innerspace

How InnerSpace Uses Enhanced Indoor Localization with Predictive Hyperbolic Location Fingerprinting (PHLF)

Executive Summary

Traditional triangulation methods for indoor localization, while foundational, often fall short in complex indoor environments due to their reliance on line-of-sight signals and the inherent variability of radio frequency propagation indoors.

InnerSpace introduces an innovative approach to indoor localization through Predictive Hyperbolic Location Fingerprinting (HLF), a method that not only addresses the limitations of triangulation but also sets a new standard for accuracy, stability, and scalability in indoor positioning systems.

Introduction

The accuracy of indoor localization impacts a wide array of applications, such occupancy tracking and space utilization services within large facilities. Traditional methods, such as triangulation (sometimes referred to a trilateration), have provided a baseline for indoor positioning. However, the dynamic nature of indoor environments, coupled with the limitations of these conventional methods, often leads to inaccuracies that can diminish the user experience and affect operational efficiency.

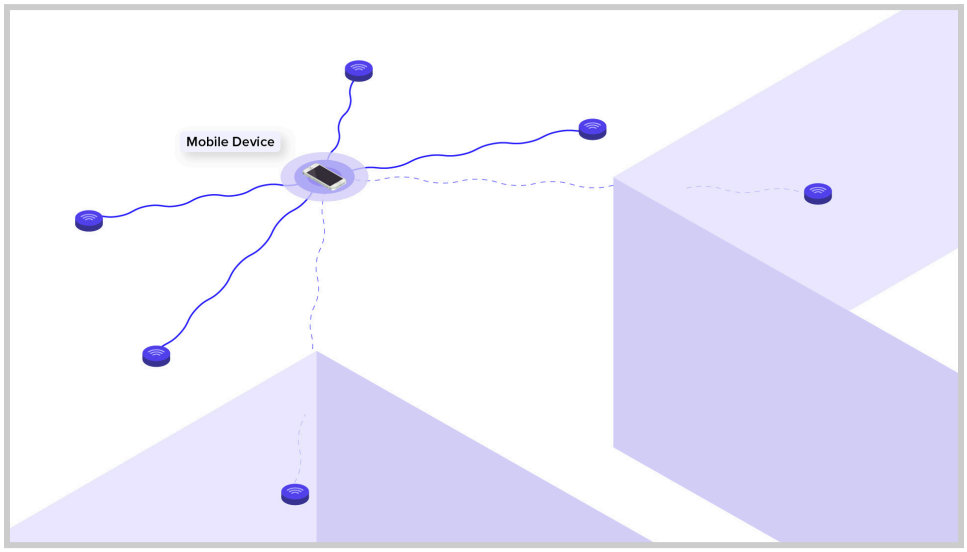
Limitations of Traditional Triangulation

Triangulation methods calculate an object's location based on the geometric properties of triangles formed between the object and known points. This approach, while effective in open, unobstructed environments, encounters significant challenges indoors:

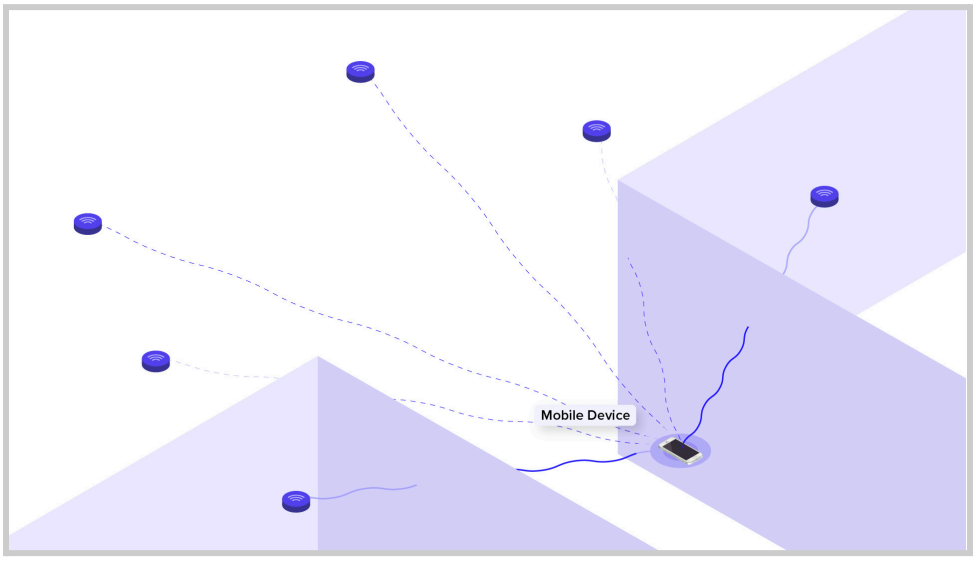
+ Multipath Interference: Signal reflection off surfaces causes multiple paths that can confuse the triangulation process.

+ Non-Line-of-Sight Conditions: Obstructions like walls and furniture can significantly attenuate or block signals.
+ Environmental Variability: Changes in the environment, such as the movement of people or alterations in the layout, can affect signal strength unpredictably.

As we see in the image below the device is attenuated by walls and other obstructions.



As the device moves through space the signal is further attenuated causing loss of location accuracy.



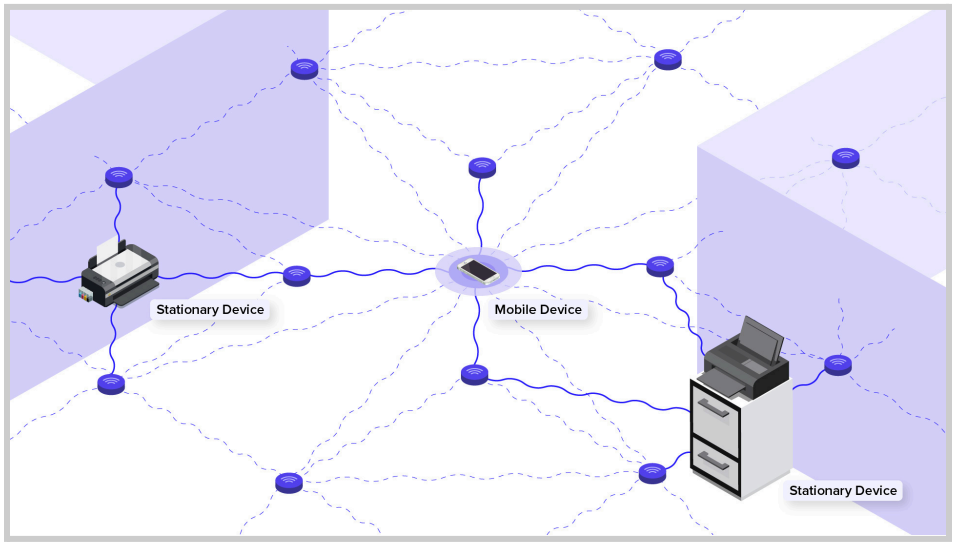
Predictive Hyperbolic Location Fingerprinting: A Novel Approach

InnerSpace leverages our patent-pending Predictive Hyperbolic Location Fingerprinting (PHLF) technology to overcome these challenges.

This method employs a predictive model based on the Received Signal Strength Indicator (RSSI) from multiple fixedly-positioned sensor devices in a 2D environment. Key components of this approach include:

+ RSSI Value Collection: Gathering RSSI values from a network of stationary sensors at known locations.
+ Fingerprint Generation: Creating both raw and log-ratio RSSI fingerprints for precise location mapping.
+ Normalization and Fusion: Enhancing accuracy through the normalization and combination of fingerprints into a comprehensive, predictive model.
+ Dynamic Adaptation: Continuously updating fingerprints to reflect changes in the environment, ensuring high accuracy over time.

What is an RSSI Fingerprint?

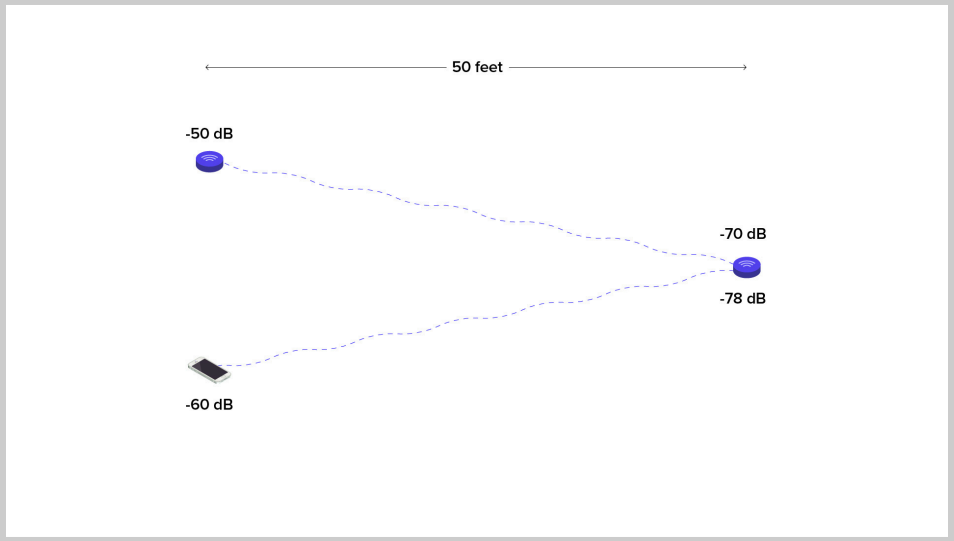


Signal strengths between Wi-Fi access points and devices vary depending on where they are located. The learning algorithm interprets these strengths and locates the device despite a noisy

signal environment. Areas with weak signal strengths are accounted for through the use of stationary devices. Once the environment is calibrated, an RSSI fingerprint is established.

Prediction

Signal loss over distances are predicted, for example over a 50 foot radius, a device is shown to attenuate at a lesser signal than the original output.



Advantages Over Triangulation

Predictive HLF offers significant advantages over traditional triangulation methods:

+ Improved Accuracy: By utilizing RSSI fingerprints and predictive modeling, HLF can more accurately determine locations in complex environments.
+ Stability in Dynamic Environments: The method's predictive nature allows it to adapt to environmental changes, maintaining high accuracy where triangulation methods might falter.
+ Scalability: PHLF can be efficiently implemented in large-scale environments, utilizing existing WiFi infrastructure without the need for extensive additional hardware.

Implementation and Use Cases

InnerSpace's Predictive HLF (PHLF) technology is versatile, supporting a range of applications:

+ Occupancy Insights: Providing data to identify how many people are in a space, plus the occupancy percentage in terms of the space's capacity.
+ Utilization Data: Data that provides information on the number of minutes a space was occupied by more than one person divided by the total time the space was occupied.
+ Groups: Providing data on how groups and teams use spaces.
+ Dwell time: Identifying how long people stay in a space.
+ Pathways: Identifying the flow of traffic between indoors spaces.

Accuracy

Formal testing was conducted with our partner Arista. We tested a device under several conditions that it would experience in a real world scenario:

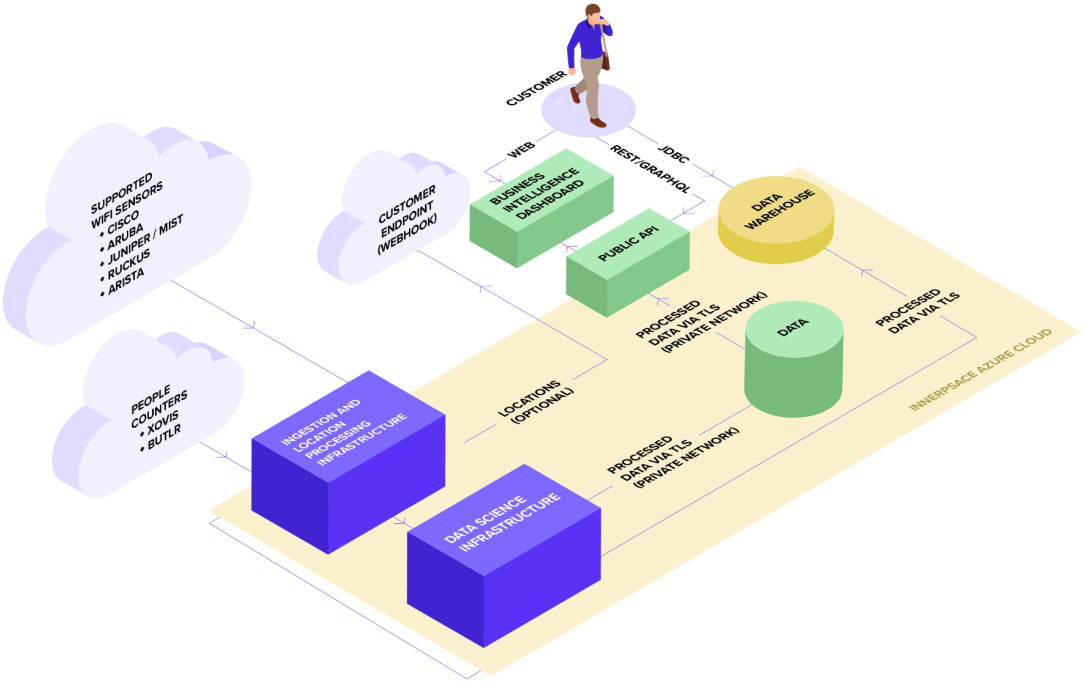
+ The device being located had a clear line of sight to all 4 APs (good conditions).
+ The device being located had clear line of sight to none of the 4 APs (not as good condition, as signal attenuation is introduced).
+ The device being located had a clear line of sight to some but not all APs (worst case conditions).

Under scenario 1, we achieved 1.3M accuracy 90% of the time. This means that 90% of the locations predicted were within 1.3M of the ground truth. 99% of the results were within 1.6M of the ground truth. The average error for all tests run in these conditions was 88 +/- 5 cm.

Under scenario 2, our approach achieved 2M accuracy 90% of the time. If we look at the 99th percentile results, performance dropped off to 4.5M accuracy. However, across all the tests run under scenario 2 conditions, the average error was 1.5M +/- 10cm.

Under scenario 3, our approach performed the worst of all conditions as expected, achieving 5.5M accuracy 90% of the time, with an average error across all tests in the scenario at 4.7M +/- 12cm.
Given the average of all the test conditions we conservatively estimate 2M accuracy 90% of the time.

InnerSpace Core Architecture



Conclusion

Predictive Hyperbolic Location Fingerprinting represents a significant advancement in indoor localization technology. By addressing the limitations of traditional triangulation methods, InnerSpace's approach ensures more reliable, accurate, and scalable indoor positioning solutions. This technology not only enhances operational efficiency and safety but also opens new avenues for innovation in indoor services and analytics.

About InnerSpace

InnerSpace is at the forefront of indoor localization technology, developing solutions that transform the way organizations understand and interact with indoor spaces. Our commitment to innovation drives us to solve the complex challenges of indoor positioning, delivering value across various applications and industries.

Interested in learning more about InnerSpace?

+ Security
+ Privacy
+ Wi-Fi Integration

Contact us for more information

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