Privacy and security Implications on Wireless (Wi-Fi)

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2013 MIS 021
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Road Map

- Introduction
- Background
- Design of the research
- Research findings
- Conclusion
- Continuing the project: future works

Introduction

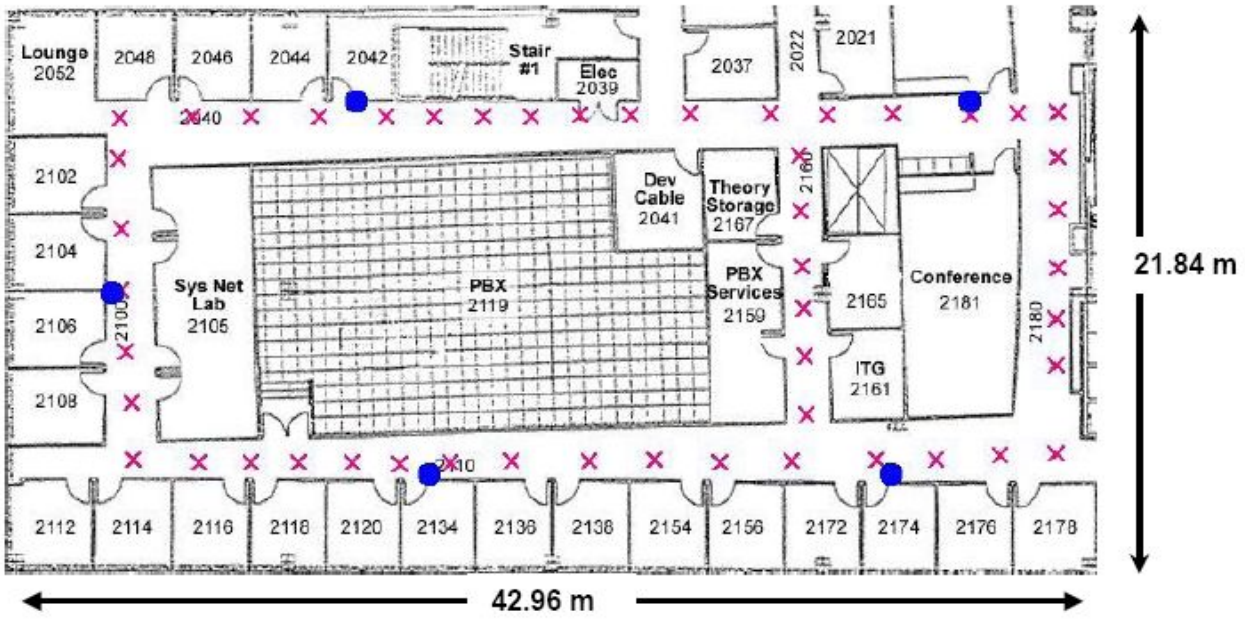
- Wi-Fi is the popular wireless networking technology using radio waves operate in 2.4GHz and 5GHz bands
- a huge growth in Wi-Fi enabled devices and Wi-Fi hotspots within past few years
- Tomography refers to imaging by sections or sectioning, through the use of any kind of penetrating wave
- Radio tomographic imaging (RTI) offers a new way to image passive objects in buildings and outdoor environments using received signal strength (RSS).
- Signal Strength is measured in decibel (db)
- RSSI is a measurement of the power present in a received radio signal

Privacy

- freedom from interference or intrusion
- the right "to be let alone,“
- Privacy and tomography???
  - In tomography it is possible to map objects
  - Objects can be anything including “HUMANS”
  - No way to know whether someone is using tomographic technologies
- “Human movements can be mapped even without their knowledge” !!!
- Privacy is breached

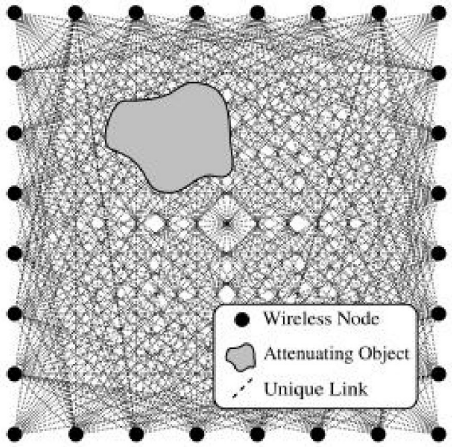
Related Work

- RADAR: An In-Building RF-based User Location and Tracking System by Paramvir Bahl and Venkata N. Padmanabhan IEEE Infocom 2000, volume 2, pages 775-784, March 2000.
  - An In-building RF-based user location and tracking system
  - WiFi-based localization
  - Fingerprinting, RSSI profiling



Related Work Contd…

- J. Wilson and N. Patwari, “Radio tomographic imaging with wireless networks,” IEEE Transactions on Mobile Computing, vol. 9, no. 5, pp. 621–632, May 2010. Published, 01/08/2010.

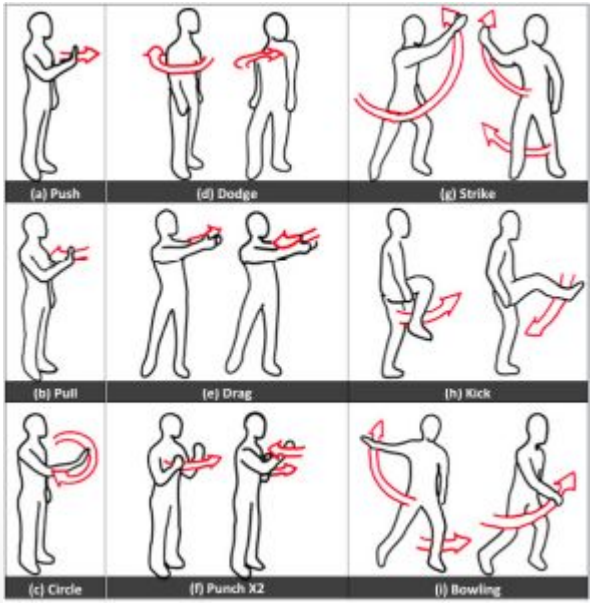


An illustration of an Radio tomographic imaging (RTI) network. Each node broadcasts to the others, creating many projections that can be used to reconstruct an image of objects inside the network area.

- tracks humans moving through a building

Related Work Contd…

- WiSee; Pu, Q., Gupta, S., Patel, S. and Gollakota, S. (2013). Whole-Home Gesture Recognition Using Wireless Signals. In: The 19th Annual International Conference on Mobile Computing and Networking (Mobicom'13).



WiSee, is a novel approach to gesture recognition that leverages Wi-Fi signals to enable whole-home sensing and recognition of human gestures. WiSee can correctly detect nine gestures with 94% average accuracy from 900 tested gestures.

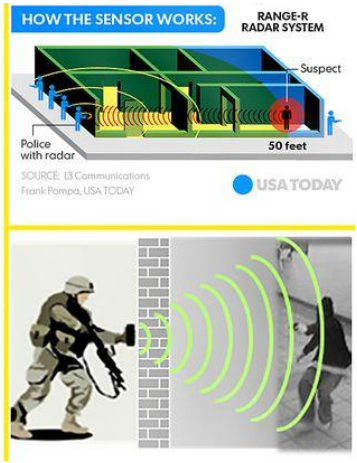
- Tracks human gestures

Related Work Contd…

- Study on wireless sensor based industrial tomography systems by Chiew Loon Goh, Nor Muzakir Nor Ayob, Ruzairi Abdul Rahim, Herlina Abdul Rahim, Muhammad Jaysuman Pusppanathan, Mohd. Hafiz Fazalul Rahiman, Leow Pei Ling, Zulkarnay Zakaria.
  - survey on wireless based industrial tomography system, and to review design challenges in the field of embedded wireless solutions

Related Work - Products

- See through walls radar – used for military and tactical purposes



Related Work–Products Contd..

- Google's Project Soli
  - Using radar to enable new types of touchless interactions
  - The Soli sensor can track sub-millimeter motions at high speed and accuracy

Research Question

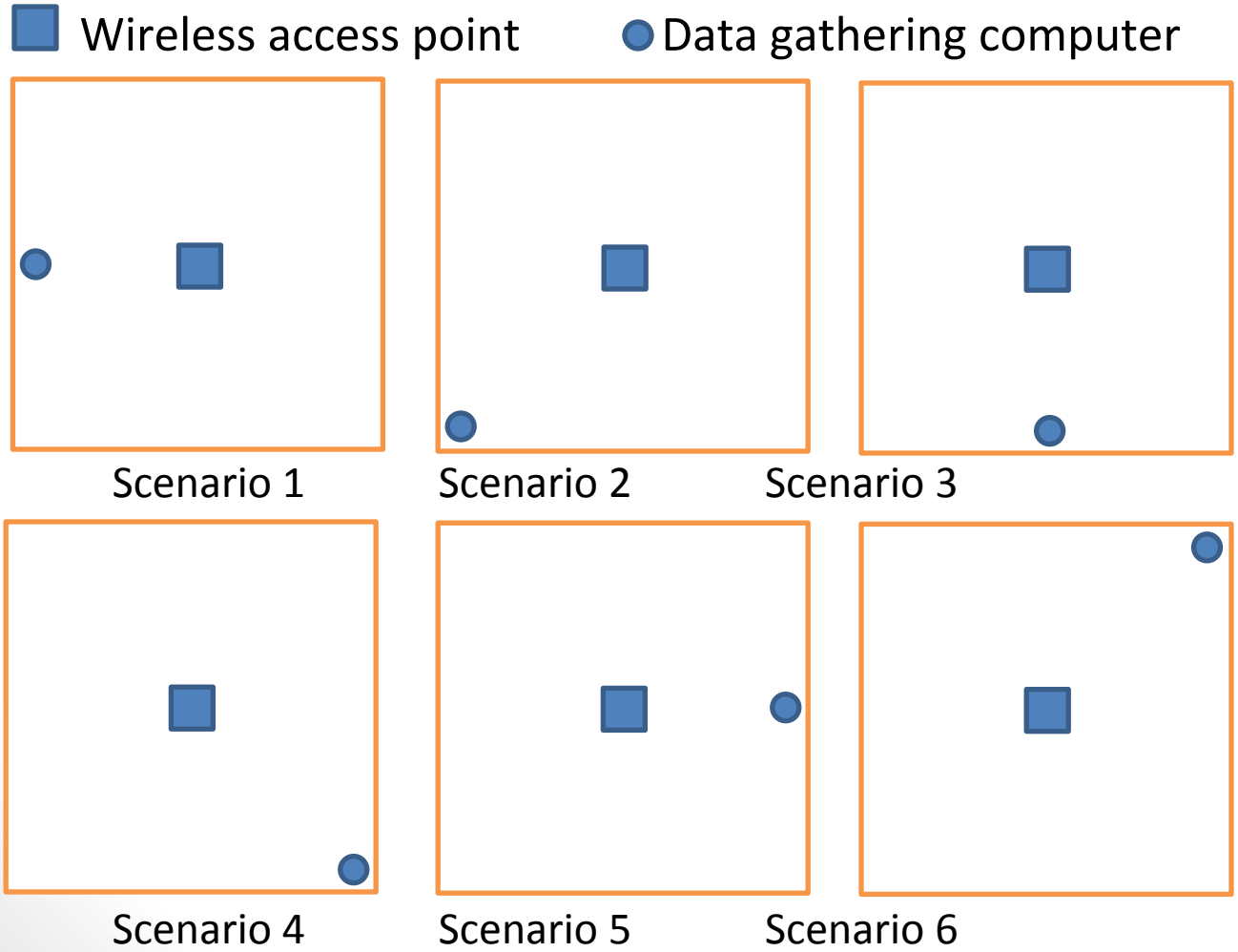
- Is there a significant amount of wireless signal strength drop when there is a human inside the line of sight of the wireless access point and data gathering computer?
- How accurately we can identify human presence by observing received signal strength indicator (RSSI) values.

Initial Design

- Creating initial scenario sets to gather data
- Developed to answer first research question
- Try to make them as close as possible to real world situations
- Two variables
  - Wireless access point
  - Data gathering computer
- At any given time one is constant

Scenarios – Set 1

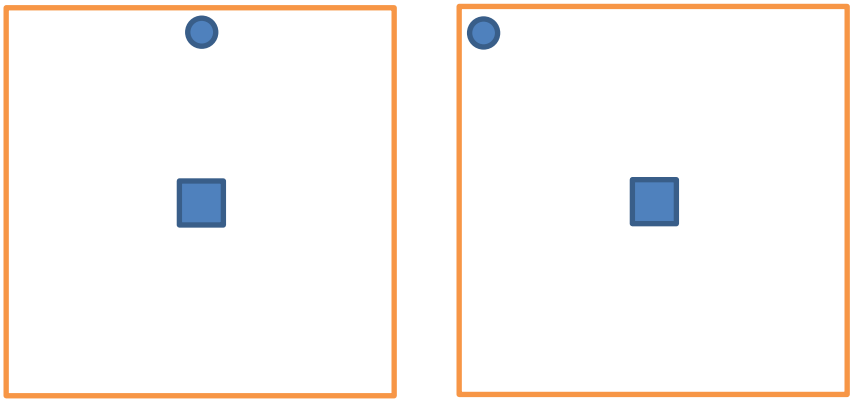
- When Wireless access points position is a constant and its in the middle of the room



Scenarios – Set 1 Contd…

- When Wireless access points position is a constant and its in the middle of the room

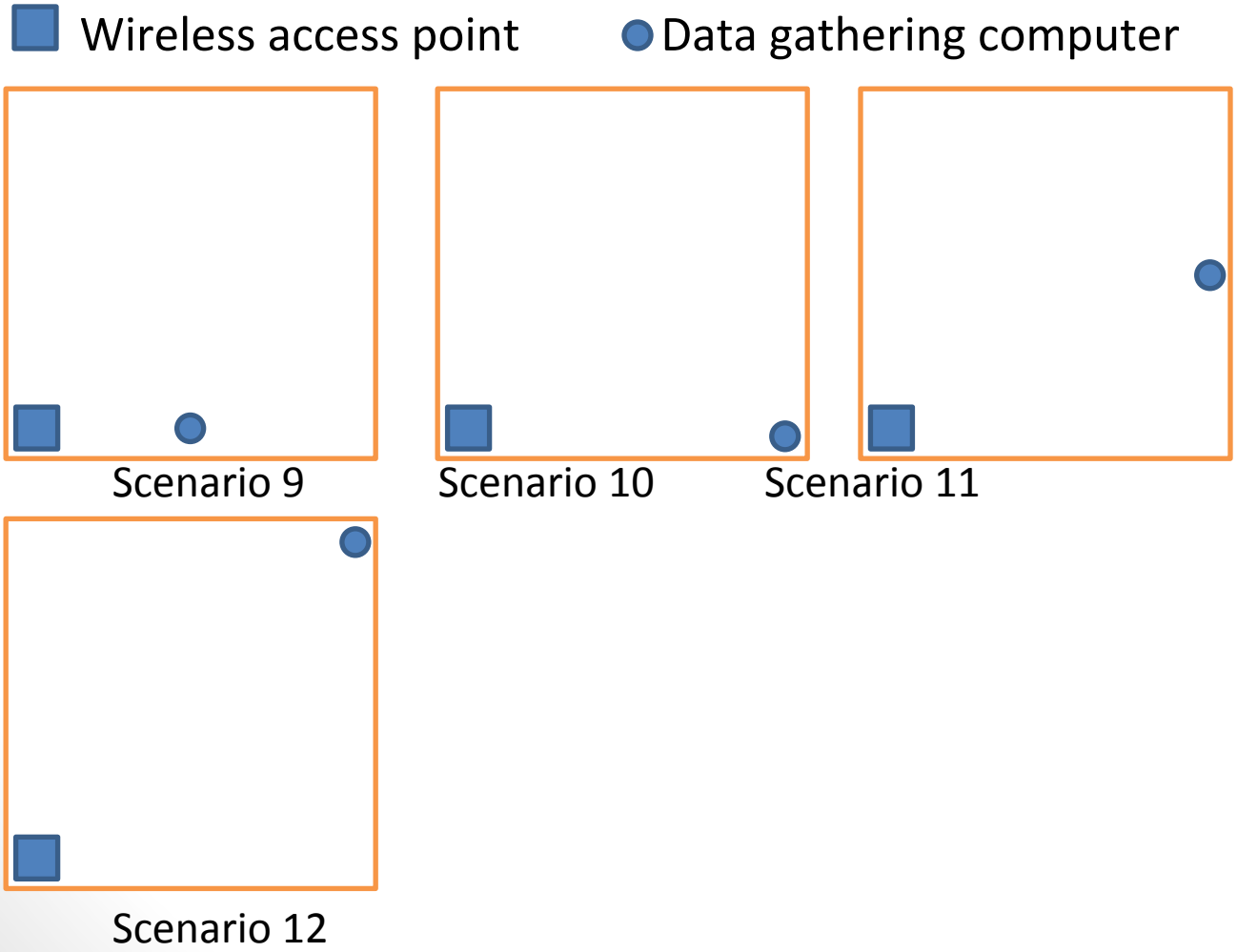
Wireless access point Data gathering computer



Scenario 7 Scenario 8

Scenarios – Set 2

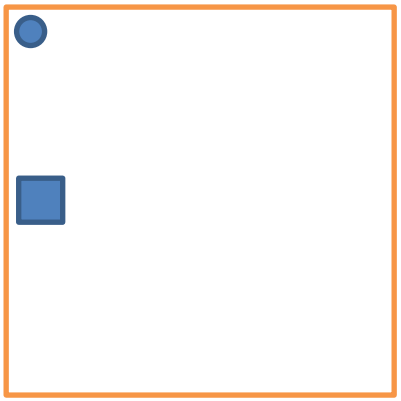
- When Wireless access points position is a constant and its in a corner of the room



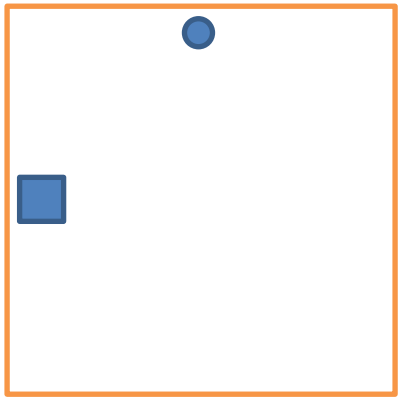
Scenarios – Set 3

- When Wireless access point's position is a constant and its in a middle corner of the room

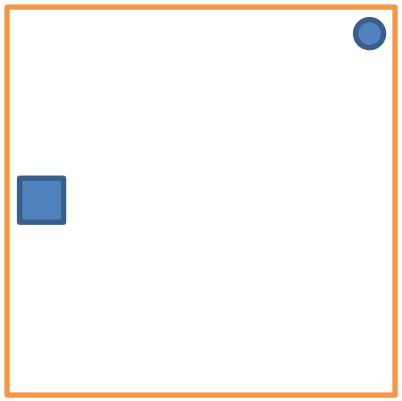
Wireless access point Data gathering computer



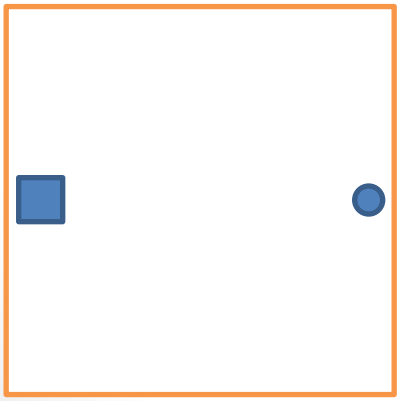
Scenario 13



Scenario 14



Scenario 15



Scenario 16

Gathering Data

- Received Signal Strength is gathered from scenarios mentioned earlier.

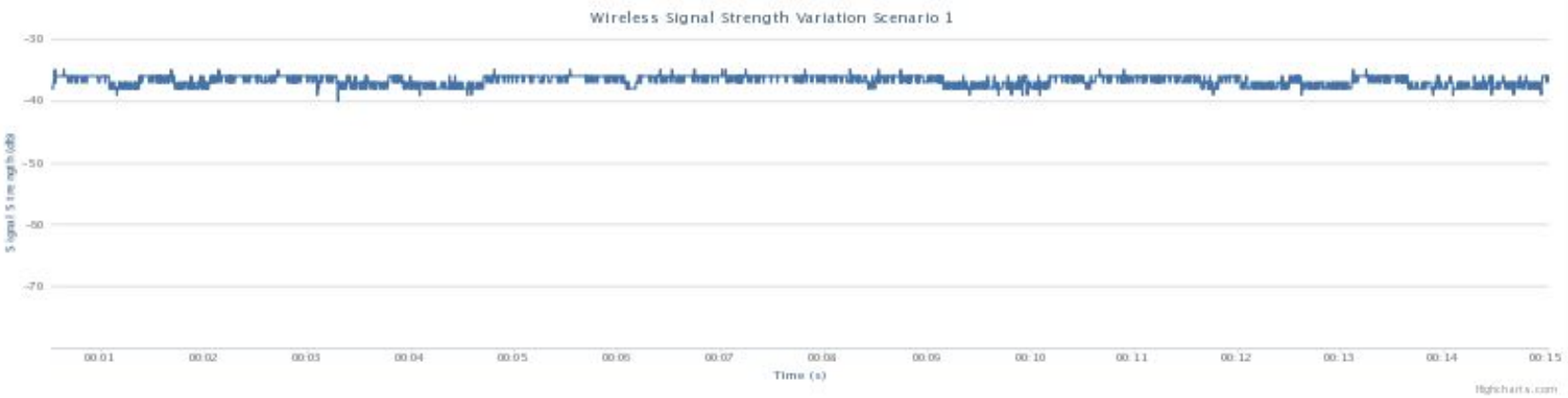
Wireless Access Point

Laptop

- Using a python script
  - http://recolog.blogspot.com/2015/03/plotting-wifi-signal-strength-variation.html
- 15 minutes of Received Signal Strength Data
- Approximately 6 samples per second (value every 0.166 ms)
- Received Signal Strength Data is saved to a text file

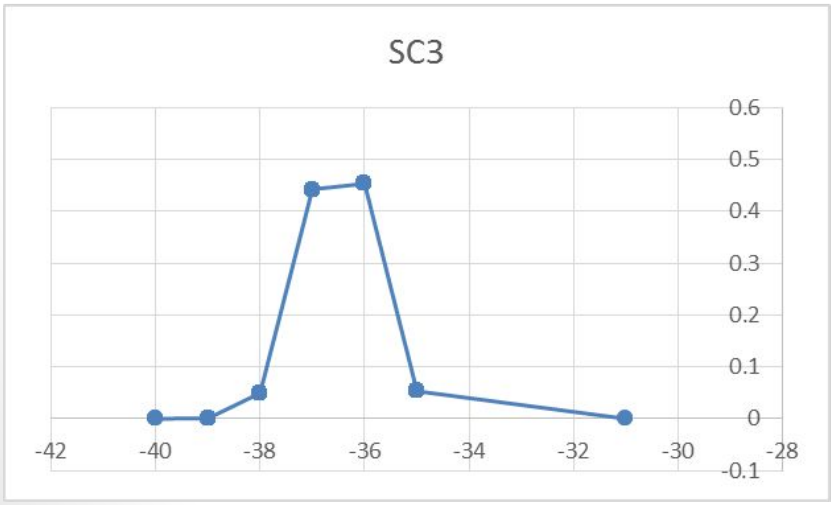
Analyzing Data

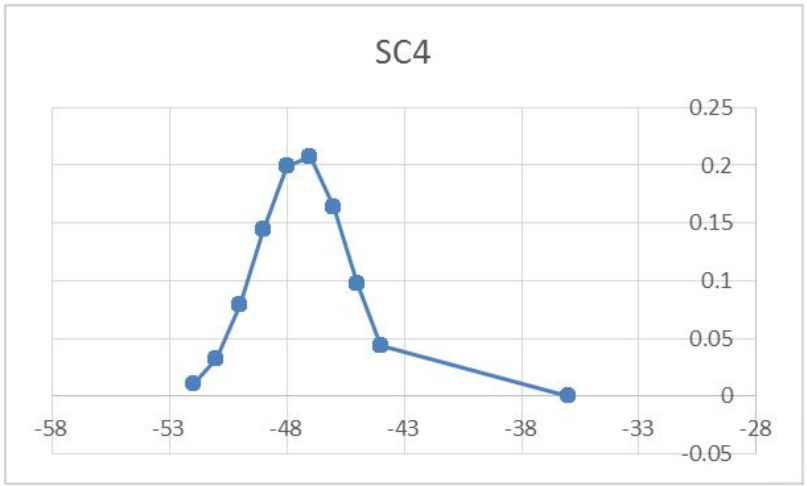
- Plot signal strength values in a graph for scenario 1



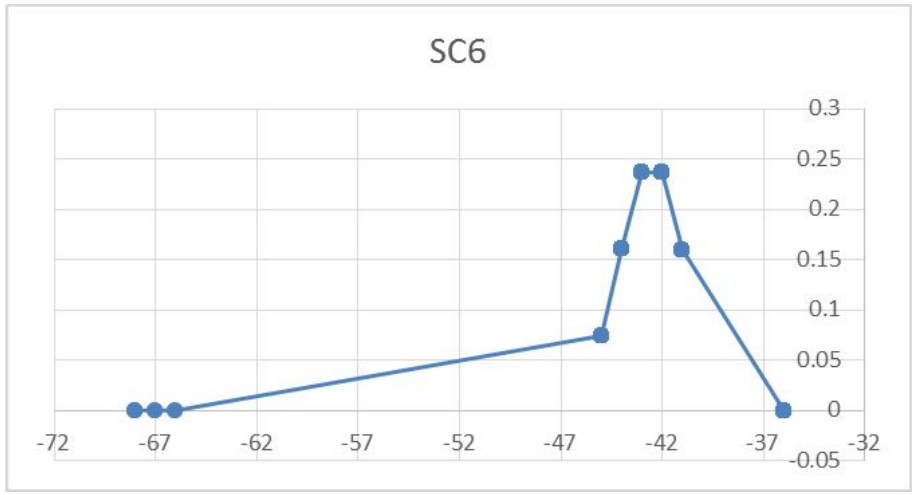
- Draw normal distribution graphs for each scenario
  - X axis = Signal Strength in db
  - Y axis = Density of probability (the chance of obtaining values near corresponding points on the X-axis)

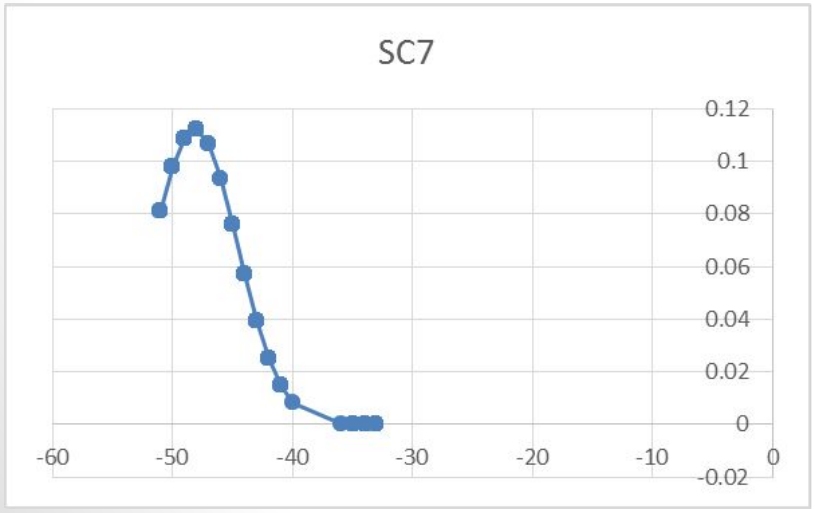
Normal Distribution Graphs Set 1

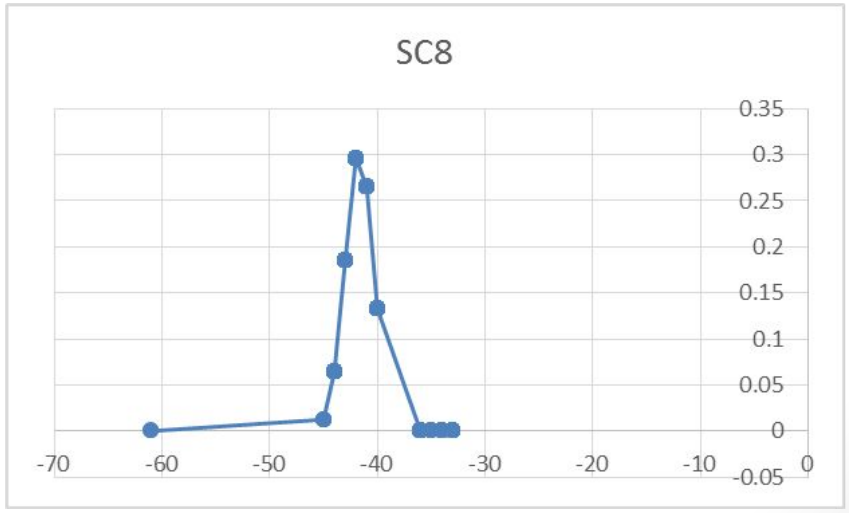




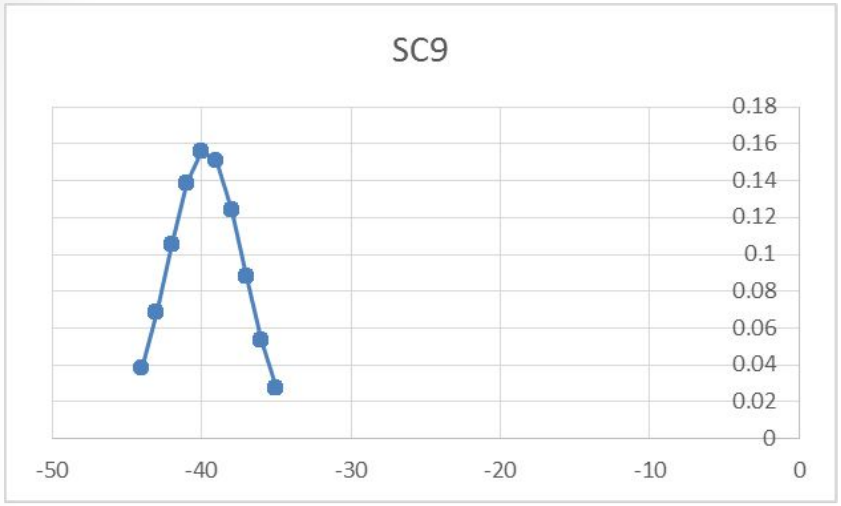
Normal Distribution Graphs Set 1 Contd…

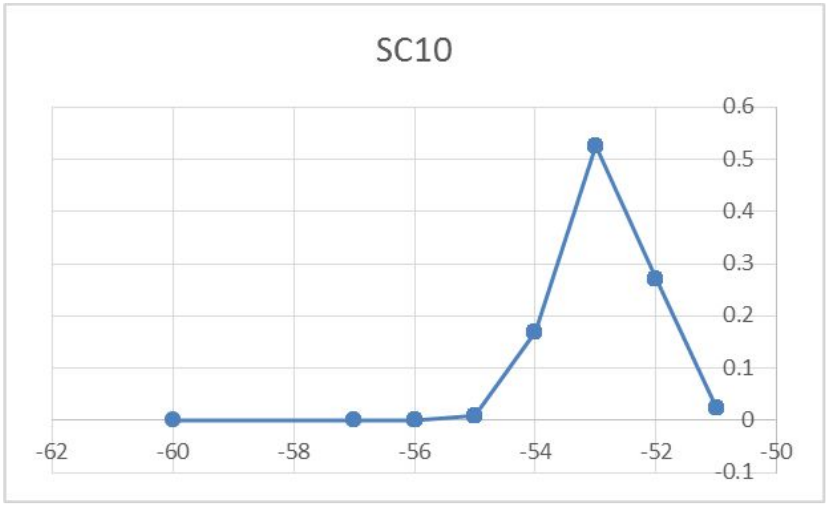


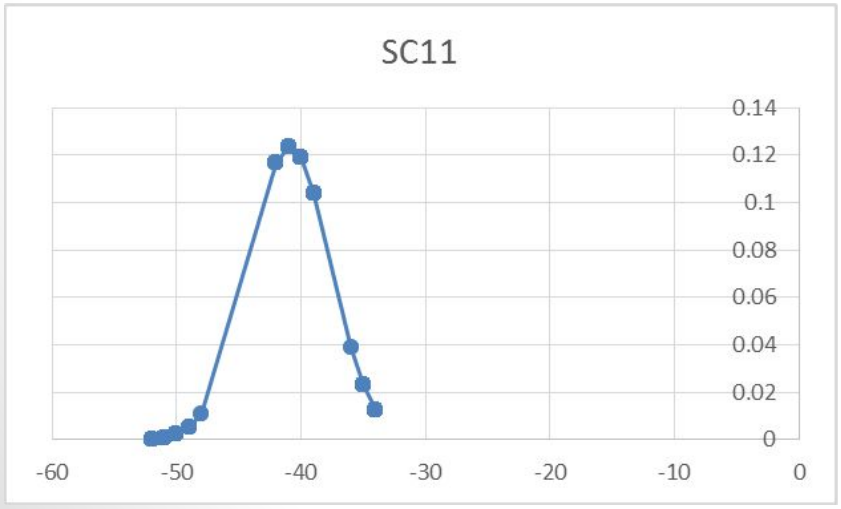


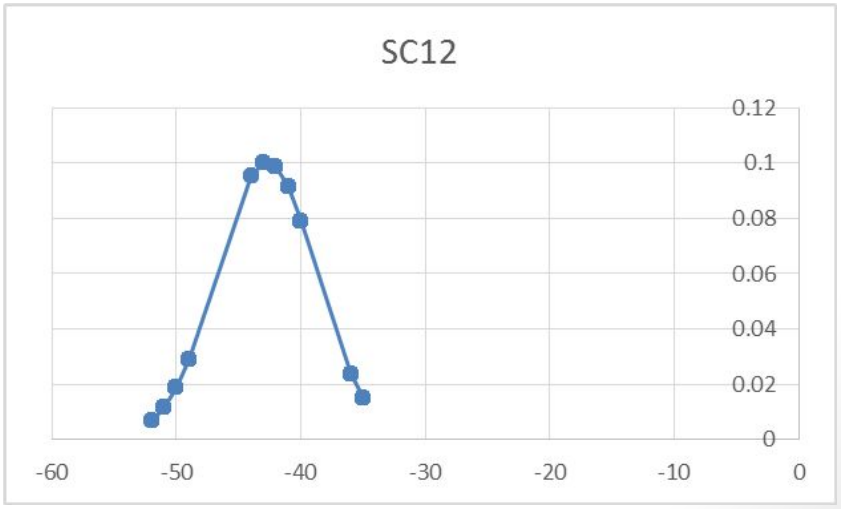


Normal Distribution Graphs Set 2

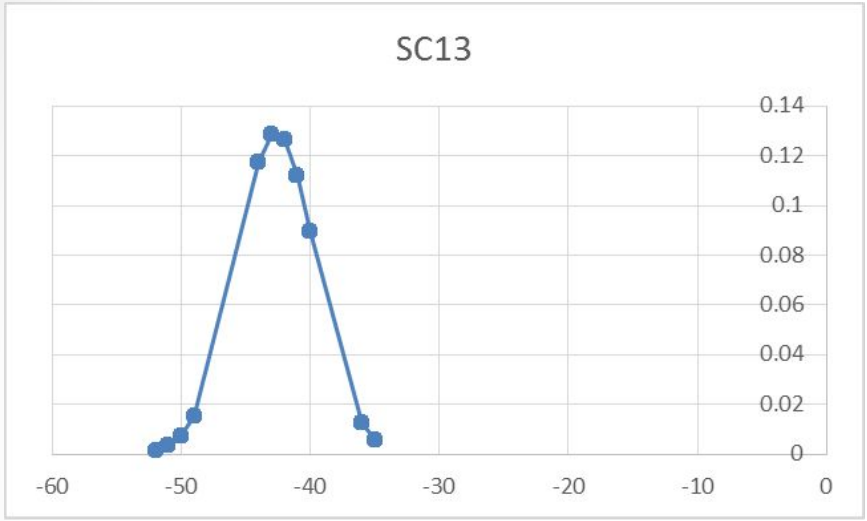


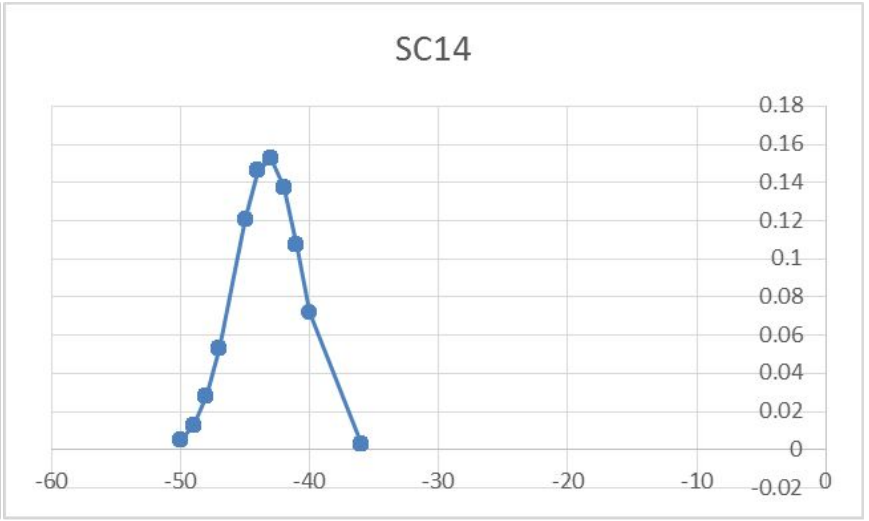


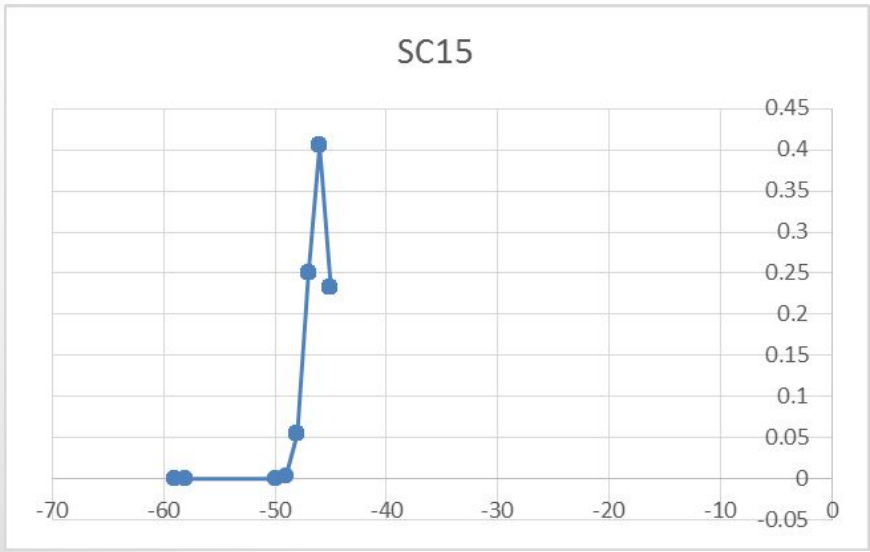


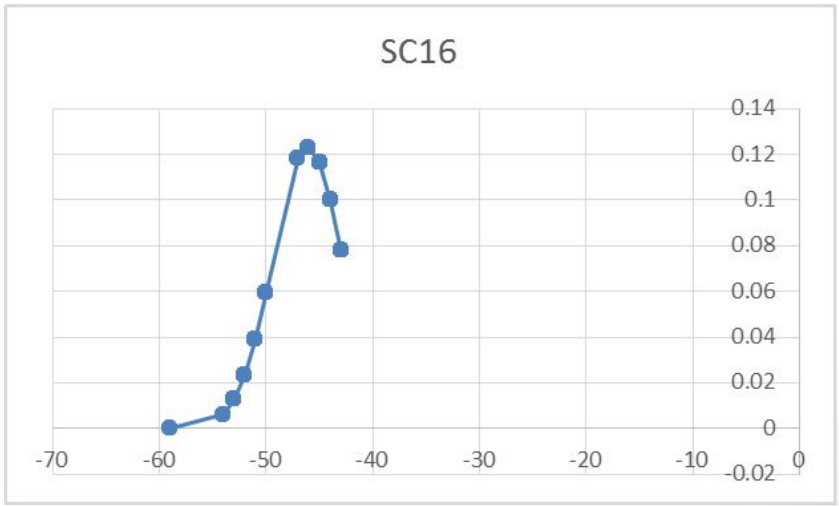


Normal Distribution Graphs Set 3









Initial Analysis Results

- We are seeing a different distribution patterns and distribution peaks for the different scenarios.
- Possible to continue the project forward
- Randomly select scenario 12
- scenario 12 will be introduced by a human object and sub scenarios will be designed based on scenario 12

Design phase 2

- Creating advance scenario sets to gather data
- Try to make them as close as possible to real world situations
- Three variables
  - Wireless access point
  - Data gathering computer
  - Human object
- At any given time two of these are constant

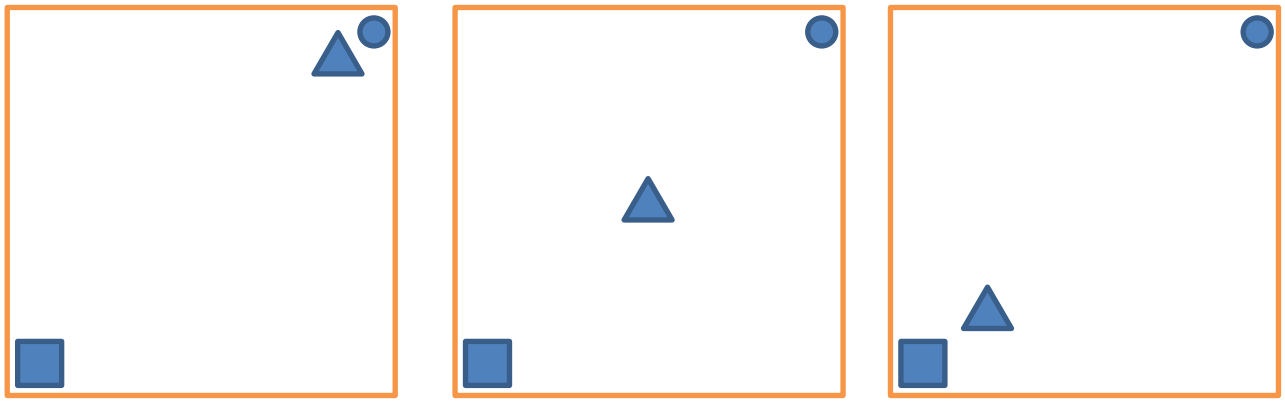
Scenarios – Set 4

- From above scenarios we randomly select scenario 12 and place a human between Wireless access point and Data gathering computer

Wireless access point Data gathering computer

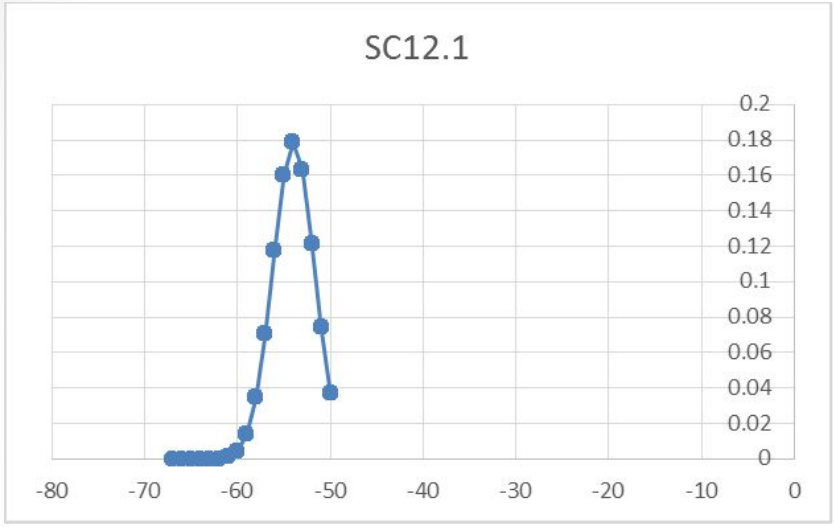
Human

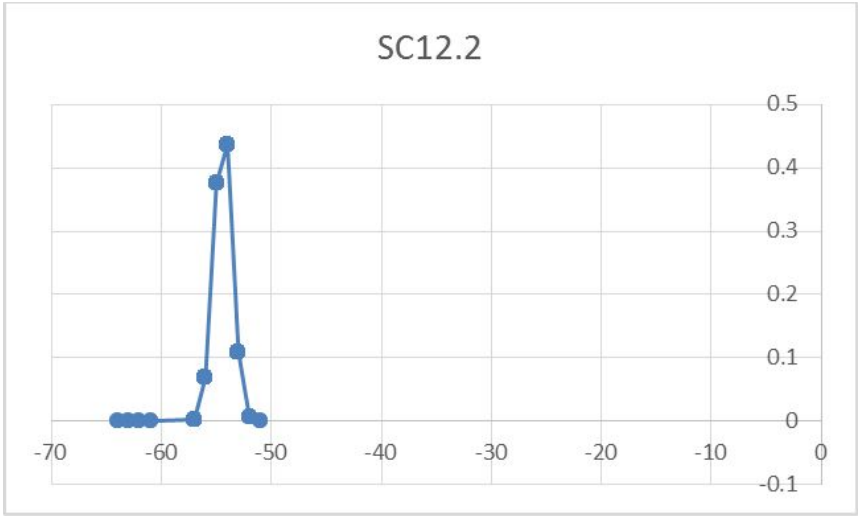
- Here position of Wireless access point and Data gathering computer is constant and human position is the variable

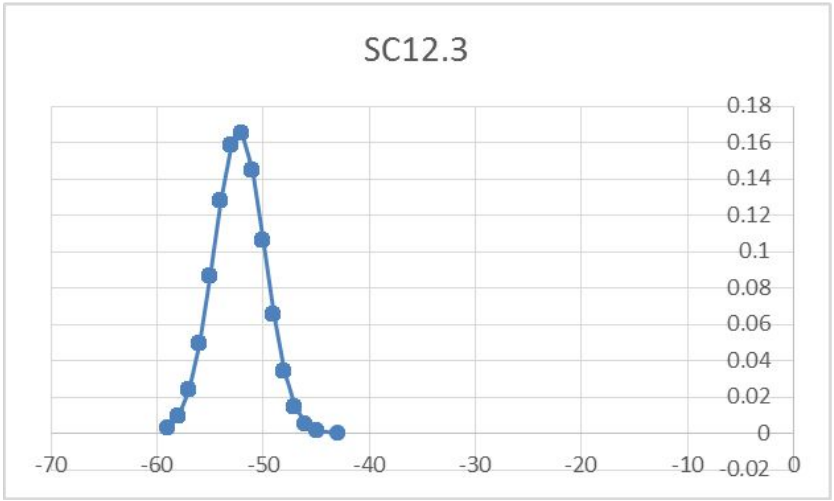


Scenario 12-1 Scenario 12-2 Scenario 12-3

Normal Distribution Graphs Set 4







Answering Research Question 1

- to answer first research question we use a statistical approach
- statistical hypothesis testing
- is an assumption about a population parameter. This assumption may or may not be true. Hypothesis testing refers to the formal procedures used by statisticians to accept or reject statistical hypotheses.
- Building the hypothesis
  - Null hypothesis – H_0 = there is no change to amount of wireless signal strength when there is a human and no human inside the line of sight of the wireless access point and data gathering computer
  - Alternative hypothesis – H_1 = there is a significant amount of wireless signal strength drop when there is a human inside the line of sight of the wireless access point and data gathering computer

Answering Research Question 1..

- Proving the hypothesis with regard to scenario 12
  - Using a 0.05 level of significance
  - Calculate values

Scenario	Mean (db)	T-Test value
Scenario 12	-42.78019231	-
Scenario 12 - 1	-53.95653846	0
Scenario 12 - 2	-54.40423077	0
Scenario 12 - 3	-52.2975	0

  - Null hypothesis: $\mu = -42.78019231$
  - Alternative hypothesis: $\mu \neq -42.78019231$
- The t-value is t = 0. This is below the .05 standard, so the result is statistically significant for all scenarios

Answering Research Question 2

- To answer second research question we use a probability based approach
- Normal Probability Density Function
- Can get the occurrence probability of a value in a distribution
- Again we are using the scenario 12 and its sub scenarios
- take the RSSI value with highest frequency from these scenarios and calculate the occurrence probability

Scenario	RSSI value with highest frequency (dBm)	Occurrence probability
Scenario 12	-42	0.577422691
Scenario 12 - 1	-53	0.665829879
Scenario 12 - 2	-54	0.692344273
Scenario 12 - 3	-51	0.705490974

Answering Research Question 2 …

- Results show that the occurrence probability and the highest frequency value differ when the human is moved in line-of-sight of the wireless access point and the data gathering computer
- With more than 50% confidence level we can derive the position of the human
- Proves by using radio tomographic methodologies can be used to violate privacy of an individual even without him knowing that he is being tracked

Conclusion

- Study opened a new area in the field of radio tomography
- Both research questions got the answers
- First research question used the statistical hypothesis testing
  - Statistical hypothesis testing uses mean and standard deviation to prove or disprove the concepts
  - For scenarios 12, 12.1, 12.2 and 12.3 [mean, standard deviation] [-42.78019231 dBm, 3.994749386] , [-53.95653846 dBm, 2.232675289] , [-54.40423077 dBm, 0.804429328], [-52.2975 dBm. 2.401623461]
  - From these results mean is different for all the scenarios.
  - After calculating the T-Test value it is 0;
  - proved that there is indeed a significant level of RSSI level drop when there is a human obstructing the line of sight and it can be easily identified

Conclusion

- Second research question is to localize the human obstacle to identify his whereabouts.
- Used probability based approach.
  - Using the normal probability density function to calculate the occurrence probability of the highest occurrence of RSSI values
  - Occurrence probability of a RSSI value is unique to a specific scenario
  - scenario 12 the highest occurrence RSSI value is -42dBm with an occurrence probability of 0.577422691, scenario 12.1 -53 dBm and 0.665829879, scenario 12.2 -54dBm and 0.692344273, scenario 12.3 -51dBm and 0.705490974.
  - can determine a person's location with more than 50% probability

Future works

- Expansion of the researching environment
  - Extending to the outdoor environments as well as in hybrid situations by converging both indoor and outdoor environments.
- Error correction for environmental factors
  - Effects on a wireless signals by weather factors like wind, temperature and humidity.
- Errors due to radio noise levels
  - Radio noises in the environment
  - Not a constant it keeps on changing
- Human fingerprinting to uniquely identify a person
  - Analyze signal level drops by individuals
  - Fingerprinting different people using signal level drops that are unique to them.

Future works Contd...

- Real-time framework to identify human presence
  - This study uses offline methods for analyzing
  - Analyze data in real time to get the outputs.
- Auditing framework to identify privacy breach points in a typical environment

Questions?

Thank You!