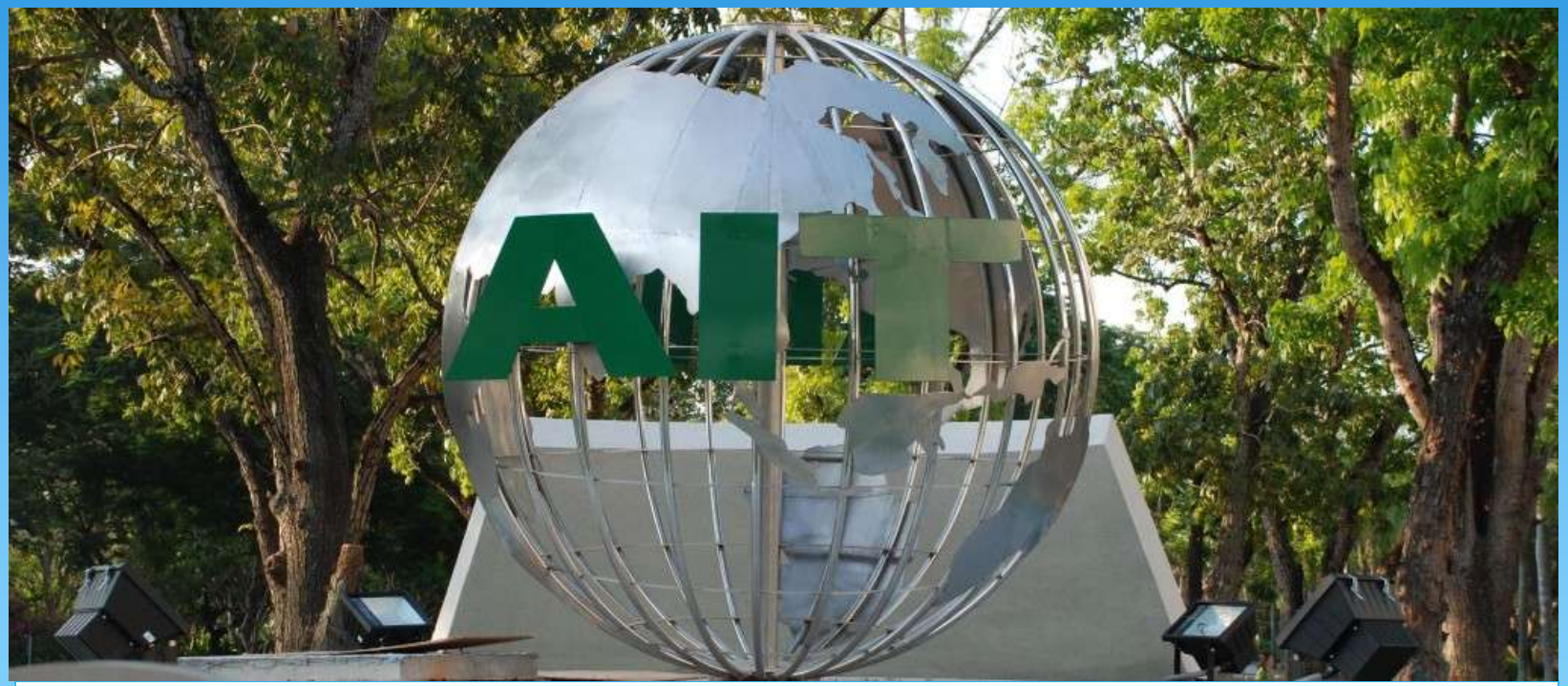
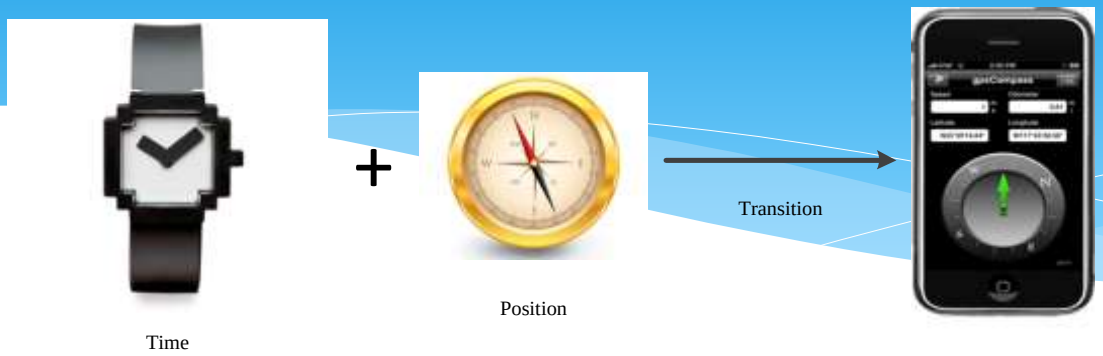
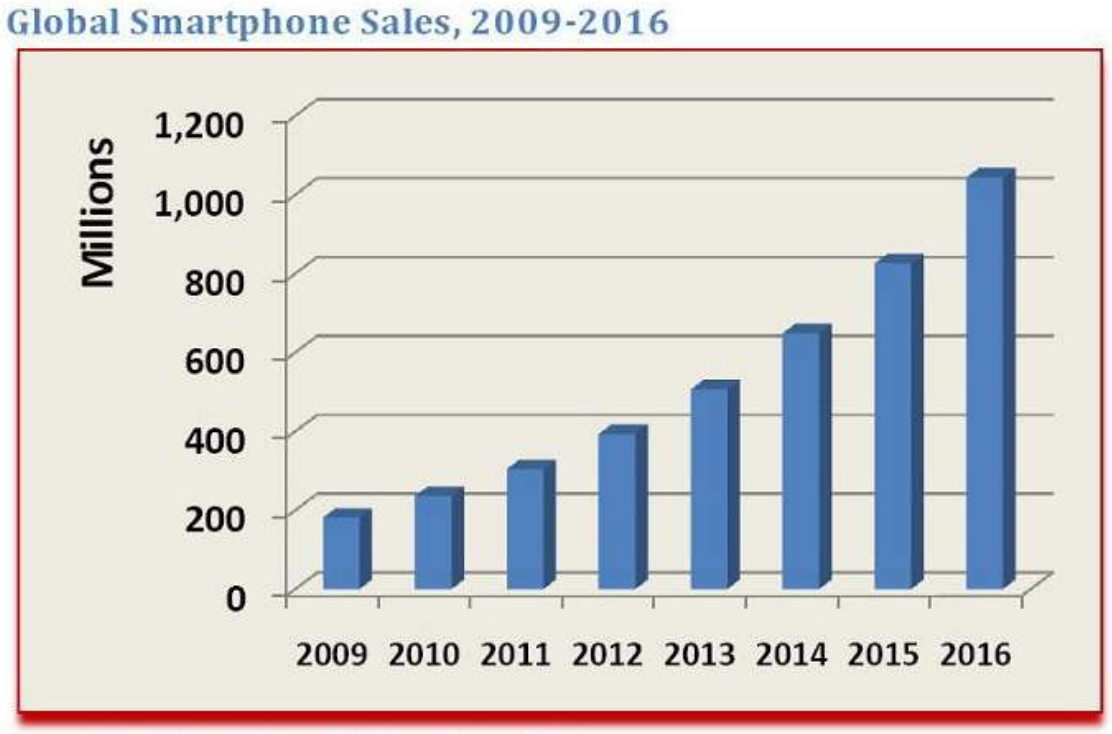
Hybrid Positioning Systems



Dr. Nitin Kumar Tripathi
Professor, Geoinformatics
Director – Special Degree Program
Asian Institute of Technology

Time & GPS on smart devices revolutionized Location Based Services (LBS)

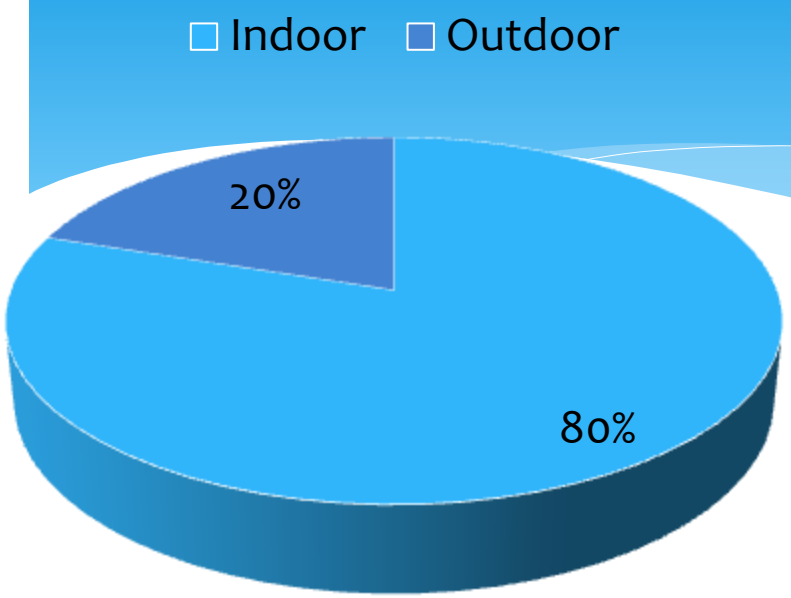




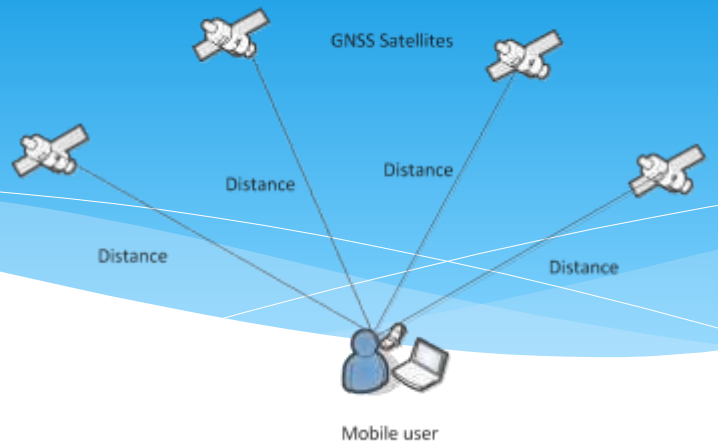
Accurate Outdoor Positioing thru multiple GNSS

Satellite Navigation Systems	2010	2014	2017	2020
GPS	31	31	32	32
GLONASS	23(+2)	24(+3)	24(+3)	24(+3)
GALILEO	0	4	18	27(+3)
BEIDOU	6	16	35	35
QZSS	1	1	4	7
IRNSS	0	1	7	7
SBAS	7	8	11	11
Total	68	86	134	149

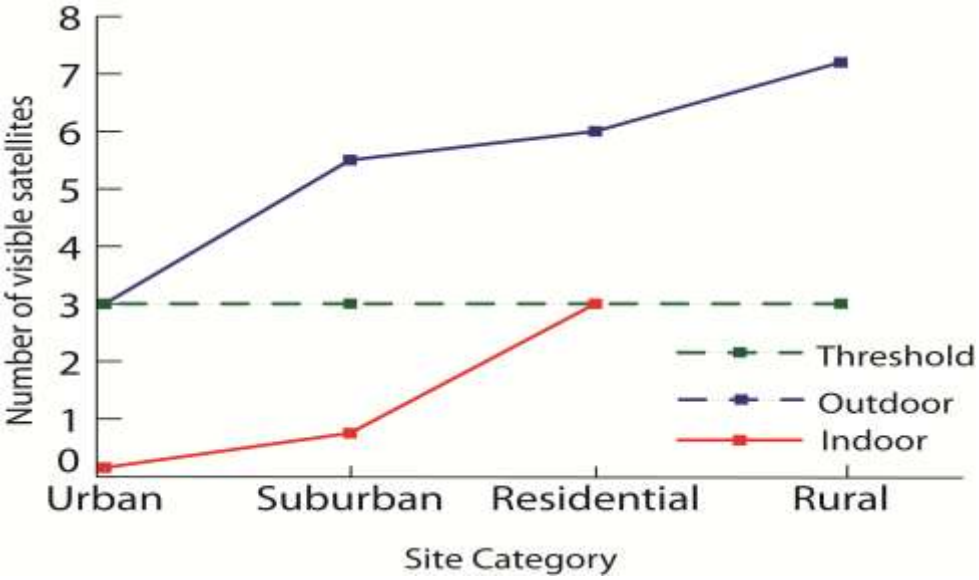
Time Spent in Indoor and Outdoor Environment



GNSS works fine in outdoor environments



Number of observed GNSS channels

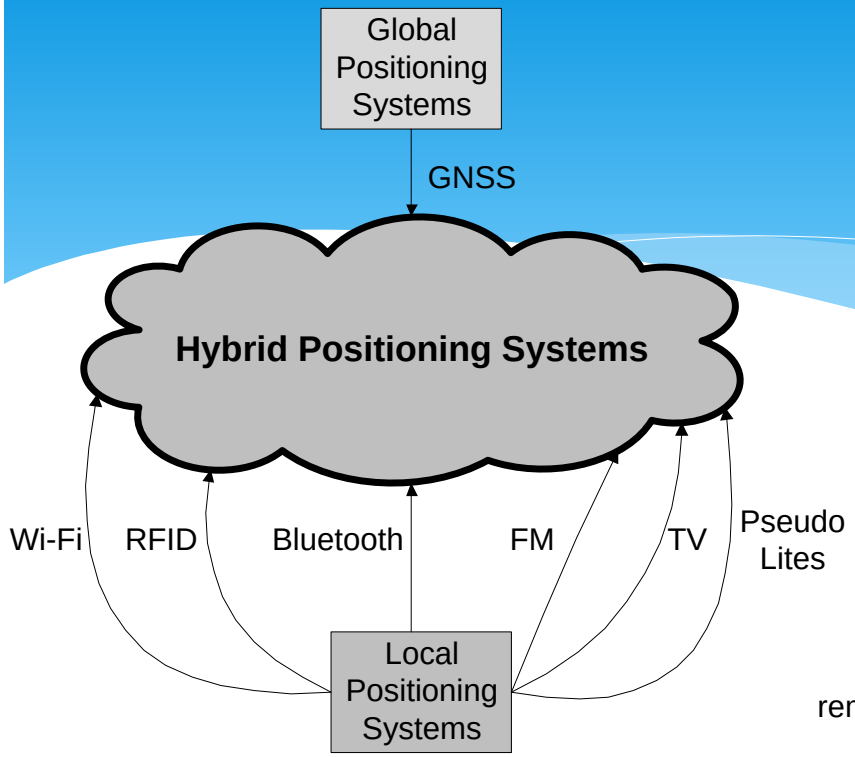


Solution !!

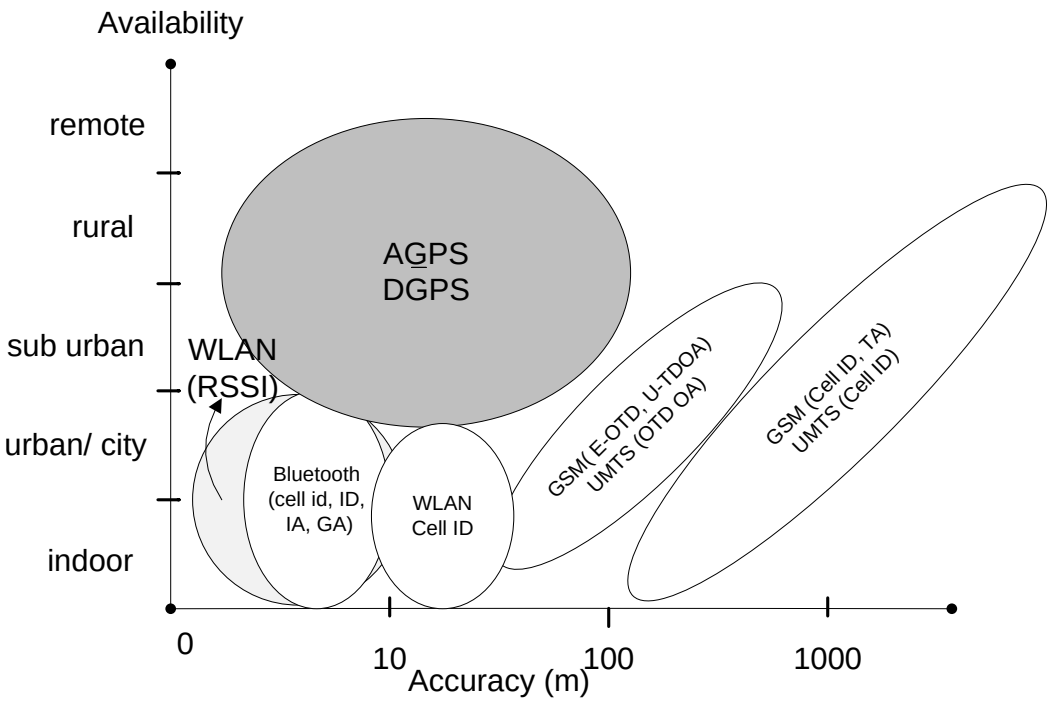
An alternate position technology that should work in indoor / outdoor / urban environments

Hybrid Positioning System (HyPos)

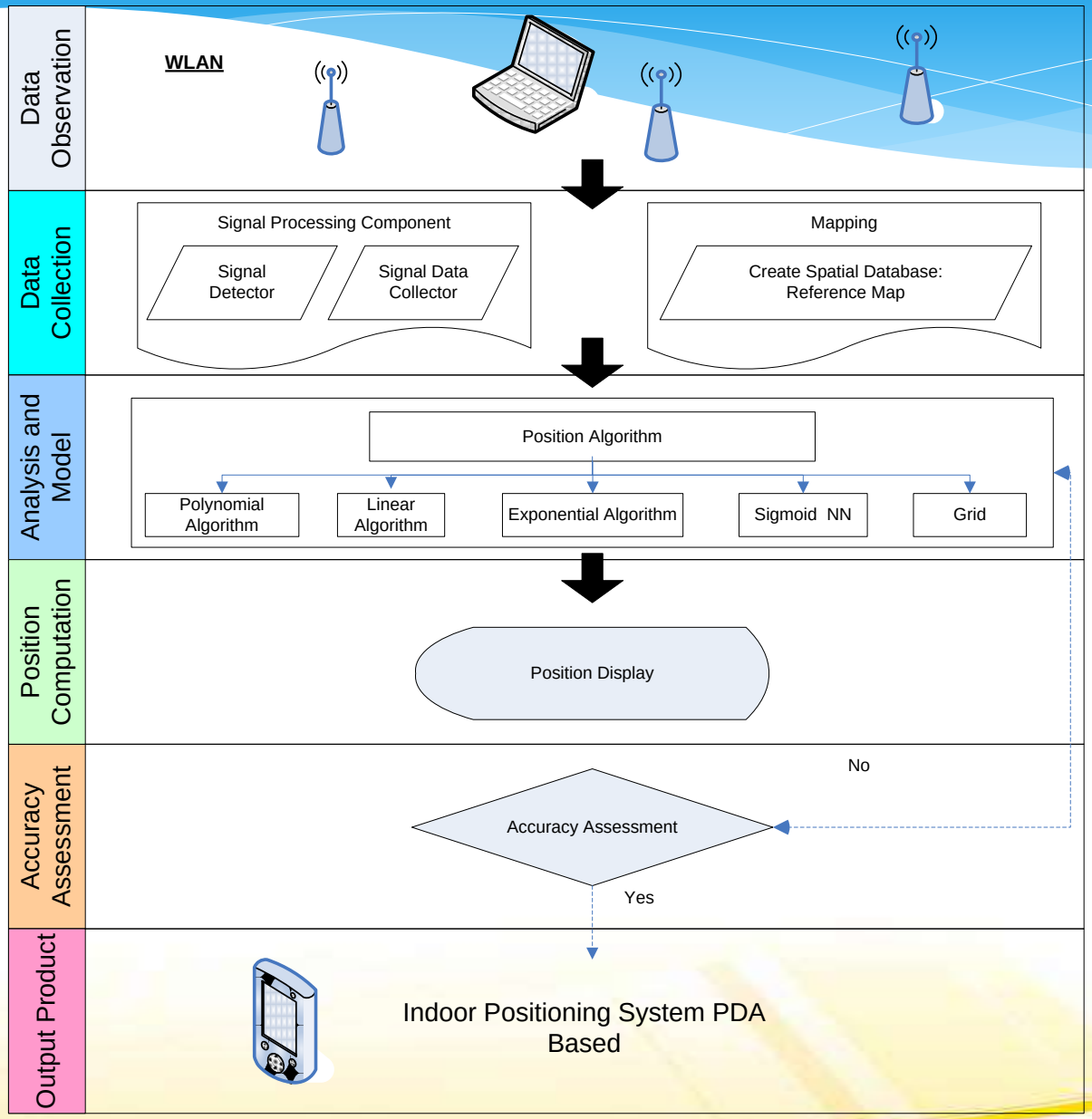
Possible combinations for HyPos



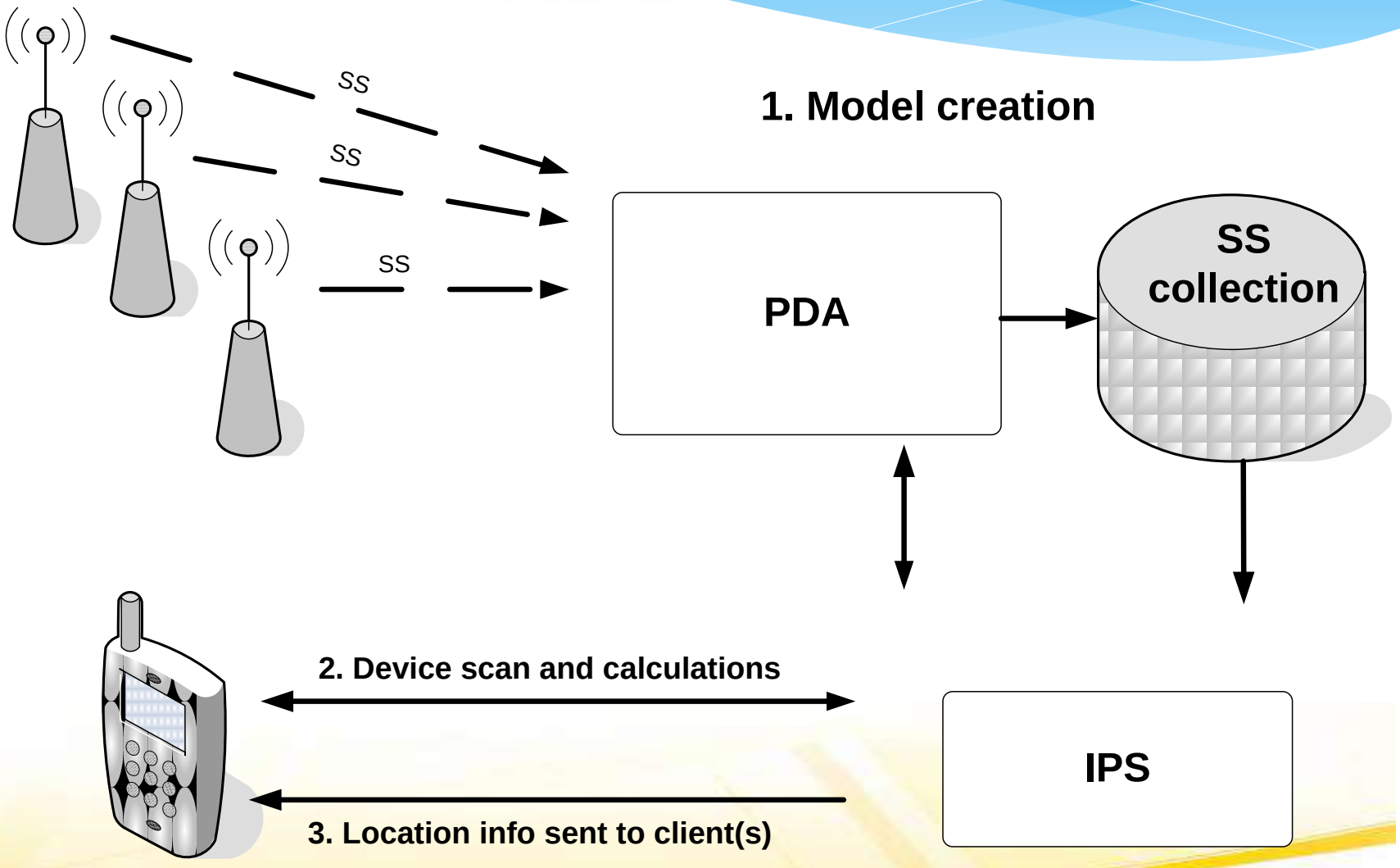
Positioning Systems accuracy vs. availability



Conceptual Framework of Indoor Position System



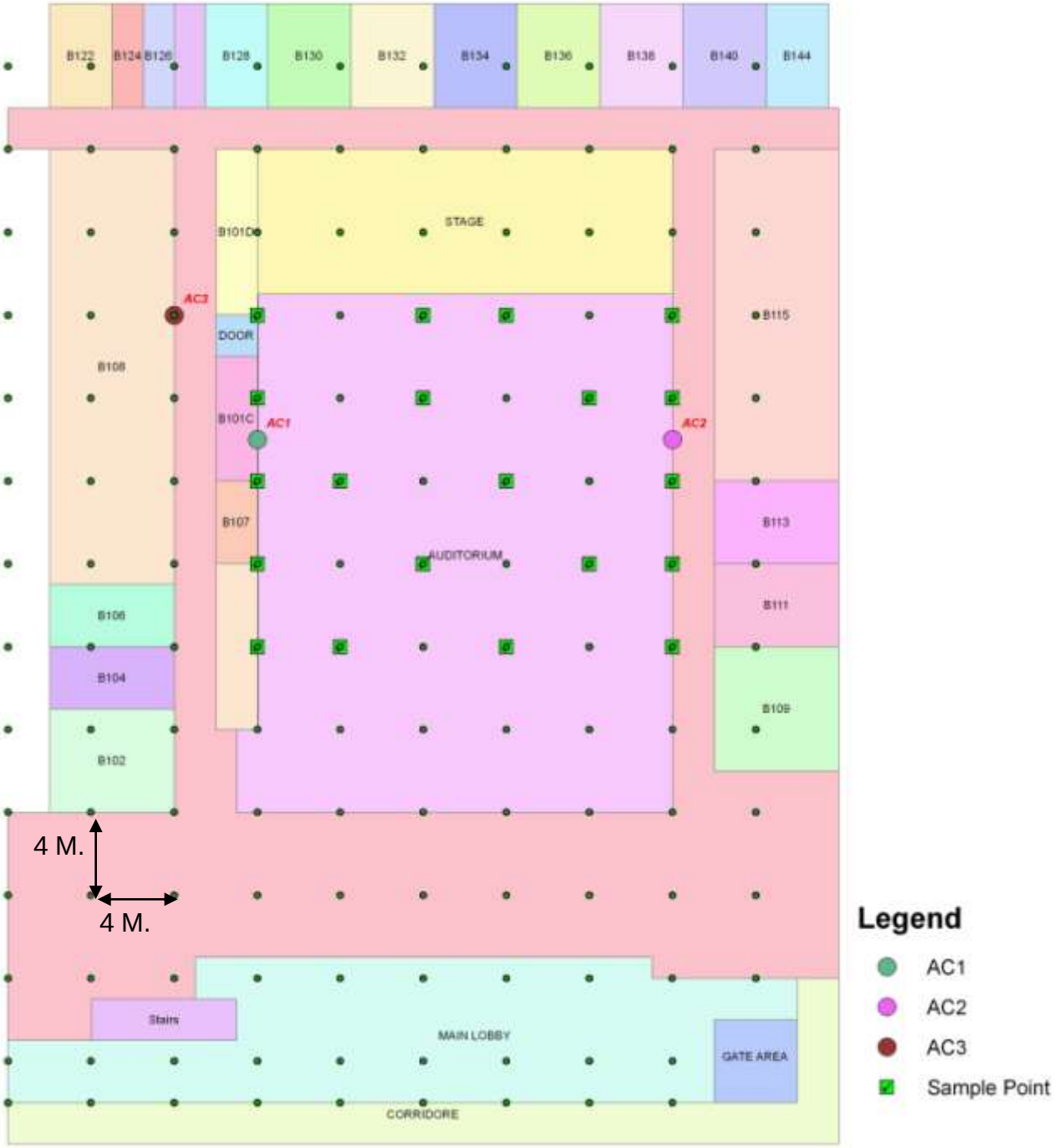
IPS


SS
SS
SS
1. Model creation
PDA
SS collection
2. Device scan and calculations
3. Location info sent to client(s)
IPS

Data Collection

The study site is in the auditorium, AIT Conference Center.

- The area is 20 X 32 meter.
- Floor Plan of AIT Conference Center
- The distribution of the-3-access points.
- The 30 points used as the sample point to collect the signal strength for analysis and develop the model



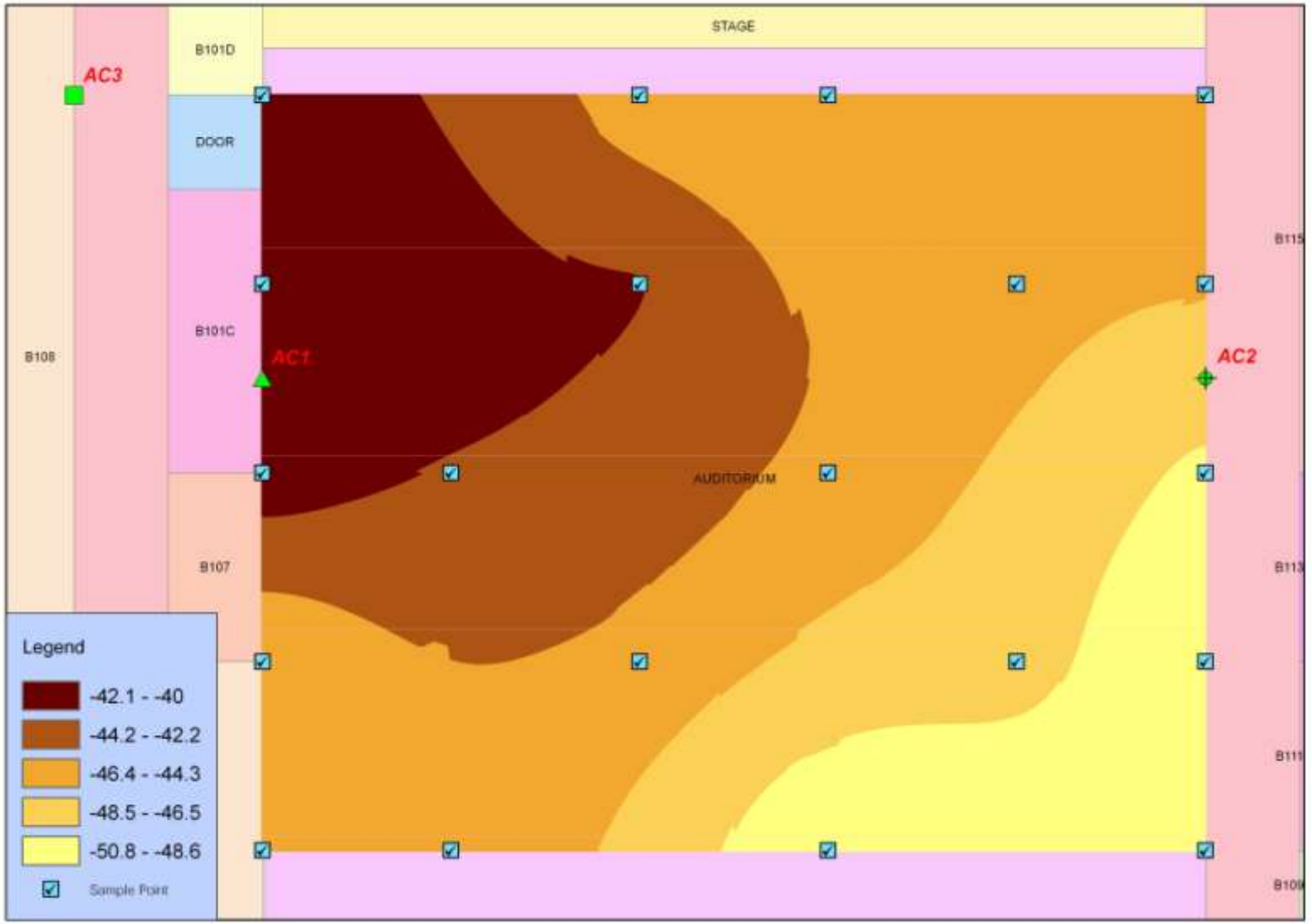
Data Analysis and Model

Parametric Model

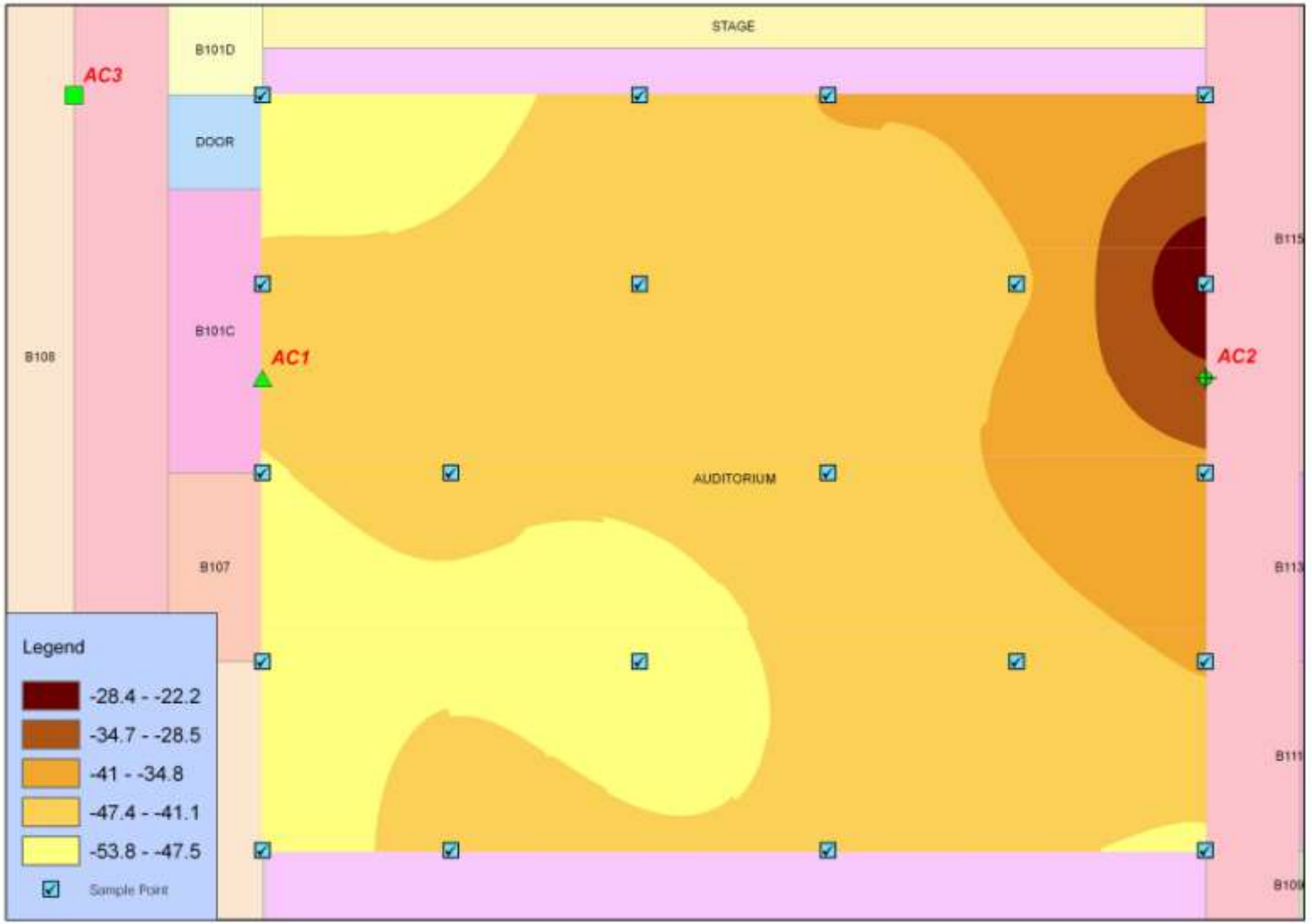
- Linear Model
- Polynomial Model
- Exponential Model

Non-parametric Model

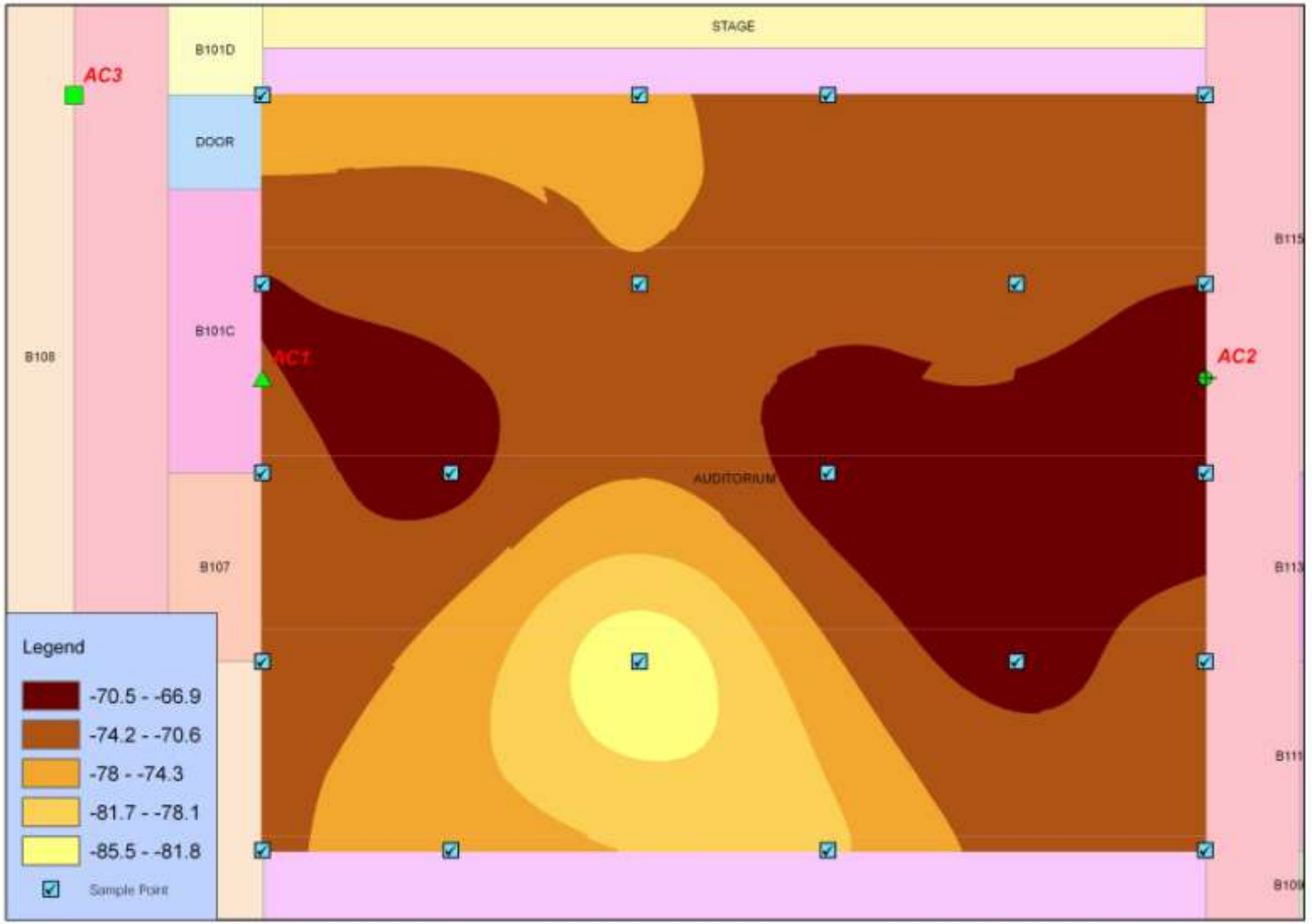
- Neural Network Model
- Grid Model



The Kriging Interpolation Map of Signal Strength from Access Point 1



The Kriging Interpolation Map of Signal Strength from Access Point 2

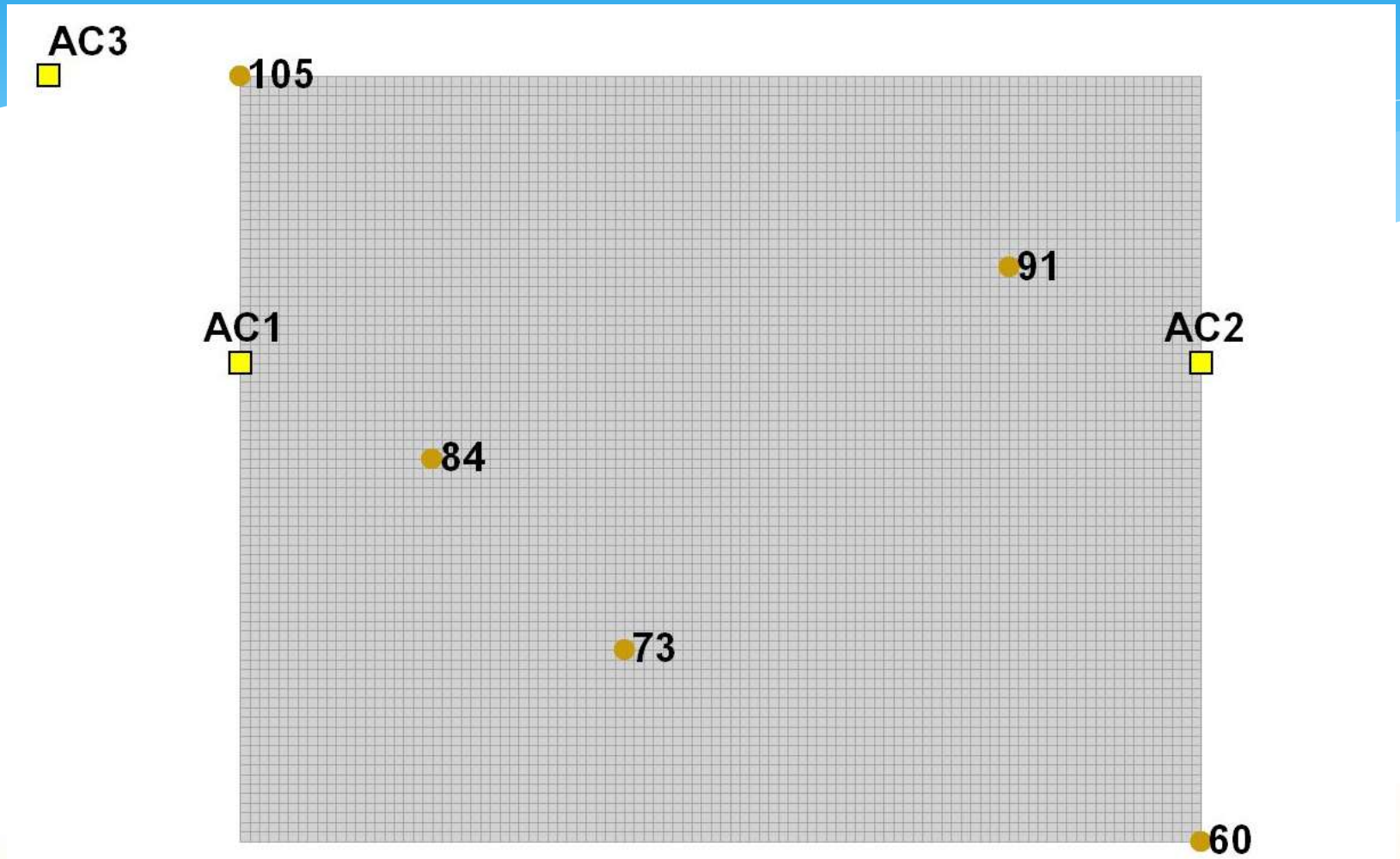


The Kriging Interpolation Map of Signal Strength from Access Point 3

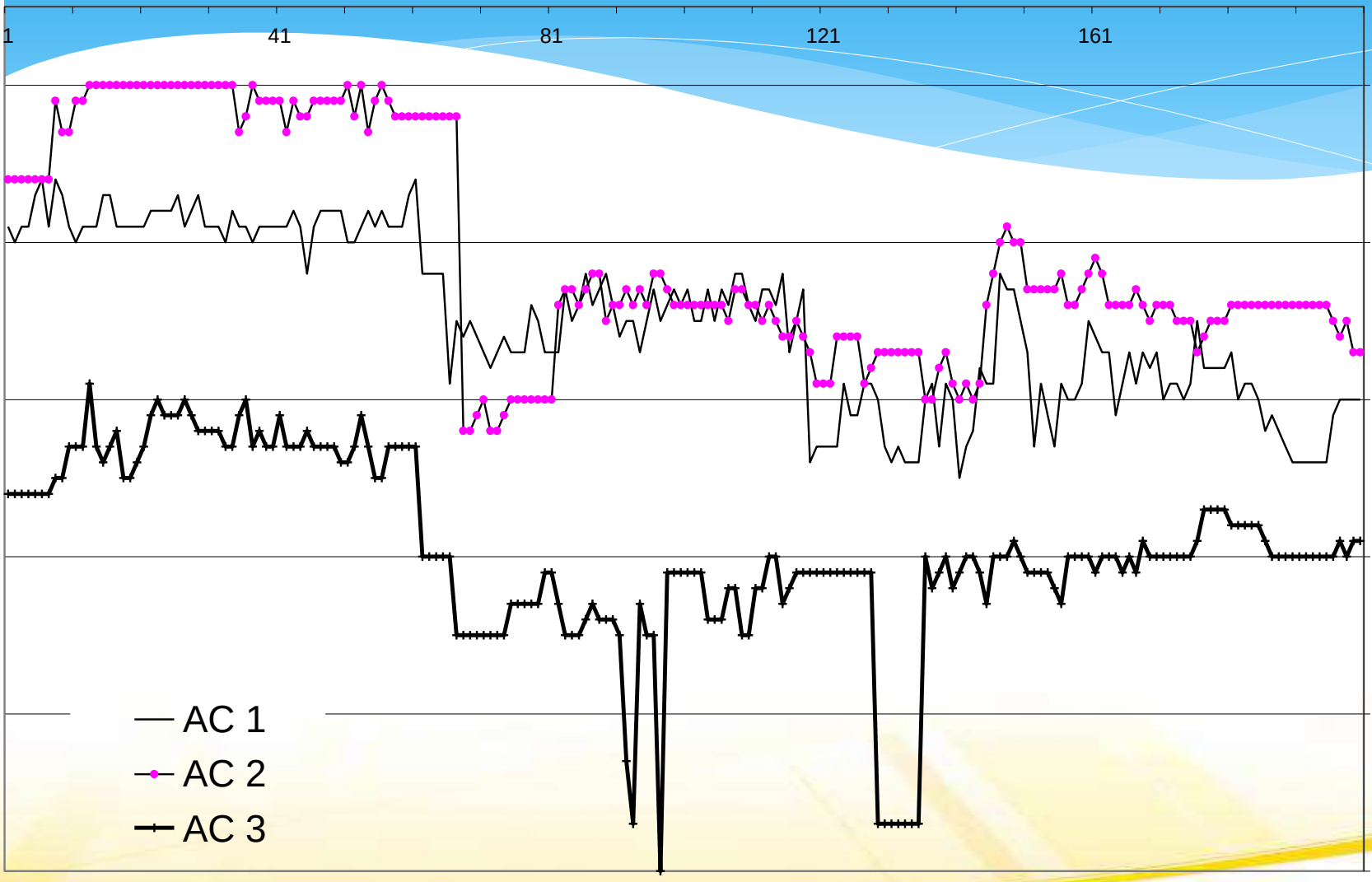
Stability of wLAN signals

- Signals unstable due to various reasons
- Number of sample
- Distribution of sample
- Stability of sample
    - When is it stable ?
    - How is it stable ?
    - What is the range ?

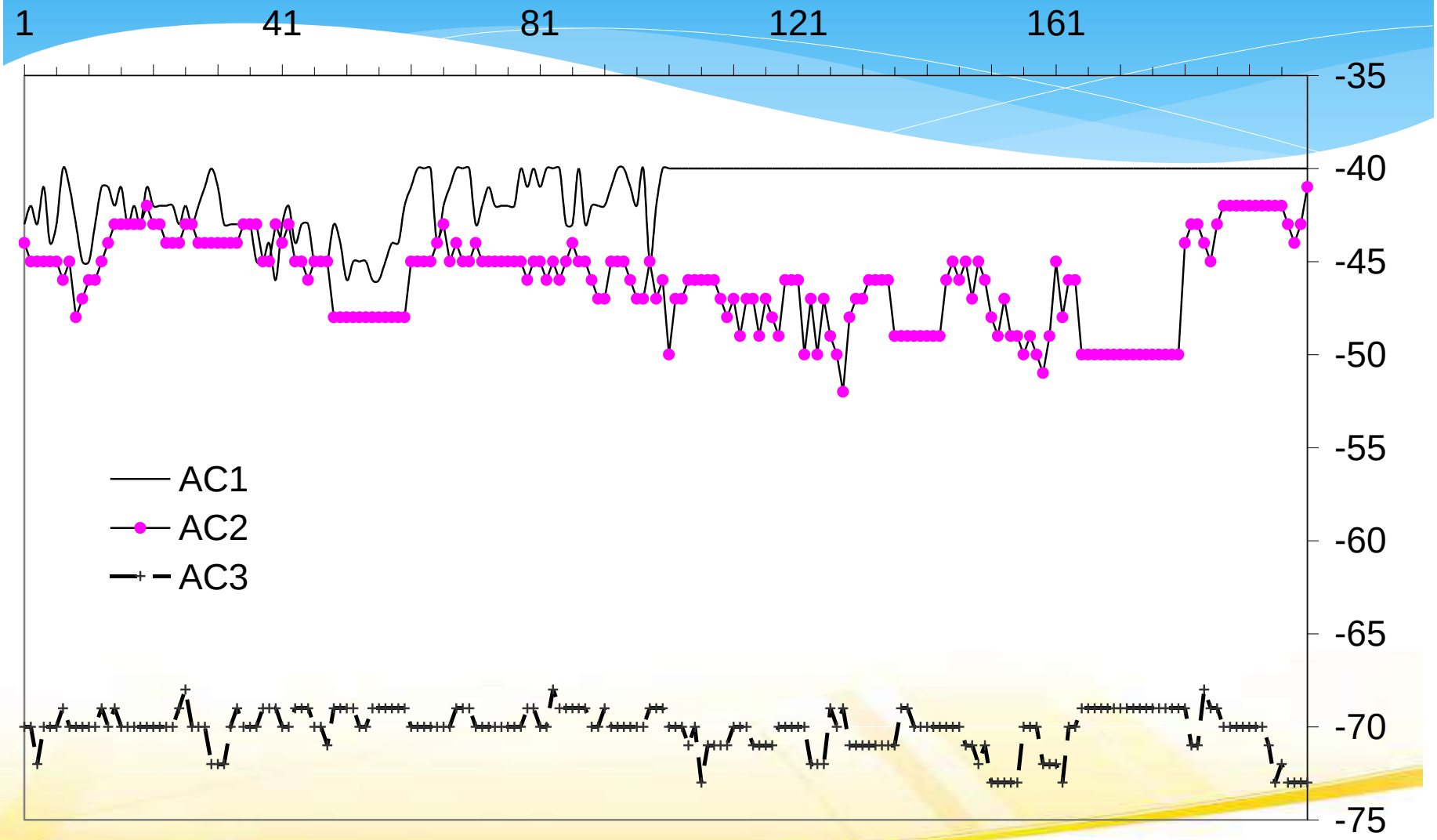
Distribution of the sample points and access points



(a) At the point no.60

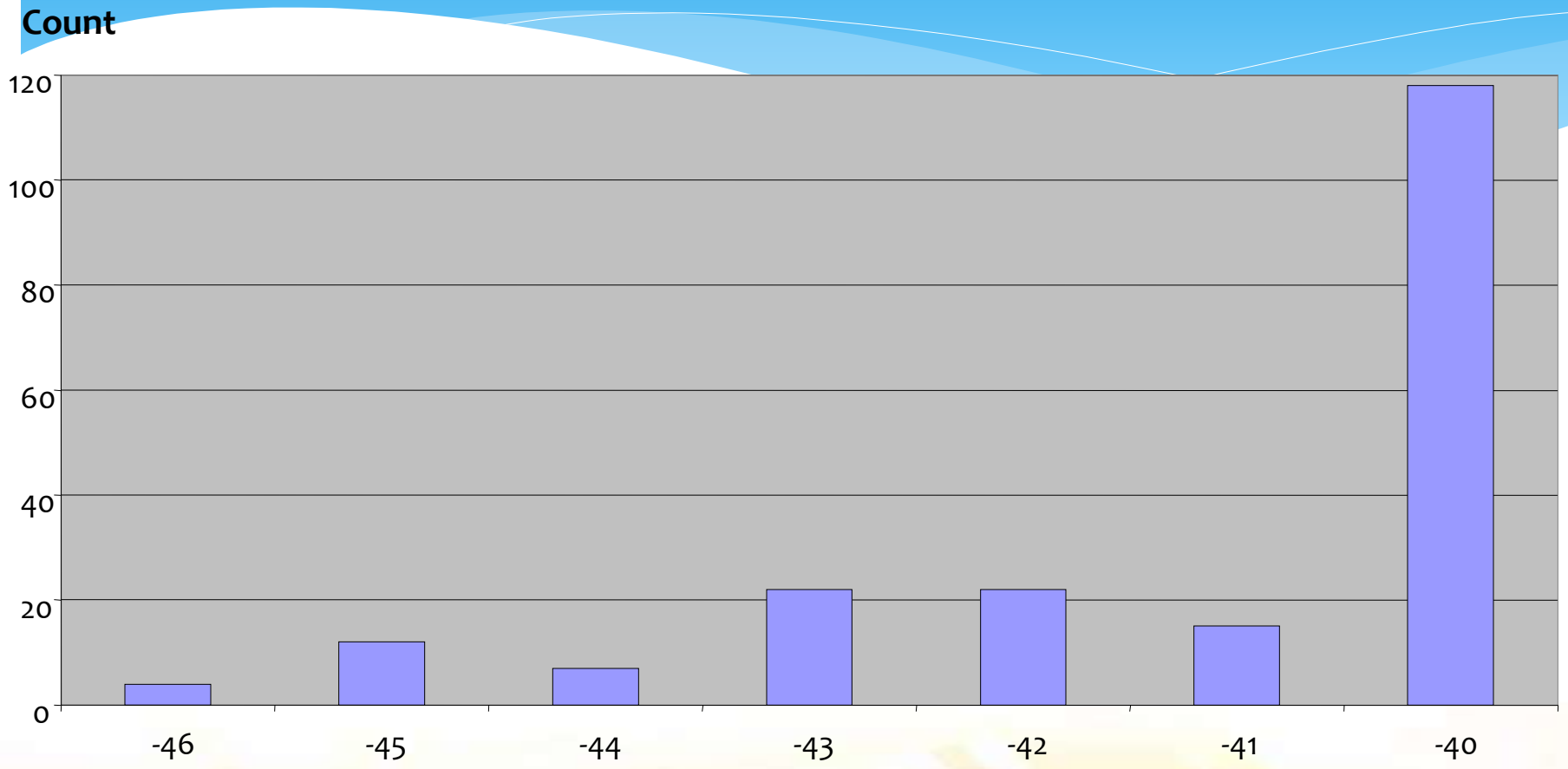


(b) At the point no.73

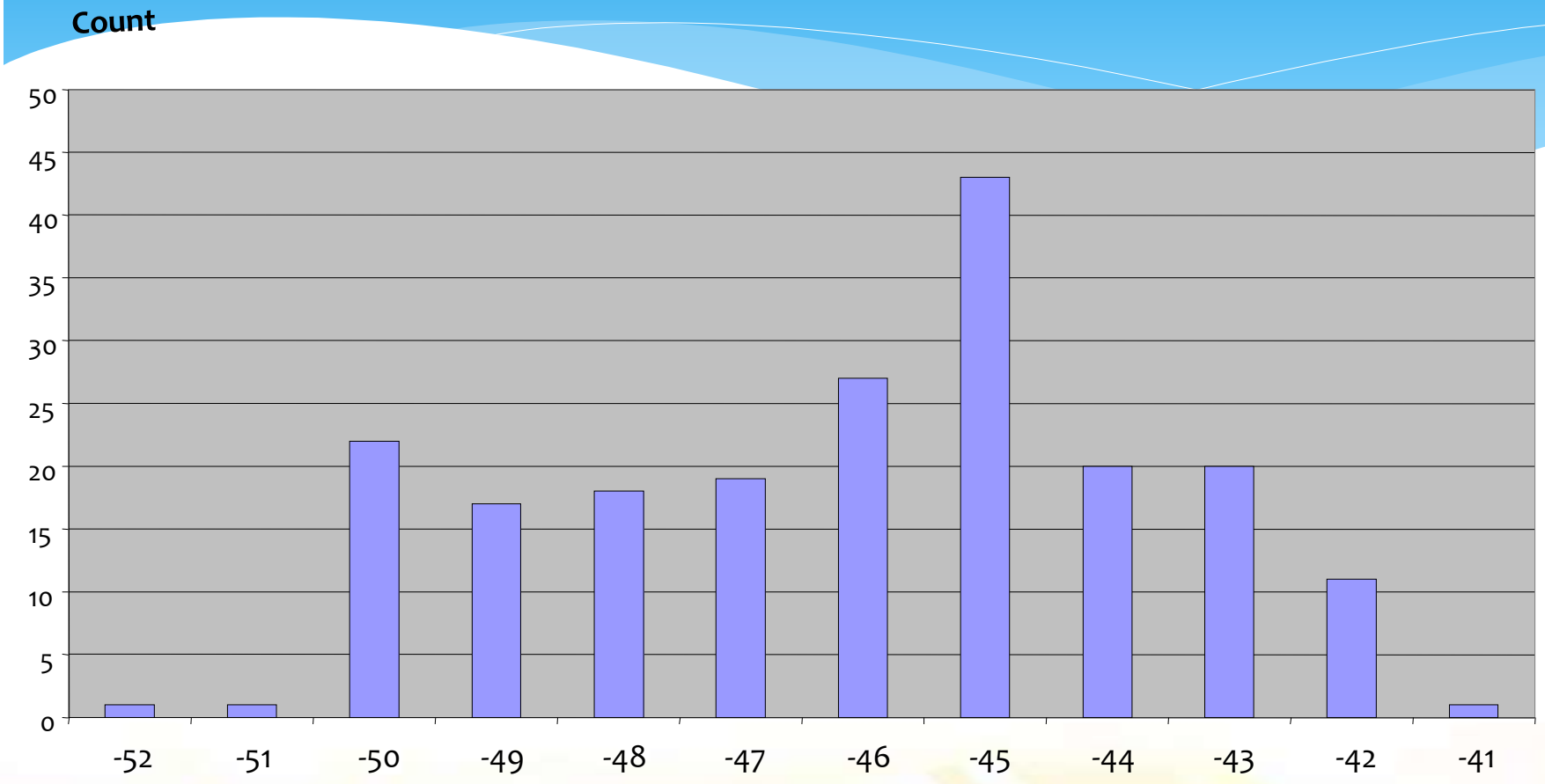


(c) At the point no. 91

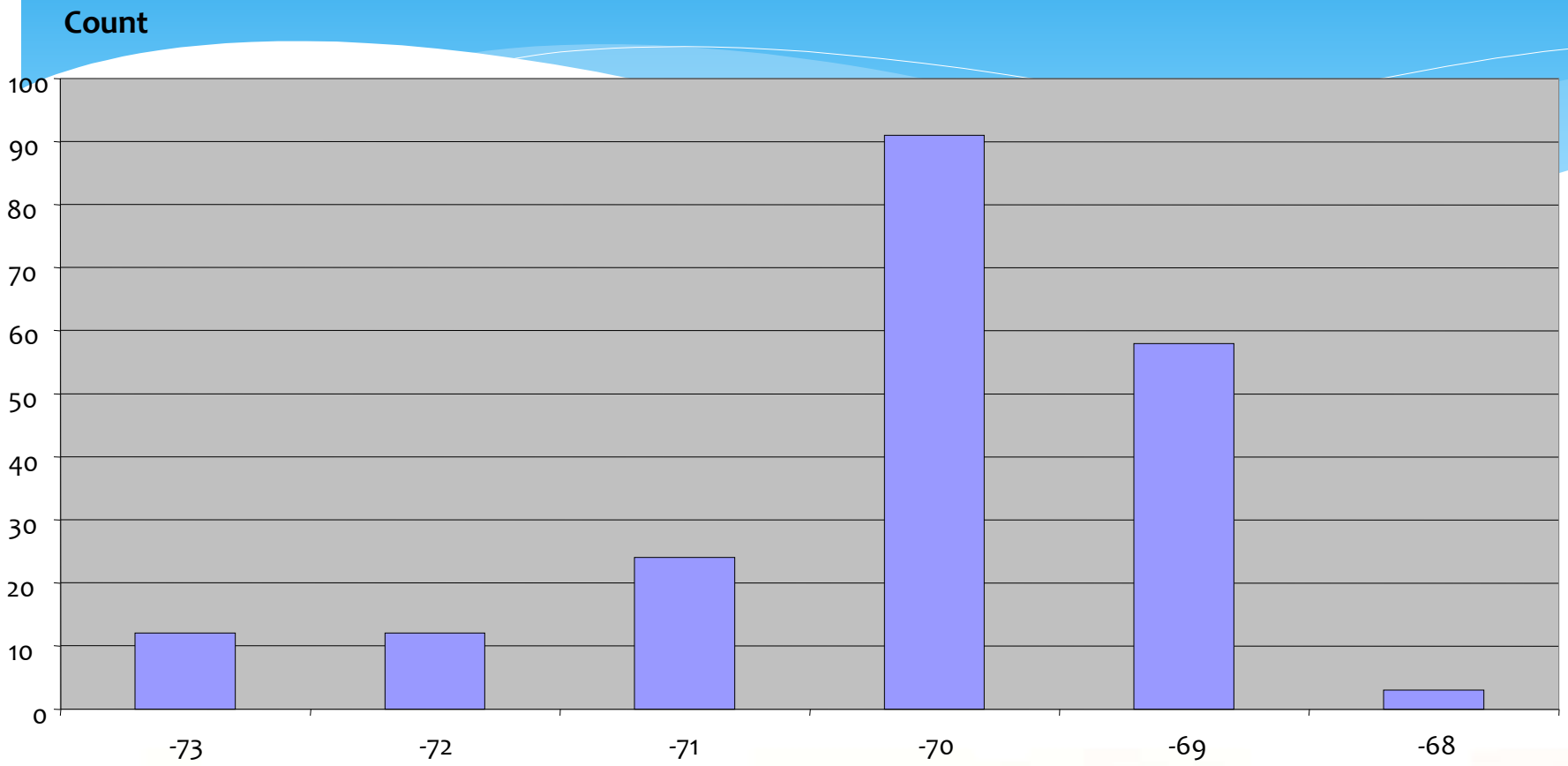
Access point 1



Access point 2



Access point 3



Stability of WLAN

Stability of sample

- How is it stable ?
  - Less moving
- When is it stable ?
  - After 100 seconds (estimate)
- What is the range ?
  - 1-6 dBm.

For accuracy and stability consideration in location observations, adopt "mean signal strength" of 25 to 35.

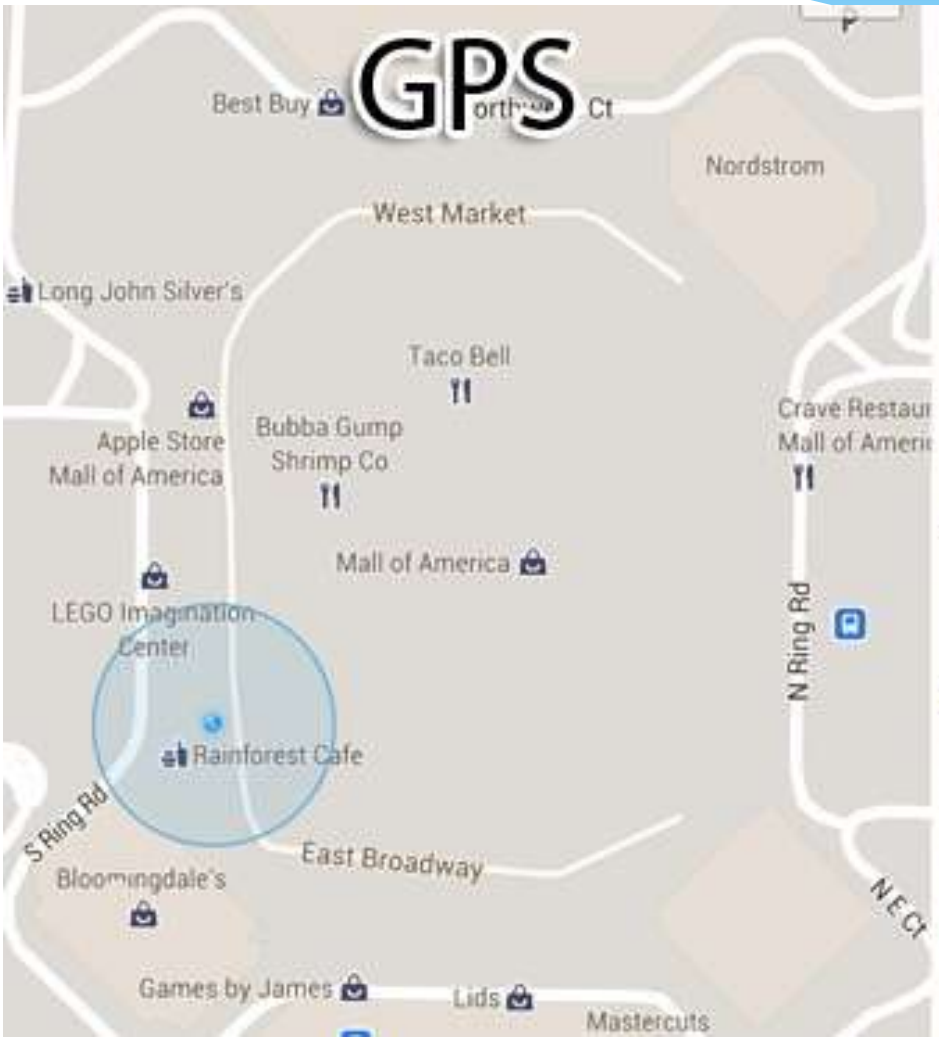
Accuracy of various models

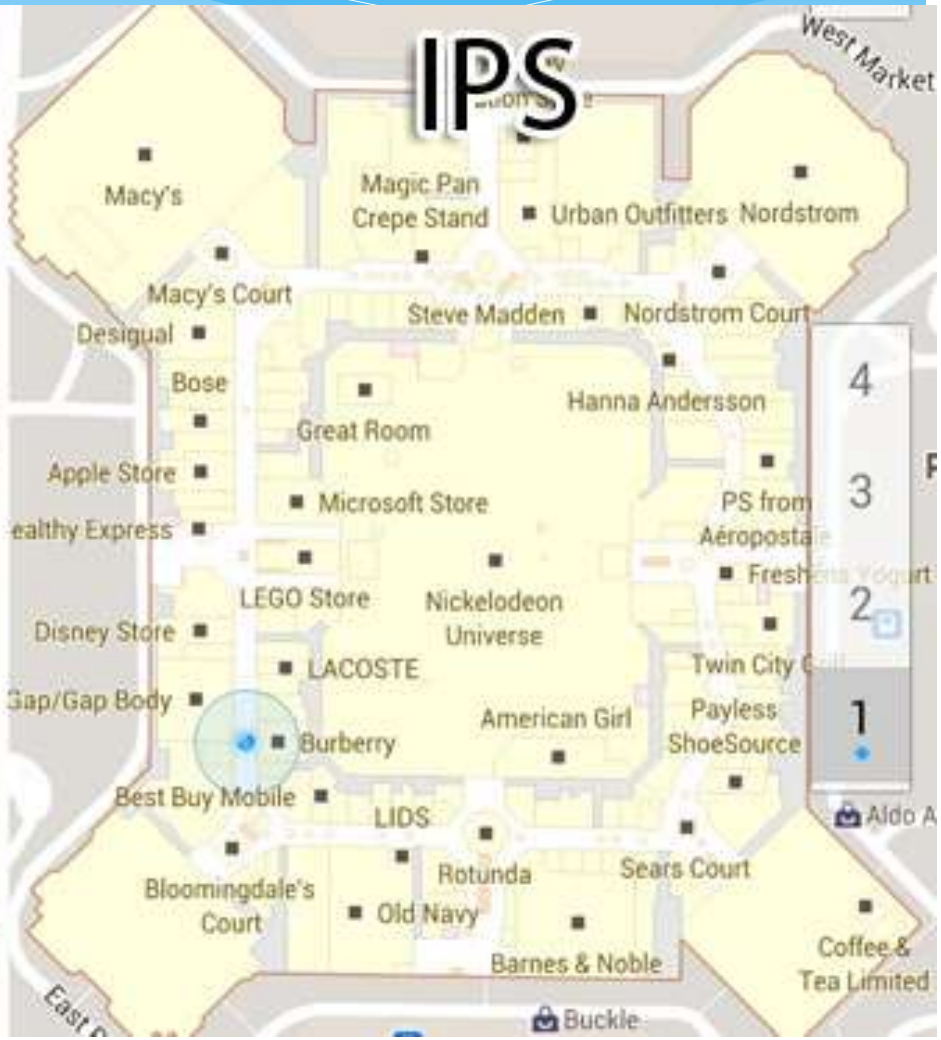
Model	ADE	Min Distance Error	Max Distance Error
Linear Model	4.378	0.103	11.361
Polynomial Model	4.148	0.008	15.042
Exponential Model	4.270	0.107	12.999
Neural Network Model	0.582	0.005	5.376
Grid Model	0.572	0.003	2.624

Unit: Meter

Conclusion

- Indoor Positioning System offers comparable accuracy in the case of Neural Network and Grid approach
- Grid approach is slightly better in terms of average distance error than Neural Network.
- Results and model are case dependent but the approach is generic
- For each condition (configuration of access points) the model should be calibrated for accurate positioning.
- The range of the signal is about 1-6 dBm, that are quite stable and reliable.


GPS
Best Buy
Nordstrom
West Market
Long John Silver's
Taco Bell
Apple Store
Mall of America
Bubba Gump
Shrimp Co
Mall of America
LEGO Imagination
Center
Rainforest Cafe
N Ring Rd
S Ring Rd
East Broadway
Bloomingdale's
Games by James
Lids
Mastercuts


IPS
West Market
Macy's
Magic Pan
Crepe Stand
Urban Outfitters
Nordstrom
Macy's Court
Steve Madden
Nordstrom Court
Desigual
Bose
Great Room
Hanna Andersson
Apple Store
Microsoft Store
LEGO Store
Nickelodeon
Universe
Disney Store
LACOSTE
Gap/Gap Body
Burberry
American Girl
Payless
ShoeSource
Best Buy Mobile
LIDS
Rotunda
Sears Court
Bloomingdale's
Court
Old Navy
Barnes & Noble
Coffee &
Tea Limited
Buckle
4
3
2
1

HyPos Needs & Objectives

Hybrid positioning systems (HyPos) are systems for finding the location of a mobile device using several different positioning technologies

Demonstrate the result of extensive field study of the performance of HyPos and IPS in terms of accuracy and precision.

SkyHook - famous commercial HPS used in America and Canada.

Skyhook has developed a hybrid positioning system called (XPS) which is a software-only location.

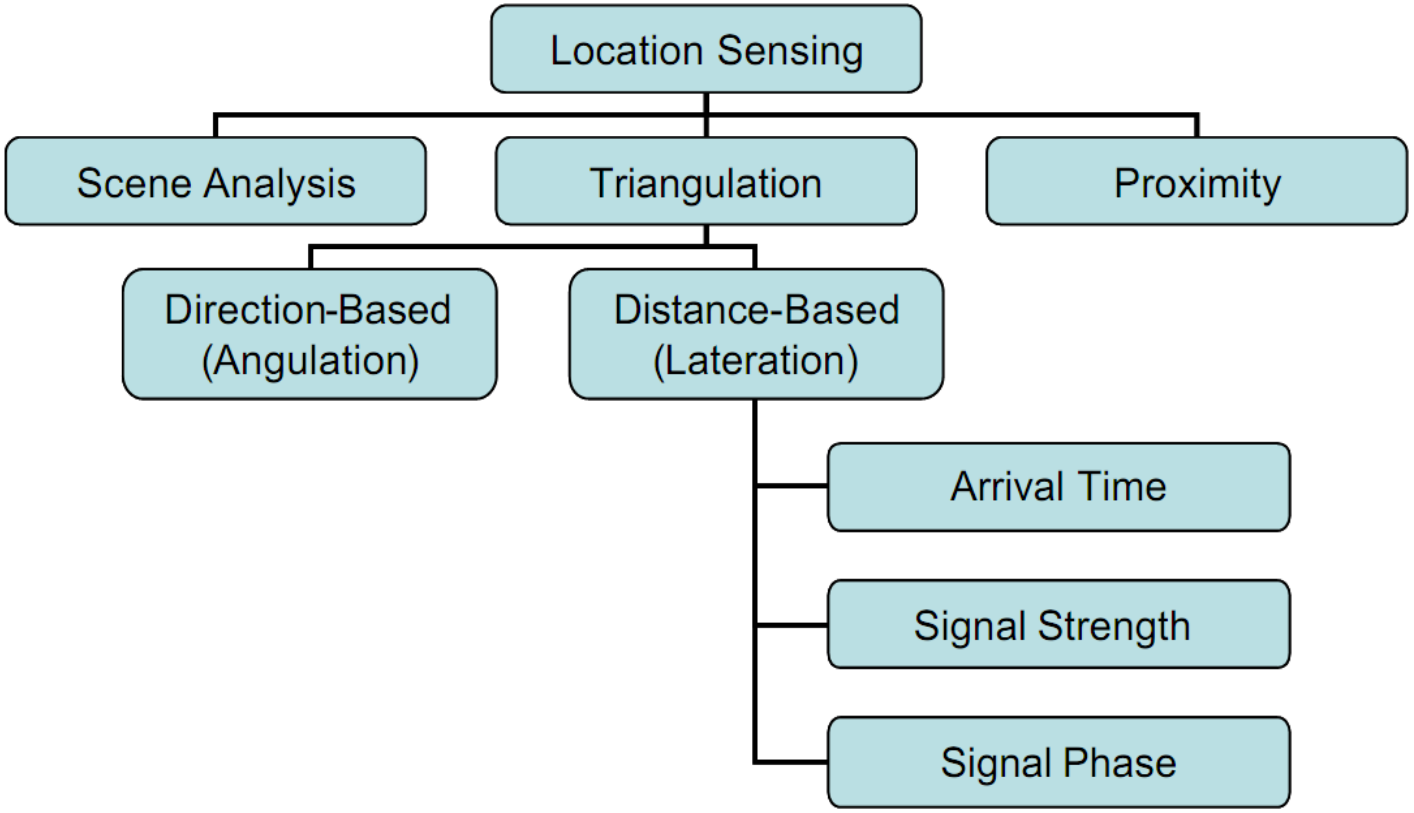
XPS allows determining position of any mobile device equipped with Wi-Fi, GPS or a cellular radio (GSM/CDMA).

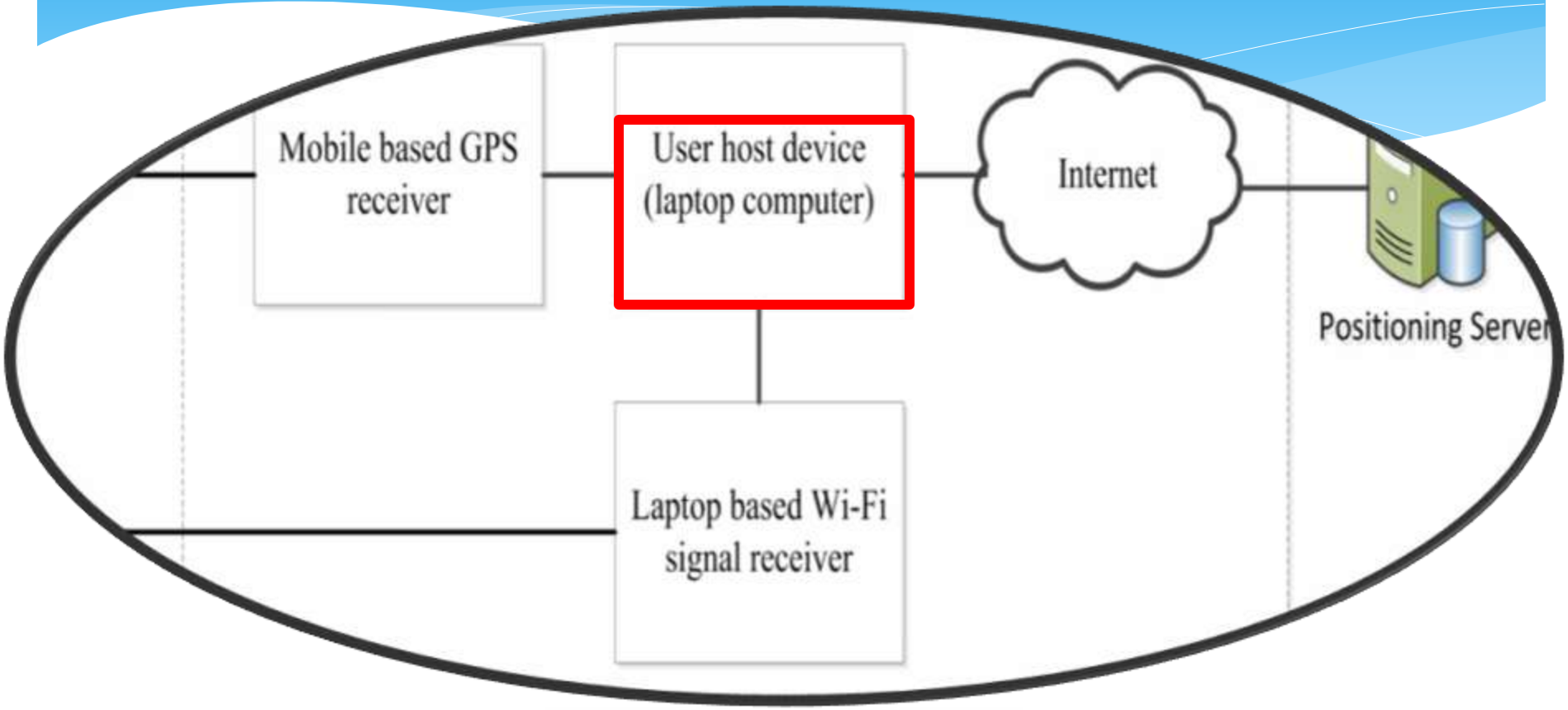
The accuracy of the system is between 10-100 meters.

Need for IPS using wLAN

Development of a Wi-Fi based IPS using cascading artificial neural network (CANN) for positioning in 3D environment and optimization of the system developed using genetic algorithm (GA)

Indoor Positioning System





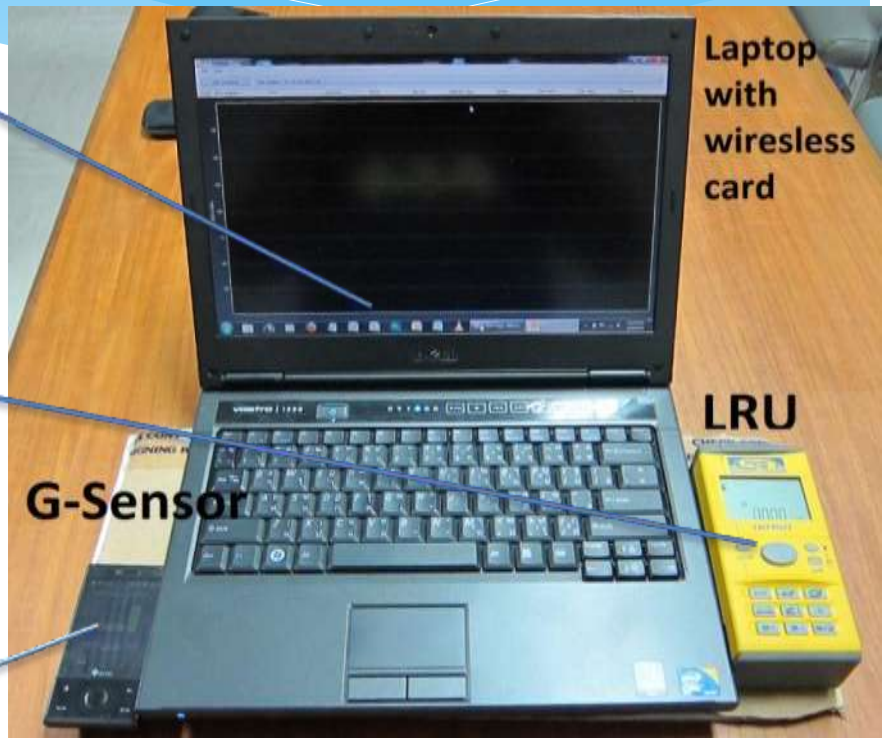
Hybrid Positioning System configuration

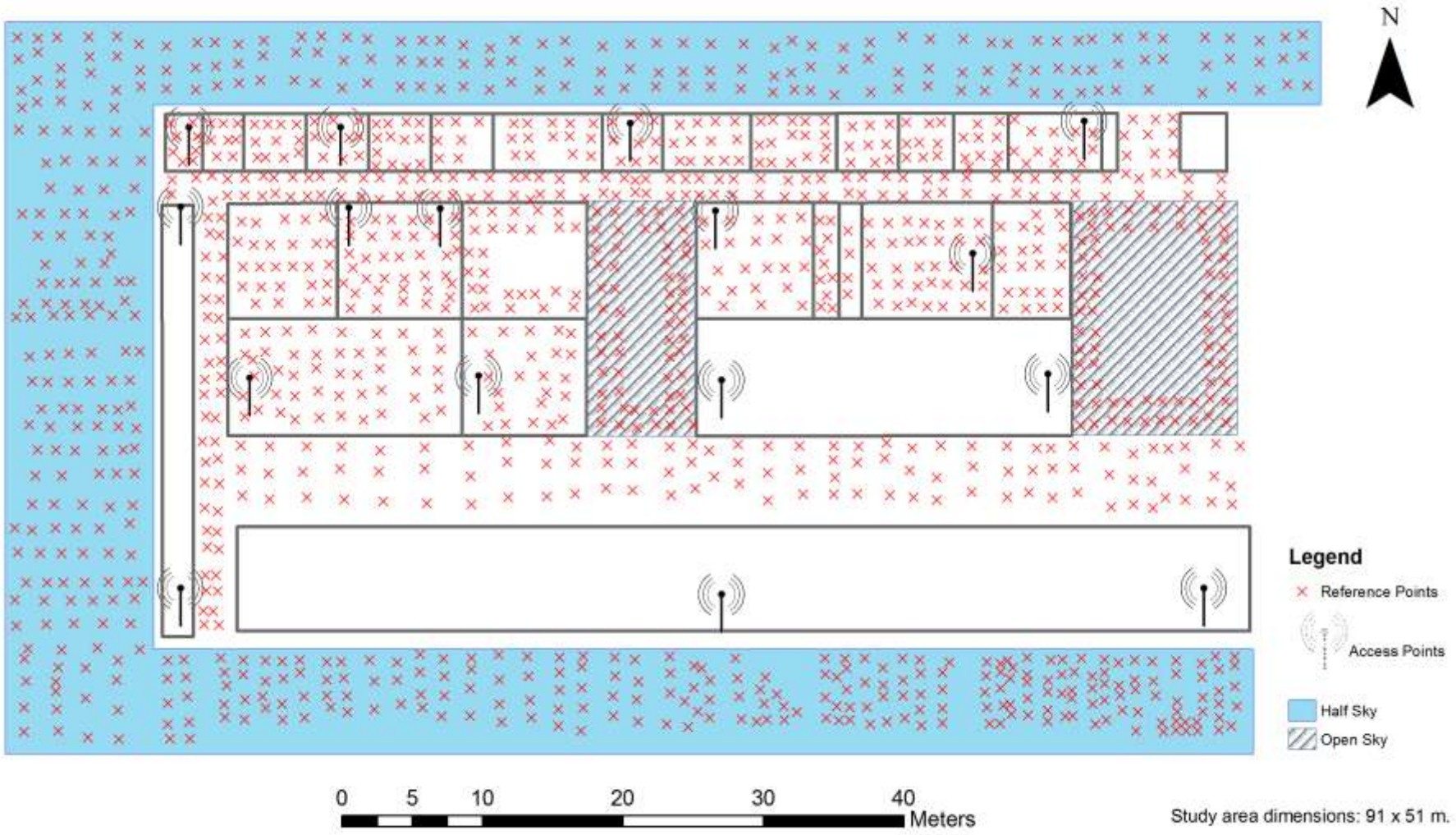
Data and Experiment Design

A laptop computer with Microsoft Windows 7, Intel i3 processor, 2GB RAM, 250 GB HDD, and equipped with a Dell Wireless WLAN DW1501 802.11 b/g/n, were used for measuring the RSSI and positioning

Trimble handheld ranging device with an accuracy of ± 2 mm was used to measure the distance between the current RP and the next RSSI measuring RP.

HTC diamond mobile p3700 equipped with an accelerometer was used to keep the apparatus level and a GPS receiver installed in the same device was used to measure the signal-to-noise ratio (SNR).





Experiment Area

Experiment Area

The experiment area consisted of a

Covered Area (CA) – 50%

Open Sky Area (OSA) – 8%

Half Sky Area (HSA) – 42%

Access Points (AP) – 15

Reference Points (RP) – 1331

Experiment Area (Covered Area)

Experiment Area (Half Sky Area)

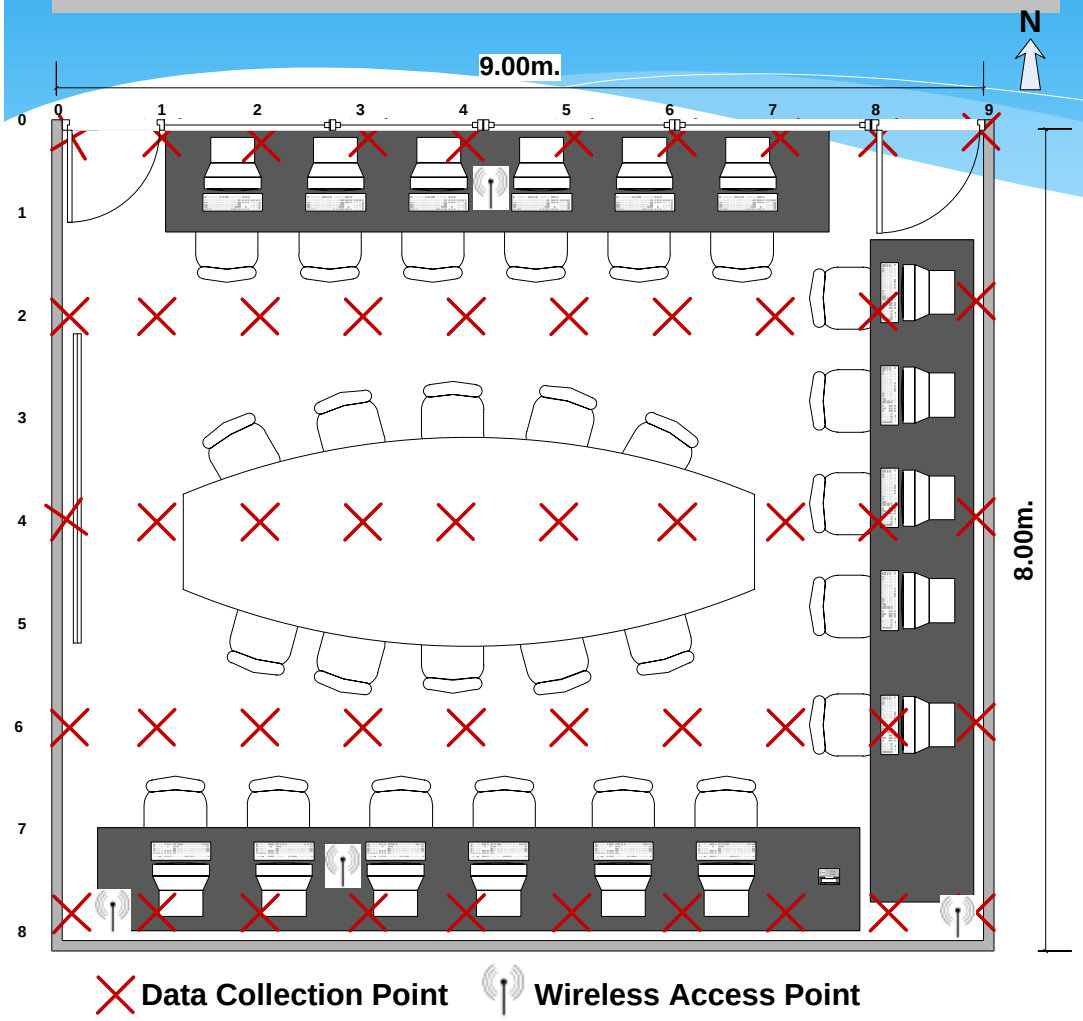
Experiment Area (Open Sky Area)

Hybrid Positioning System

Development of the hybrid positioning system (HyPos) was modeled upon client-server architecture. The HyPos consists of three modules:

* Indoor Positioning System (IPS)
* Forwarding Block (FB)
* Outdoor Positioning System (OPS)

Indoor Positioning System



Average distance error of

1.43 m

Experiment area 1

Methodology

Indoor Positioning System

2 outputs

412 RPS

102 Test points

X-axis mean error **4.35 m**

Y-axis mean error **3.03 m**

Mean Distance Error = 5.30

12 Inputs

2 outputs

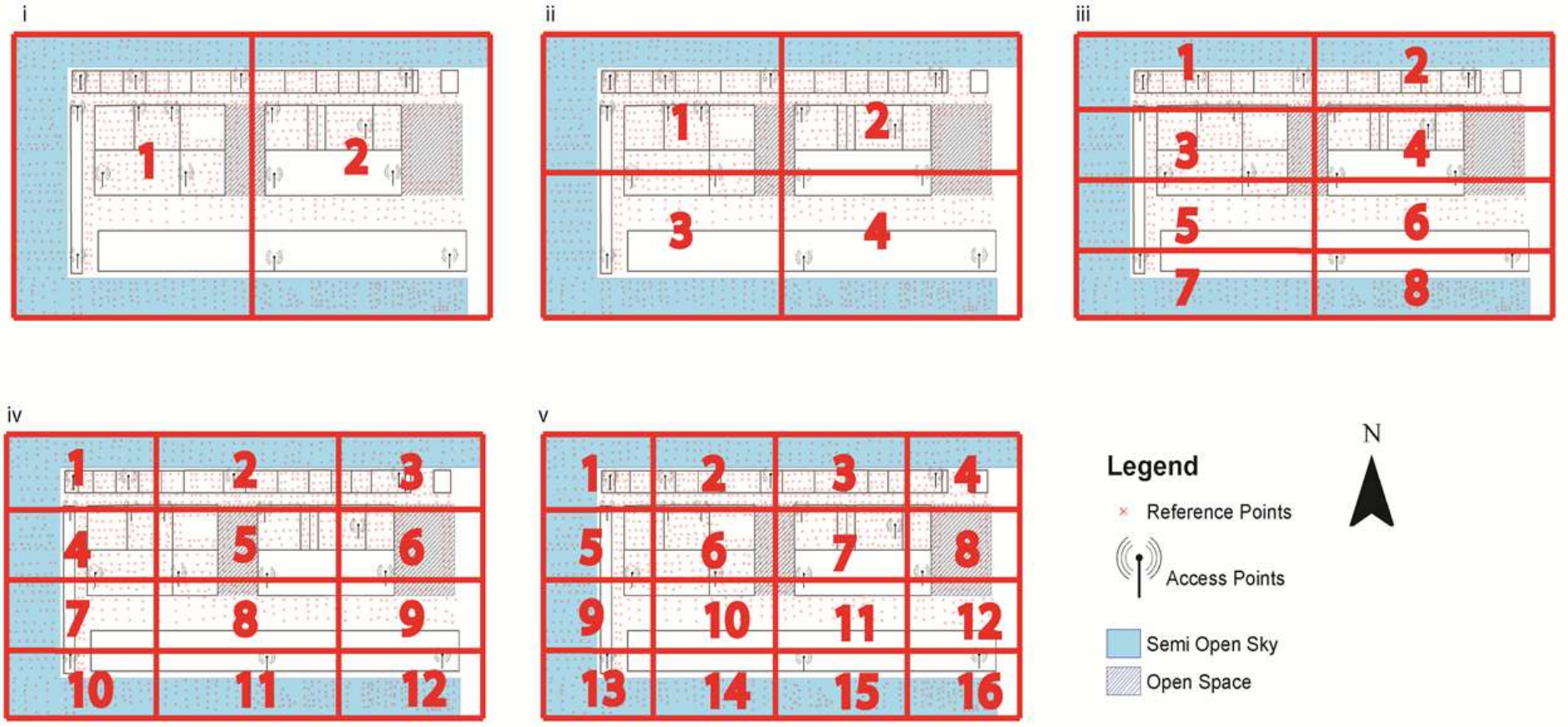
283 RPS

70 Test points

X-axis mean error **4.97 m**

Y-axis mean error **3.11 m**

Mean Distance Error = 5.86



Subsections patterns: (i) 1 × 2, (ii) 2 × 2, (iii) 4 × 2, (iv) 4 × 3, (v) 4 × 4

CA-ANN

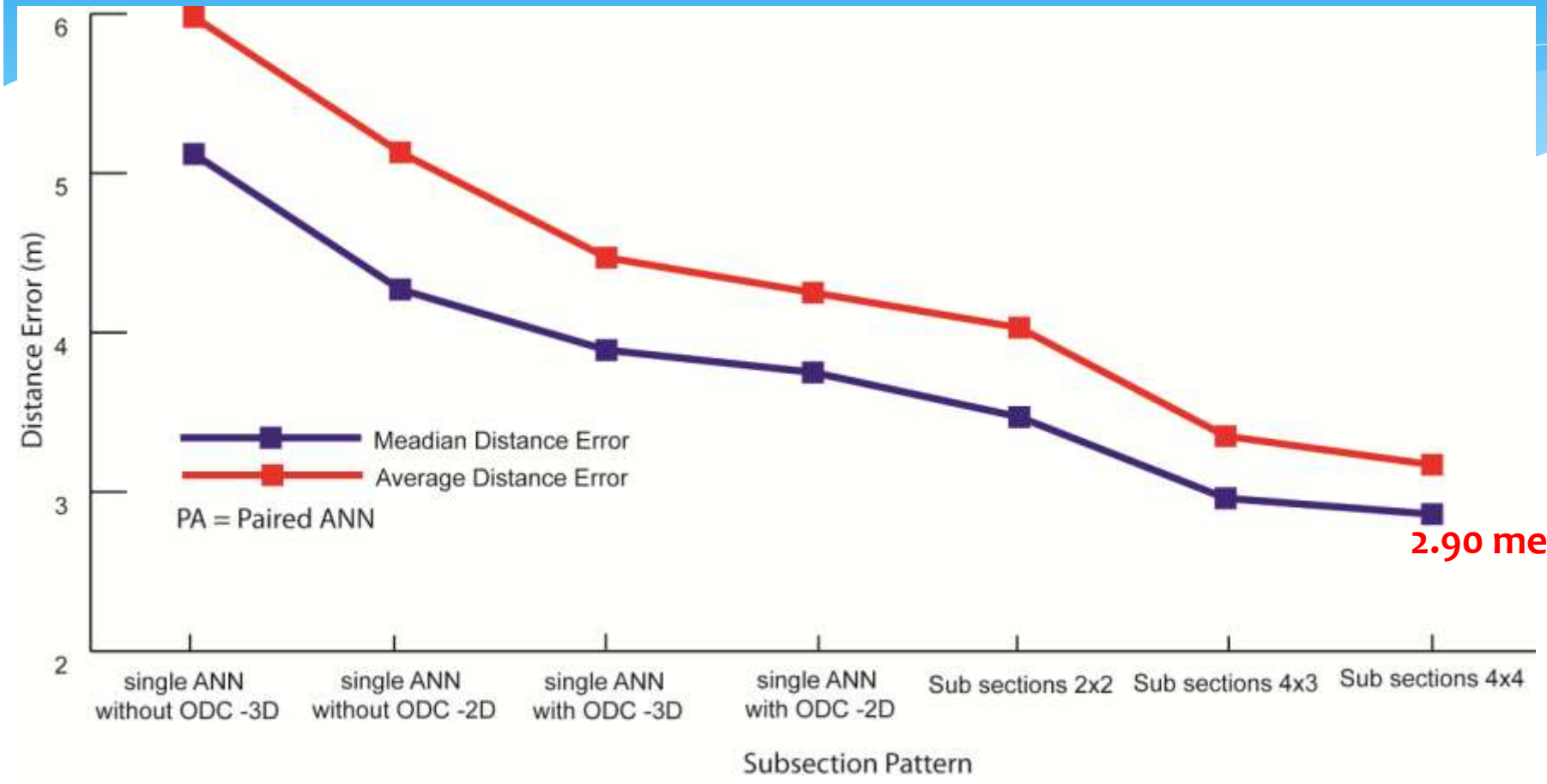
Indoor Positioning System

To select the sub-section from which the position request is originating a **cascading artificial neural network structure (CA-ANN)** was developed.

CA-ANN consists of two ANN called as

* ANN-1
* ANN-2

Indoor Positioning System



CA-ANN Accuracy Results

Outdoor Positioning System

The OPS consists of a GPS receiver that is installed in a handheld device

GPS gave accuracy within **2–5 m** in OSA and **2–7 m** in HSA.

HSA locations that have access to open sky showed a higher degree of accuracy than the location that was near the CA.

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GPS accuracy in HSA and OSA

Results and Analysis

Accuracy and Precision results for

* Single ANN
* Cascading ANN
* GA-optimized cascading ANN

Comparison of CA-ANN and GA-CA-ANN with other WLAN based IPS

Accuracy and Precision results for

* HyPos

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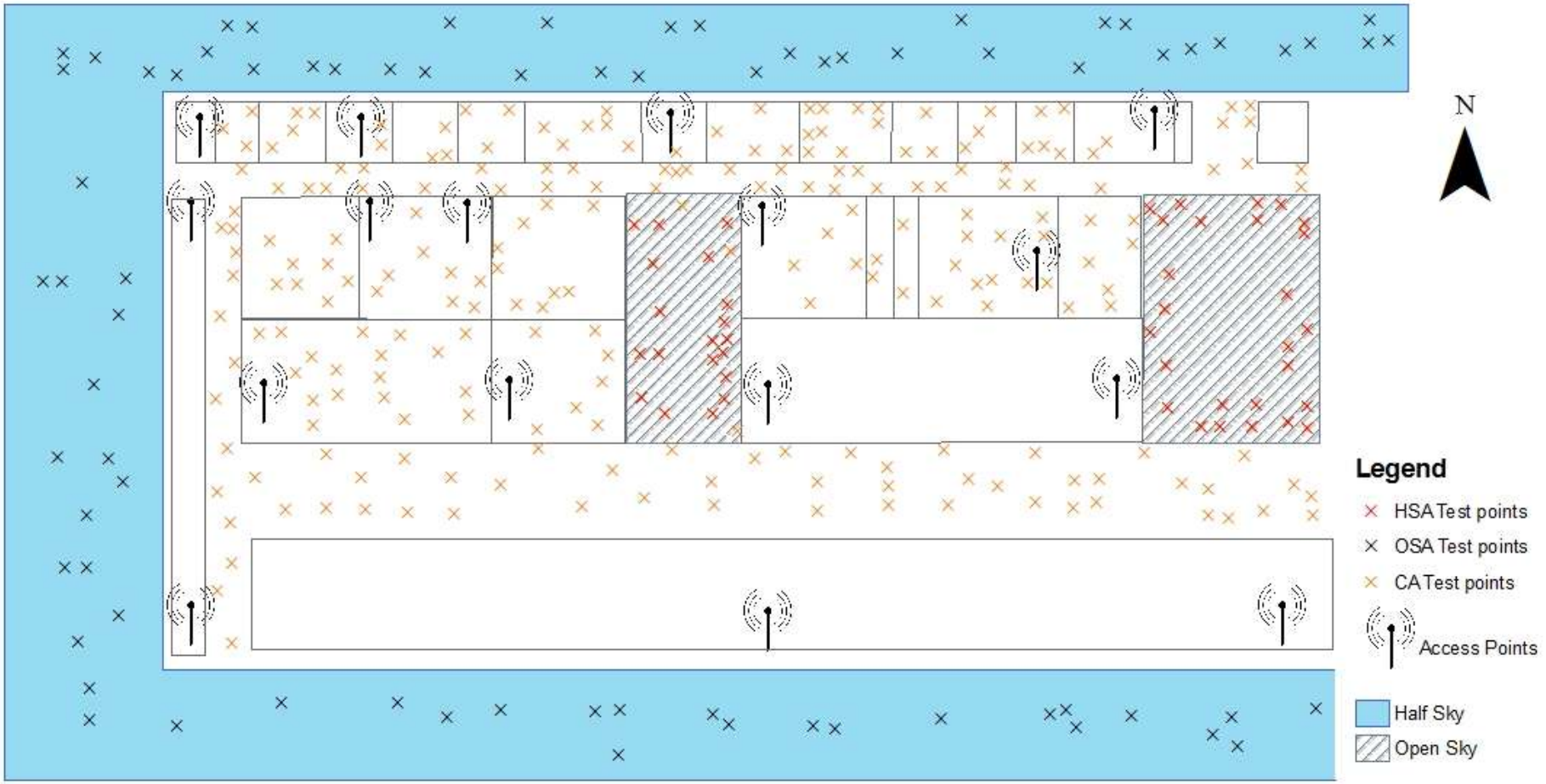
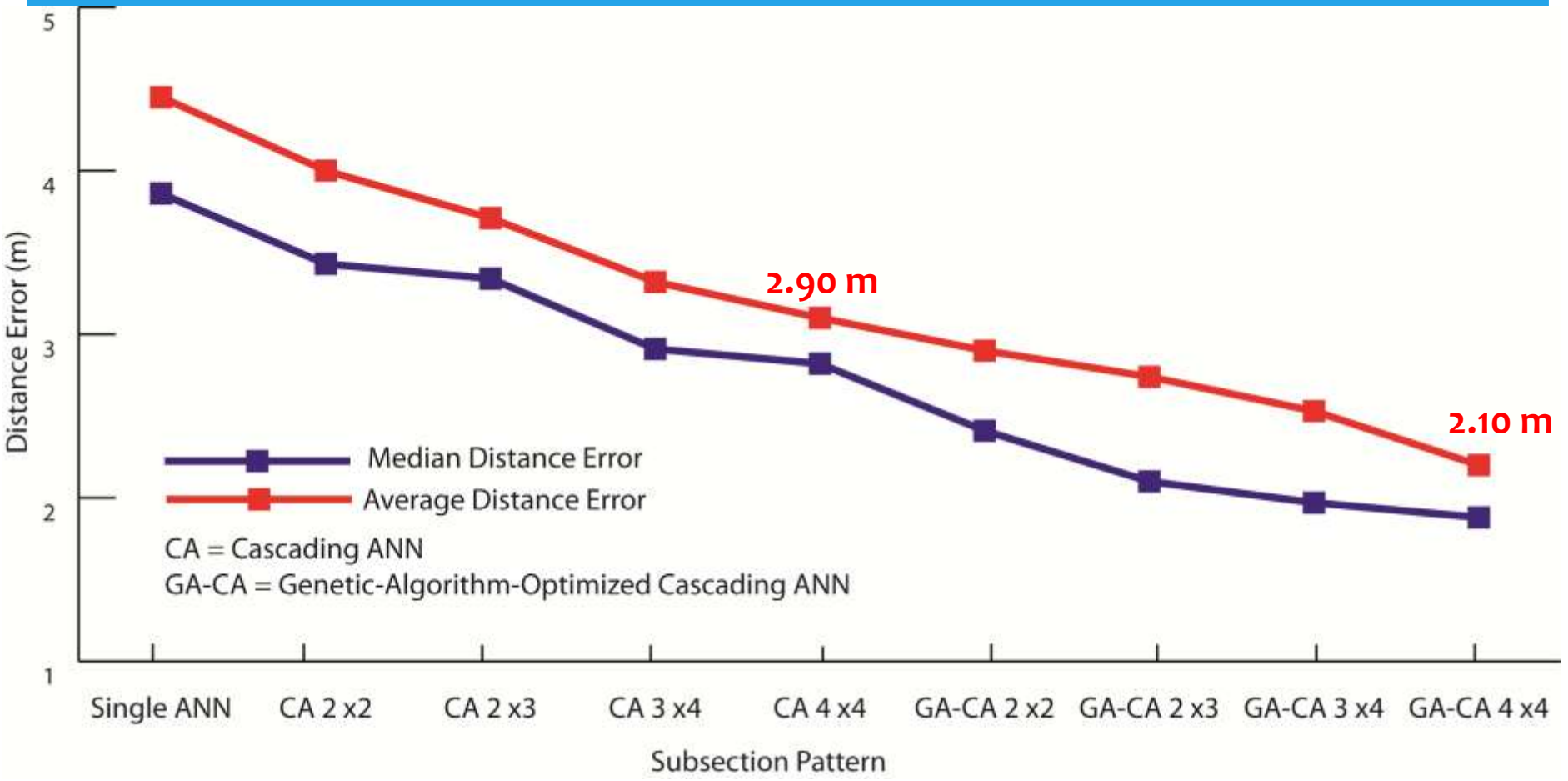
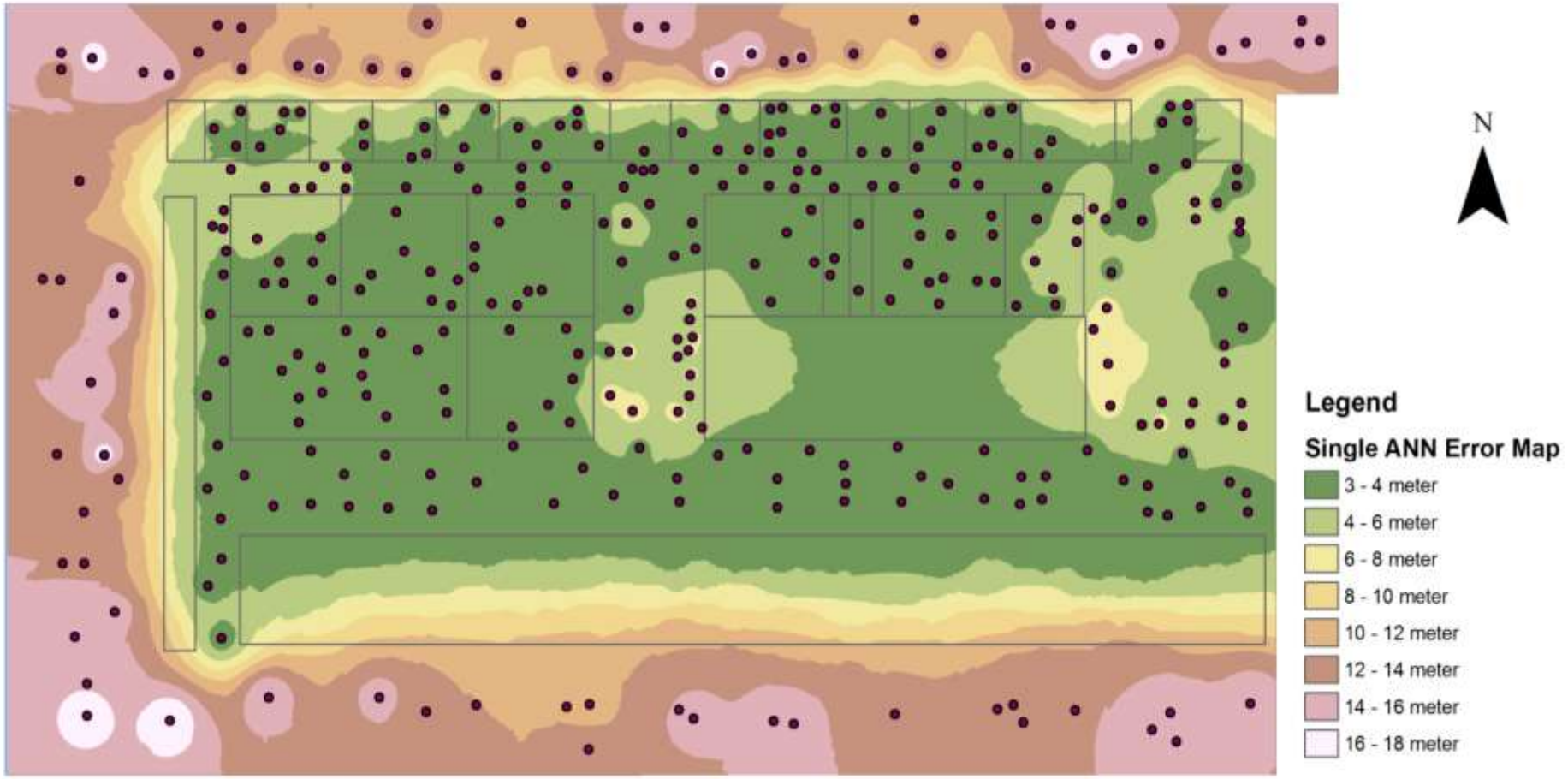


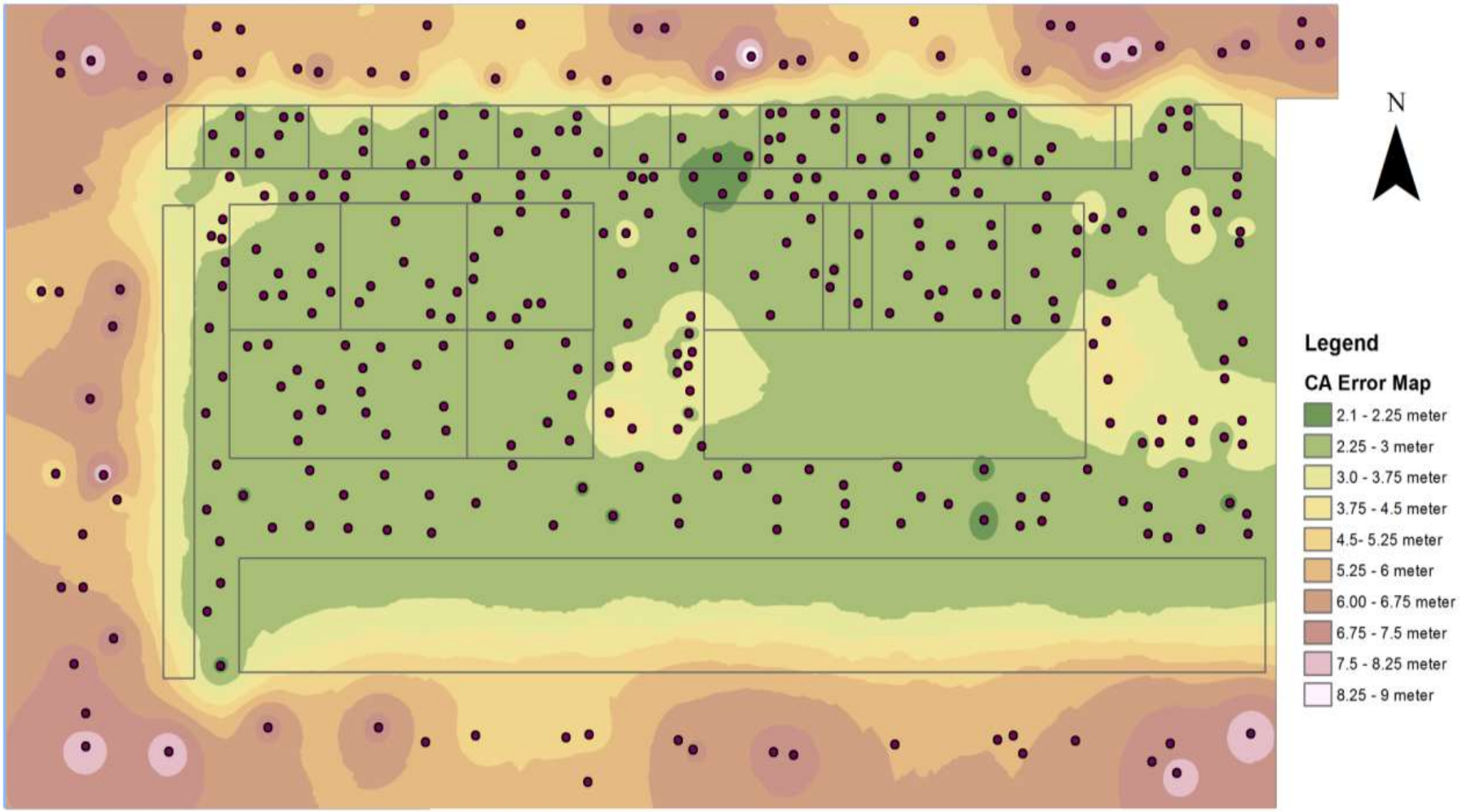
Test Point Distribution



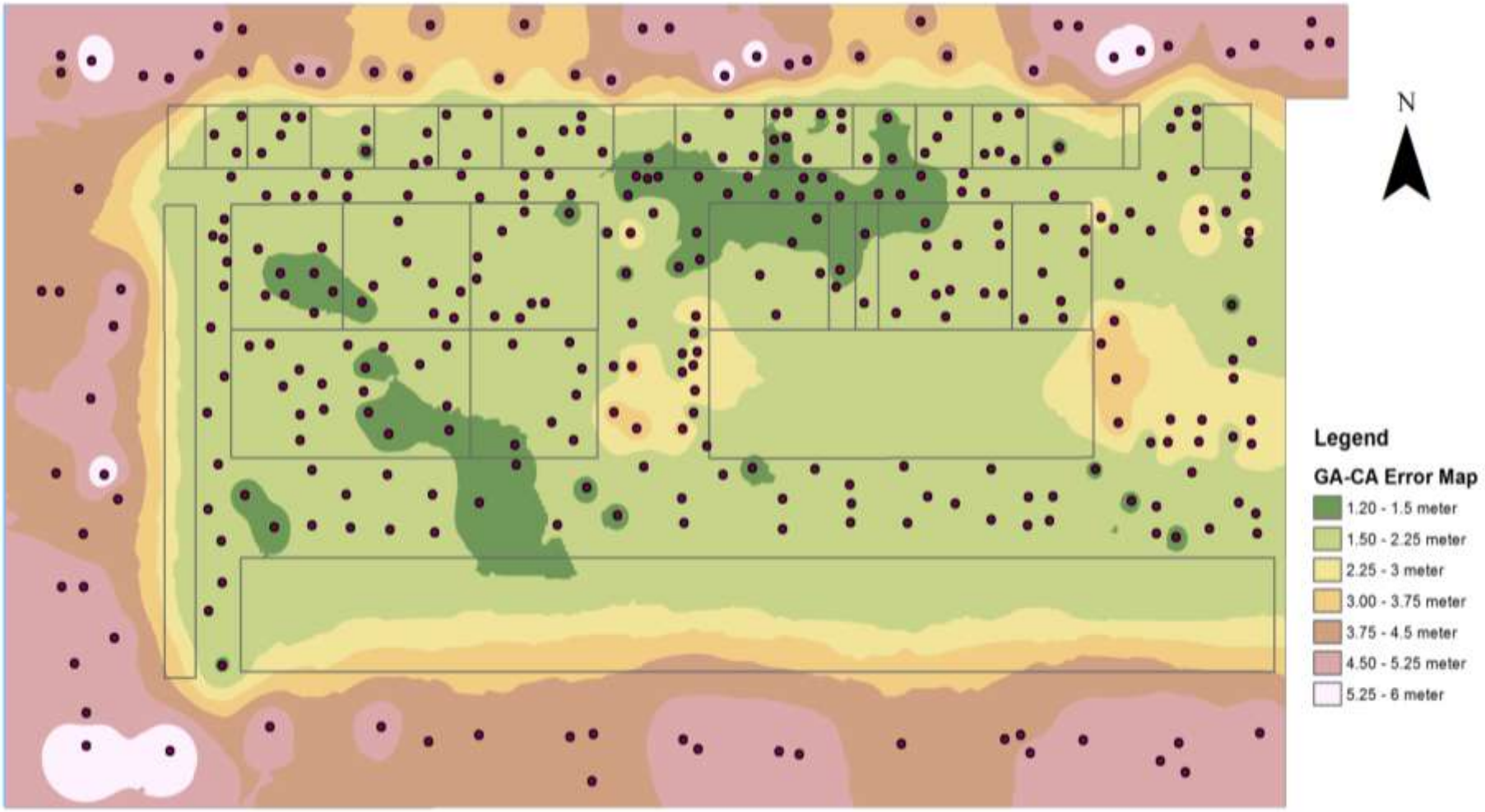
Comparison of accuracy: cascading ANN vs. GA-optimized cascading ANN for different numbers of subsections



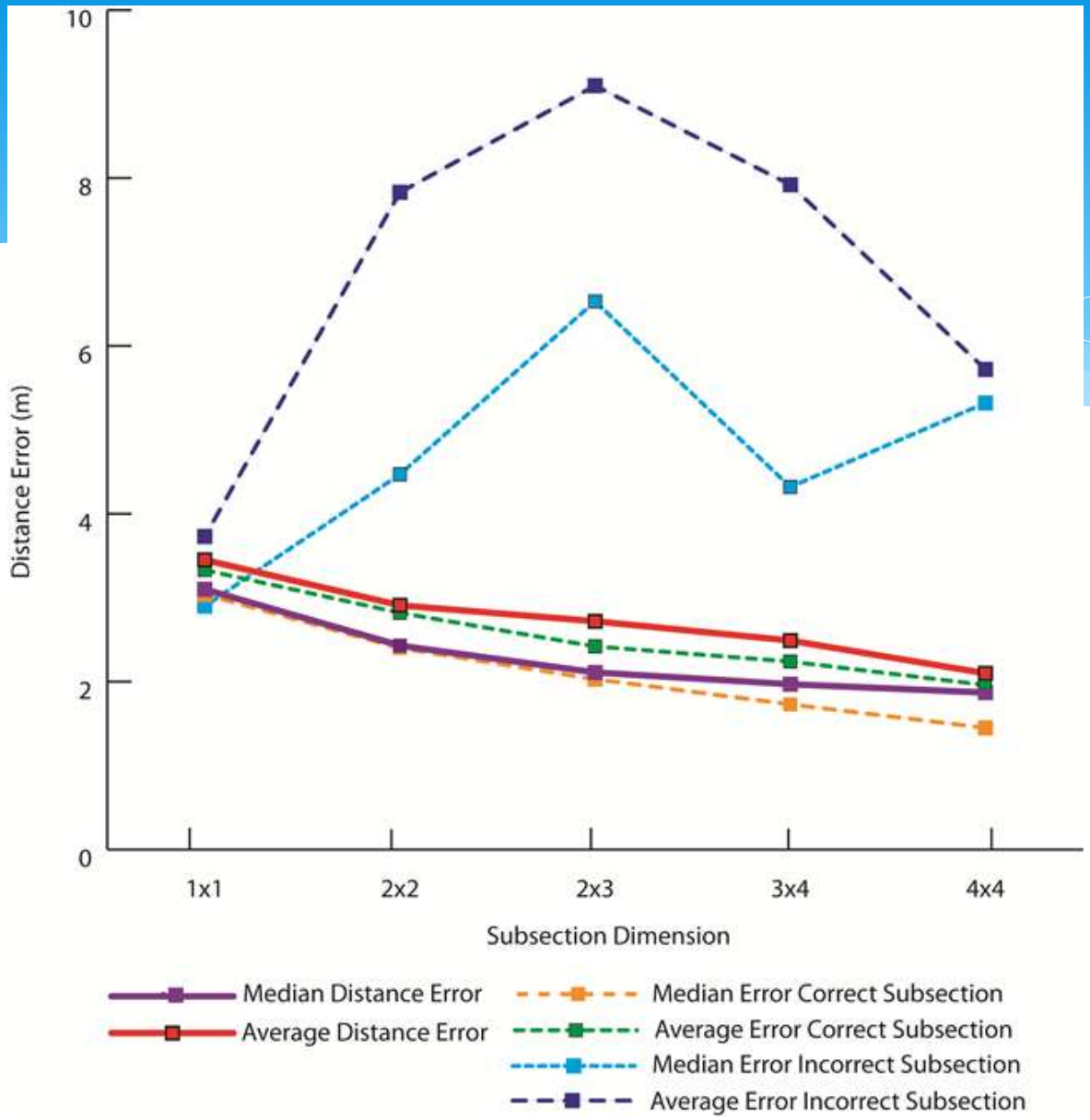
Error map for single ANN



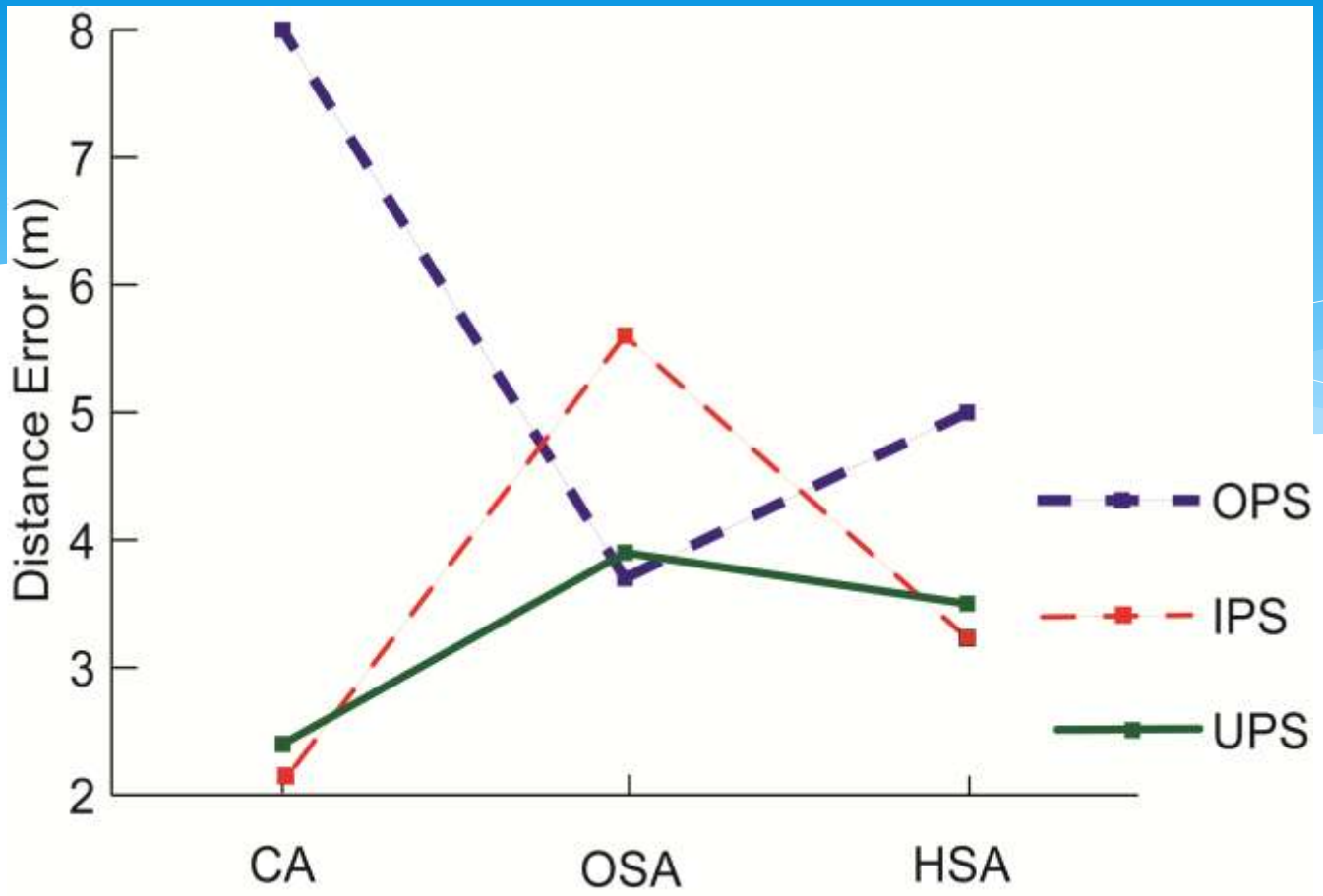
Error map for single cascading ANN with 16 subsections



Error map for GA-optimized cascading ANN with 16 sub sections



Accuracy analysis for GA-optimized cascading ANN for different numbers of subsections



Accuracy analysis for OPS, IPS, and HyPos in different environments

In **CA** IPS was activated **171** times and GPS was activated **6** times.

In **HSA**, IPS was activated **41** times and **GPS** was activated **26** times.

In **OSA**, GPS was activated **59** times and IPS was activated **7** times.

HyPos New Paradigm

Development of a novel Wi-Fi based IPS using cascading artificial neural network (CANN) for positioning in 3D environment and optimization of the system developed using genetic algorithm (GA)

Hybrid Positioning Systems

will lead to

precise location everywhere & finally cruise in the era of robotic world

Thank you