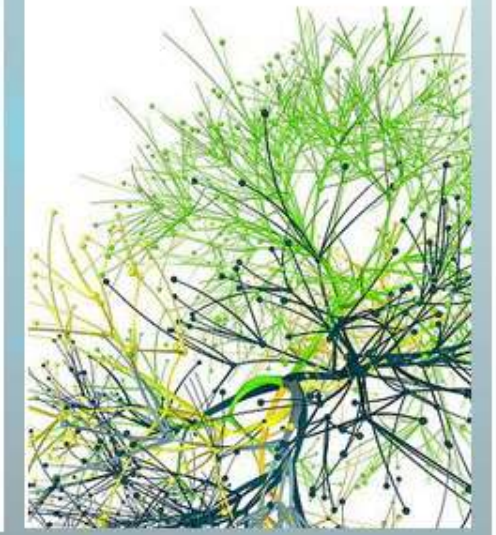
Time of Arrive(ToA)

Distance measurement method

- Distance d = wave velocity v * Δ t transmission time
- Travel time Δ t = received time t – issued time t0

Q: how does the receiver know about t0?

Base on distance



Time of Arrive(ToA)

Base on distance

Method 1: use wave velocity difference

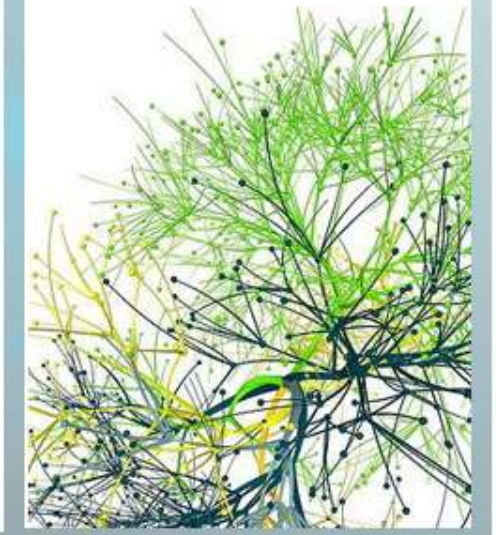
The transmitter sends both an electromagnetic wave and a sound wave

Receiver record:

- Arrival time of electromagnetic wave t_r
- Arrival time of sound wave t_s

Distance $d = \frac{v_r v_s (t_s - t_r)}{v_r - v_s}$

Since v_r is much larger than v_s, the above equation can be simplified to $d = v_s (t_s - t_r)$

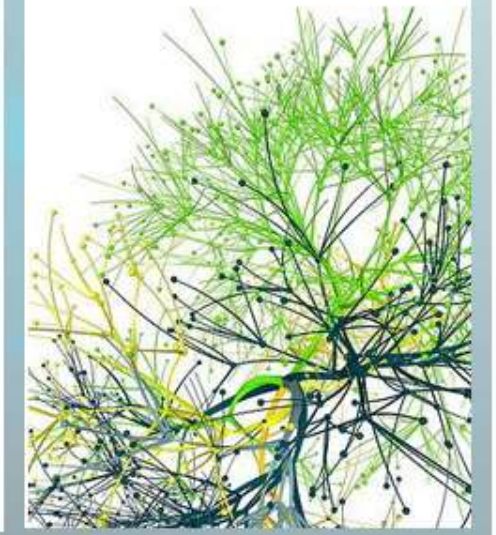


Time of Arrive(ToA)

Base on distance

Method 2:
measure the round-trip time of the wave

The sender sends the wave at time t_0
After receiving the wave, wait time Δt to return the same wave
The sender records the time t it takes to receive a reply
Distance $d = \frac{v(t - t_0 - \Delta t)}{2}$



Time of Arrive(ToA)

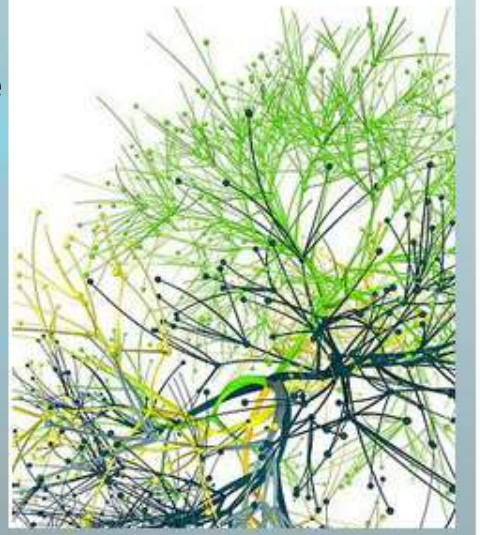
Base on distance

Position calculation method

Multilateral measurement (also known as multi-point measurement)

- Position on the plane, take three reference points
- Draw a circle with each reference point as the center of the circle and the distance from the reference point as the radius. The target must be on the circle
- The three circles in the plane intersect at a point

In practice, more than three reference points are used, and **the least square method** is used to reduce errors



Time Delay of Arrive（TDoA）

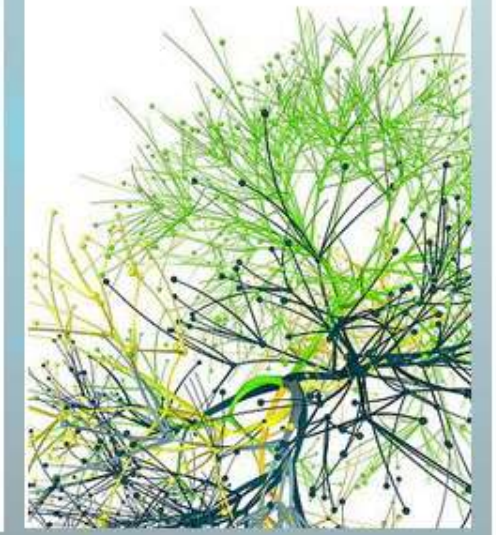
The limitations of ToA

- Reference points and measured target clock synchronization are required

TDoA

- No reference point and measurement target clock synchronization is required
- Clock synchronization is still required between reference points

Base on Distance difference



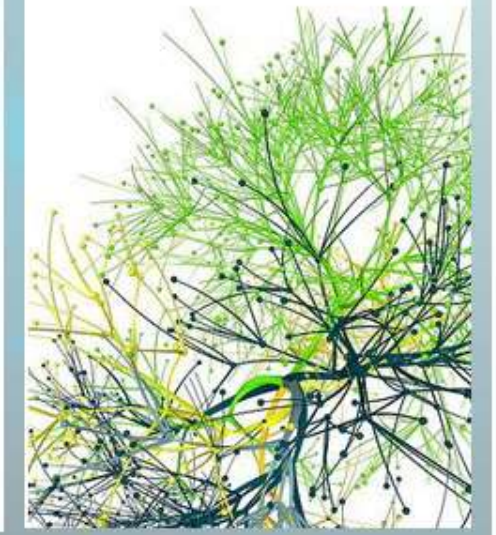
Time Delay of Arrive(TDoA)

Range difference ranging method

- Measure the target broadcast signal
- Reference points I and j record ti and tj at the time of signal reception respectively
- Measure the distance difference between the target and i and j

$$\Delta d_{ij} = v\left(t_i - t_j\right)$$

Base on Distance difference



Time Delay of Arrive(TDoA)

Base on Distance difference

Position calculation method

At least two sets of data are solved simultaneously

In practice, the least square method is used to solve the problem

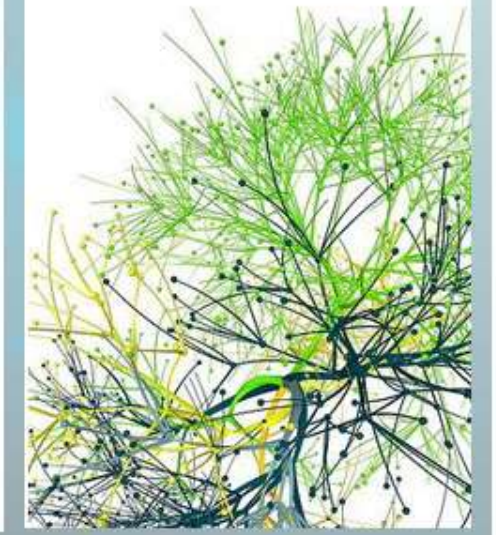
Results of each measurement

Reference coordinates (x_i, y_i) (x_j, y_j)

Distance from the reference point Δd_{ij}

Construct the equation:

$$\left[(x-x_i)^2+(y-y_i)^2\right]-\left[(x-x_j)^2+(y-y_j)^2\right]=\Delta d_{ij}^2$$



Location based on signal features

Both ToA and TDoA require special receiver devices

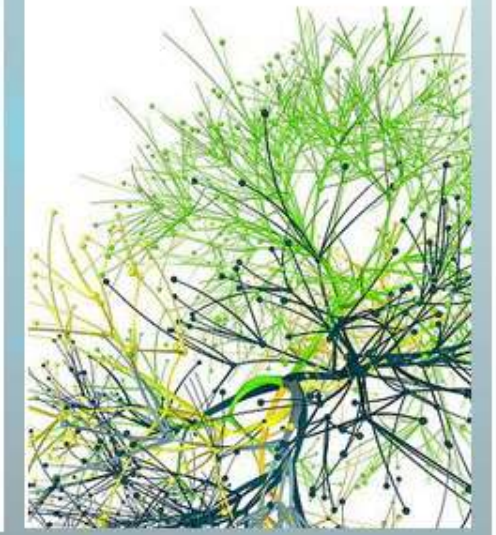
The location based on signal characteristics
Directly utilizes the radio frequency signal location of wireless communication, and no additional equipment is required

Principle: signal strength decays with propagation distance

$$P_r(d) = \left(\frac{\lambda}{4\pi d}\right)^2 P_t G_t G_r$$

Problem: ideal formulas are hard to apply in practice

Based on signal features



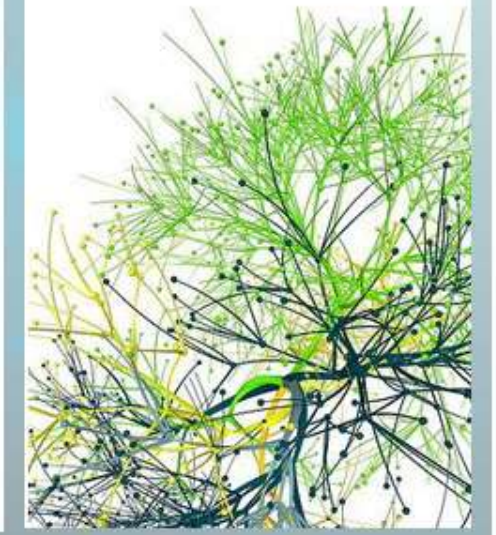
Location based on signal features

Solutions:

- Think of signal strength as a "feature."
- Arrange N reference nodes in advance
- The signal intensity of N reference nodes is measured and an n-dimensional vector is obtained
- Measure the eigenvector of each position in the region in advance
- Compare the eigenvector measured by the target with the pre-measured value to find the position

Disadvantages: Unable to cope with dynamic changes

Based on signal features

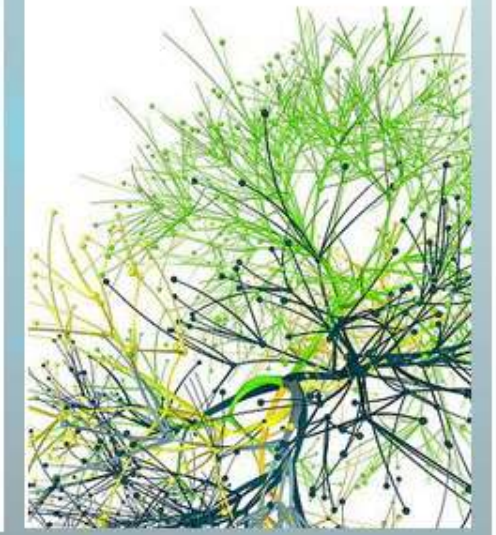


Location based on signal features

LANDMARC: Dynamic location method based on signal features

- In addition to the signal source, a series of RFID tags are arranged as reference marks
- Each flag keeps track of the RSS signal strength feature vector it receives
- Compare the signal characteristic vector measured by the target with the characteristic vector of the reference mark to determine the position. The error is within 1m

Based on signal features



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4.3 Positioning technology
4.4 New challenges of the Internet of things to positioning technology

What are the new requirements for positioning technology in the background of Internet of things?


4.4 New challenges

Heterogeneous network

- The devices connected to the Internet of things are various
- The networks connected are different
- How to make different devices in different networks under the accurate positioning

Environment variable

- Outdoor vs. indoor
- Open Spaces vs. lots of obstacles
- Stationary devices vs. frequent motion


4.4 New challenges

Information security and privacy protection

- Location information is rich and private
- The leakage of high-precision location information has serious consequences
  - How to ensure information accuracy and protect personal privacy

Large-scale application

- In the era of the Internet of things, there will be more than 50 billion devices connected to the Internet
  - How to deal with the huge quantity growth
  - How to make positioning technology available for simple devices such as RFID tags


Conclusion

Review

This chapter introduces the basic concepts of location information, discusses four kinds of positioning systems and three typical positioning technologies, and finally discusses the new challenges of the Internet of things to positioning technology.

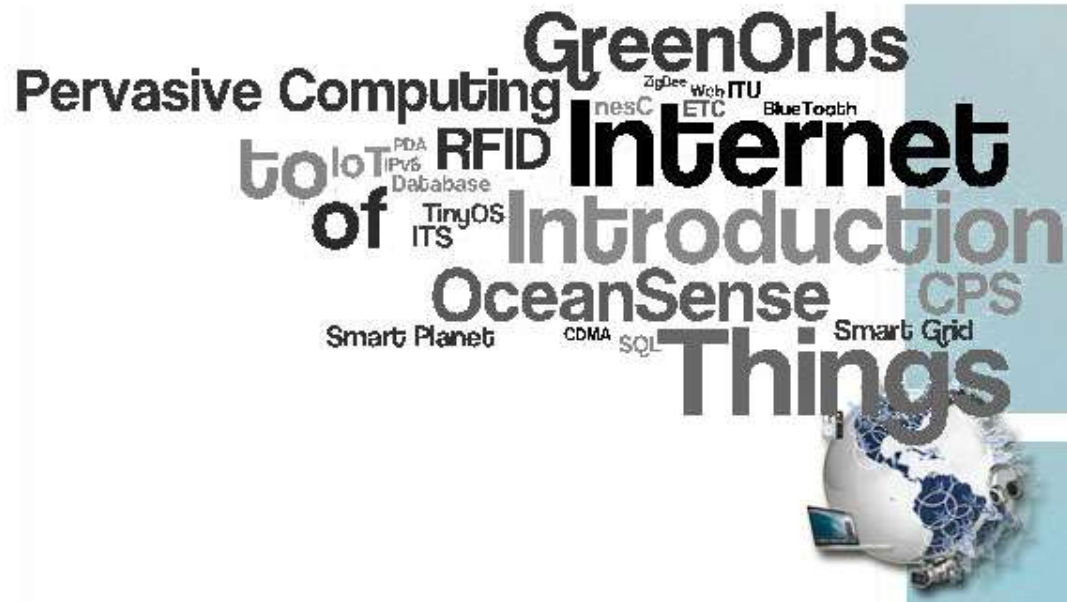
Key Points

- Understand the three elements of location information.
- Understand GPS system composition, positioning principle, typical applications and advantages and disadvantages.
- Understand the methods and advantages and disadvantages of cellular base station positioning (single base station and multi-base station).
- Review the basic concepts of RFID, illustrate the application of RFID positioning, illustrate the emerging positioning technology.

Conclusion

Key Points(Next)

- Master two methods of location - based distance measurement.
- Master the location measurement method and location calculation method based on TDoA, and compare the advantages and disadvantages of ToA.
- Understand the location method based on signal characteristics.
- Examples are given to illustrate the new challenges of location technology in physical network environment.



Thank you!

Internet of Things