Beidou-3 For Smart City applications

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Positioning, Navigation and Timing (PNT) Infrastructure

- Many crucial services depends on PNT
  - Navigation
  - Transportation
  - Construction
  - Farming
  - Surveying
  - Communication
  - Internet
  - Internet of Things
  - Power supply
  - Finance
  - ……



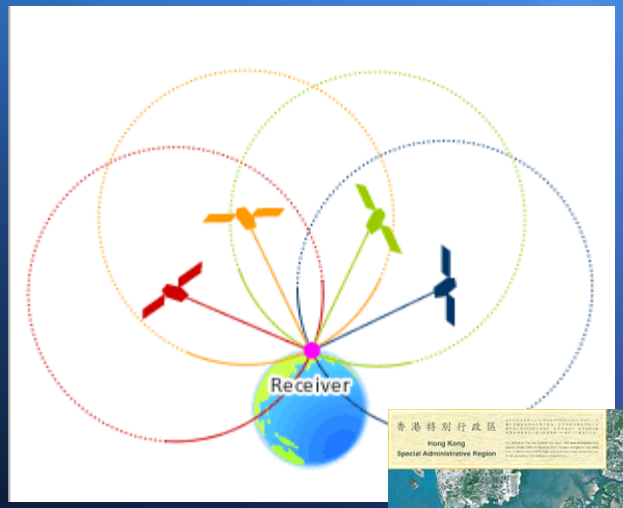

- Many users or applications were not aware of the use of PNT

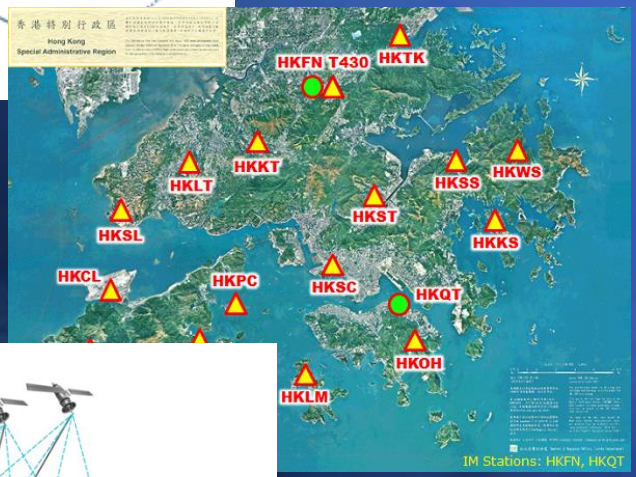
Reliance on PNT Services

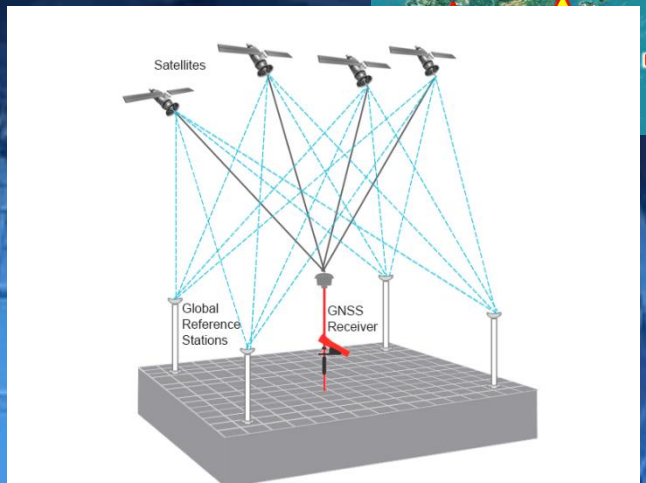
- 80% of information is PNT related
- Department of Home Security
  - In 16 designated critical infrastructure sectors. DHS considers 13 of the 16 critical infrastructure sectors to be critically dependent on PNT. The other 3 sectors are considered to be somewhat dependent.
- European Commission
  - 6-8% of EC GDP relies on PNT services
- GNSS (GPS, Beidou, etc.) is the backbone of Global PNT infrastructures

GNSS Positioning methods

- Stand-alone
  - Accuracy: 5-10 m
- Network Real-Time Kinematics (RTK) Positioning
  - Using Local Reference Network to reduce errors
  - Accuracy: 1-2 cm
- Wide Area DGNSS
  - Reliable service for safety of life applications
  - Accuracy: 1 m
- Precise Point Positioning (PPP)
  - Precise Orbit and satellite Clock
  - Estimate other errors
  - Global coverage
  - Accuracy: 10 cm







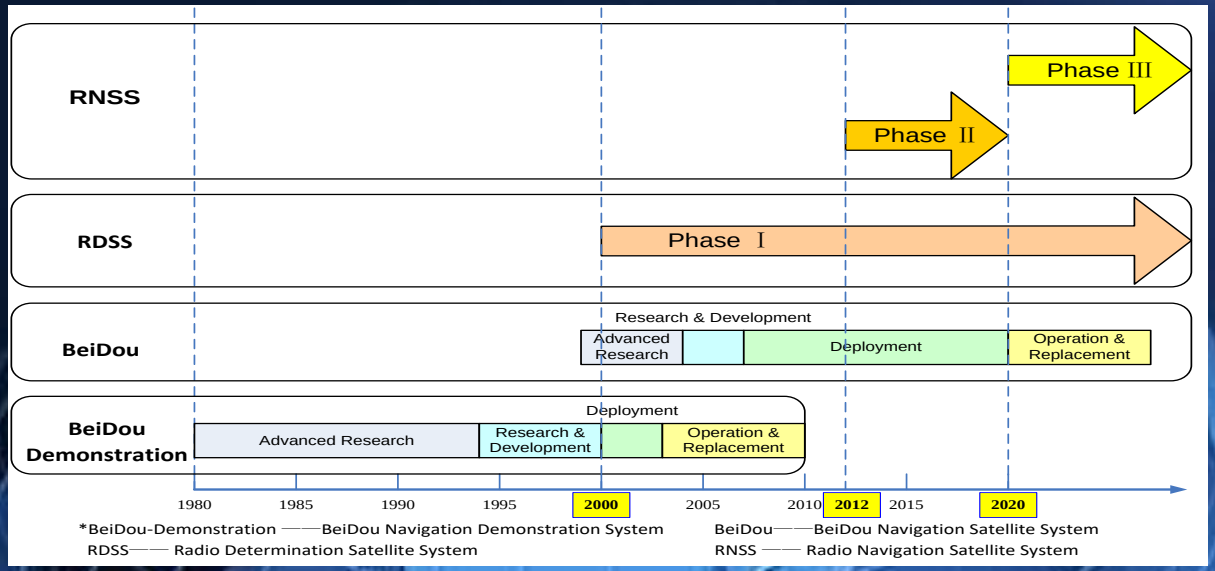
Development of Chinese Beidou Systems

GNSS development

- The first generation of Satellite Navigation Systems: i.e. TRANSIT (US, 1958)
  - Doppler (velocity) measurements
  - 2D positioning (200 m)
  - Not 24 hour service (typically 1 hour)
- The second generation of satellite navigation systems (started from 1972)
  - GPS, GLONASS, Beidou, Galileo, etc.
  - Space-borne Atomic Clock to allow range measurements
  - 24 hour service

History of Chinese Satellite Navigation Programme

- China initiated its GNSS programme in the 1980s
- In 1994, the Beidou project was approved
- Demonstration system: 2000-2003
- Regional System: 2012-
- Global system: 2020-



RDSS and RNSS

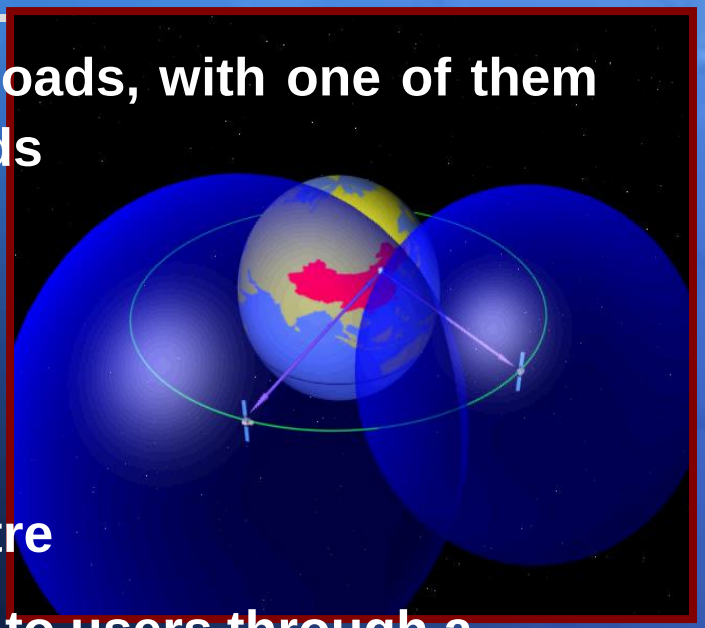
RDSS

- Radio Determination Satellite Service (RDSS)
- Provide information of both the user's location, velocity and time parameters （X, Y, Z, Vx, Vy, Vz, T）
- Provide location reports among the users, short message and timing services at the same time

RNSS

- Radio Navigation Satellite System (RNSS)
- One-way positioning system
- Similar to other GNSS

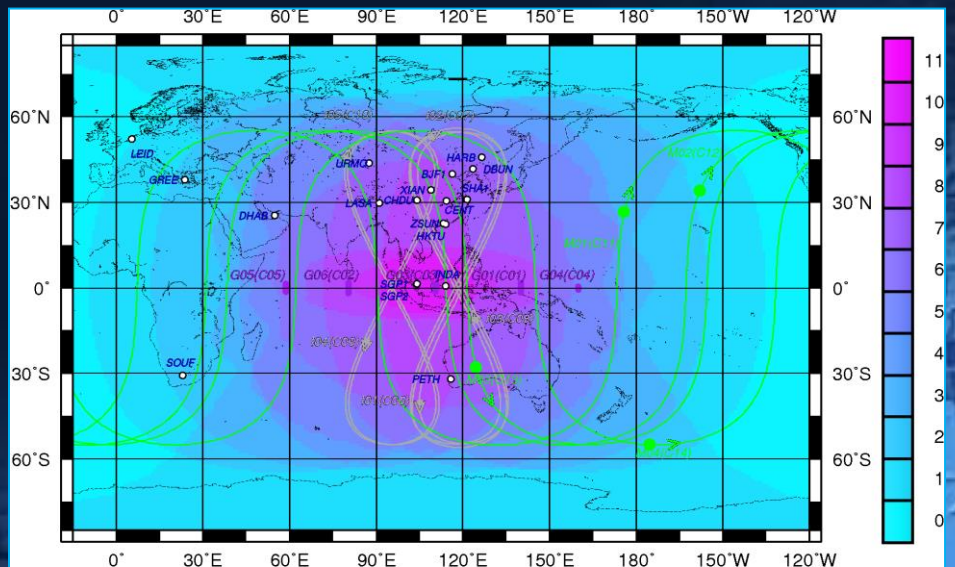
Demonstration System: Beidou I

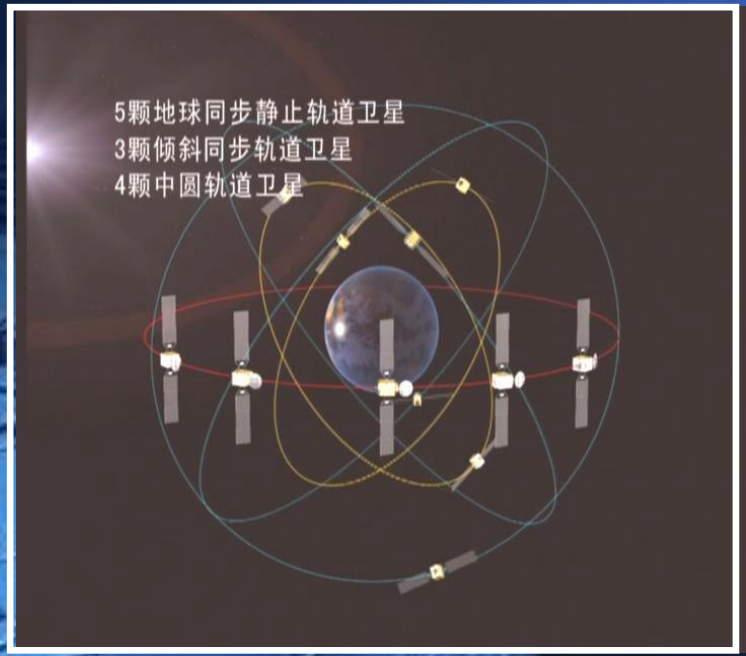


- Three GEOs all equipped with RDSS payloads, with one of them equipped with RNSS experimental payloads
- Its main service: RDSS
  - Two-way ranging
  - Avoid the use of Atomic Clock
  - Position computation is at control centre
  - Position and velocity of users are sent to users through a satellite communication channel
- Integrate three functions into one system
  - Positioning
  - Monitoring
  - Communication
- Regional System

Regional Coverage: Beidou II

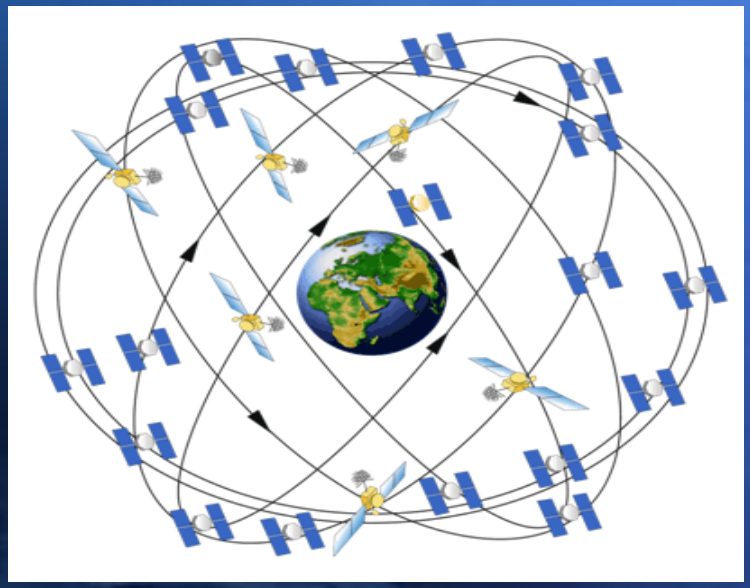
- Cover Asia-Pacific region
- A constellation of 14 satellites
  - 5 GEO, 5 IGSO, 4 MEO
- RDSS and RNSS
- To provide continuous positioning,
- velocity measurement and
- location report services

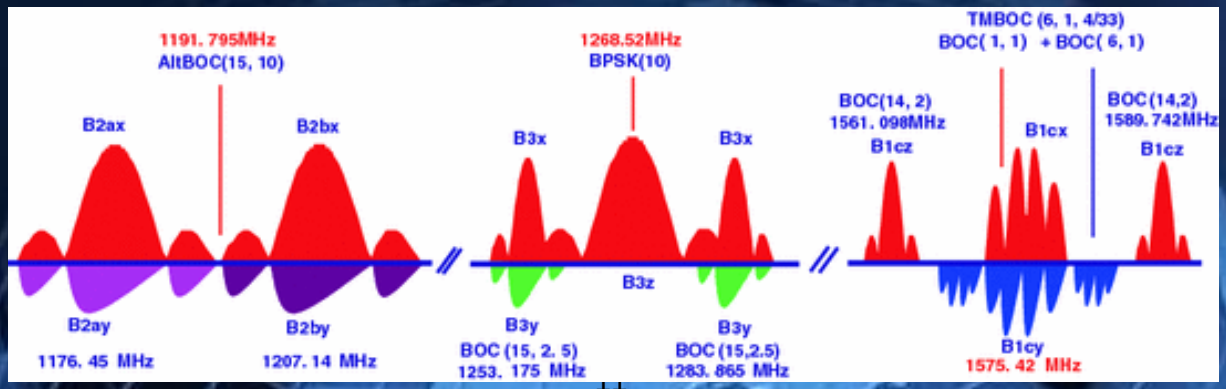




Global System: Beidou III (2020)

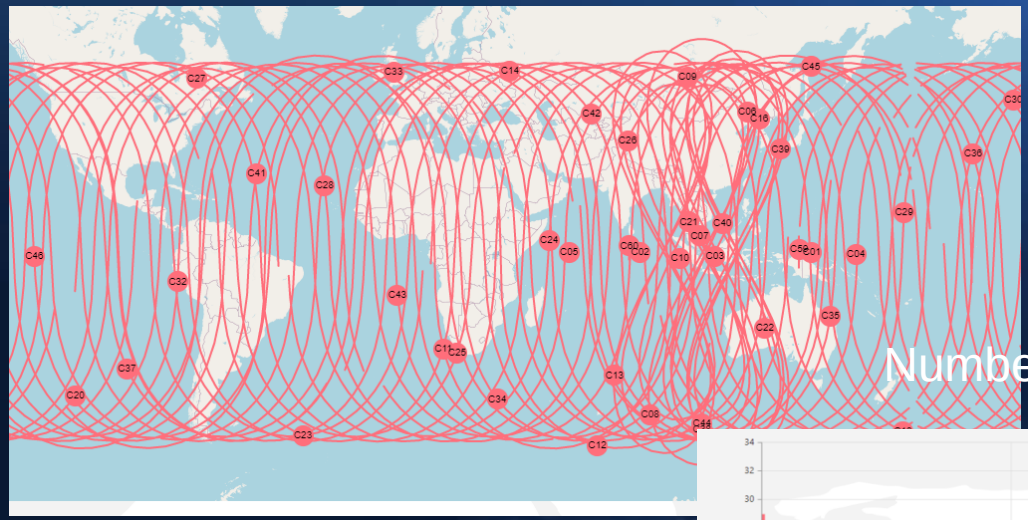
- A global system
  - 24 MEO, 3 GEO, 3 IGSO
- RDSS and RNSS
- Achieve compatibility and interoperability with GPS and Galileo within multi-frequency bands





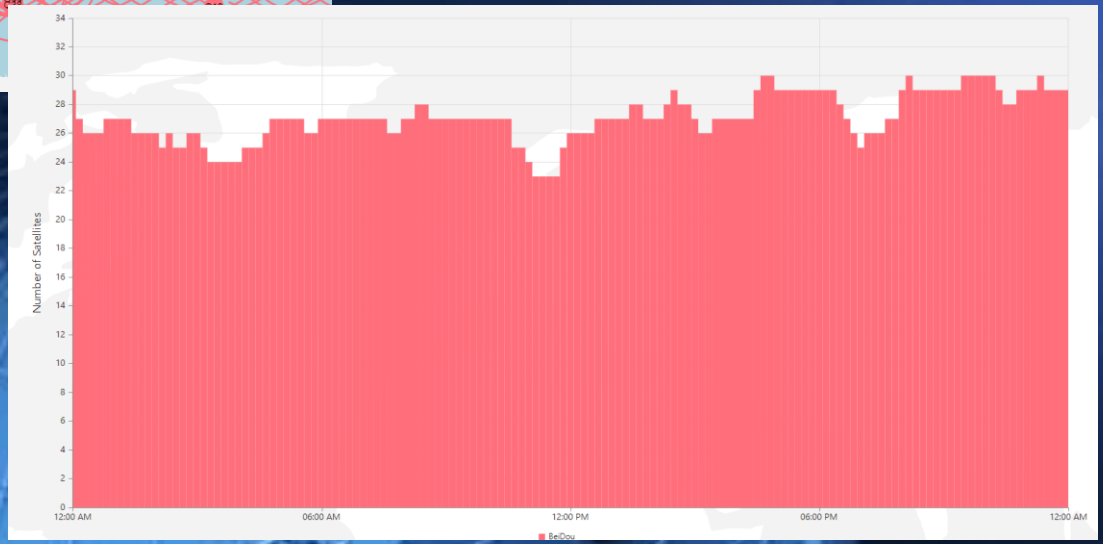
Current Beidou Constellation

- **Global coverage + enhanced coverage in Asia-Pacific**



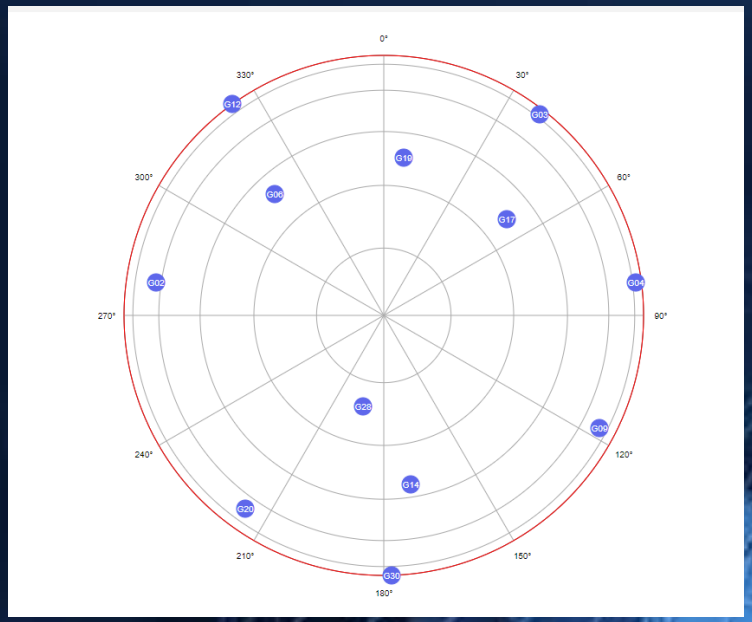
Satellite global coverage

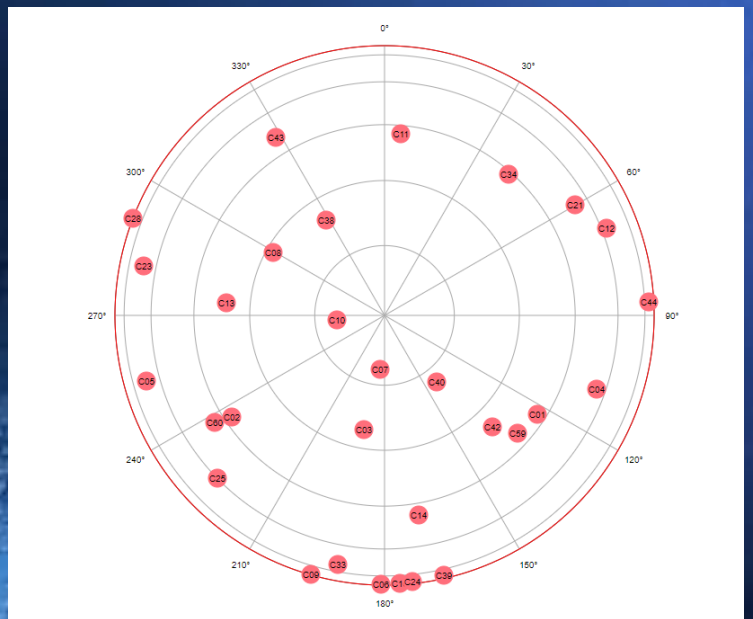
Number of satellite viewed at Hong Kong



GPS vs Beidou

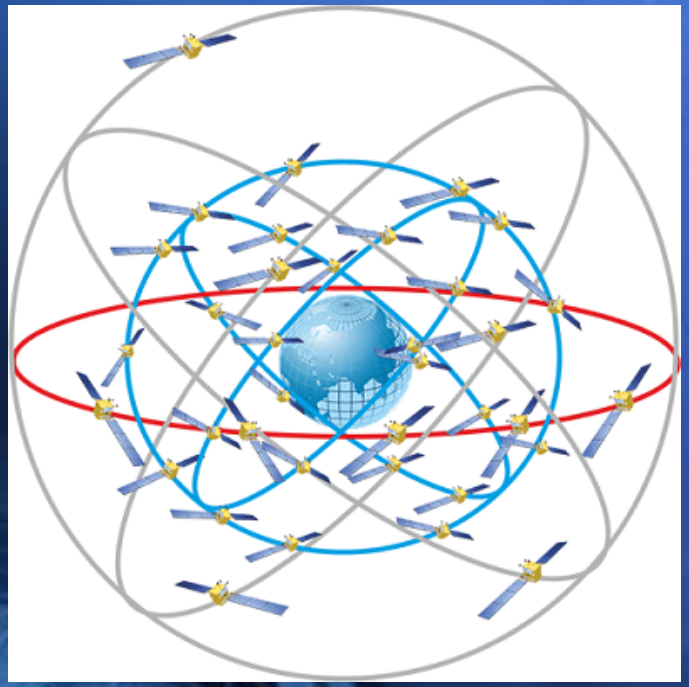
- Number of satellites observed at HK now





Multiple Orbit Constellations and

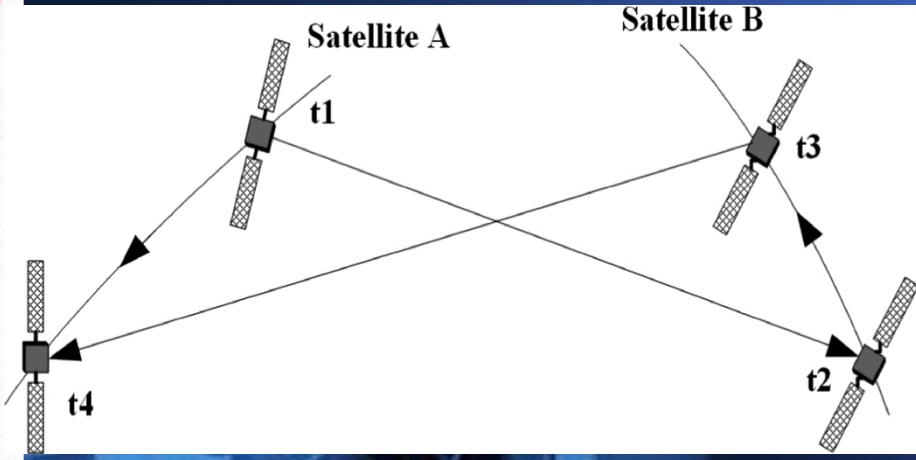
- Global coverage and enhance regional and polar coverage
- GEO satellites for wide area communication coverage



Inter-satellite tracking

- Allow to use regional tracking to achieve high precision orbit and time synchronization among satellites

Tracking stations in China

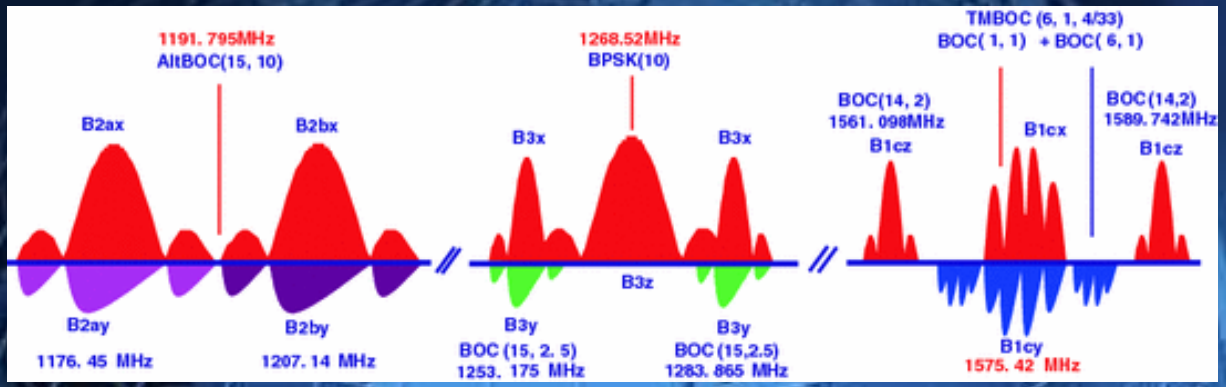


Integrated Communication, Navigation and Surveillance (CNS)

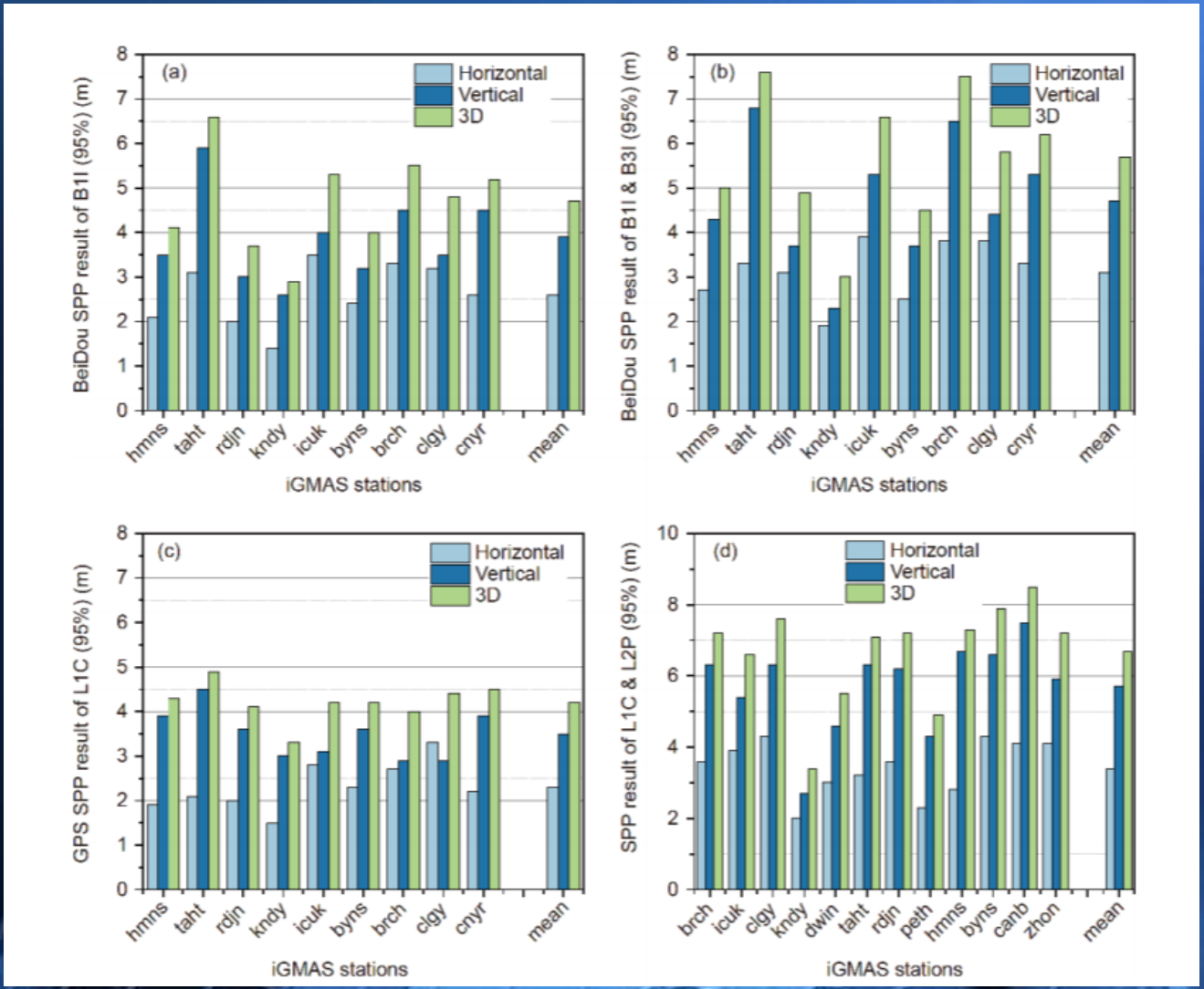
- Provide RDSS and RNSS services
- Communication:
  - Short message
    - 2000 bits
  - Continuous data communication (~4K)
- Positioning/Timing
  - 5-10 m/50 ns (stand-alone mode)
- Surveillance
  - Position report to centre

Multiple Services

- Multiple frequency signals
  - Different services for positioning
  - Military/Civilian signal separation
- Support different positioning modes
  - Standalone: 5-10 m
  - Wide-area Augmentation: 1 m
  - Precise Point Positioning: 10 cm
- Search And Rescue Service (SARS)
  - Emergency service



Positioning Performance



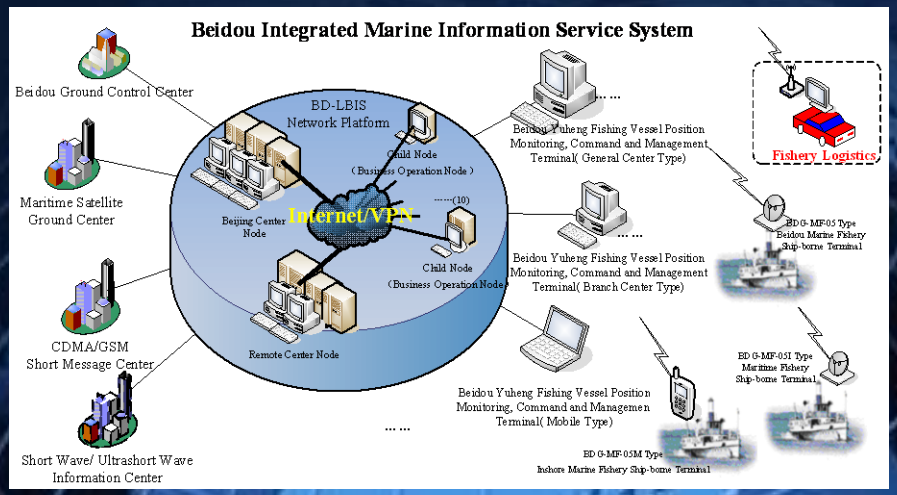
Applications of Beidou-3 for smart cities

Advantages of Beidou

- Provides both RDSS and RNSS services
- Dual-way communication
  - SMS
  - Continuous data communication (~4K)
- Provide Wide Area Augmentations/PPP
  - GEOs
  - Nav. data with GEOs: 200 bits/s
- Multiple Frequency data
  - Fast RTK solutions
- SARS

Beidou Dispatching System in Marine Fishery

- Real-time monitoring of 20,000 fishing vessels
- Rapid positioning, location report and short message communication
- Alarm for dangerous zone and bad weather, monitoring and commanding, ship tracking, operation track recording and oil fuel data collection etc.



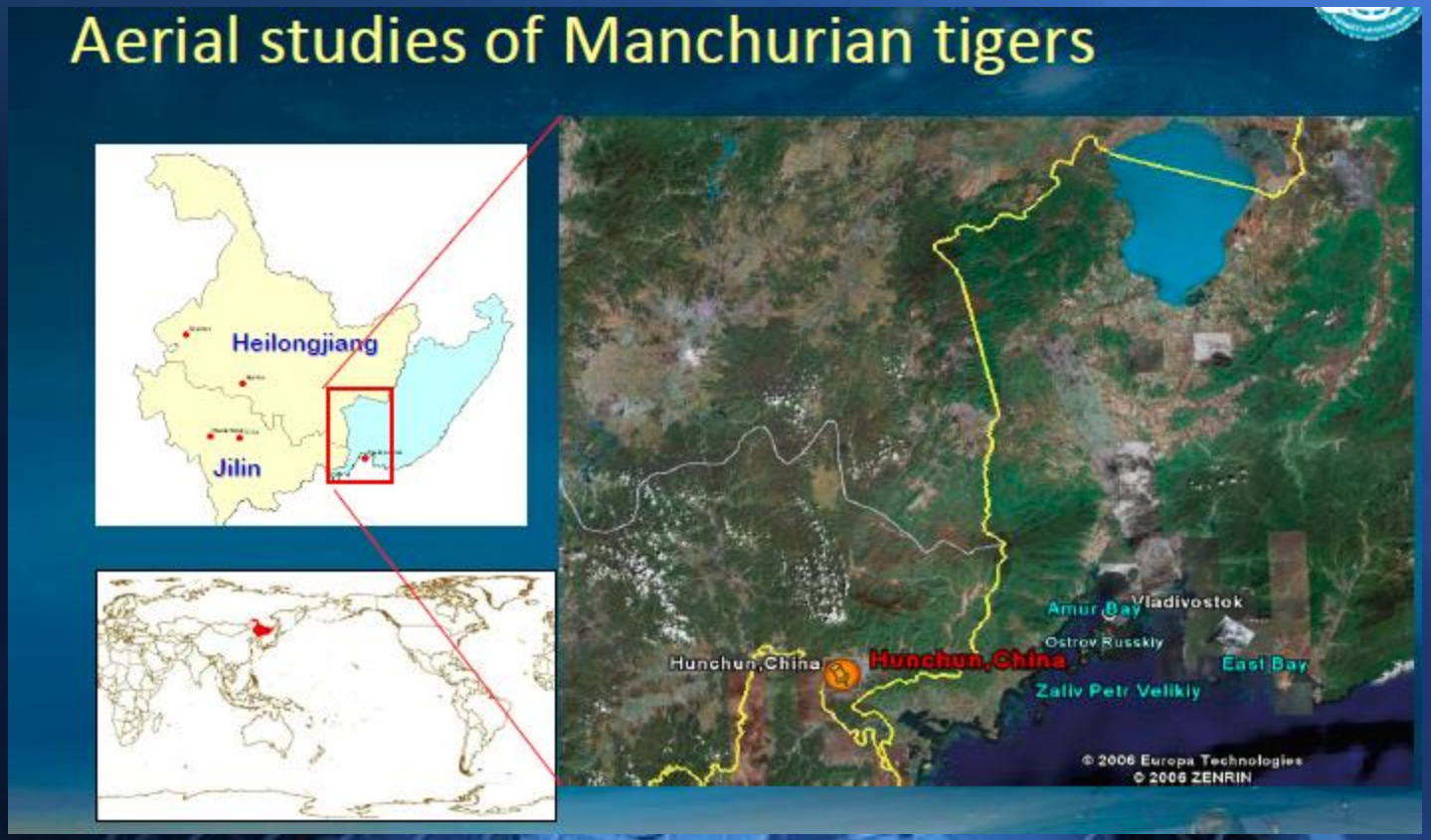
Beidou Hydrological Data Collection System for flood warning along the Yangtze River

- To get the reports on the tributaries along the upstream of the Yangtze River covering an area of about 370,000 square kilometers
- To provide automatic monitoring and reporting for cascade hydroelectric stations on the downstream of Jinsha River, with a coverage of 45.443 square kilometers
- Successfully solved these problems
  - Delays in flood forecasting for its upstream
  - Scarce monitoring stations
  - Inconvenient communication

Beidou for civil aviation

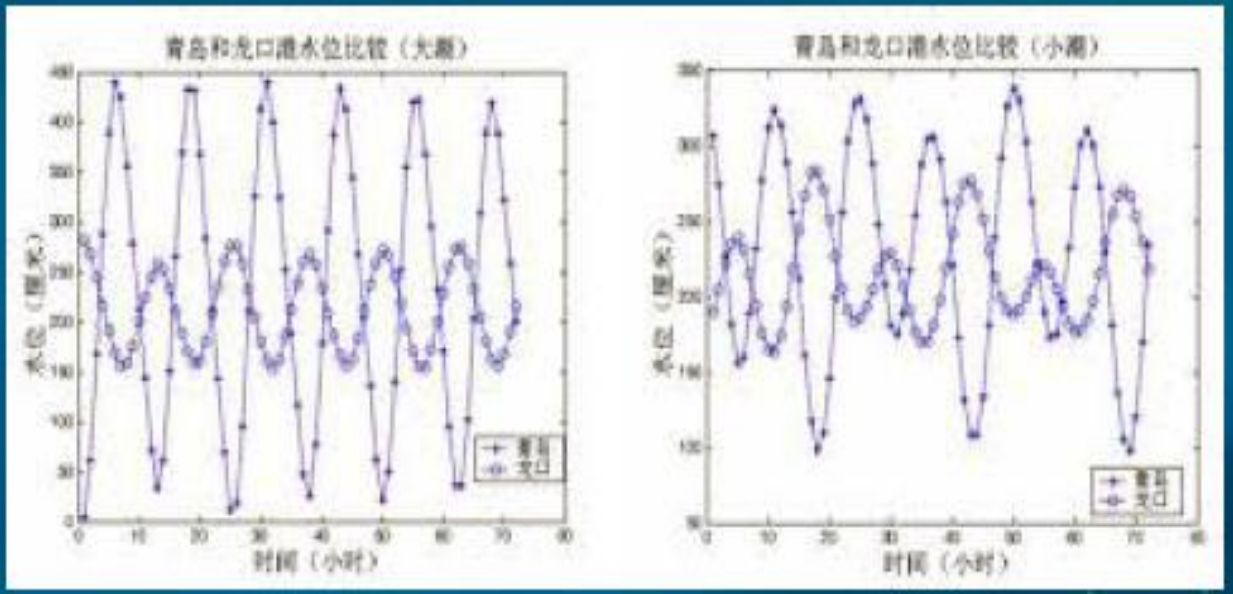
- Integrated CNS systems

Monitoring wild animals

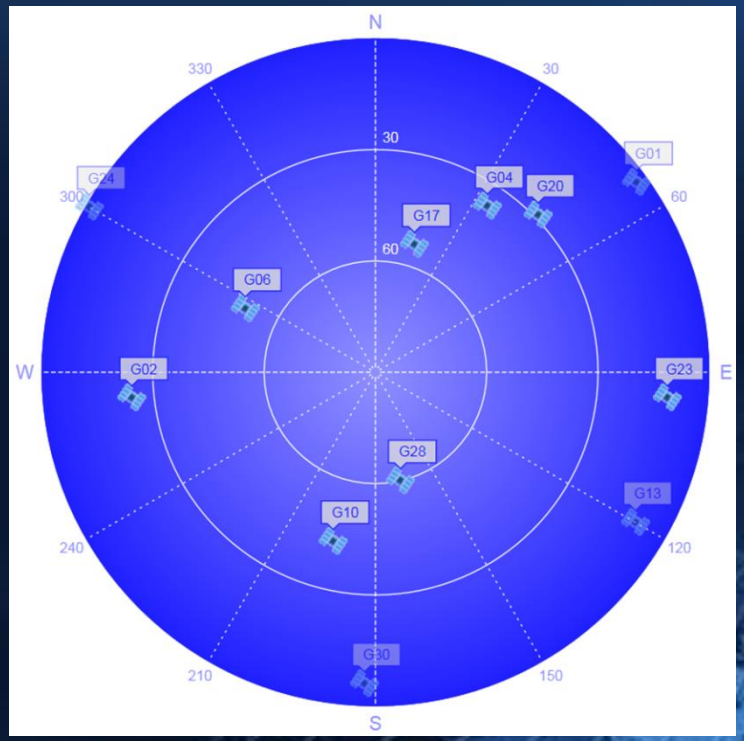


Monitoring oil spills

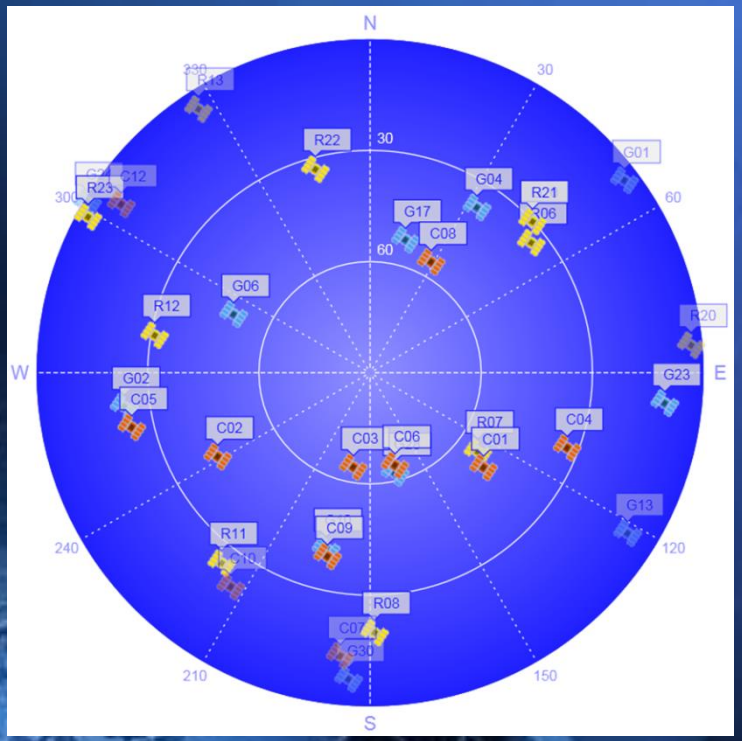
Tidal Measurements



Multiple GNSS Systems – Coverage Improvement

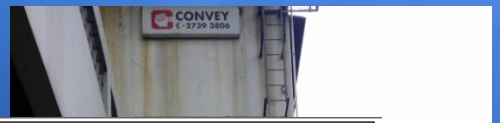


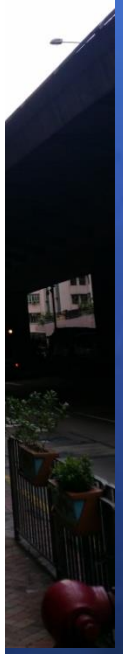
GPS only: 12



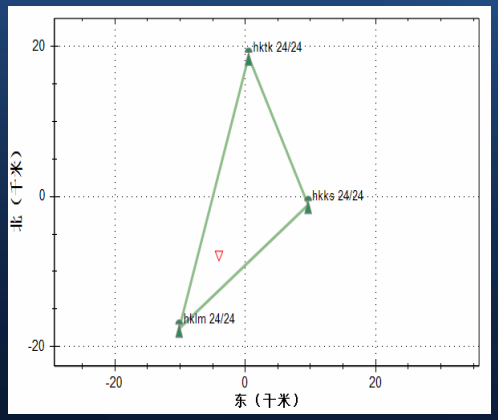
GPS+GLONASS+Beidou: 33

GNSS RTK Positioning in difficult environments





RTK based on GPS, GLONASS and Beidou



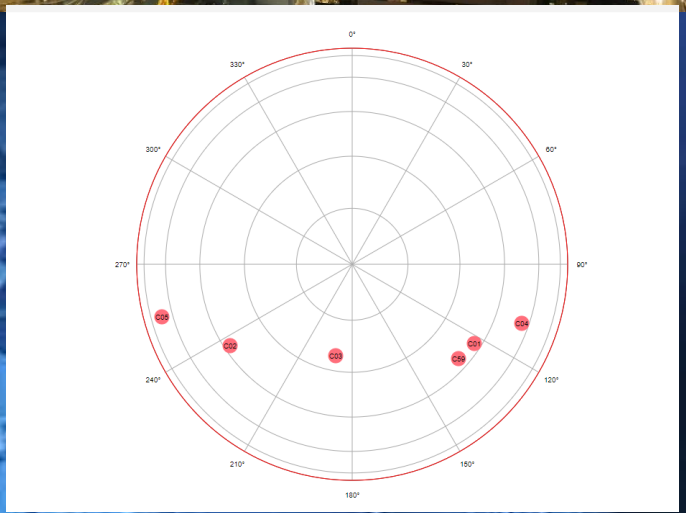
模式	坐标平均值/米			内符合精度/毫米			外符合精度/毫米		
	N	E	U	N	E	U	N	E	U
G	818695.192	836542.245	31.931	5	5	14	5	9	22
C	818695.193	836542.232	31.965	7	19	51	7	20	54
G+C	818695.190	836542.237	31.960	3	3	11	5	3	16
G+R	818695.194	836542.240	31.936	6	4	11	6	5	17
C+R	818695.197	836542.231	31.935	5	10	42	7	12	44
G+C+R	818695.192	836542.240	31.964	3	3	8	3	4	18

GPS+GLONASS

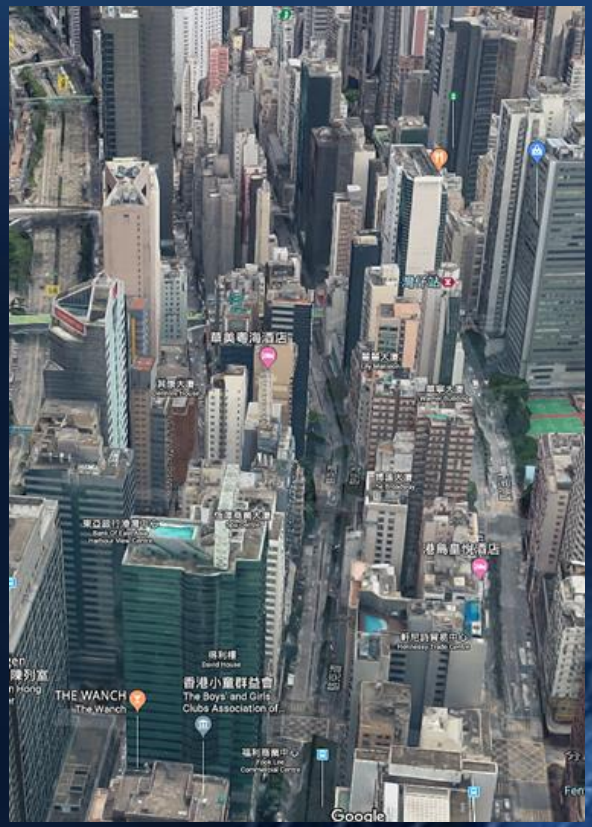
GPS+GLONASS+BDS

Multipath mitigation in urban environment

- *Multi-constellation GNSS data*
- *3D city model*
- *Other positioning sensors in mobile phone*
- *Beidou GEO satellites*
  - *Range error does not change with time*
  - *Can be calibrated*



Positioning performance with mobilephones (GPS+Beidou)



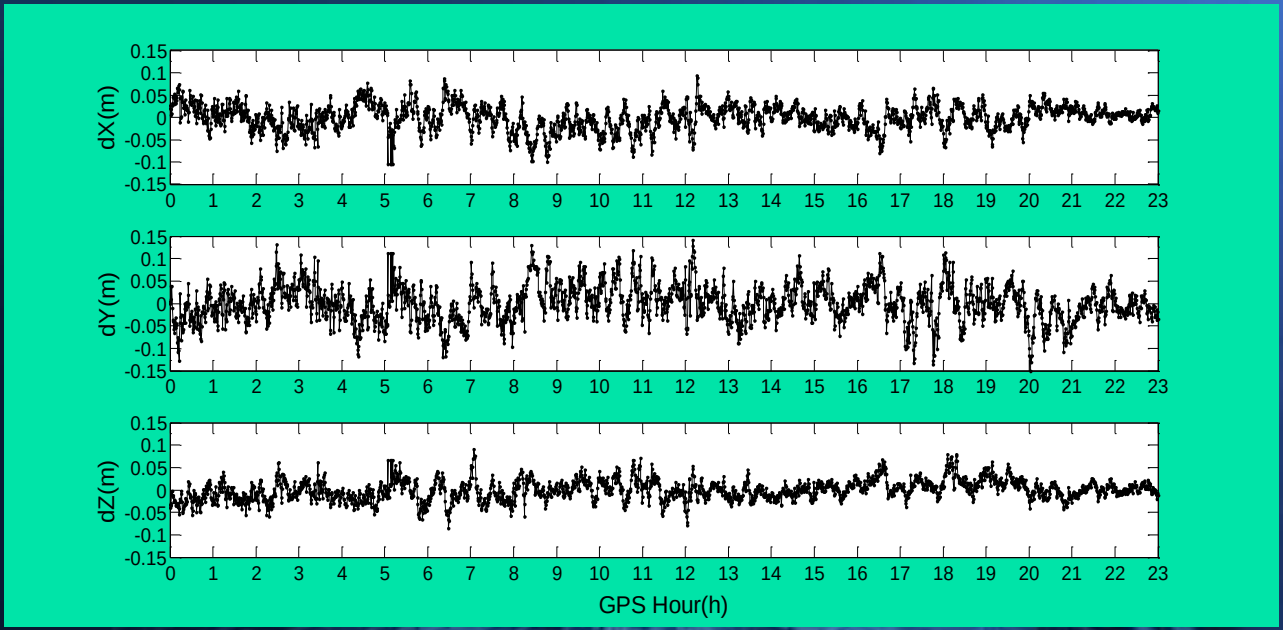
Wan Chai in HKSAR

Site	Accuracy	Northing (m)	Easting (m)
Mong Kok	Smartphone result (Cyan)	24.98	11.54
	Our platform result (Blue)	8.4	6.2
Wan Chai	Smartphone result (Cyan)	9.32	20.52
	Our platform result (Blue)	8.1	8.87

Beidou Multiple Frequency data

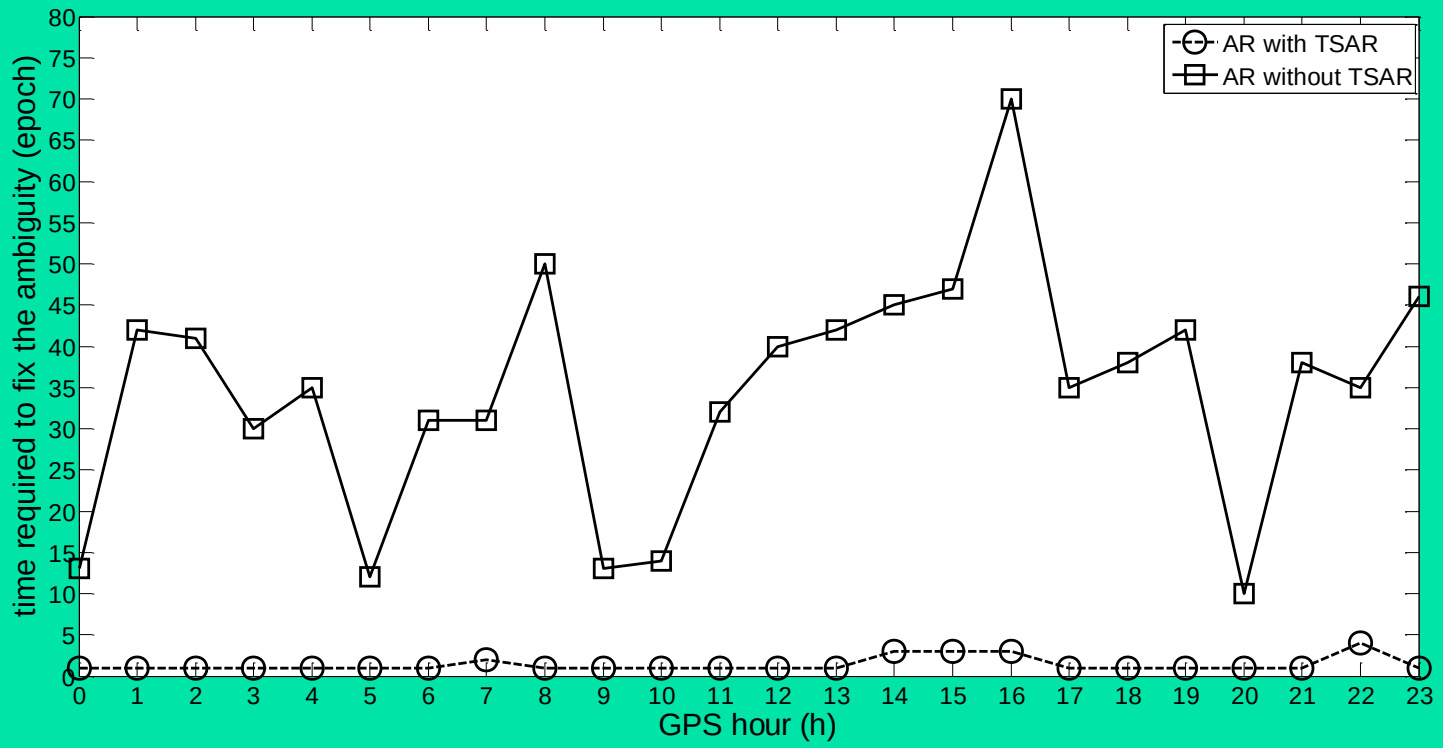
- Better estimation of ionosphere
- Extend GNSS positioning baseline and convergence time
  - (normal GNSS RTK are within 20 km)
- We proposed a new Triple Search Ambiguity Resolution (TSAR) method using multiple frequency Beidou signals
  - Able to extend the distance to 100 km

RTK solution for a 70 km baseline - Beidou +GPS



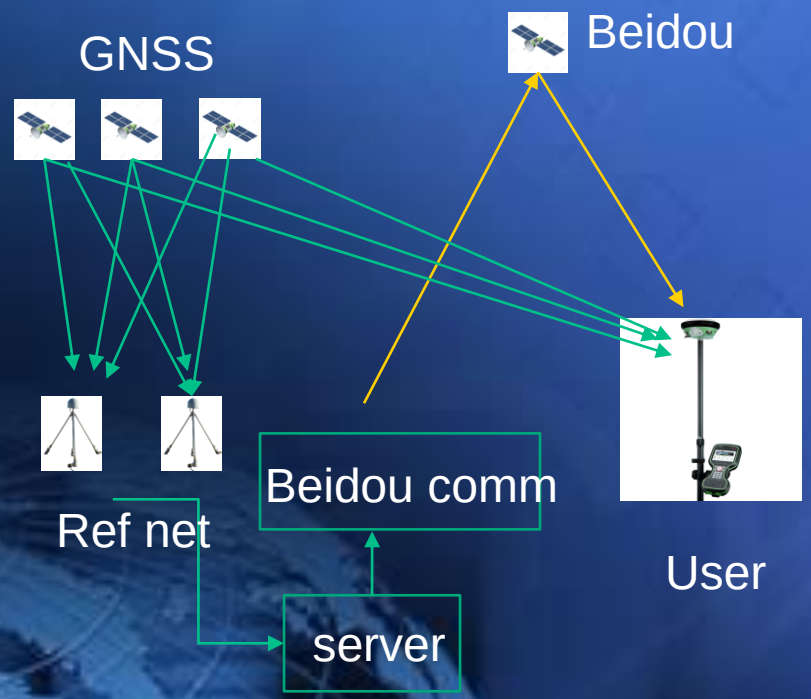
	dX	dY	dZ
std	0.028	0.042	0.023

Time for ambiguity fixing - Beidou +GPS



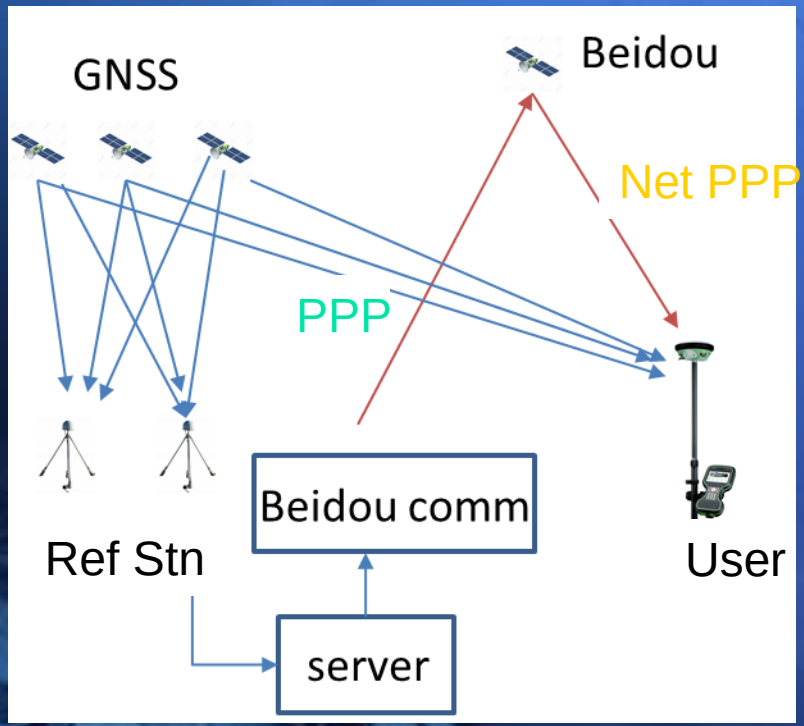
Improve HK GNSS network RTK coverage with Beidou-3 communication

- GNSS RTK needs communication channel to transfer network corrections to users
- In Hong Kong, many areas without mobilephone signal coverage
  - Cannot use GNSS RTK surveying
- Beidou-3 one-to-more communication mode
- To provide GNSS RTK coverage in area no mobile communication coverage



Multiple GNSS network PPP

- Network PPP (integration of PPP and local network corrections)
  - Significantly reduce PPP initialization time (30 min.) to similar to network RTK (a few seconds)
  - Better performance than network RTK
- Can extend RTK services to offshore engineering and other PPP users (i.e. autonomous vehicle)



Summary

- Unique Characteristics of Beidou-3
  - RDSS and RNSS
  - Stand-alone, WADGNSS, and PPP
  - The first operational multiple frequency system
  - Satellite to Satellite Tracking
  - Search and Rescue Service
  - Integrated Communication, Navigation and Surveillance services


Thanks !