Technical and Practical Aspects for Locating and Tracking Mobile Users within a Wireless LAN

Prof. Joseph Kee-Yin NG

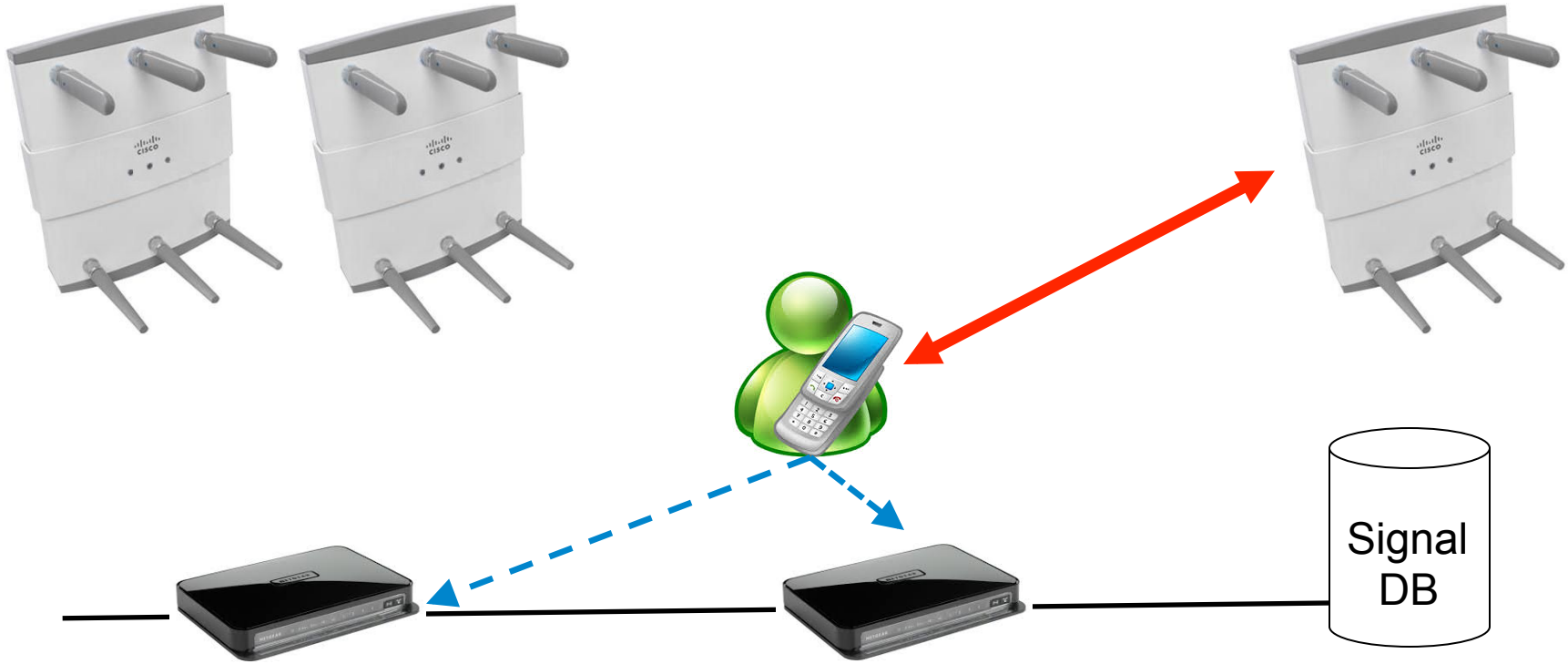
- Director, Research Centre for Ubiquitous Computing
- Professor, Department of Computer Science
- Programme Coordinator, CS Programme
- Hong Kong Baptist University

Outline

- Background about Localization
- Classical Approach on Localization
  - Radio Propagation + Triangulation / Trilateration
  - Fingerprinting
- Our Approach
- Technical & Practical Aspects
- DOPresence Project at DOP Center
- Demonstration
- Summary

Background about Localization

- Users – Users with wireless device (mobile phone)
- Off the shelf component – Routers as Sensors
- Router OS Platform – OpenWRT (Linux)
- WLAN – Separated and independent of the ISP network
- Signals – Received Signal Strength (phone → sensors)



Classical Approach on Localization (I)

- Radio Propagation Model – RSS → Distance
- Triangulation & Trilateration

The ITU indoor path loss model is formally expressed as:

$$L = 20 \log f + N \log d + P_f(n) - 28$$

where,

L = the total path loss. Unit: decibel (dB).

f = Frequency of transmission. Unit: megahertz(MHz).

d = Distance. Unit: metre (m).

N = The distance power loss coefficient.

n = Number of floors between the transmitter and receiver.

$P_f(n)$ = the floor loss penetration factor.

Classical Approach on Localization (I)

- Radio Propagation Model – RSS → Distance
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Log-distance path loss model is formally expressed as:

$$PL = P_{Tx_{dBm}} - P_{Rx_{dBm}} = PL_0 + 10\gamma \log_{10} \frac{d}{d_0} + X_g,$$

where

PL is the total path loss measured in Decibel (dB)

$P_{Tx_{dBm}} = 10 \log_{10} \frac{P_{Tx}}{1mW}$ is the transmitted power in dBm, where

P_{Tx} is the transmitted power in watt.

$P_{Rx_{dBm}} = 10 \log_{10} \frac{P_{Rx}}{1mW}$ is the received power in dBm, where

P_{Rx} is the received power in watt.

PL_0 is the path loss at the reference distance d_0. Unit: Decibel (dB)

d is the length of the path.

d_0 is the reference distance, usually 1 km (or 1 mile).

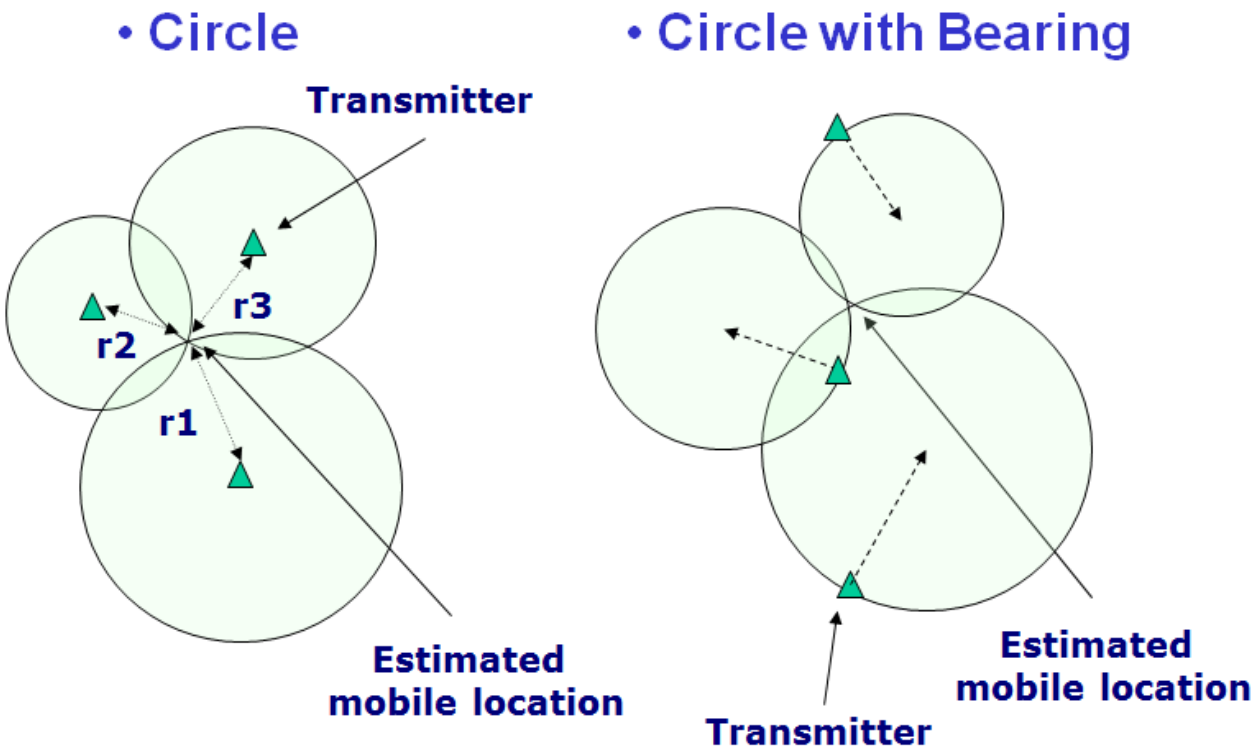
γ is the path loss exponent.

X_g is a normal (or Gaussian) random variable with zero mean, reflecting the attenuation (in decibel) caused by flat fading

Classical Approach on Localization (I)

- Radio Propagation Model – RSS → Distance
- Triangulation & Trilateration

Circular Trilateration & its Variations



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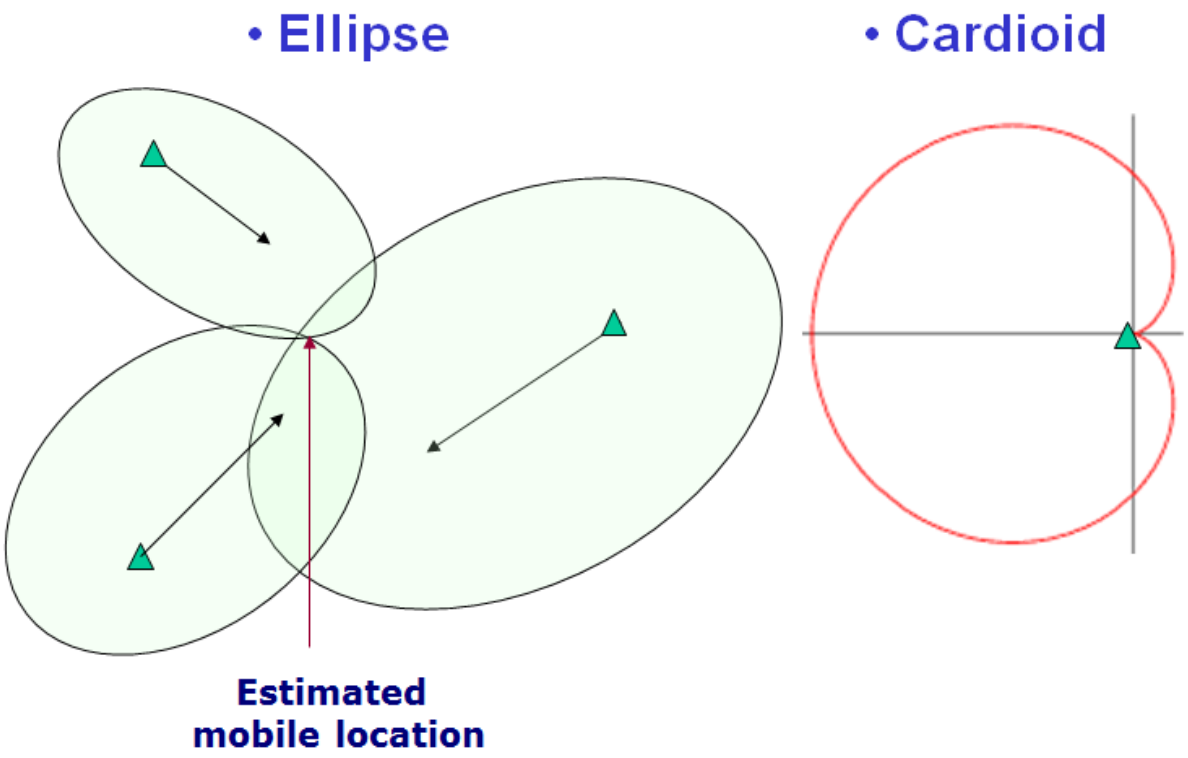
Circular Trilateration with Directional Models



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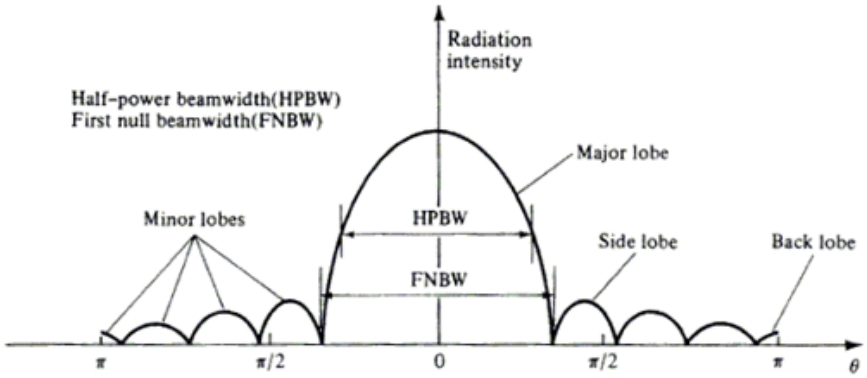
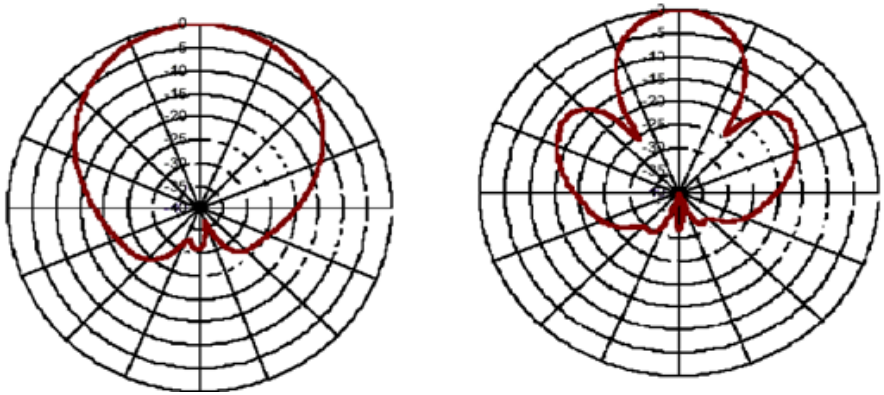
Directional Signal Propagation Model



Involve Directional Property of All Antenna Types



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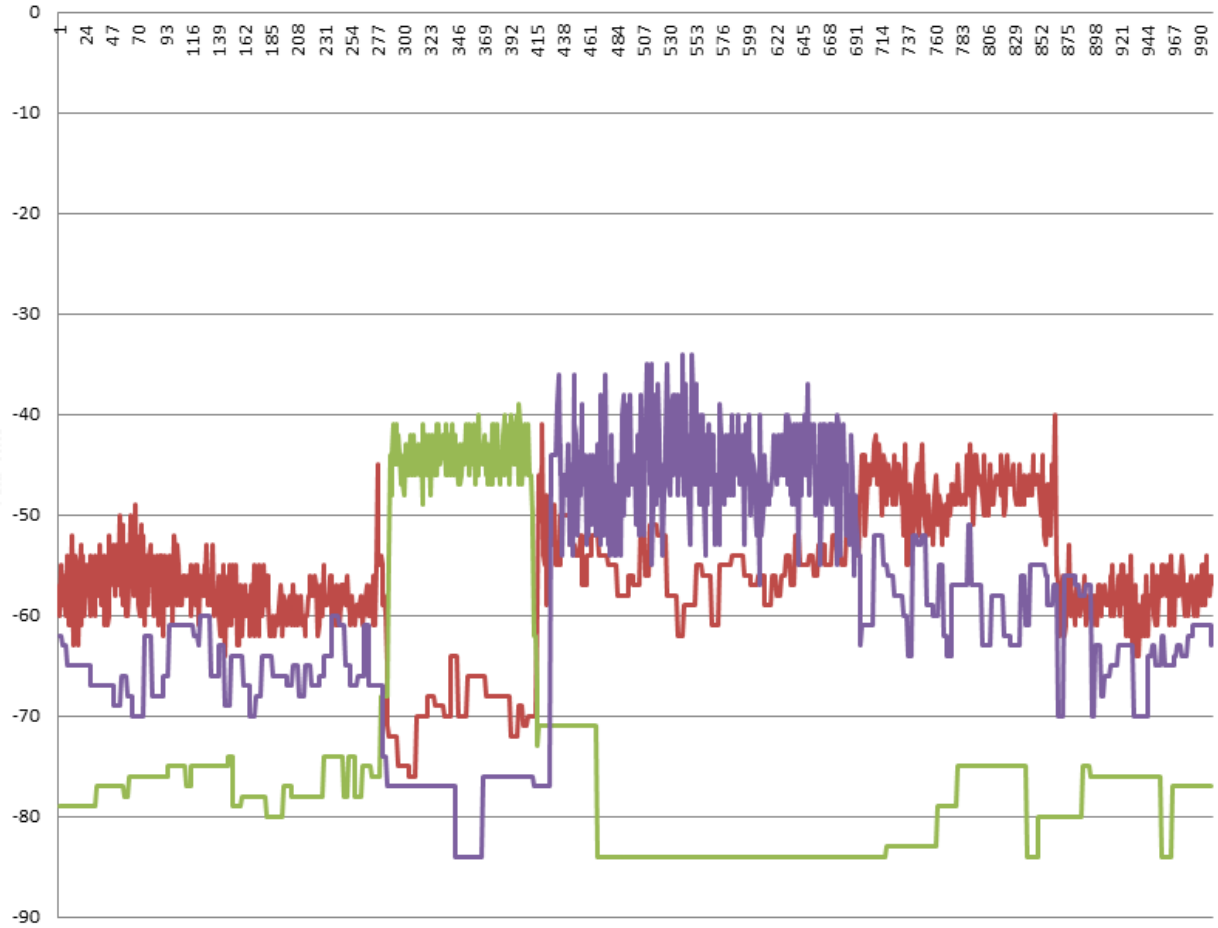
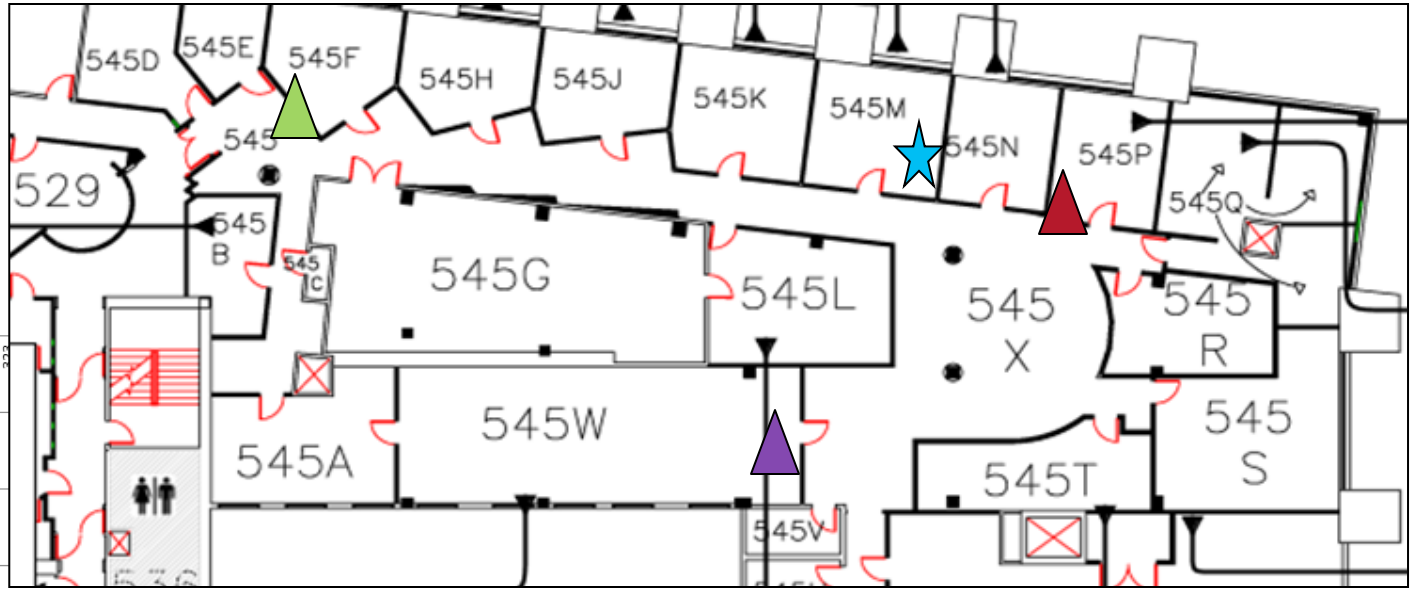
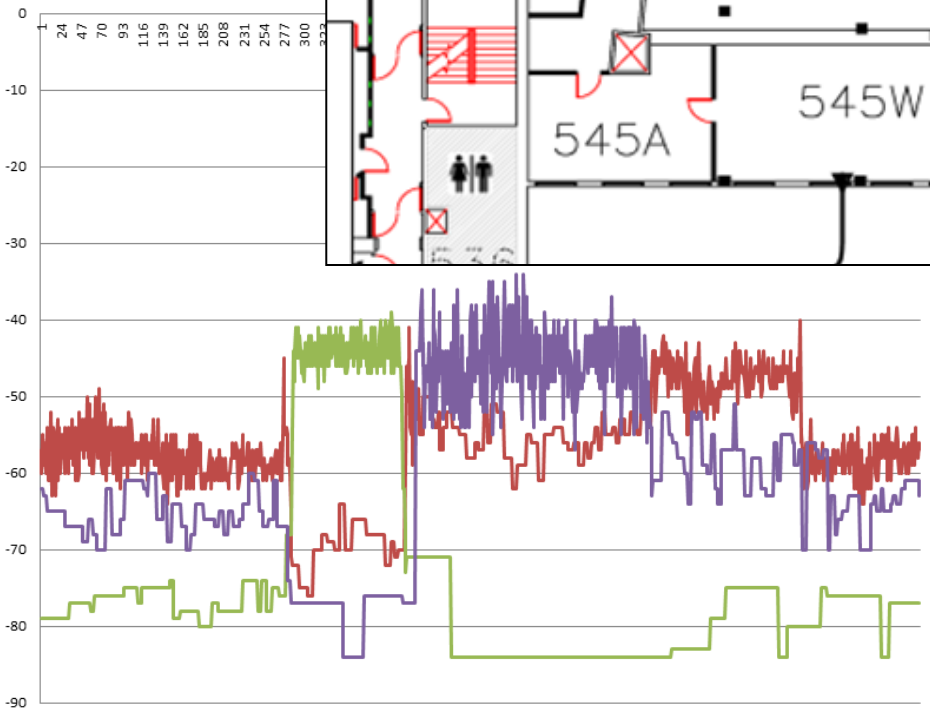


Classical Approach on Localization (II)

- Fingerprinting





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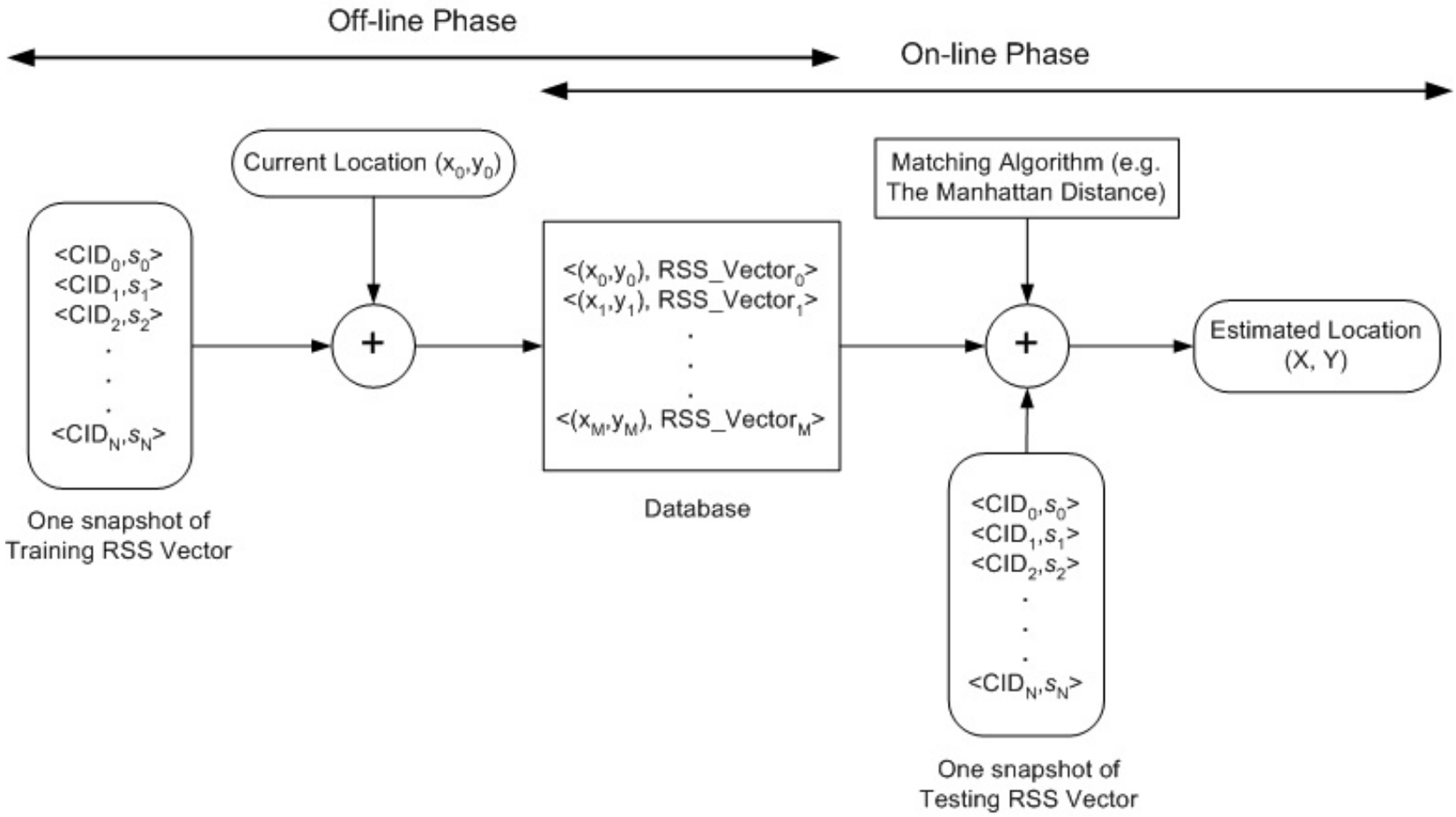
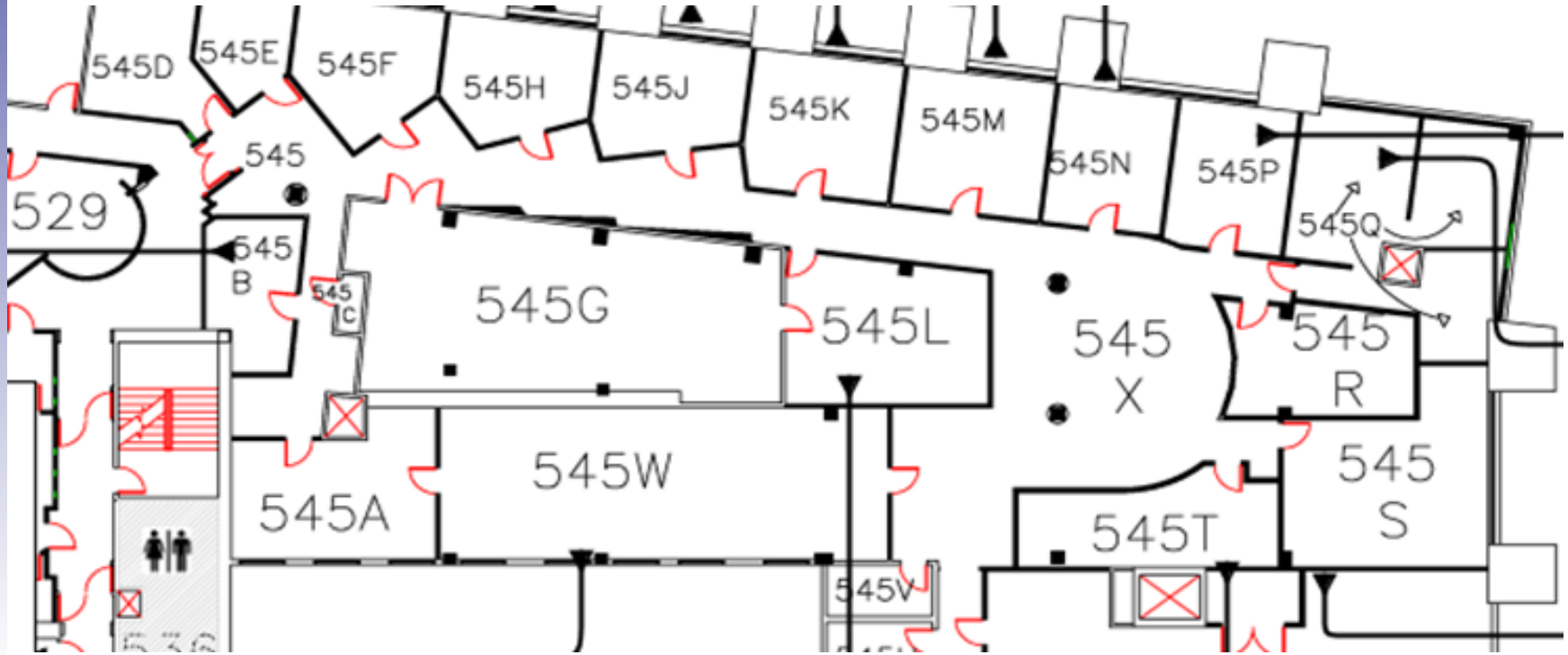


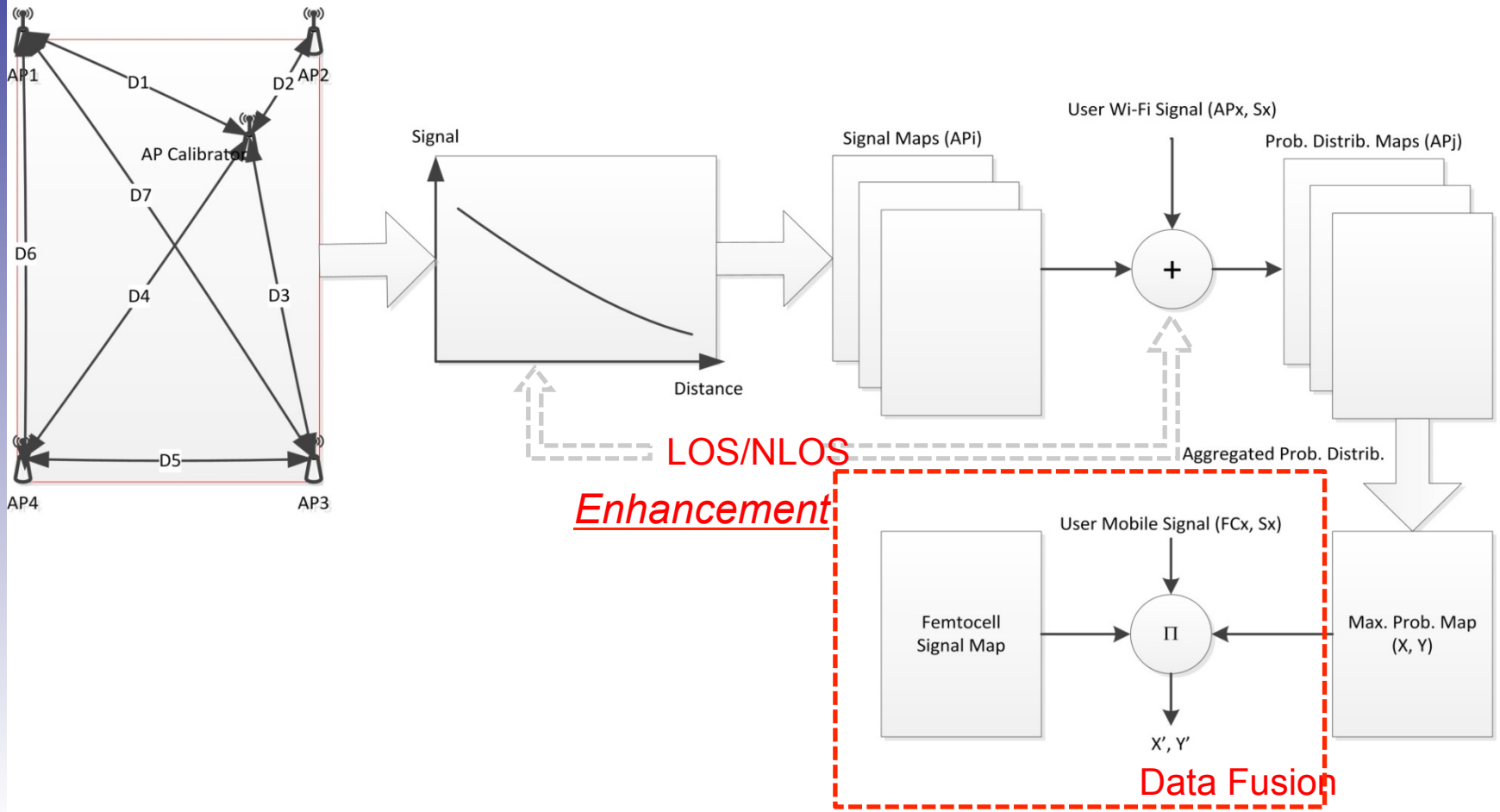
Classical Approach on Localization (II)

- Fingerprinting
  - Marker Positions / Grid size
  - What is stored in DB & Matching Algorithm
  - Setup & Maintenance Cost

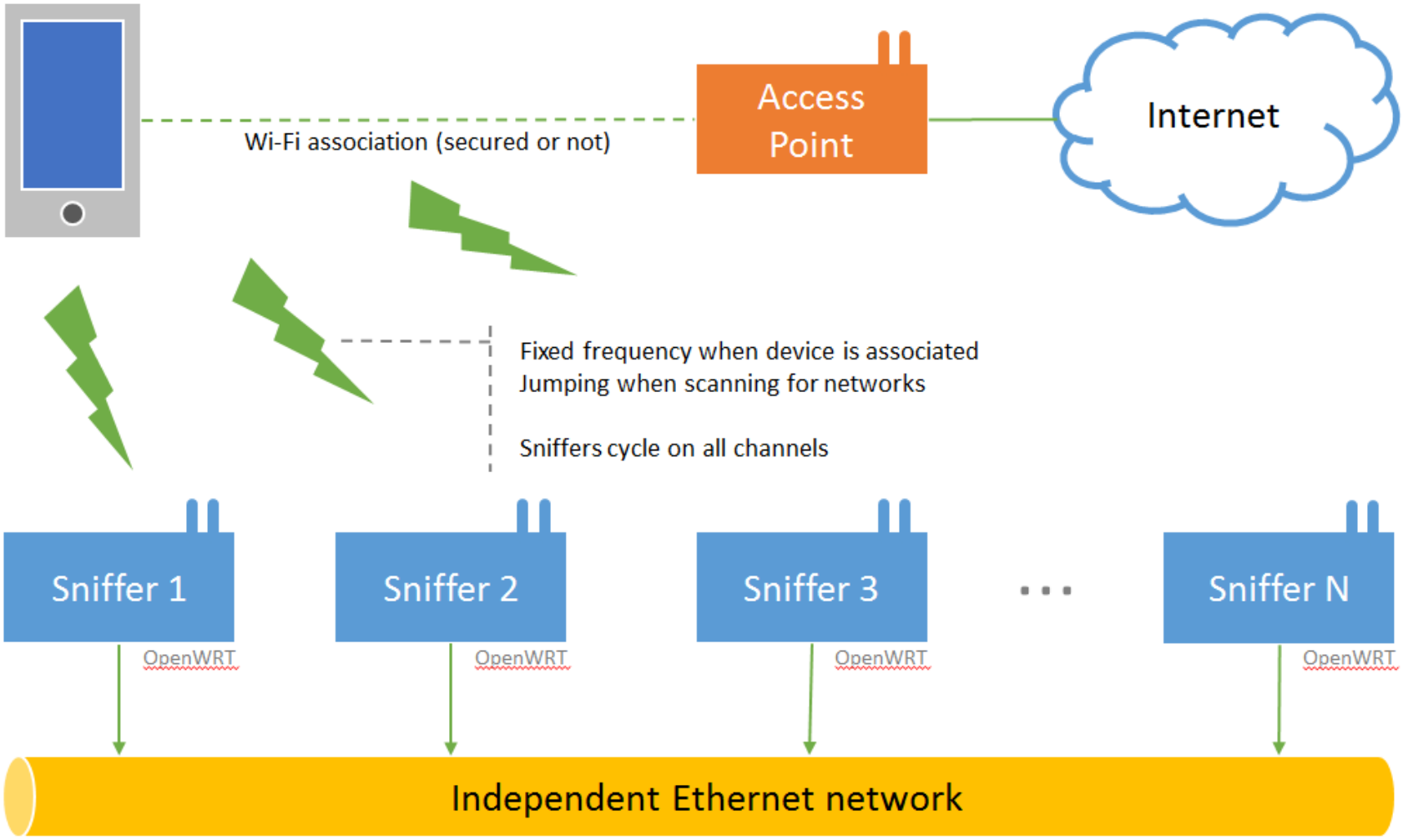


Our Approach on Localization

- Real-Time Calibration of Sensor Signal Maps & Max. Aggregated Probability with Dynamic Grid on users' presence
- Data Fusion with other LBS (e.g. Femtocell) & LOS/NLOS for enhancement



Our Approach on Localization - Architecture



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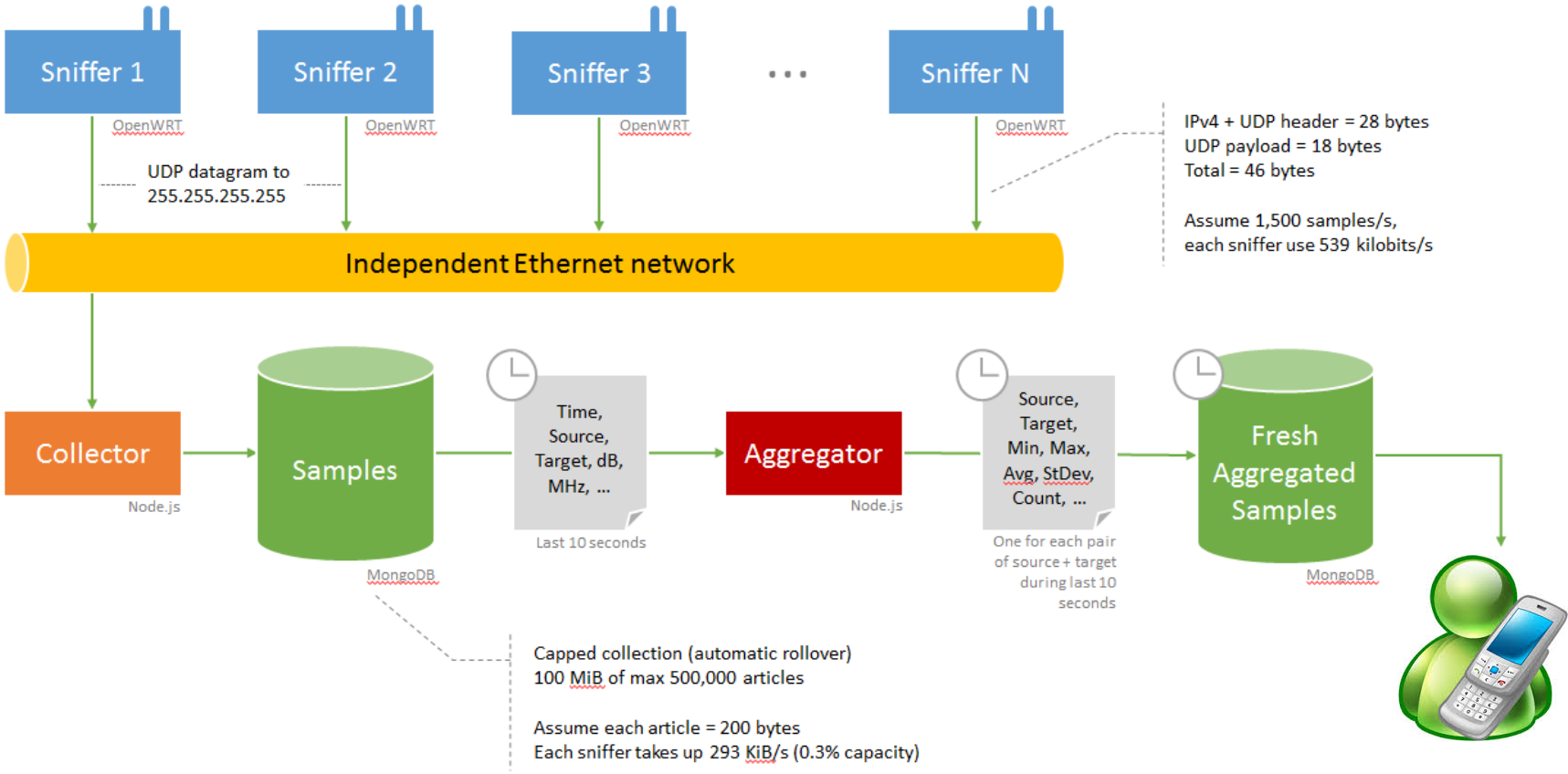

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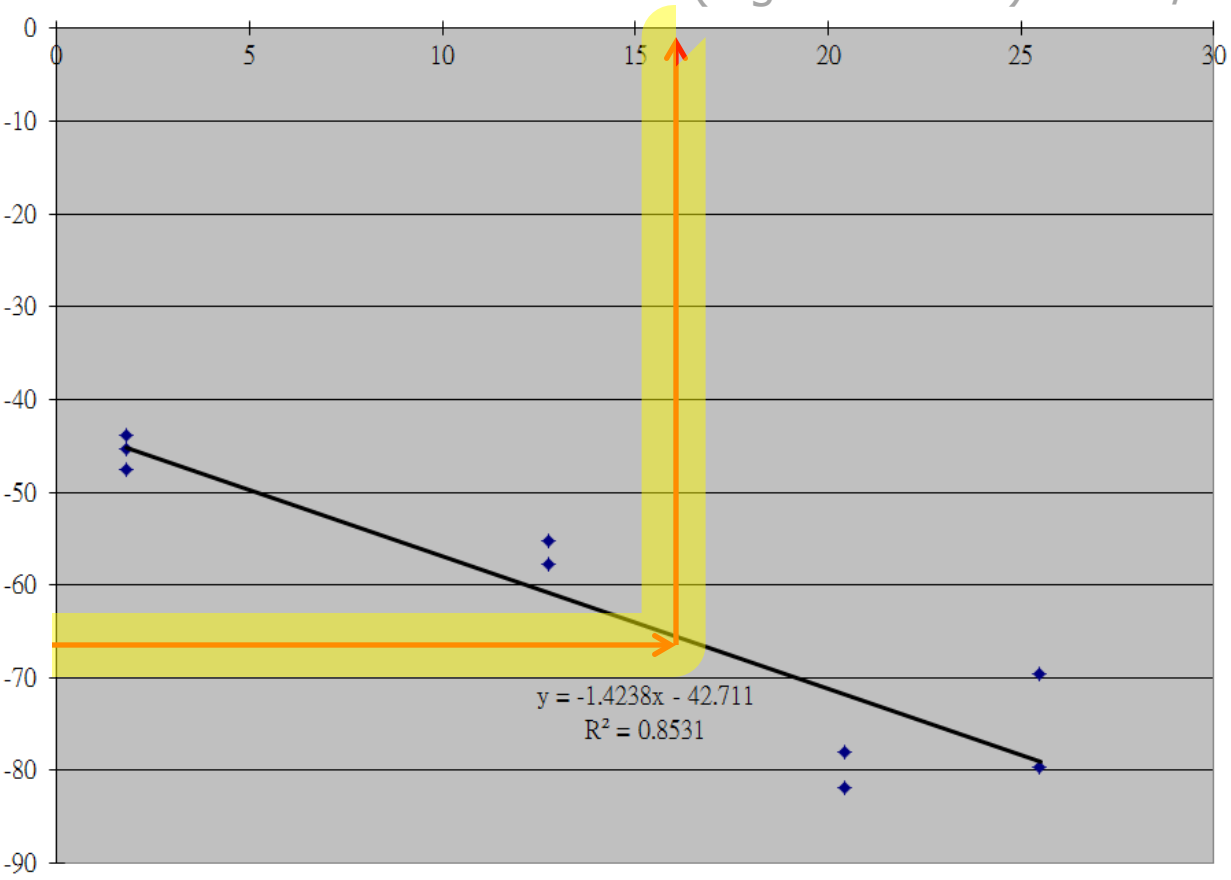

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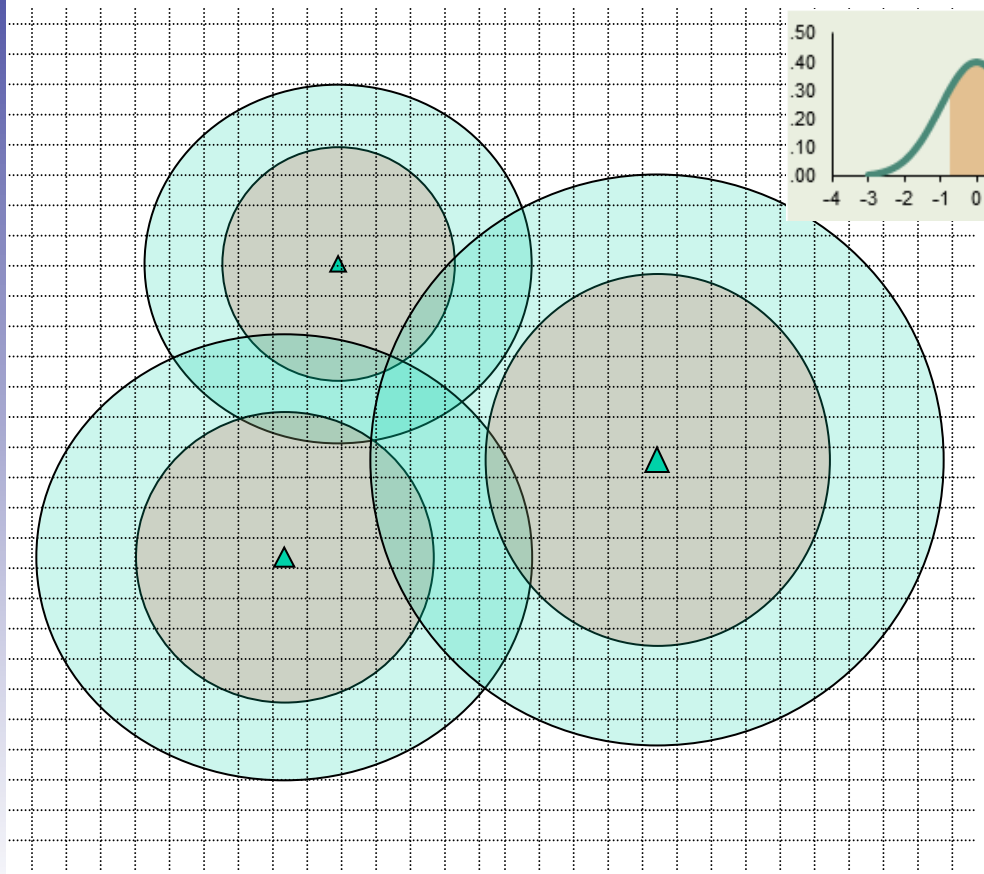

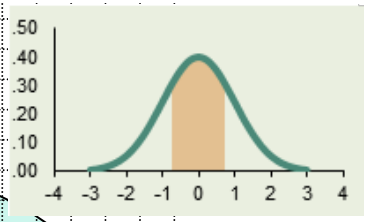

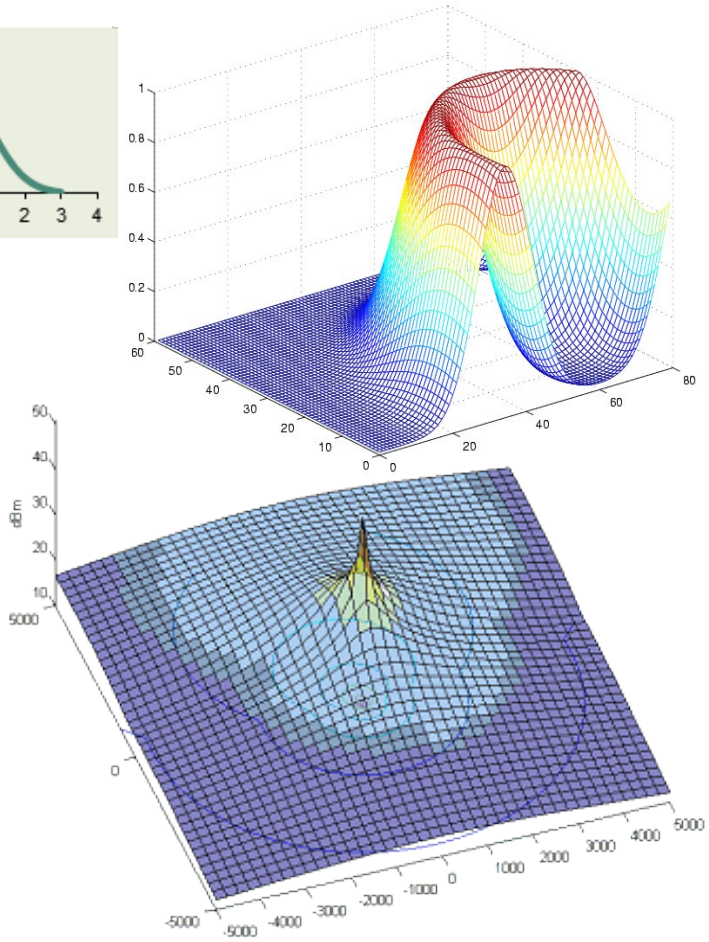

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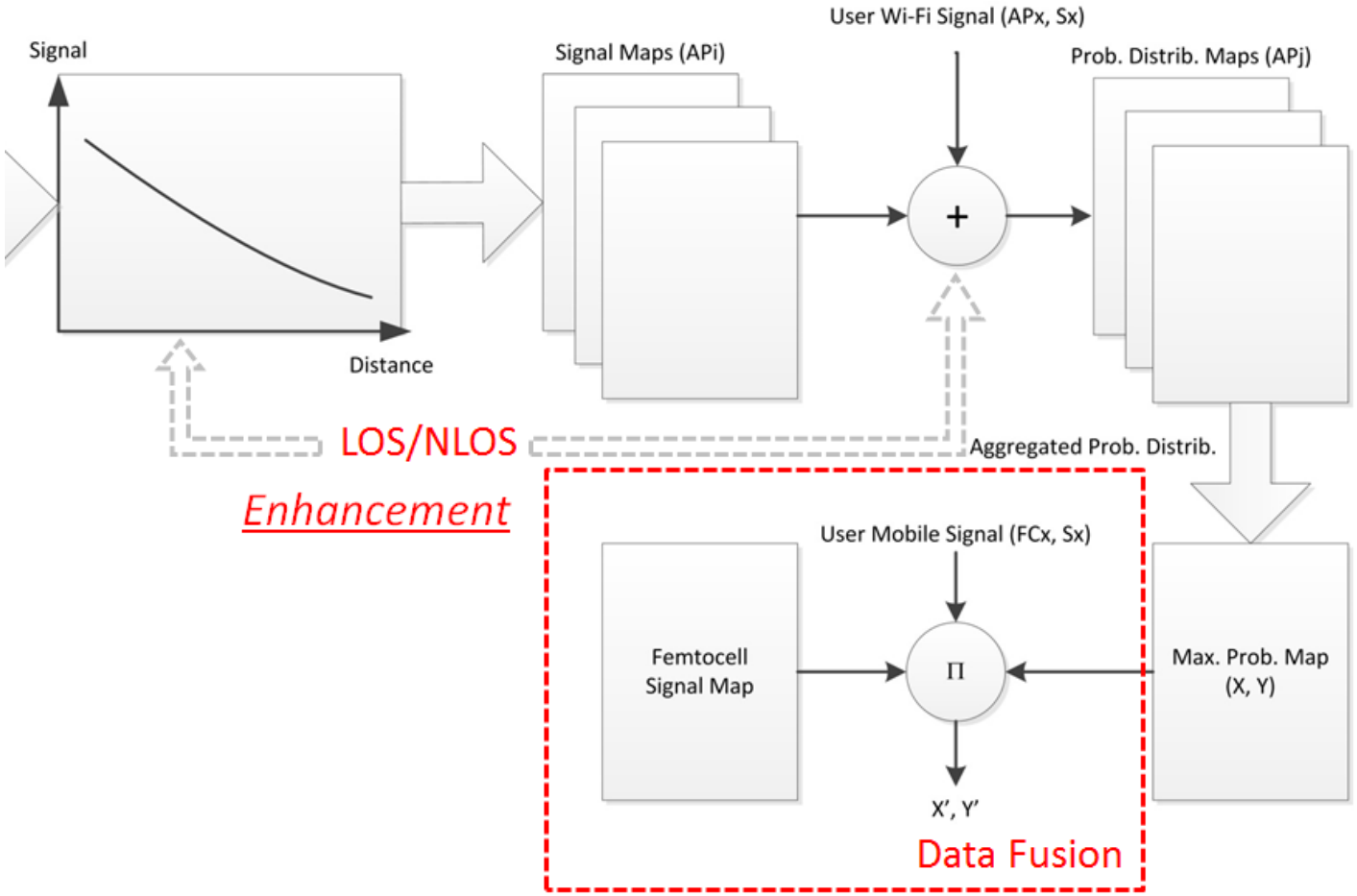


Practical Aspects and Decision Points

- Signal Calibrator (Router vs. Phone)
- Channel Scanning & Real-Time issues
- Localization using 2D or 3D Model
- Effective range of Received Signal Strength
- Signal Fluctuation (Signal Data Sampling)
- Linear Regression vs. Higher Order Curve Fitting
- Choices of Dynamic Grid Size (Accuracy)
- Aggregated Probability Map (Σ vs. Π)
- LOS and NLOS
- Data Fusion Approach (Weighted vs. Selection)

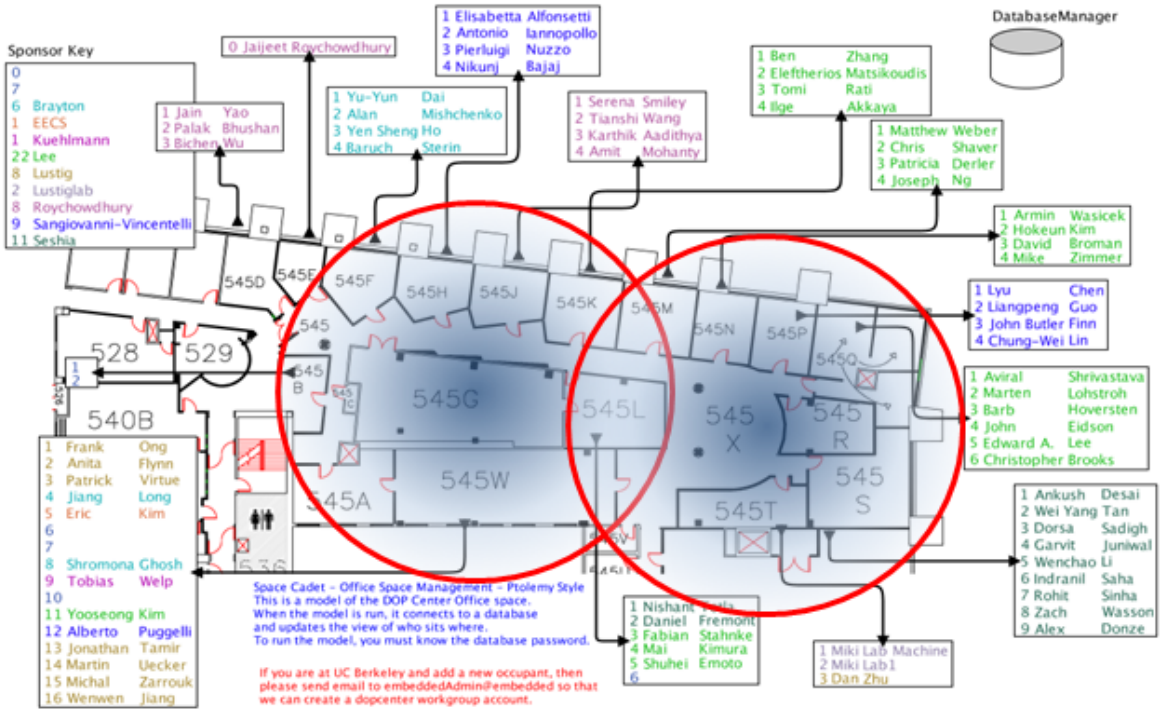
DOPresence Project at DOP Center

Design: Wifi User Detection

Approach: A WiFi Sensor for detecting all the packets emit from the user's mobile device

Current Status:

- Localization Development Server (running Debian OS) – setup & running
- WiFi Sensor (running OpenWRT) – setup & running
- Sniffer Program for capturing IEEE 802.11 packets – cross compiled & Version 1 running
- Sniffer Program Version 2 - Scan all 11 channels in both bands (2.4GHz & 5GHz) & store it in a database (MongoDB)



Demonstration

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Related Publications

Journal Publications

- Kam-Yiu Lam, Joseph K. Ng, Jiantao Wang, and Calvin Kam"A Pervasive Promotion Model for Personalized Promotion Systems On Using WLAN Localization and NFC Techniques", to appear in Mobile Information Systems - Special Issue on Emerging Trends in Networking and Ubiquitous Technologies.
- Joseph Kee-Yin Ng, Kam-Yiu Lam, Quan Jia Cheng, Kevin Chin Yiu Shum, "An Effective Signal Strength Based Wireless Location Estimation System for Tracking Indoor Mobile Users", Journal of Computer and System Sciences - Special Issue on Intelligent and Innovative Information Systems, Volume 79, Issue 7, November 2013, Pages 1005-1016. Elsevier 2013.
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- Joseph K. Ng, Junyang Zhou, Kenneth M. Chu, and Karl R.P.H Leung, "A Train-Once Approach for Location Estimation using the Directional Propagation Model (DPM)", IEEE Transactions on Vehicular Technology, Vol 57, Issue 4, pp. 2242-2256, July 2008, IEEE Vehicular Technology Society.
- Zhi-li Wu, Chun-hung Li, Joseph K. Ng, and Karl R.P.H. Leung, "Location Estimation via Support Vector Kernel Regression", IEEE Transactions on Mobile Computing, Vol. 6, No. 3, pp. 311-321, March 2007.
- Junyang Zhou and Joseph K. Ng, "Using LDA Method to Provide Mobile Location Estimation Services within a Cellular Network", Journal Of Computers (JCP), Vol. 1, Issue 7, pp.41-50, ISSN: 1796-203X, Academy Publisher, 2006.
- William H. Wong, Joseph K. Ng, and Karl R.P.H. Leung, "Large-Scale Location Estimation over GSM networks: the Gear Approach", in The International Journal of Wireless and Mobile Computing (IJWMC), Inderscience Publishers.

Related Publications

Conference Publications

- Kam-Yiu Lam, Joseph Kee-Yin Ng, and Jiantao Wang, "A Business Model for Personalized Promotion Systems On Using WLAN Localization and NFC Techniques", Proceedings of The First International Workshop on Collaborative Enterprise Systems (COLLABES-2013), Barcelona, Spain, March 24-28, 2013, pp. 1129-1134, IEEE CPS.
- Quan Jia Cheng, Joseph Kee-Yin Ng, and Kevin Chin Yiu Shum, "A Wireless LAN Location Estimation System using Center of Gravity as an Algorithm Selector for enhancing Location Estimation", in proceedings of The 26th IEEE International Conference on Advanced Information Networking and Applications(AINA 2012), Fukuoka, Japan, March 26-29, 2012, pp. 261-268, IEEE CPS.
- Kevin Chin Yiu Shum, Joseph Kee-Yin Ng, and Quan Jia Cheng, "The Design and Implementation of a Wireless Location Estimation System in a Wireless Local Area Network", Proceedings of The Eighth International Workshop on Heterogeneous Wireless Networks (HWISE-2012), Fukuoka, Japan, March 26-29, 2012, pp. 623-628, IEEE CPS.
- Kevin Chin Yiu Shum, Quan Jia Cheng, Joseph K. Ng, and Donna Ng, "A Signal Strength Based Location Estimation Algorithm within a Wireless Network" Proceedings of The 25th IEEE International Conference on Advanced Information Networking and Applications(AINA 2011), Biopolis, Singapore, March 22 - 25, 2011, pp. 509 - 516, IEEE CS Press.
- Kevin C. Shum, and Joseph K. Ng, "Detecting, Locating, and Tracking Hacker Activities within a WLAN Network" Proceedings of The 16th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA 2010), Macau, China, 23-25 August 2010, pp. 53 – 58, IEEE CS Press.
- Junyang Zhou, Kenneth Man-Kin Chu, and Joseph Kee-Yin Ng, "A Probabilistic Approach to Mobile Location Estimation with Cellular Networks", Proceedings of The 15th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA 2009), Beijing, China, 24-26 August 2009, pp. 341-348, IEEE CS Press.
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- Junyang Zhou, Joseph K. Ng, "A Data Fusion Approach to Mobile Location Estimation based on Ellipse Propagation Model within a Cellular Radio Network", Proceedings of the IEEE 21st International Conference on Advanced Information Networking and Applications (AINA 2007), pp. 459-466, May 21-23, 2007, Niagara Falls, Canada.
- Joseph K. Ng, "The Many Kinds Of Location Based Technologies & Services For 2007 And Beyond", Proceedings of The Intelligent Transport Systems Hong Kong Forum and Exhibition 2007, pp. 47, 19 April 2007, Hong Kong, China.
- Wilson M. Yeung, and Joseph K. Ng, "An Enhanced Wireless LAN Positioning Algorithm based on the Fingerprint Approach", Proceedings of IEEE TENCON 2006, IEEE CS Press (CD-Rom), 14-17 November 2006, Hong Kong, China.
- Chui Ying Hui, Joseph Kee-Yin Ng and Victor Chung-Sing Lee, "A Broadcast Algorithm that trade off between Data Freshness and Commit Rate for facilitating Mobile Transaction Processing", Proceedings of the 12th International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA 2006), pp. 147-153, August 16-18, Sydney, Australia 2006.

Related Publications

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- Kenneth Man-Kin Chu, Joseph K. Ng, and Karl R.P.H. Leung, "A New Approach for Locating Mobile Stations under the Statistical Directional Propagation Model", Proceedings of The 20th International Conference on Advanced Information Networking and Applications (AINA 2006), pp. 932-937, 18-20 April, 2006, Vienna, Austria.
- Junyang Zhou, Kenneth Man-Kin Chu, and Joseph K. Ng, "An Improved Ellipse Propagation Model for Location Estimation in facilitating Ubiquitous Computing", Proceedings of the 11th International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA 2005), pp. 463-466, August 17-19, 2005, Hong Kong.
- William H. Wong, Joseph K. Ng, and Wilson M. Yeung, "Wireless LAN Positioning with Mobile Devices in a Library Environment", Proceedings of ICDCS-MDC 2005 Workshop, pp. 633-636, June 6-10, 2005, Columbus, Ohio, USA.
- Junyang Zhou, Kenneth M. Chu, Joseph K. Ng, "Providing Location Services within a Radio Cellular Network using the Ellipse Propagation Model", Proceedings of the 19th International Conference on Advanced Information Networking and Applications (AINA 2005), 1:559-564, March 28-30, Taipei, Taiwan, 2005.

Related Publications

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- Karl R.P.H. Leung, Joseph K. Ng, Tim K. Chan, Kenneth M. Chu, and Chung Hung Li, "Network Based Mobile Station Positioning in Metropolitan Area", Proceedings of the International Conference on Parallel and Distributed Computing (Euro-Par 2003), pp. 1017 - 1026, Springer-Verlag, August 26-29, 2003, Klagenfurt, Austria.
- Zhi-li Wu, Chun-hung Li, Joseph K. Ng, and Karl R.P.H. Leung, "Support Vector Regression for Location Estimation", Proceedings of ICANN/ICONIP 2003, June 26-29, 2003, Istanbul, Turkey.
- Kenny K.H. Kan, Stephen K.C. Chan, and Joseph K. Ng, "A Dual-Channel Location Estimation System for providing Location Services based on the GPS and GSM Networks", Proceedings of The 17th International Conference on Advanced Information Networking and Applications (AINA 2003), pp. 7 - 12, March 27-29, 2003, Xi'an, China.
- Joseph K. Ng, Stephen K. Chan, and Kenny K. Kan, "Location Estimation Algorithms for Providing Location Services within a Metropolitan Area based on a Mobile Phone Network", Proceedings of the 5th International Workshop on Mobility Databases and Distributed Systems (MDDS 2002), pp. 710 - 715, Aix-en-Provence, France, September 2-6, 2002

Contact Information

Prof. Joseph Kee-Yin NG

- Research Centre for Ubiquitous Computing
- Department of Computer Science
- Hong Kong Baptist University
- Kowloon Tong, Hong Kong

- Email: jng@comp.hkbu.edu.hk
- Email: jkng@berkeley.edu
- URL: http://www.comp.hkbu.edu.hk/~jng

香港浸會大學
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普適計算研究中心 Research Centre for Ubiquitous Computing

I will be here until 15th July 2014!

Please contact me if you are interested in any part of the Localization Project.

Thank You!!