

Address, City, State, and/or Zip

3405 Michigan Union 530 S. State Street

Current City

-  Ann Arbor, Michigan
51,001 like this · 752,64...
-  Lake Ann, Michigan
785 like this · 8,350 wer...
-  Saint Ann'S Bay, Saint A...
742 like this · 3,583 wer...
-  Saint Ann, Missouri
533 like this · 3,920 wer...

Location
Where in the world are you?

家乡 :

-  安庆
-  安顺
-  安康

SKYHOOK
WIRELESS



YAHOO!
BOSS

Google
Developers

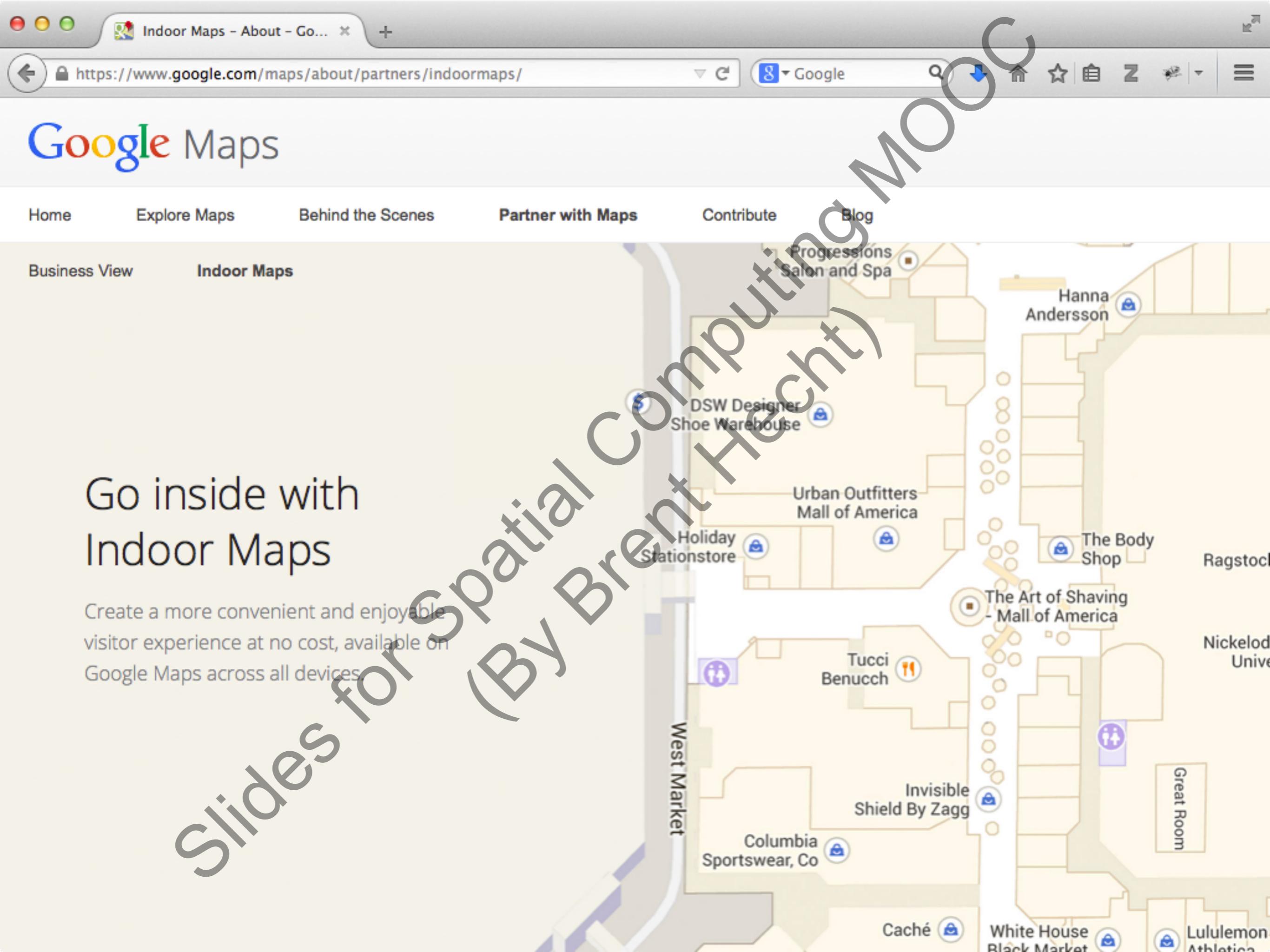
Positioning

Spatial Computing – University of Minnesota



GPS limitations

1. Does not work well indoors
(that's changing a bit)
2. Accuracy can be limited
3. Time-to-first-fix stinks
4. Multipath issues (urban canyon effect)
5. Drain on power



Google Maps

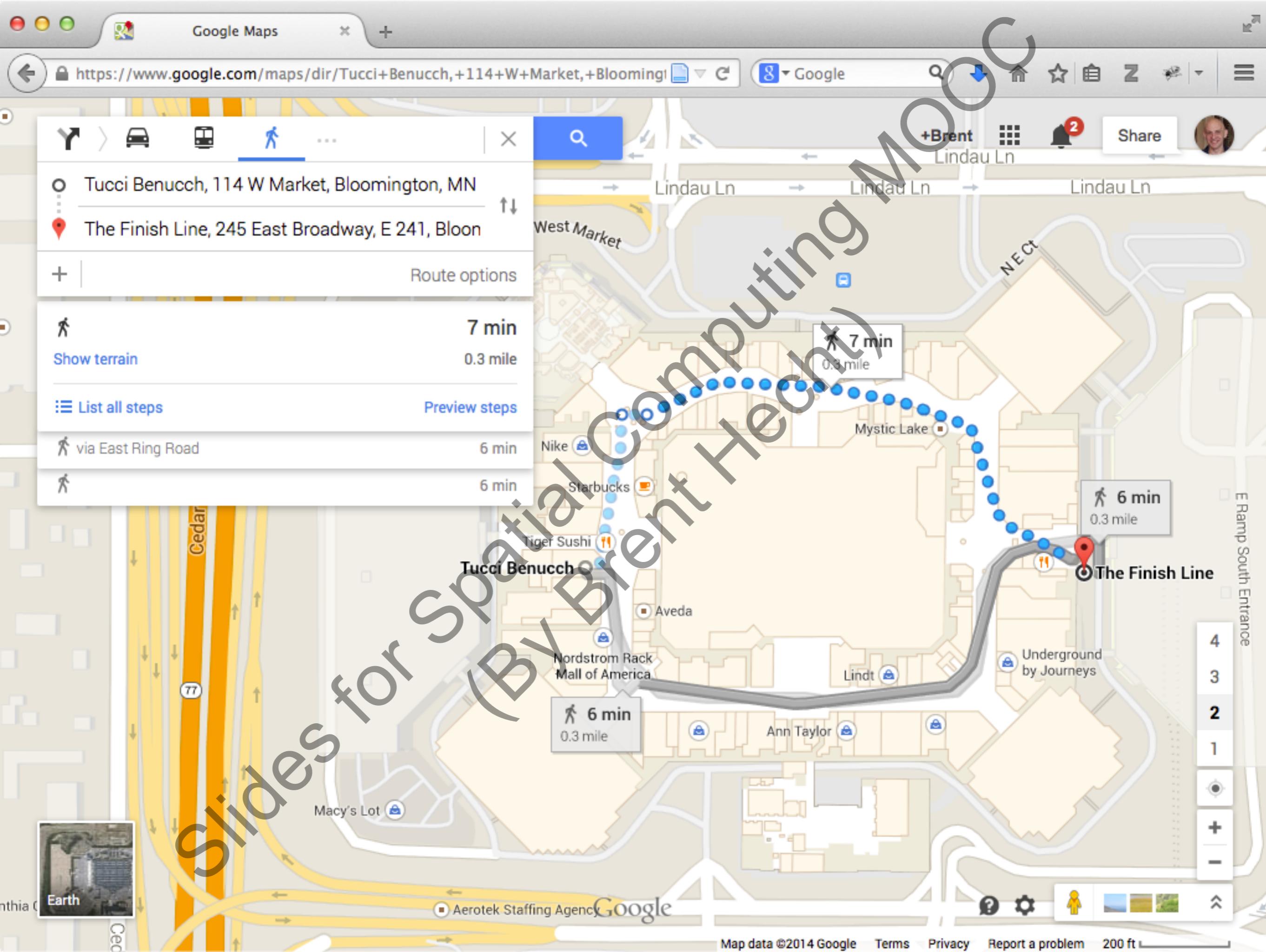
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Go inside with Indoor Maps

Create a more convenient and enjoyable visitor experience at no cost, available on Google Maps across all devices.



Slides for Spatial Computing MOOC
(By Brent Hecht)



Slides for Spatial Computing Mooc
(By Bart Fidder)

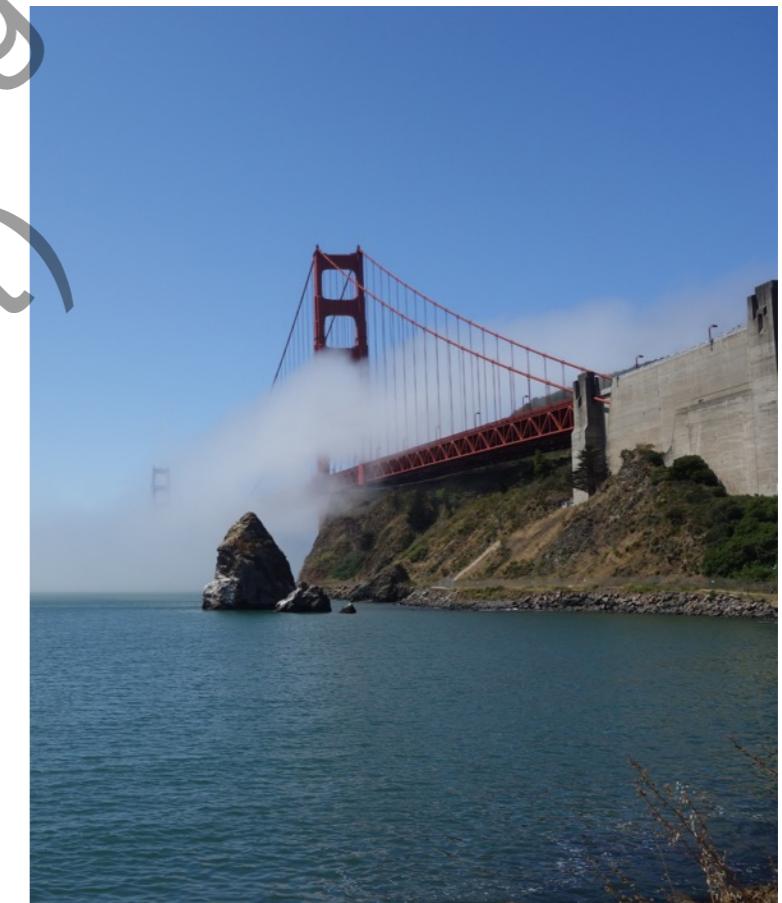
Wifi positioning to the rescue!



Coit Tower



Candlestick Park

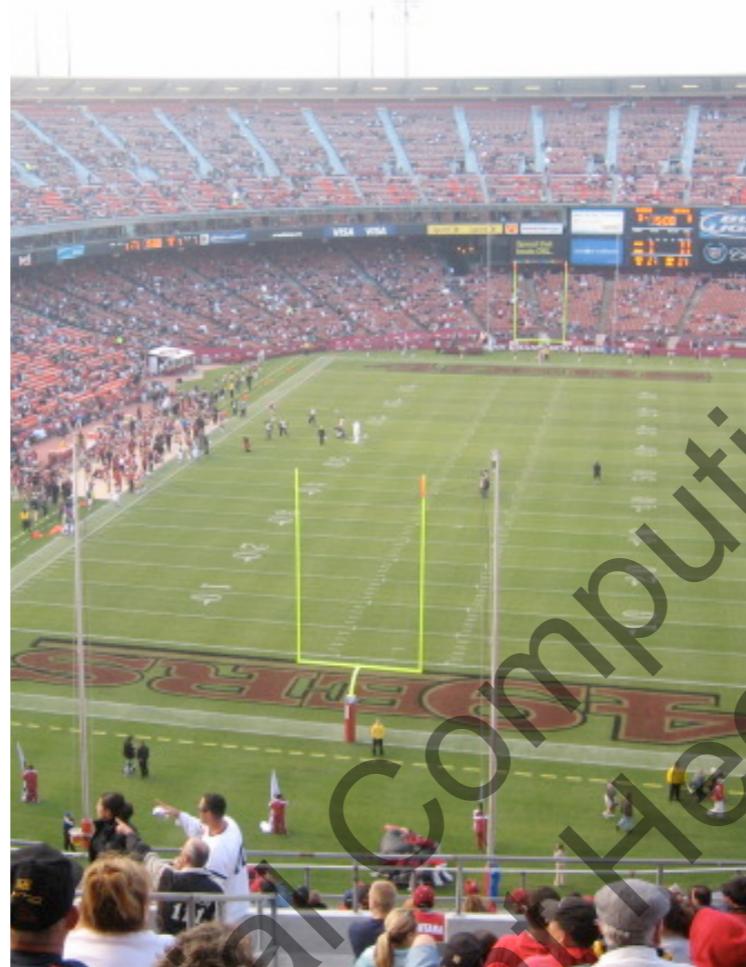


Golden Gate Bridge

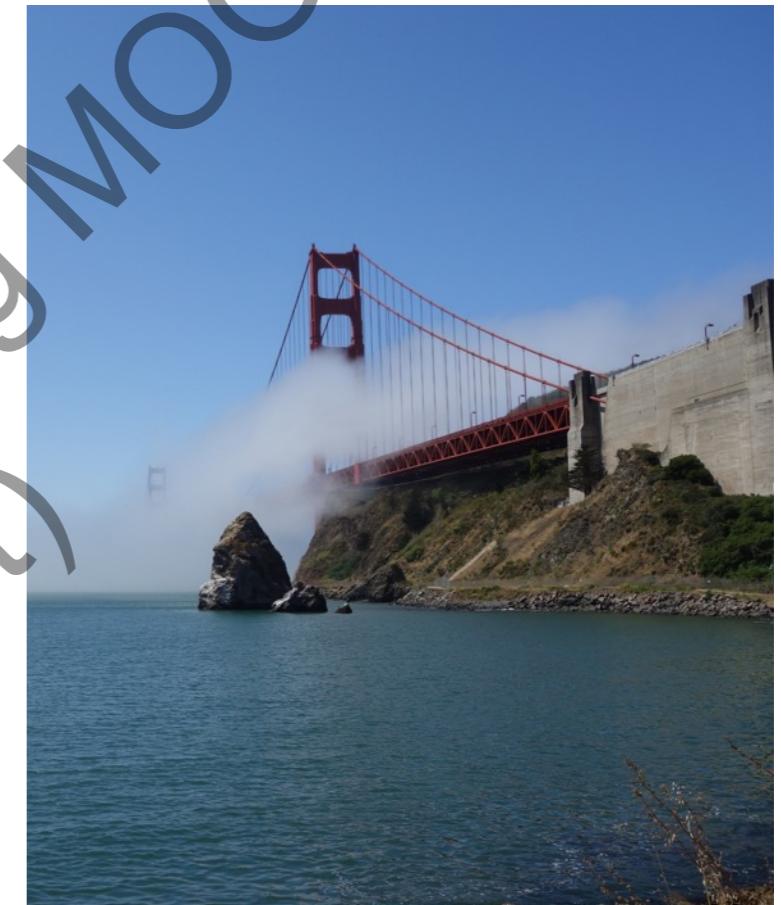
Slides for Spatial Computing
by Brent Hecht
BY
Slides for Spatial Computing
Hecht, Brent
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Coit Tower

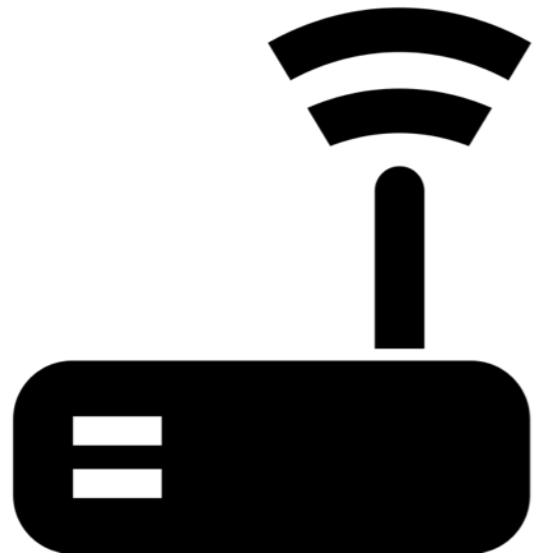


Candlestick Park

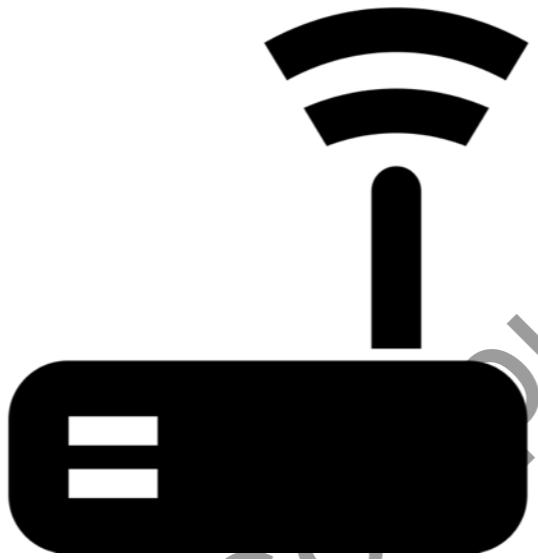


Golden Gate Bridge

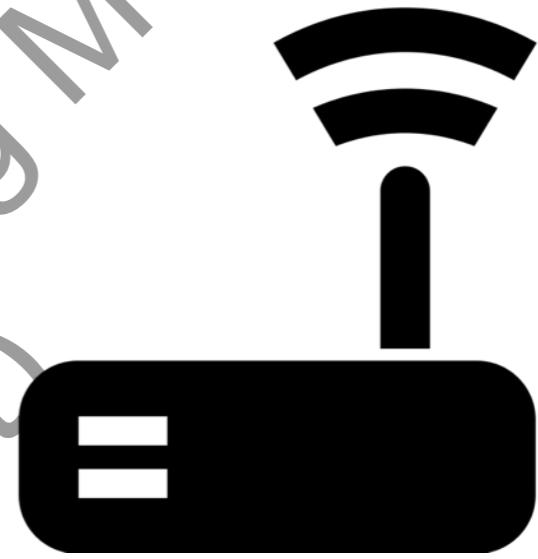
San Francisco, CA



Unique MAC
Address



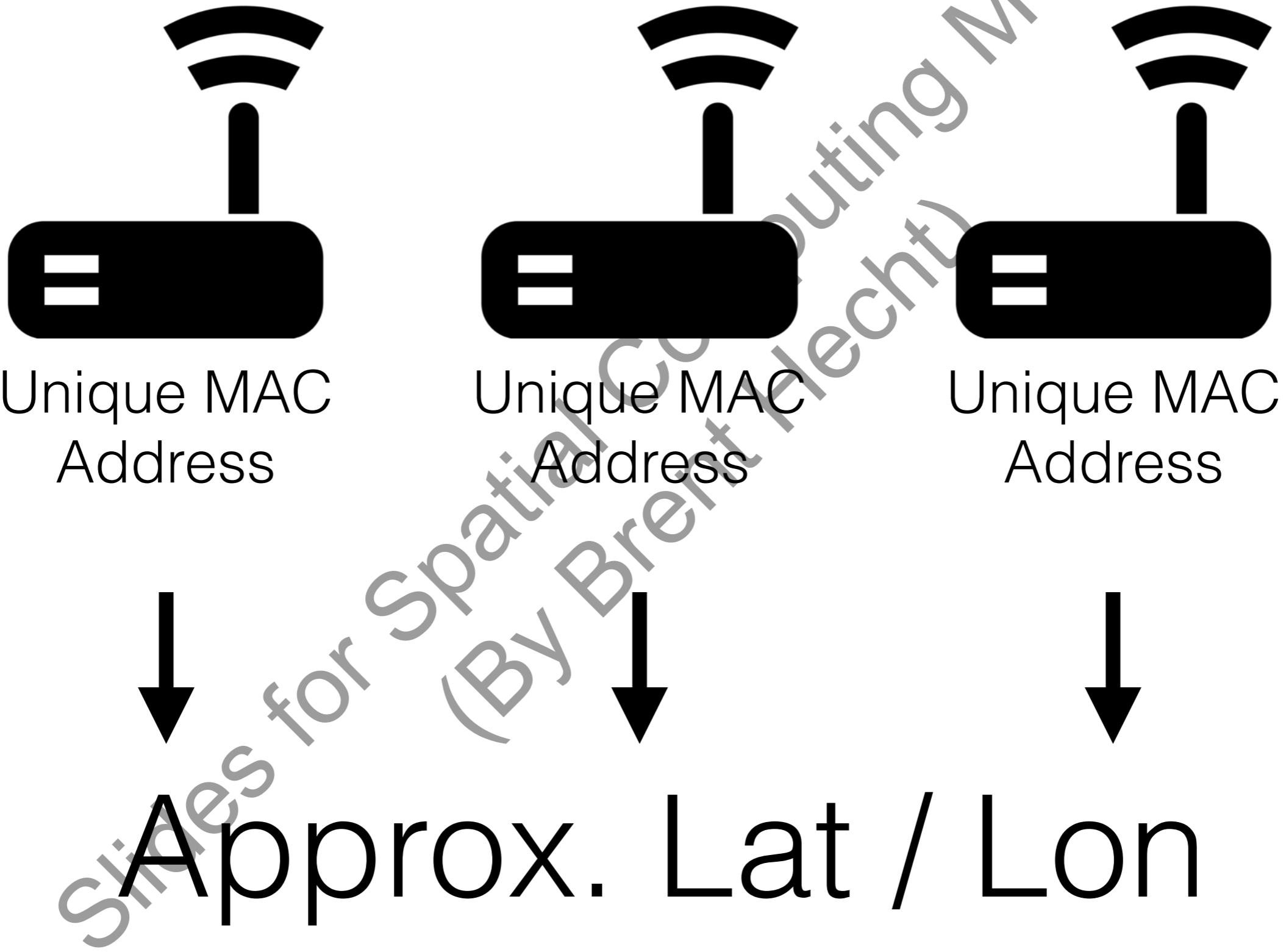
Unique MAC
Address



Unique MAC
Address

San Francisco, CA

*Spatial Computing
for Sensors
(By Brent Hecht)*



How does wifi positioning work?



PHASE 1

calibration phase

PHASE 2:

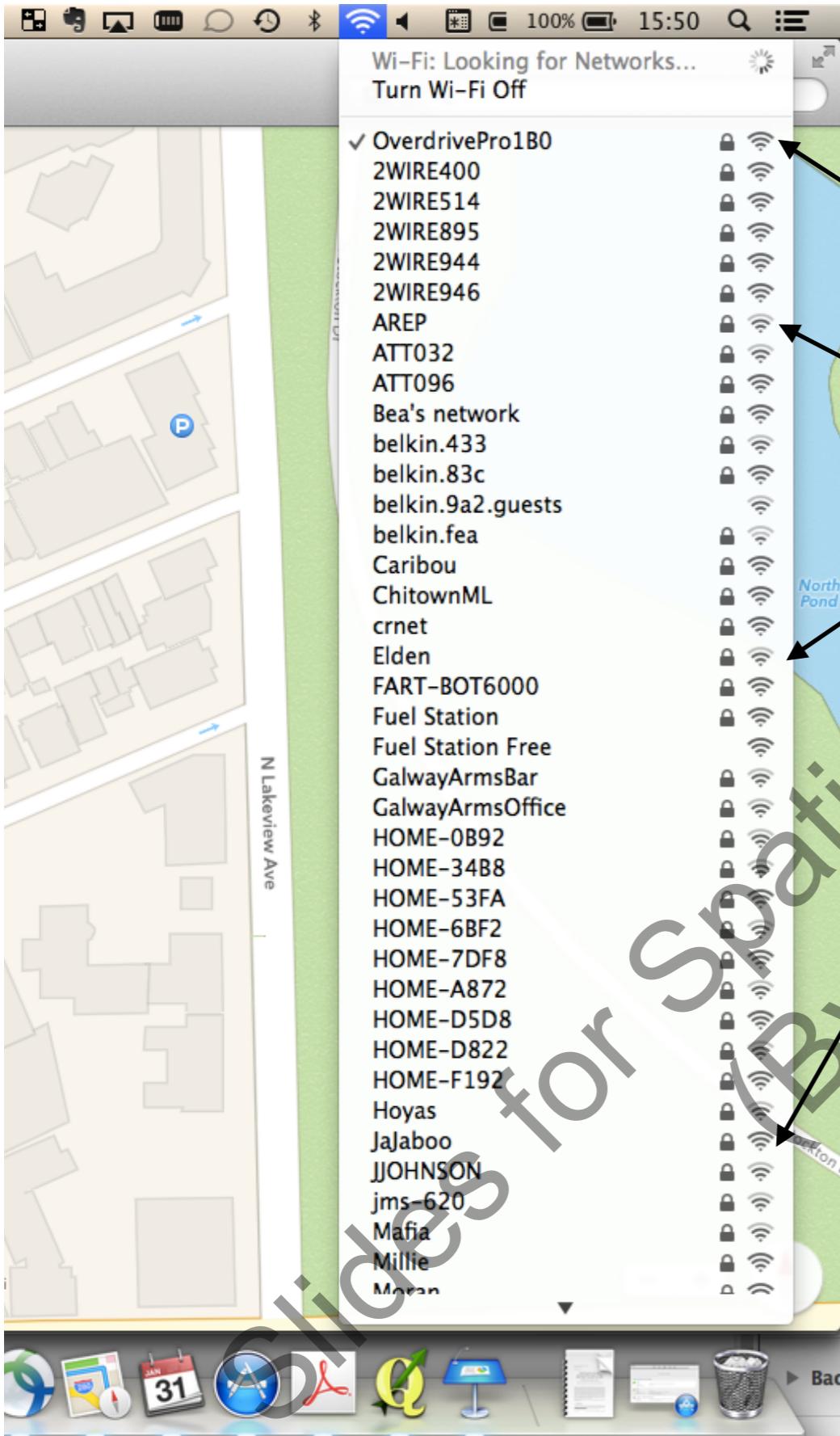
positioning phase
Fingerprinting!

Slides for Space Computing
(By) MG OOC

Wifi Fingerprint

Collecting these is goal of Calibration stage

(MAC addresses, signal
strengths, location of
fingerprint collector)



Two-Thirds of a Wifi Fingerprint

(missing the location at which this reading was taken)

Calibration Phase

aka collecting fingerprints



War Driving

Slides for 2D Real-Time Computing
OCW

Google Street
View cars: also
used to collect
Wi-Fi fingerprints



g Google told to delete Stre... +

www.theguardian.com/technology/2013/jun/21/google-street-view-payload Google

Edition: UK US AU Sign in Beta



\$20 OFF on weekly rentals  BOOK NOW Hertz.

the guardian

Google™ Custom Search

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News > Technology > Google Street View

Google told to delete Street View payload data or face UK prosecution

Information commissioner's office says it will launch contempt of court proceedings if data is not deleted within 35 days

Josh Halliday

theguardian.com, Friday 21 June 2013 07.45 EDT

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Technology

[Google Street View](#) · [Google](#)

UK news

[Information commissioner](#)





The New Street View
Car Driver

“[Positioning calculations] are performed live on the iPhone using a crowd-sourced database of Wi-Fi hotspot and cell tower data that is generated by tens of millions of iPhones sending the geo-tagged locations of nearby Wi-Fi hotspots and cell towers in an anonymous and encrypted form to Apple.”

(Apple, Inc. 2011)



3G Apple iOS Devices Secr... +

bits.blogs.nytimes.com/2011/04/20/3g-apple-ios-devices-secretly-storing Google

The New York Times

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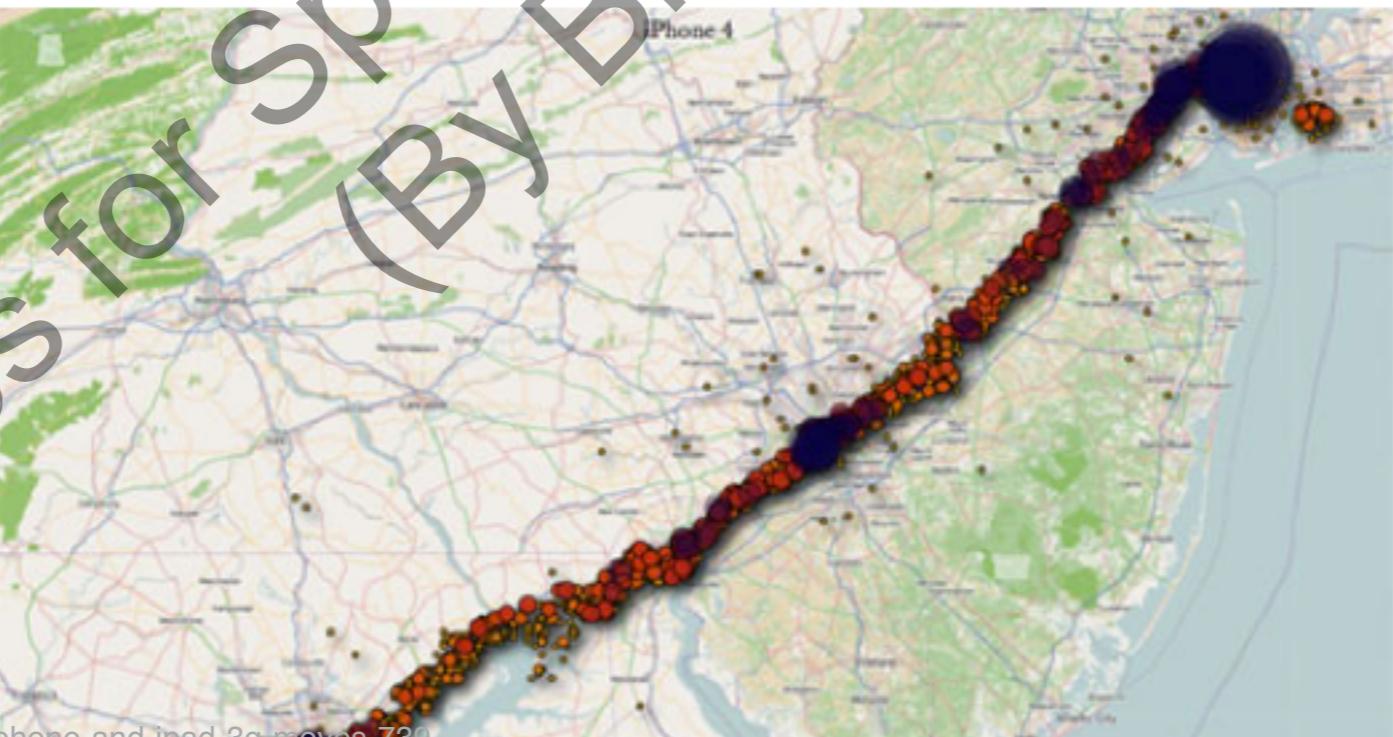
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Slides for Spatial Computing (By Brent Hecht)

Bits

3G Apple iOS Devices Are Storing Users' Location Data

By NICK BILTON APRIL 20, 2011 3:04 PM ▾ 109 Comments



<http://www.vincentabry.com/en/apple-tracks-iphone-and-ipad-3g-moves-739>

adclick.g.doubleclick.net/aclk?sa=L&ai=BNTRIIImHzU6y6GoShpgOXg4HQCwAAAAAQASAAOA...CLVFn5QHAqtc96AFkmALD0QOoAgWoAgY; redirecturl2=https://www.tivo.com/roamiodvrs

How does wifi positioning work?



Fingerprinting!

PHASE 1

calibration phase

PHASE 2:

positioning phase

Spatial Computing
(By Brent Hecht)

MG OOC

Positioning Phase

aka using machine learning to determine position



These Wi-Fi networks are in range, so where am I?

Positioning Phase

aka using machine learning to determine position

✓ OverdrivePro1B0	lock	Wi-Fi
2WIRE400	lock	Wi-Fi
2WIRE514	lock	Wi-Fi
2WIRE895	lock	Wi-Fi
2WIRE944	lock	Wi-Fi
2WIRE946	lock	Wi-Fi
AREP	lock	Wi-Fi
ATT032	lock	Wi-Fi
ATT096	lock	Wi-Fi
Bea's network	lock	Wi-Fi
belkin.433	lock	Wi-Fi
belkin.83c	lock	Wi-Fi
belkin.9a2.guests	lock	Wi-Fi
belkinfea	lock	Wi-Fi
Caribou	lock	Wi-Fi
ChitownML	lock	Wi-Fi
crnet	lock	Wi-Fi
Elden	lock	Wi-Fi
FART-BOT6000	lock	Wi-Fi
Fuel Station	lock	Wi-Fi
Fuel Station Free	lock	Wi-Fi
GalwayArmsBar	lock	Wi-Fi
GalwayArmsOffice	lock	Wi-Fi
HOME-0B92	lock	Wi-Fi
HOME-34B8	lock	Wi-Fi
HOME-53FA	lock	Wi-Fi
HOME-6BF2	lock	Wi-Fi
HOME-7DF8	lock	Wi-Fi
HOME-A872	lock	Wi-Fi
HOME-D5D8	lock	Wi-Fi
HOME-D822	lock	Wi-Fi
HOME-F192	lock	Wi-Fi
Hoyas	lock	Wi-Fi
Jajaboo	lock	Wi-Fi
JJOHNSON	lock	Wi-Fi
jms-620	lock	Wi-Fi
Mafia	lock	Wi-Fi
Millie	lock	Wi-Fi
Moran	lock	Wi-Fi

fingerprint matching
algorithm (e.g. kNN,
neural networks)

✓ OverdrivePro1B0	lock	Wi-Fi
2WIRE400	lock	Wi-Fi
2WIRE514	lock	Wi-Fi
2WIRE895	lock	Wi-Fi
2WIRE944	lock	Wi-Fi
2WIRE946	lock	Wi-Fi
AREP	lock	Wi-Fi
ATT032	lock	Wi-Fi
ATT096	lock	Wi-Fi
Bea's network	lock	Wi-Fi
belkin.433	lock	Wi-Fi
belkin.83c	lock	Wi-Fi
belkin.9a2.guests	lock	Wi-Fi
belkinfea	lock	Wi-Fi
Caribou	lock	Wi-Fi
ChitownML	lock	Wi-Fi
crnet	lock	Wi-Fi
Elden	lock	Wi-Fi
FART-BOT6000	lock	Wi-Fi
Fuel Station	lock	Wi-Fi
Fuel Station Free	lock	Wi-Fi
GalwayArmsBar	lock	Wi-Fi
GalwayArmsOffice	lock	Wi-Fi
HOME-0B92	lock	Wi-Fi
HOME-34B8	lock	Wi-Fi
HOME-53FA	lock	Wi-Fi
HOME-6BF2	lock	Wi-Fi
HOME-7DF8	lock	Wi-Fi
HOME-A872	lock	Wi-Fi
HOME-D5D8	lock	Wi-Fi
HOME-D822	lock	Wi-Fi
HOME-F192	lock	Wi-Fi
Hoyas	lock	Wi-Fi
Jajaboo	lock	Wi-Fi
JJOHNSON	lock	Wi-Fi
jms-620	lock	Wi-Fi
Mafia	lock	Wi-Fi
Millie	lock	Wi-Fi
Moran	lock	Wi-Fi

Available Wi-Fi
Networks and Signal
Strengths

Lat/Lon =
41.93635, -87.64332

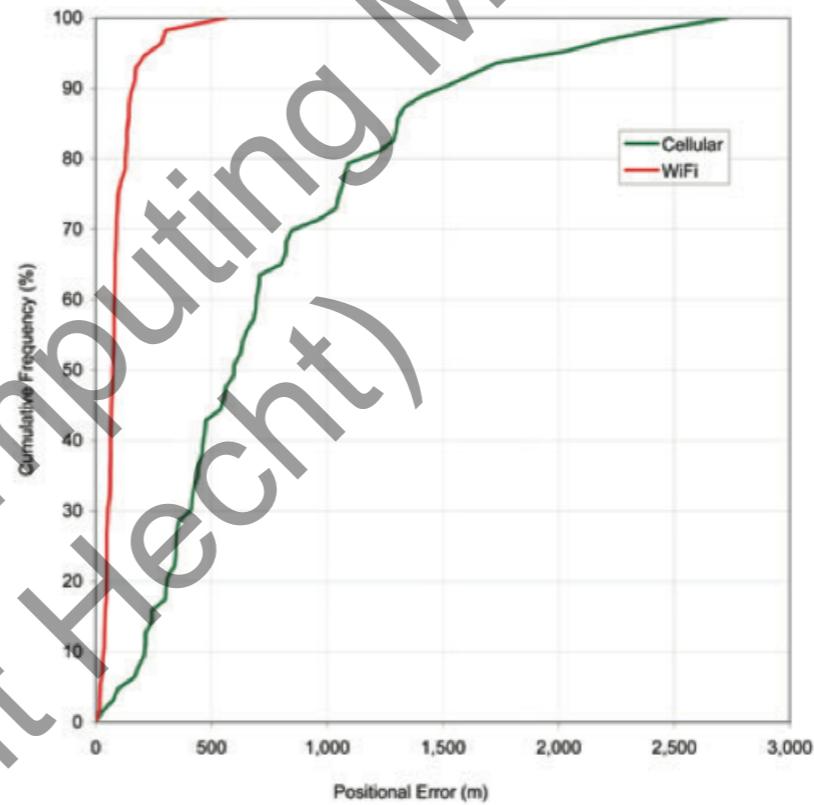
Wi-Fi Positioning Accuracy

Worse than GPS, better than cellular

Slides for Spatial Computing MOOC
(By Brent Hecht)



20m accuracy



74m accuracy
(median)

Images from “Accuracy of iPhone Locations: A Comparison of Assisted GPS, WiFi and Cellular Positioning” by Paul Zandbergen. *Transactions in GIS*, 2009, 13(s1): 5–26

Wi-Fi Positioning Accuracy

Worse than GPS, better than cellular

Can be used *in combination with*
GPS for improved accuracy

Slides for Spatial Computing MOOC
(By Brent Hecht)

“Skyhook Location’s hybrid positioning improves upon Wi-Fi positioning accuracy up to 35% in difficult environments by leveraging signals from as few as two GPS satellites. In deep urban settings Skyhook Location uses weak GPS signals and WiFi to acquire a location 100% of the time (A-GPS works only 70% of the time). From a complete cold start, Skyhook Location delivers a full hybrid location in 4 seconds (compared to 30-60 seconds for A-GPS).”

(Skyhook Wireless 2014)

Slides for  SKYHOOK°

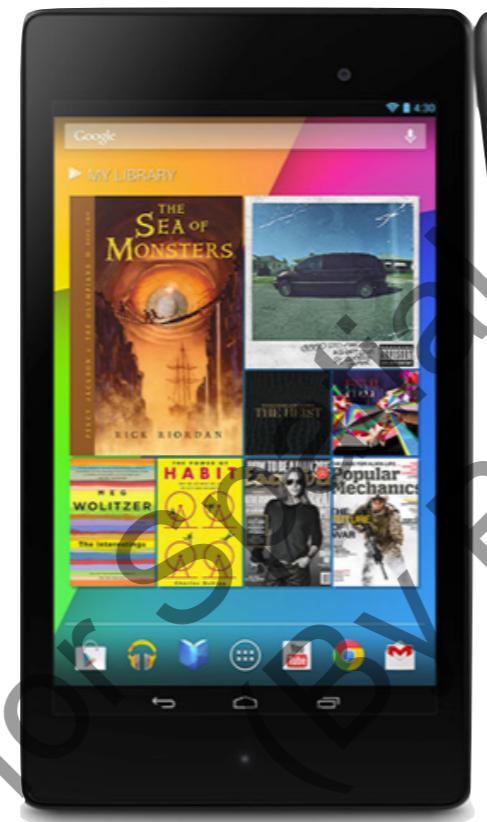
Predictors of Performance

1. Number of access points
2. Quality of fingerprint database (degrades over time, conditions)
3. Quality of machine learning algorithm in positioning phase

No Wi-Fi hotspots in range out here...



Wi-Fi Positioning provides positioning for devices without GPS....

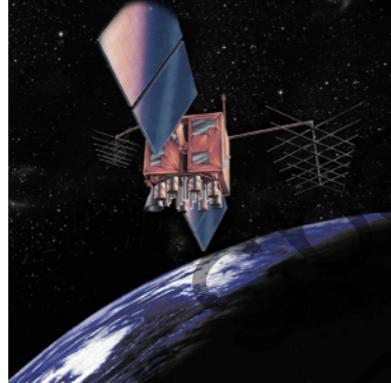


Slides
Tablets

Computers
(e.g. MacBooks)

Key Types of Signal-based Positioning

in your smartphone and in general



**Signal-based
Positioning**

**1. Satellite-based
Positioning**

2. Wifi Positioning

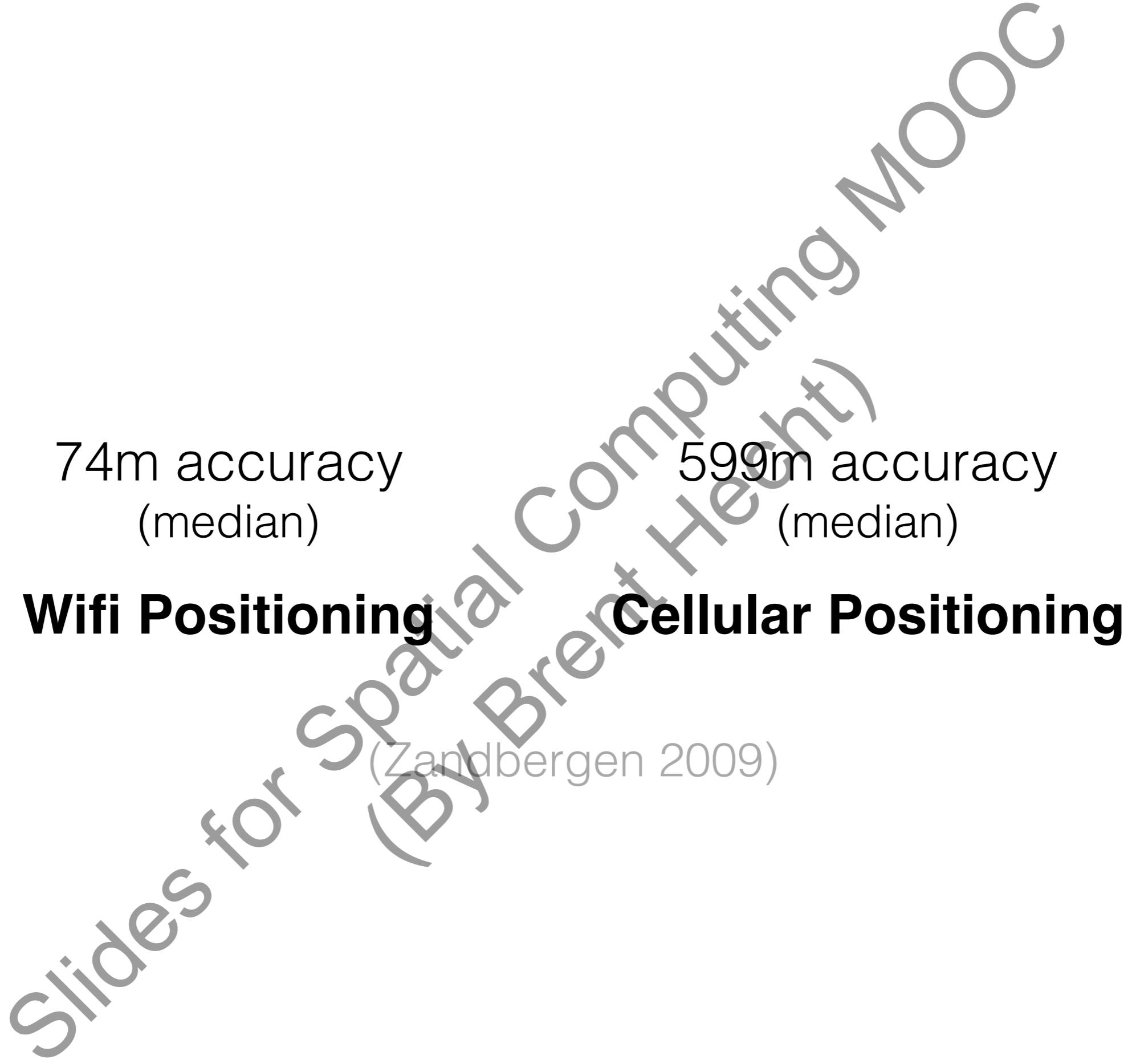
**3. Cellular
Positioning**

Cellular Positioning

1. Algorithms: Location of tower with strongest signal, Time Difference on Arrival, Angle of Arrival, Fingerprinting
2. Accuracy highly-dependent on number of towers
3. Least accurate of all three



Slides for Spatial Computing
(By Brent Wiens)



Positioning

Spatial Computing – University of Minnesota

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Fingerprint by Wilson Joseph from The Noun Project

"Blue iPod touch 5th Generation" by Guess Who - Created in Photoshop CS6.. Via Wikipedia - http://en.wikipedia.org/wiki/File:Blue_iPod_touch_5th_Generation.png#mediaviewer/File:Blue_iPod_touch_5th_Generation.png

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Router by Pedro Lalli from The Noun Project

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