Wi-Fi and Indoor Localization

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Contents

- Introduction
- How Wi-Fi Location System Works?
- Received Signal Strength Indication (RSSI)
- Process of Determining Users Position using Wi-Fi
- Applications of Wi-Fi and Indoor Localization
- Advantages of Wi-Fi and Indoor Localization
- Limitation Wi-Fi and Indoor Localization.

Introduction

- In recent years Wi-Fi positioning system (WPS) has found more and more applications in many spheres.

- It is used not only outside but also inside buildings where GPS navigation can’t work properly because of signal blocking, the multiplicity of paths, and some other reasons.

- Wi-Fi provides the exact location of objects and persons, which helps to optimize Industry, business processes.

Source: https://navigine.com/blog/wifi-for-indoor-positioning-and-navigation/

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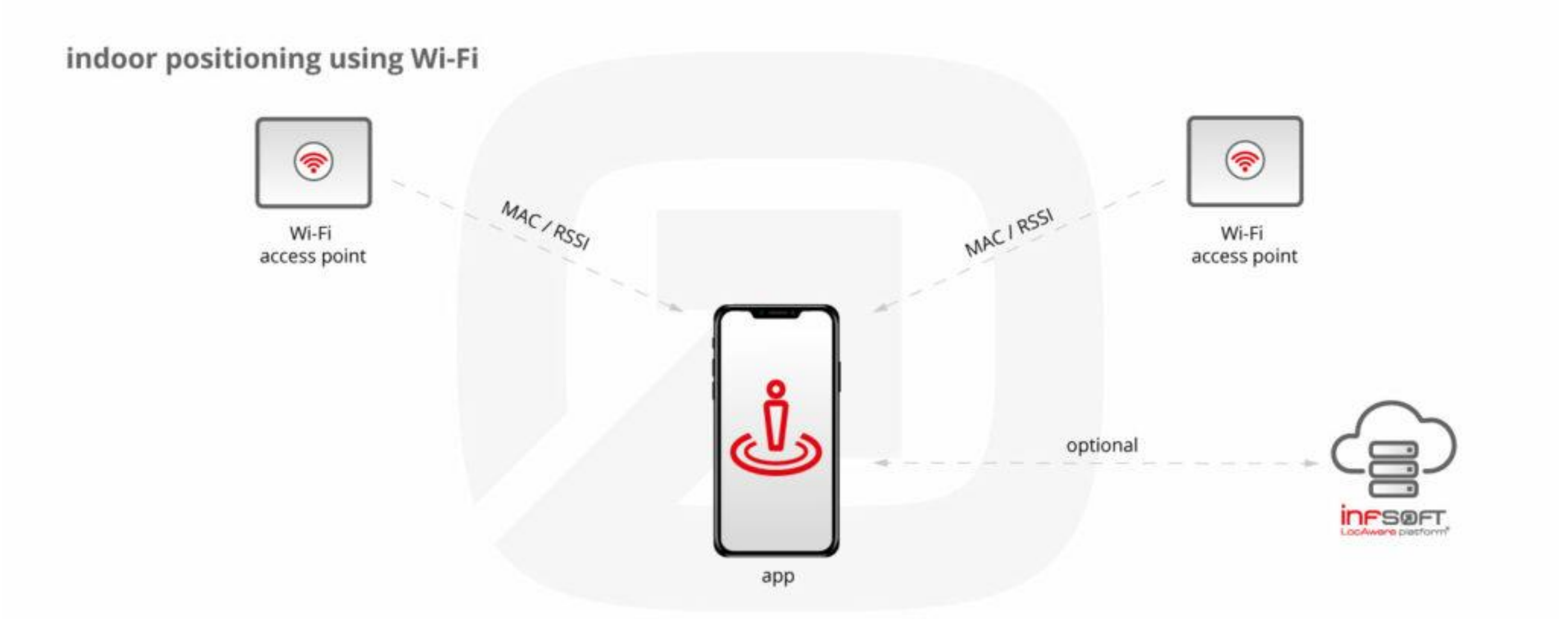
How Wi-Fi Location System Works?

- The wireless indoor positioning system works by defining coordinates using Wi-Fi access points that can transmit certain data. Using the **RSSI** (received signal strength indicator) and MAC-address, the system can define exactly the current location of the user's device using the multilateration approach



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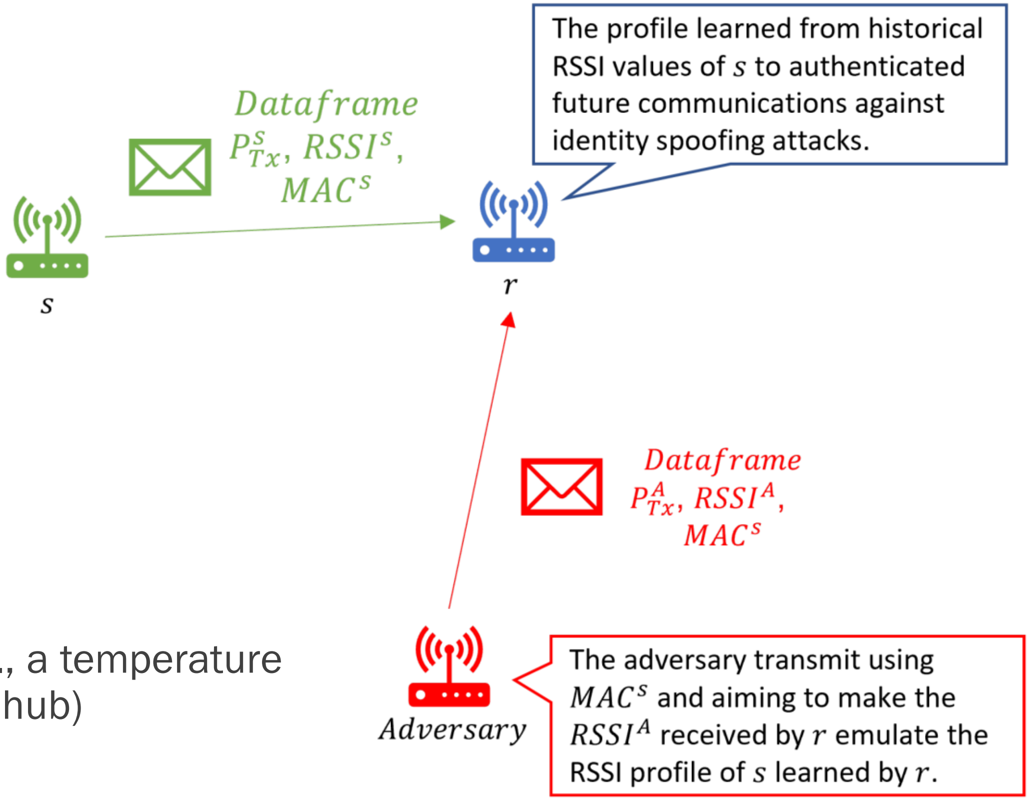
How Wi-Fi Location System Works?

- The accuracy of Wi-Fi positioning depends on the number of access points, the topology of the building, and the smartphone type. Modern Android-based smartphones could provide indoor positioning as precise as 2 - 3 m.

- Wi-Fi location sysem uses the entire Wi-Fi infrastructure that includes not only Wi-Fi routers, but also phones, tablets. By employing Wi-Fi access points, the system can easily define any Wi-Fi-powered devices' location and monitor their movement inside the building.



Note: From given fig, the s denotes legitimate transmitting node (e.g., a temperature sensor) and the r denotes the legitimate receiving node (e.g., an IoT hub) communicating over a wireless channel.

Received Signal Strength Indication (RSSI)

- Some devices, like smartphones and tablets, use RSSI to determine which Wi-Fi network they should connect to. RSSI is a measure of how well the receiver and transmitter antennas are matched.

- Use of RSSI (Received Signal Strength Indication):
  - It is a measure of the power or intensity of a radio signal.
  - It is a unit that measures the strength of a received radio signal.
  - It is a measure of the power of a radio signal that is received by a receiver, usually expressed in decibels relative to one milliwatt (dBm).

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Received Signal Strength Indication (RSSI)

- The RSSI value varies depending on the following factors:
  - The transmission power at which the device communicates;
  - The sensitivity of the receiver at that frequency;
  - The distance from transmitter to receiver.

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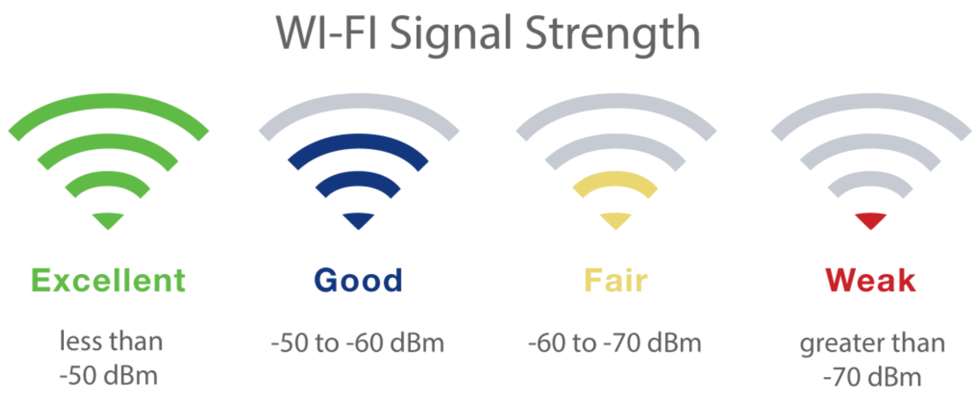
Received Signal Strength Indication (RSSI)

- A lower number indicates less power and a higher number indicates more power. If the RSSI is too low, then the signal will be significantly weaker than it needs to be. This can lead to dropped calls or text messages, slow internet speeds, or other issues.
- A high RSSI does not mean that you will have better connection than someone with a low RSSI, but it does mean that you are likely to receive better service in terms of voice calls, data, and texting (though this may depend on other factors such as surrounding interference or network congestion).
- The signal strength ranges from -60 dBm to -120 dBm.
  - -40 dBm usually corresponds to the best possible signal reception, while -100 dBm would be an unusable signal.
  - Since a larger negative dBm value means a weaker signal, therefore, -40 dBm is better value than -50 dBm.



Sourse: https://support.aquascapeinc.com/hc/en-us/articles/360055224992-How-to-Improve-Wi-Fi-Strength-for-Aquascape-Smart-Control-Products

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Process of Determining Users Position using Wi-Fi

- When using WIFI device requires the following information for calculation of distance.

1. The latitude and longitude
2. The relative position of device to each Wi-Fi, is calculated by making use of Wi-Fi frequency (usually 2.4GHZ) and signal strength as depicted in formula below.

$$10^{((27.55-(20*log(frequency))+signallevel)/20)}$$

This is modified free-space path loss formula where the frequency is in dBm and signal strength in megahertz.

3. The absolute position of a WIFI tower is also calculated using the above information (point 1 and 2).

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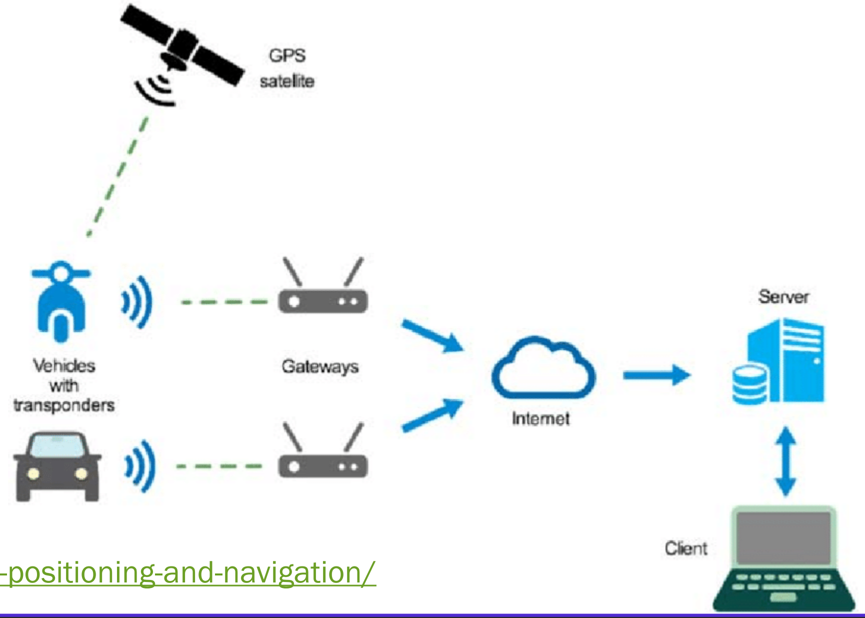
Applications of Wi-Fi and Indoor Localization

- Indoor location-based on Wi-Fi is used in many spheres – from **transport** and **logistics** to **industry**, **offices**, **exhibitions**, and **museums**.

- **Transport:**
  - The technology helps to optimize transport processes and lets passengers quickly find the route to the necessary place inside airports, railway stations. Using this system, it becomes possible to make interactive maps with points of interest, track people's flows, ensure staff navigation in traffic centers. Constant monitoring of passenger transportation enables to quickly react to changing conditions and improve the quality of passenger services.



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Applications of Wi-Fi and Indoor Localization

- **Logistics and Warehouses:**
  - The companies, which specialize in logistics and warehousing, can use Wi-Fi for positioning order pickers, vehicles, and cargo. The system provides detailed information on asset location and helps to automate many warehousing operations. Thanks to the constant navigation of the warehouse staff, it is possible to adjust daily tasks in real-time, increase efficiency, and timely react to emergencies.

Applications of Wi-Fi and Indoor Localization

- **Industry:**
  - The companies, which specialize in logistics and warehousing, can use Wi-Fi for positioning order pickers, vehicles, and cargo. The system provides detailed information on asset location and helps to automate many warehousing operations.
    - increase staff safety;
    - reduce costs on vehicle downtime;
    - decrease the number of emergencies;
    - adjust the routes of special vehicles in real-time;
    - perform analytics for making effective management decisions.

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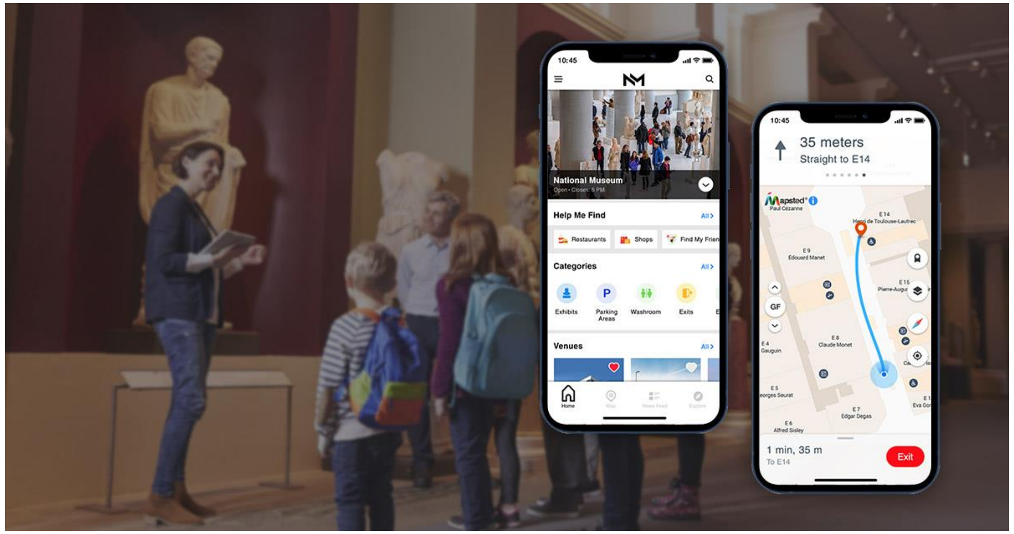
Applications of Wi-Fi and Indoor Localization

- **Offices:**
  - Wi-Fi can be successfully implemented in indoor positioning at large administrative buildings.
  - The wireless system can build step-by-step routes to the required office, send notifications and tips that depend on the person's location.
  - Thanks to the continuous gathering of information on movements in an office, it's possible to perform exact analytics and optimize the work of office systems.

Applications of Wi-Fi and Indoor Localization

- **Museums and exhibitions:**
  - Using Wi-Fi, you can create guides and mobile applications that will improve the performance of exhibitions and museums. The indoor wireless positioning system helps to build interactive maps of halls, develop the easiest and best routes to the required exhibit. The exhibition organizers can collect geodata on visitors and carefully study their behavior to plan expositions rationally.
  - Navigine offers a precise solution for Wi-Fi positioning systems. With our help, you get an accurate and functional tool for positioning that can be effectively implemented in your mobile applications (Android, iOS).



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Wi-Fi and Indoor Localization Limitations

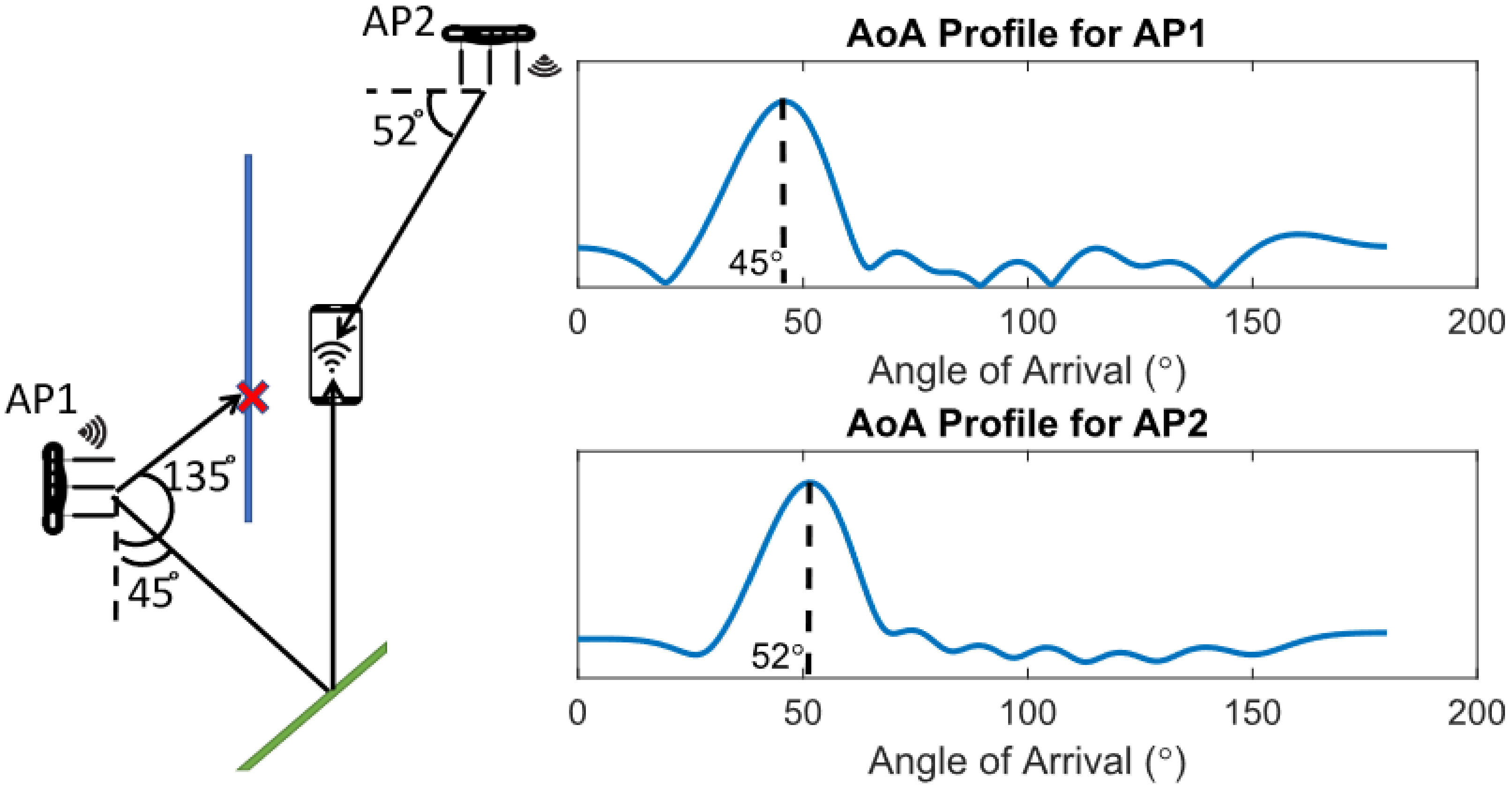
- Wi-Fi RSSI-based positioning works well for Android devices. However with the latest Android version (see table below) there are some changes that limit Wi-Fi scanning capabilities.

OS version	Wi-Fi Scanning Frequency	Wi-Fi Throttling	Pure Wi-Fi Positioning Accuracy	Indoor positioning accuracy (Wi-Fi + inertial sensors)
Any iOS device	N/A	N/A	N/A	N/A
Android 8 and earlier	1 sec	-	3-5 m	2-3m
Android 9	4 times / 2 min	+	10-30 m	8-15 m
Android 10	4 times / 2 min	+/-	10-30 m	8-15 m
Android 11	4 times / 2 min	+/-	10-30 m	8-15 m

Note: Unfortunately, it is not possible to use Wi-Fi for indoor positioning on **iPhones/iPads as Apple** prevents applications from getting Wi-Fi environment data due to privacy concerns.

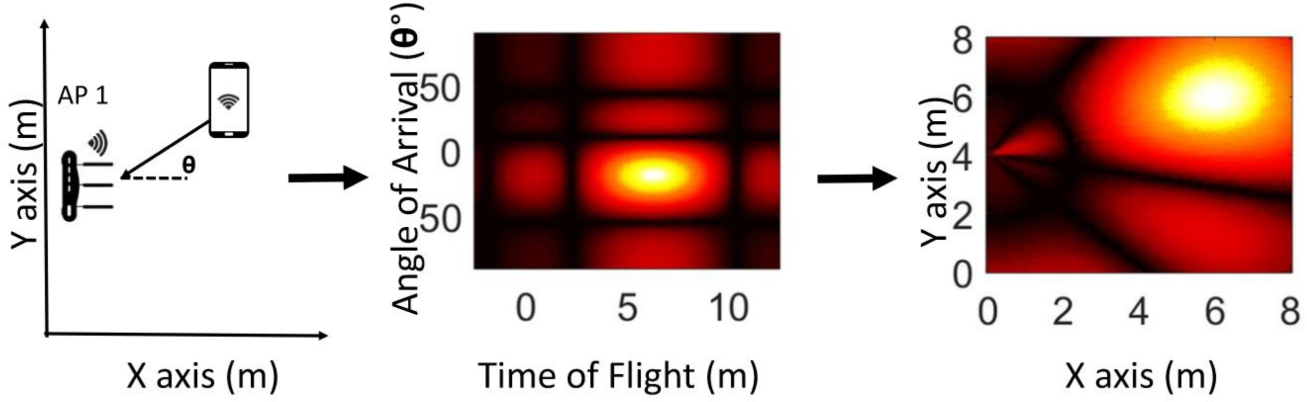
DL based WiFi Localization for Indoor Navigation

- Traditional localization approach:

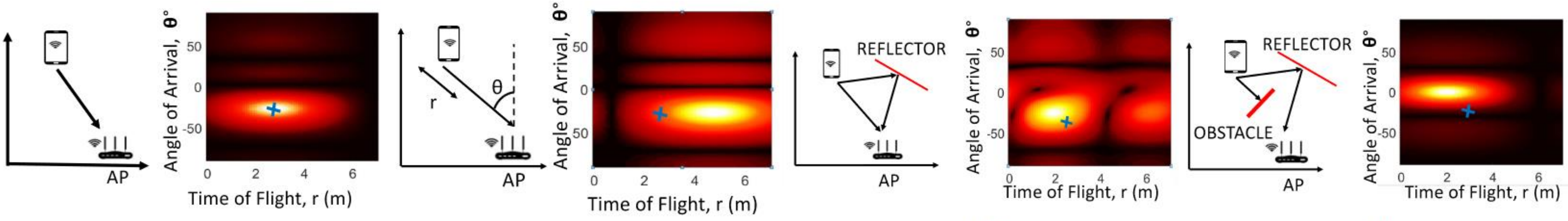


DL based WiFi Localization for Indoor Navigation

- DL approach:



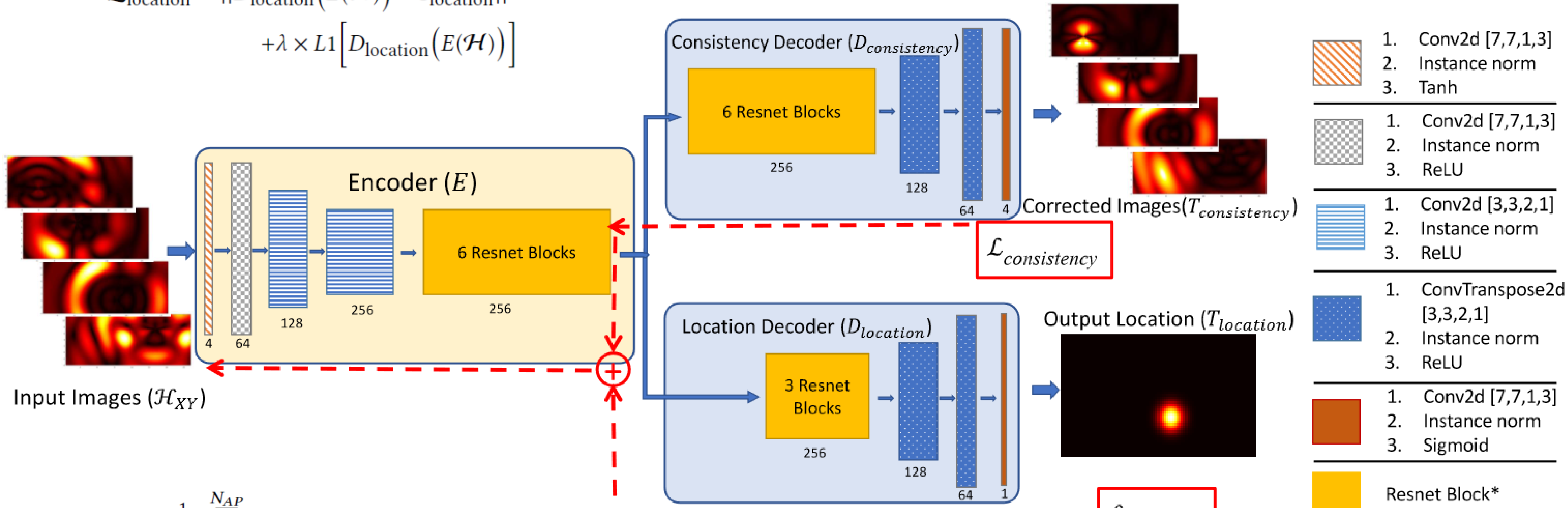
Challenges: DLoc needs to counter three error-inducing effects. First, random time-of-flight (ToF) offsets shift the ideal image (a) along the ToF axis (shown in (b)). The presence of reflectors add spurious peaks, as shown in (c). Finally, in (d), the absence of direct path makes the user device appear at a wrong location, in both angle and distance axes. (`x’ denotes the actual location.)



(a) (b) (c) (d)

DL based WiFi Localization for Indoor Navigation

$$\mathcal{L}_{\text{location}} = ||D_{\text{location}}\left(E(\mathcal{H})\right) - T_{\text{location}}||^2 + \lambda \times L1\left[D_{\text{location}}\left(E(\mathcal{H})\right)\right]$$



$$\mathcal{L}_{\text{consistency}} = \frac{1}{N_{AP}} \sum_{i=1}^{N_{AP}} ||D_{\text{consistency}}\left(E(\mathcal{H})\right) - T_{\text{consistency}}||_i^2$$

Mobicom’20

Thank you

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