An Example of Indoor Positioning Possibility Using WiFi Network and Mobile Phone

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Presentation outline

- Introduction
- Indoor positioning algorithms
- WiFi in indoor positioning
- Positioning in FERIT building
  - Measurements and analysis
  - Positioning
- Conclusions and future work

Introduction

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- In **outdoor environment** different types of **global navigation satellite systems** (GNSS) are used for the purposes of precise navigation and localization (GPS, Galileo, GLONASS, Beidou).
- These services require **line of sight (LoS)** between the satellite and the receiver.
- Localization based on GNSS is in most cases **unavailable** in indoor environments.
- At the same time, there is an increased need for **precise indoor localization** in different environments and applications (e.g. large buildings, garages, shopping malls, industrial plants).
- Indoor localization mechanisms are in most cases used to **improve the experience** of the user and **raise the quality** of different services.

Indoor positioning algorithms

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- Indoor localization mechanisms are in most cases based on **wireless technologies**, such as Bluetooth, RFID (radio frequency identification device), UWB (ultra-wideband) and WiFi.
- Localization techniques may utilize **different aspects and parameters of wireless signal**, such as the angle of arrival (AoA), time of flight (ToF), return time of flight (RToF), and received signal strength (RSS).
- Although localization techniques can be oriented towards tracking various items and resources, the emphasis here is on **tracking user devices** (smartphones) which is then equated with **tracking users**.

Indoor positioning algorithms

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- **Time of arrival (ToA)** involves measuring the signal transmission time between transmitter and receiver, requiring precise synchronization (the transmitted signal includes timestamp which enables receiver to calculate the transmitter distance).
- **Time difference of arrival (TDoA)** algorithm measures the propagation time difference between the transmitter and the multiple base stations (access points) and calculates the distance difference from the time difference.
- **Angle of arrival (AoA)** algorithm is based on estimation of the signal reception angles from multiple base stations (access points) at known locations.
- **Received signal strength (RSS)** method estimates the distance from the measurement of signal strength attenuation.

Indoor positioning algorithms

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Algorithm	Advantages	Disadvantages
TOA	Most accurate	Requires precise time synchronization; complex implementation; expensive
TDOA	Only base stations require synchronization	May be affected by multipath propagation
AOA	No need for synchronization (timing information encoded into signal)	Requires additional antennas, may be affected by multipath propagation and reflections; accuracy significantly decreases with distance
RSS	Simple for implementation; do not require any additional hardware	May be affected by obstacles (that have influence on attenuation)

Indoor positioning algorithms

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- RSS may employ the **propagation model algorithm** or the **fingerprinting algorithm**.
- **Propagation model algorithm** connects the RSS and the distance (multipath propagation, reflection, refraction may negatively affect accuracy).
- **Fingerprinting algorithm** relies on comparison and matching of some characteristic of a signal (such as RSS) with previously constructed maps (in training stage radio signatures at different locations are collected and stored for later comparison and matching).
- **Offline stage (training stage):** the RSS values of the available access points are collected for every position (cell) for a certain period to create the radio map.
- **Online stage (serving stage):** currently observed RSS is compared with previously recorded data in order to estimate the position according to closest matching.

WiFi in indoor positioning

- **WiFi** is common name for the **IEEE 802.11 standard**, which is widely used to provide network connectivity to different types of user devices (e.g. smartphones, laptops).

- There are several facts that support **the use of WiFi for indoor localization**:
  - It is a very widespread and ubiquitous standard for wireless local networking
  - It is supported by a very large number of user devices
  - In its work (in infrastructure mode) it relies on access points, which are in known fixed locations and can be used as reference points

Positioning in FERIT building

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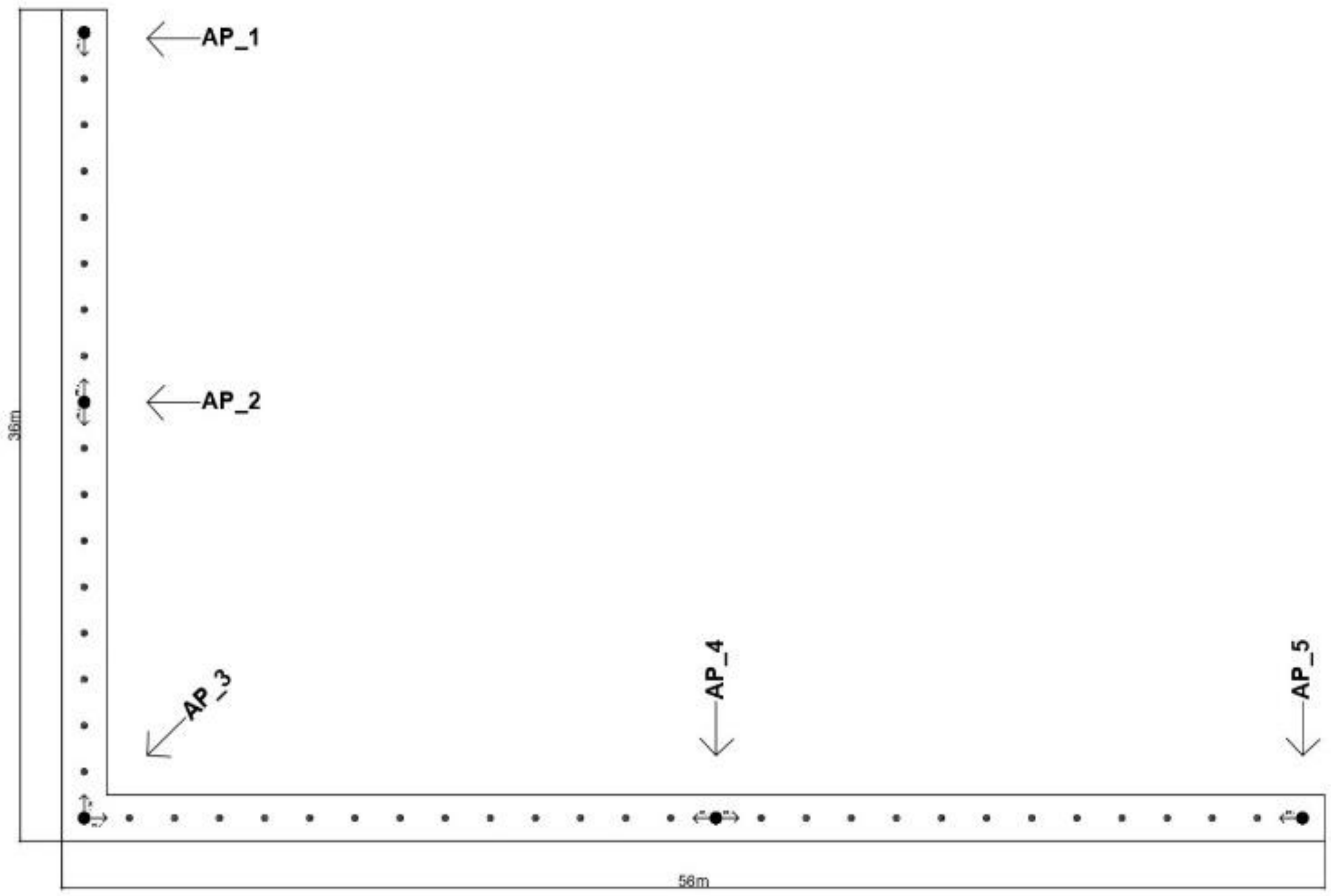
- **Five access points** (AP1-AP5) are arranged in an L-shaped corridor.
- **Measuring points** are located **every two meters** from each AP in both directions along the corridor.
- The **signal strength** was measured by using a **smartphone** with the **WiFi Analyzer** application.
- Despite the lower accuracy compared to specialized measuring equipment, the mobile application was used to measure the received signal strength since the idea is to use a smartphone for localization purposes.

Positioning in FERIT building



Positioning in FERIT building

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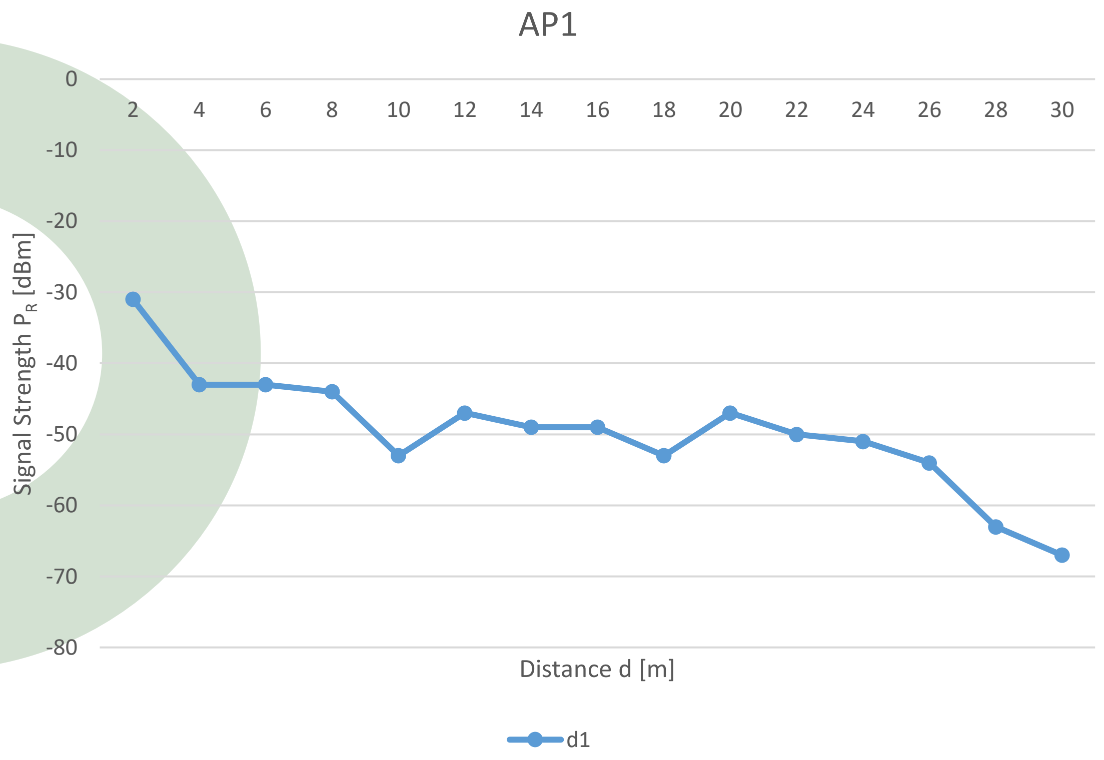
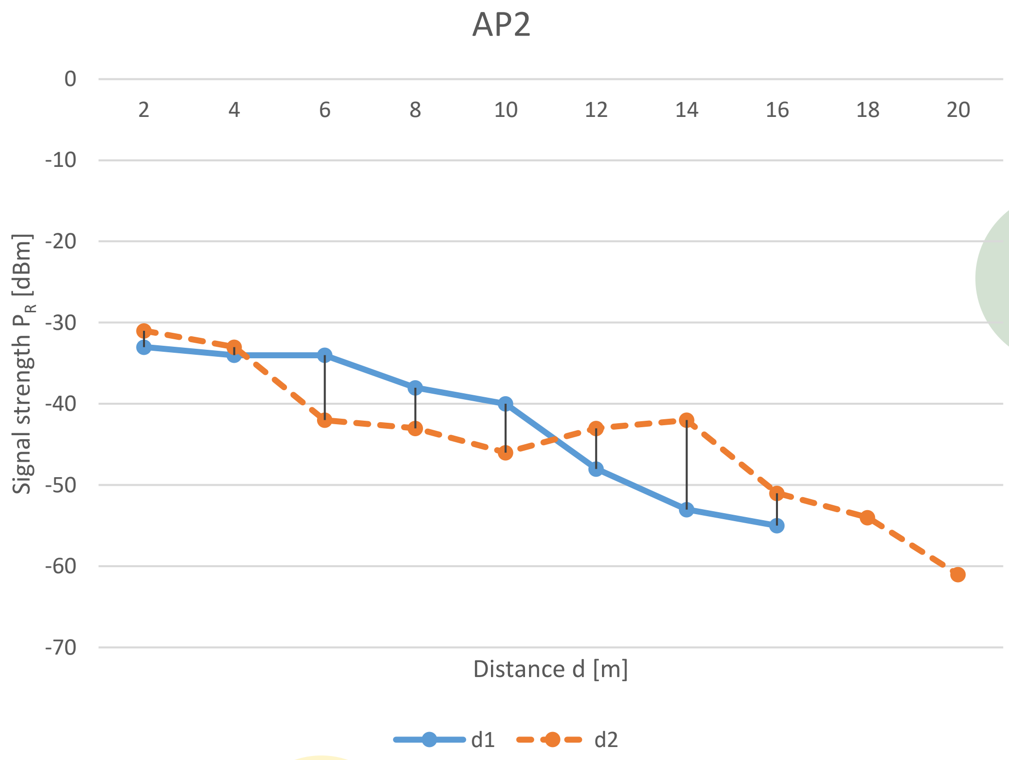
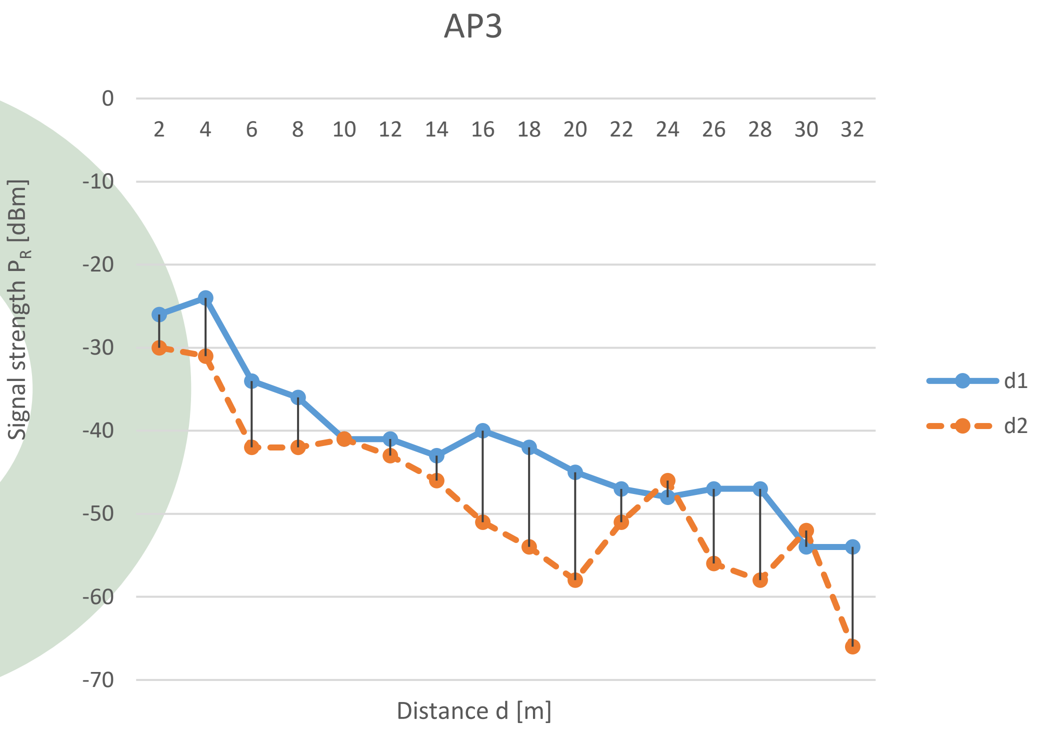
d[m]	P_R [dBm] (AP1-d1)	P_R [dBm] (AP2-d1)	P_R [dBm] (AP2-d2)	P_R [dBm] (AP3-d1)	P_R [dBm] (AP3-d2)	P_R [dBm] (AP4-d1)	P_R [dBm] (AP4-d2)	P_R [dBm] (AP5-d1)
2	-31	-33	-31	-26	-30	-28	-35	-28
4	-43	-34	-33	-24	-31	-27	-41	-30
6	-43	-34	-42	-34	-42	-35	-42	-40
8	-44	-38	-43	-36	-42	-43	-41	-46
10	-53	-40	-46	-41	-41	-38	-44	-46
12	-47	-48	-43	-41	-43	-45	-48	-46
14	-49	-53	-42	-43	-46	-42	-51	-46
16	-49	-55	-51	-40	-51	-50	-52	-48
18	-53	-	-54	-42	-54	-55	-59	-53
20	-47	-	-61	-45	-58	-45	-54	-49
22	-50	-	-	-47	-51	-50	-53	-55
24	-51	-	-	-48	-46	-55	-55	-56
26	-54	-	-	-47	-56	-55	-64	-63
28	-63	-	-	-47	-58	-56	-	-65
30	-67	-	-	-54	-52	-	-	-
32	-	-	-	-54	-66	-	-	-

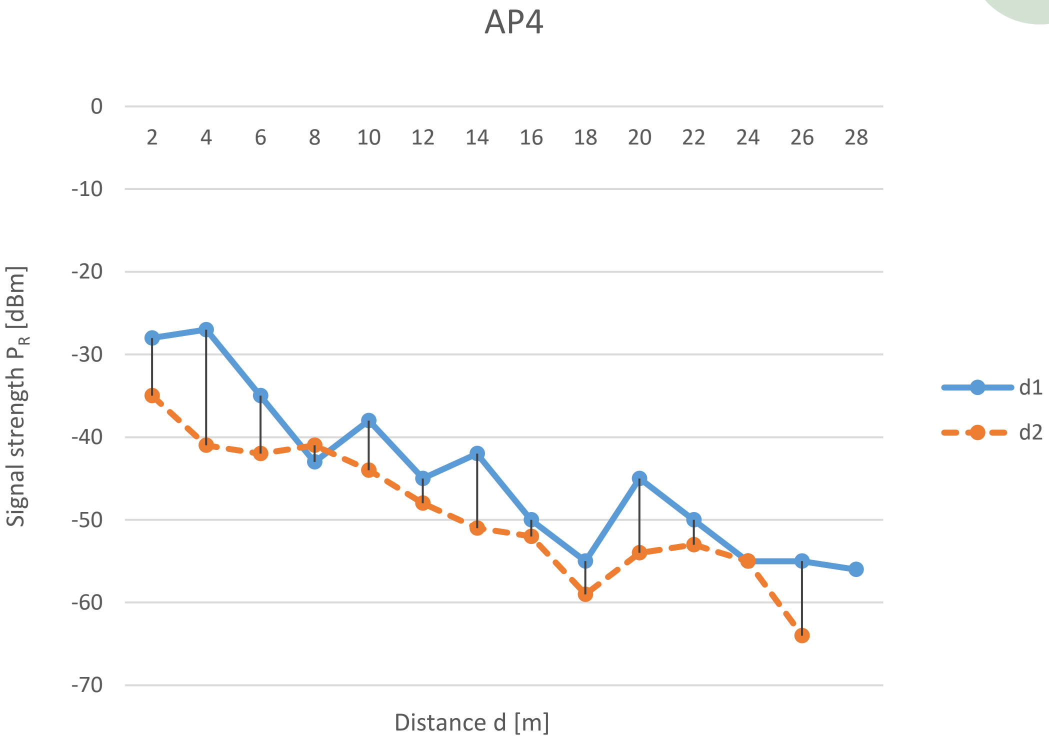
Positioning in FERIT building



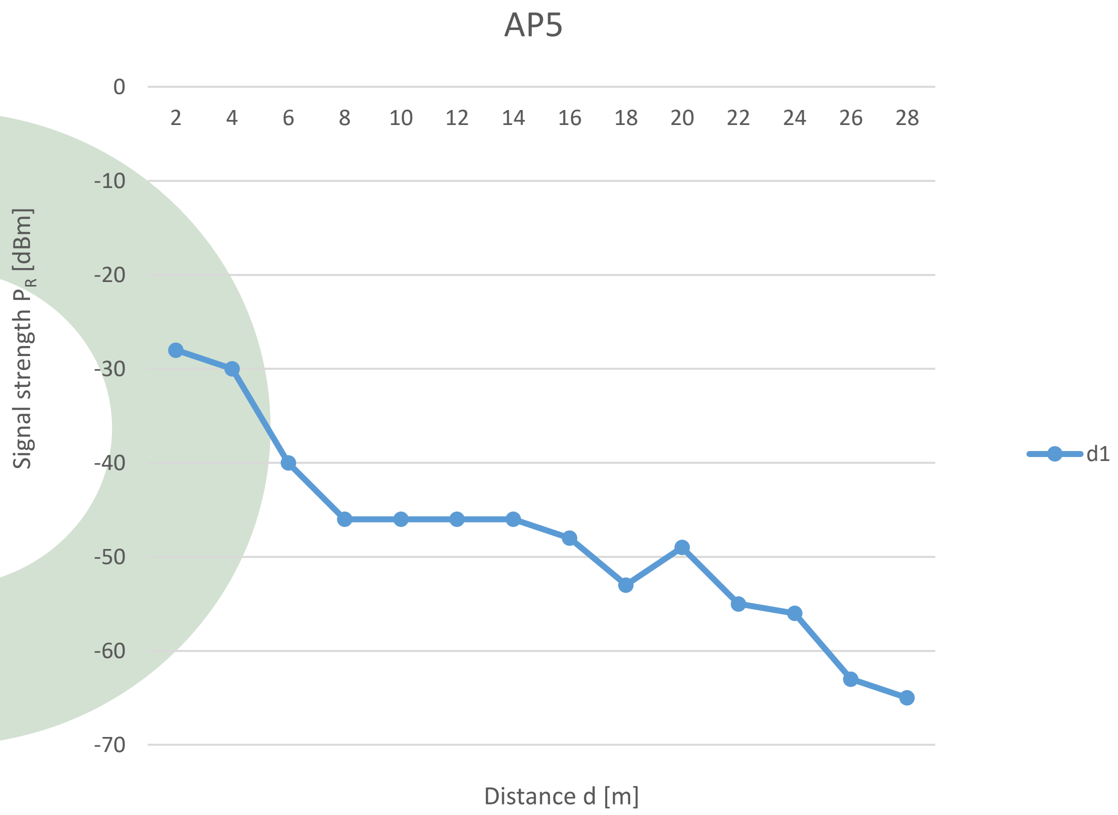


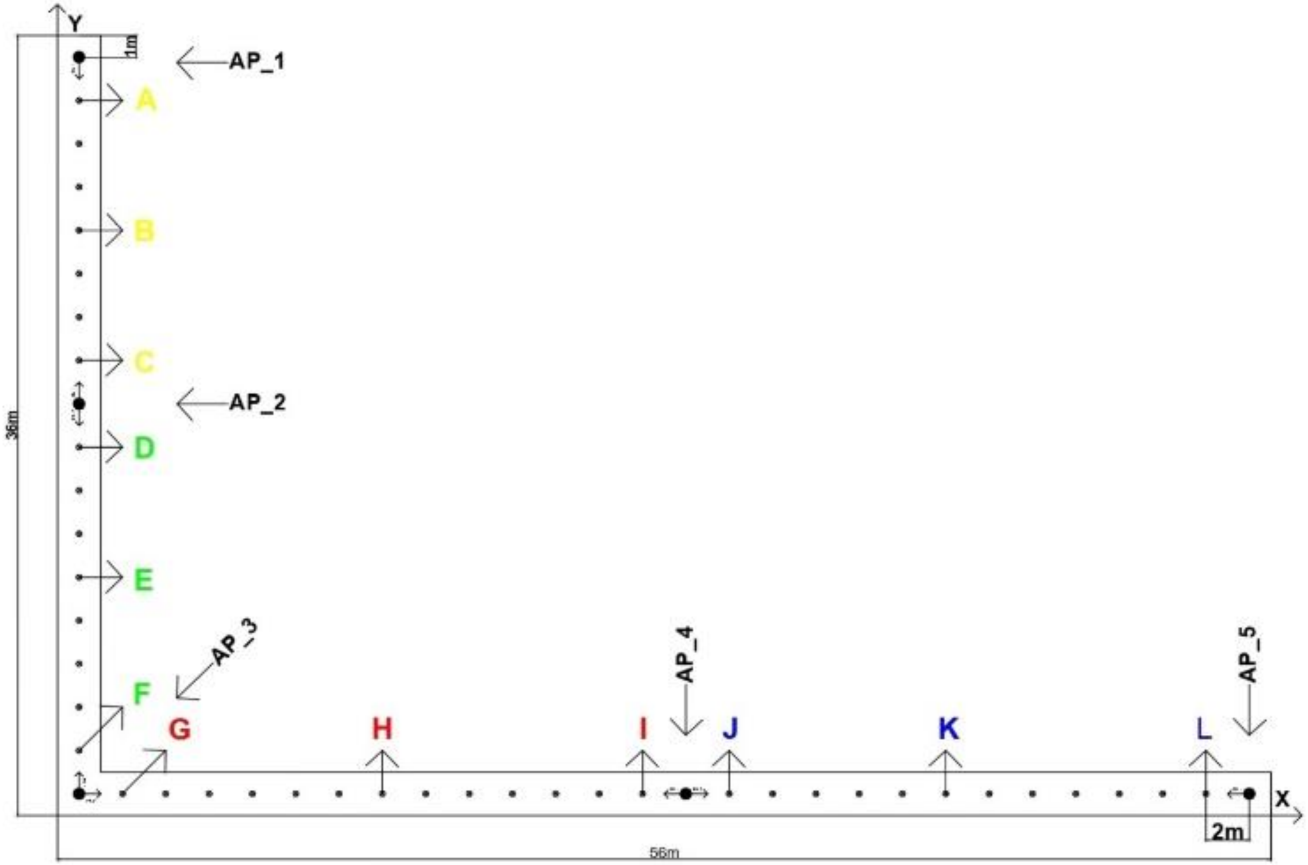
Positioning in FERIT building





Positioning in FERIT building





Positioning in FERIT building

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- Measurements and analysis determined the **change in the received signal strength** from all five access points (AP1-AP5), as the distance from them increases in both directions (where possible).
- A **selection of measurement points** evenly distributed between the access points (three points between every two adjacent APs) is observed (these points are marked with letters A-L).
- The aim is to show the **measured signal strength of all five APs** at each of these points and based on that try to determine the position of the selected point by comparing it with the actual position of the measuring point (which is known).

Positioning in FERIT building

Point	AP1 P_R [dBm]	AP2 P_R [dBm]	AP3 P_R [dBm]	AP4 P_R [dBm]	AP5 P_R [dBm]
A	-31	-53	-54	-	-
B	-44	-38	-47	-	-
C	-49	-33	-45	-	-
D	-53	-31	-40	-	-
E	-51	-43	-41	-	-
F	-	-51	-26	-	-
G	-	-61	-30	-55	-
H	-	-	-46	-42	-
I	-	-	-56	-28	-65
J	-	-	-52	-35	-56
K	-	-	-	-48	-46
L	-	-	-	-55	-28

Positioning in FERIT building

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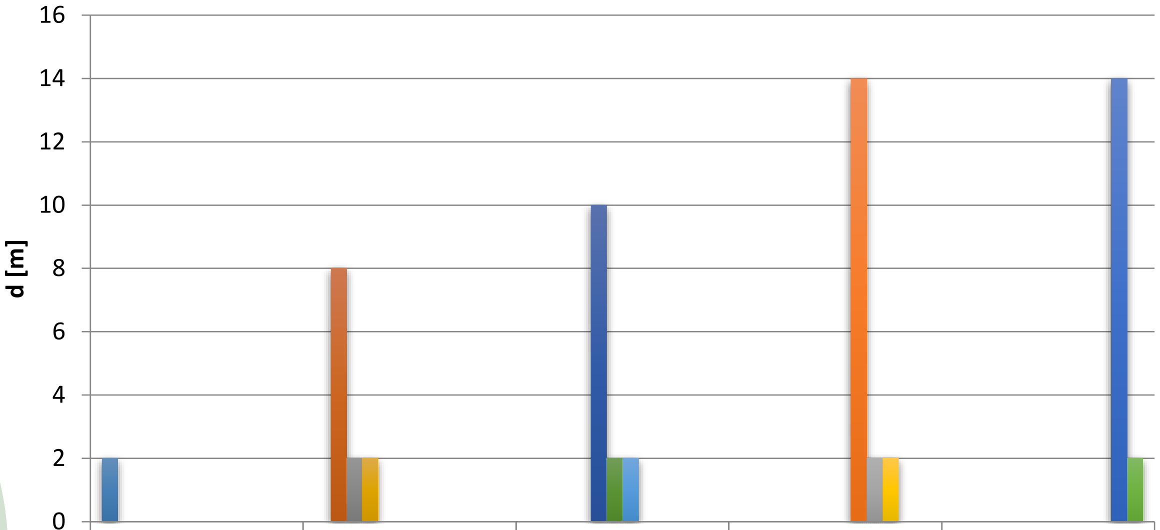
- In the **preparatory phase**, the **coordinates of all five access points** are collected, based on a **floorplan** of the corridor in which the measurements were performed.
- **The positioning method** is based on assigning the location of the nearest transmitter to the unknown location of the user (device).
- The **position of the mobile user** is estimated to be equal to the position of the access point (AP) that is **dominant** for a given measurement point.

Positioning in FERIT building



	AP_1	AP_2	AP_3	AP_4	AP_5
A	2				
B		8			
C		2			
D		2			
E			10		
F			2		
G			2		
H				14	
I				2	
J				2	
K					14
L					2

A B C D E F G H I J K L

Conclusions

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- The analyzed example showed that the WiFi network signal can be used in a **practical and easy way** for indoor positioning.
- The largest advantage of using a WiFi signal for positioning is its **ubiquity – no additional investments** in infrastructure and equipment.
- Even with such a simple approach, **satisfactory indoor positioning accuracy** can be achieved.
- This approach can be easily extended to the issue of positioning within the **entire building** by arranging additional access points and covering the entire interior.

Future work

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- The **idea** for this analysis came from a broader analysis of wireless communication technologies within the „IoT-field" project.

- **Plans for future work** and expansion of the conducted analyzes include the following:
  - Development of a smartphone application that will be used for real-time indoor navigation
  - Implementation of several different indoor positioning algorithms (and their integration into smartphone application)
  - Test and analyze different propagation models in indoor environment
  - Apply similar positioning solution in a very specific outdoor environment – sensor nodes distributed in the corn fields.

Thank you!