A two-phase location measurement system for indoor static sensors

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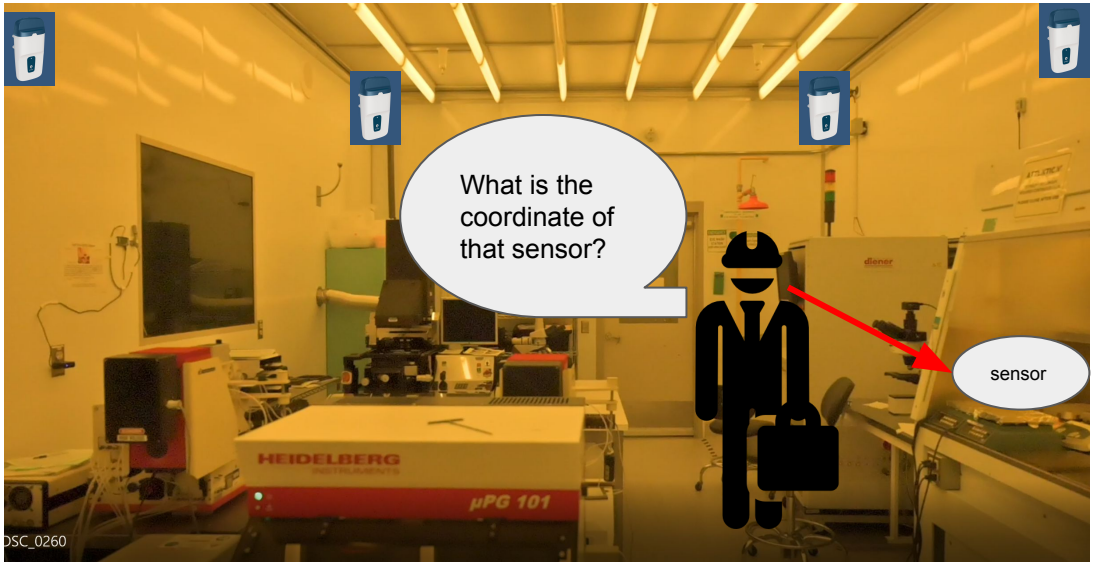
Motivation

- IoT, Digital Twin… More and more sensors are deployed in **indoor environment** to make our indoor environment and equipment “intelligent”
- **Location-aware** sensor networks is necessary to build intelligent / context-aware indoor IoT systems
- How can we get coordinates of those sensors in complex indoor environment?
- Manually measure the coordinates if infeasible: (1) labor & time consuming (2) not scalable (3) hard-to-measure spot (4) inconsistent measure results

Problem

Can we use **wireless indoor location system** to help us **automatically** localize **static sensors** in a **complex indoor environment**?

It is a challenging problem.



Why is it challenging?

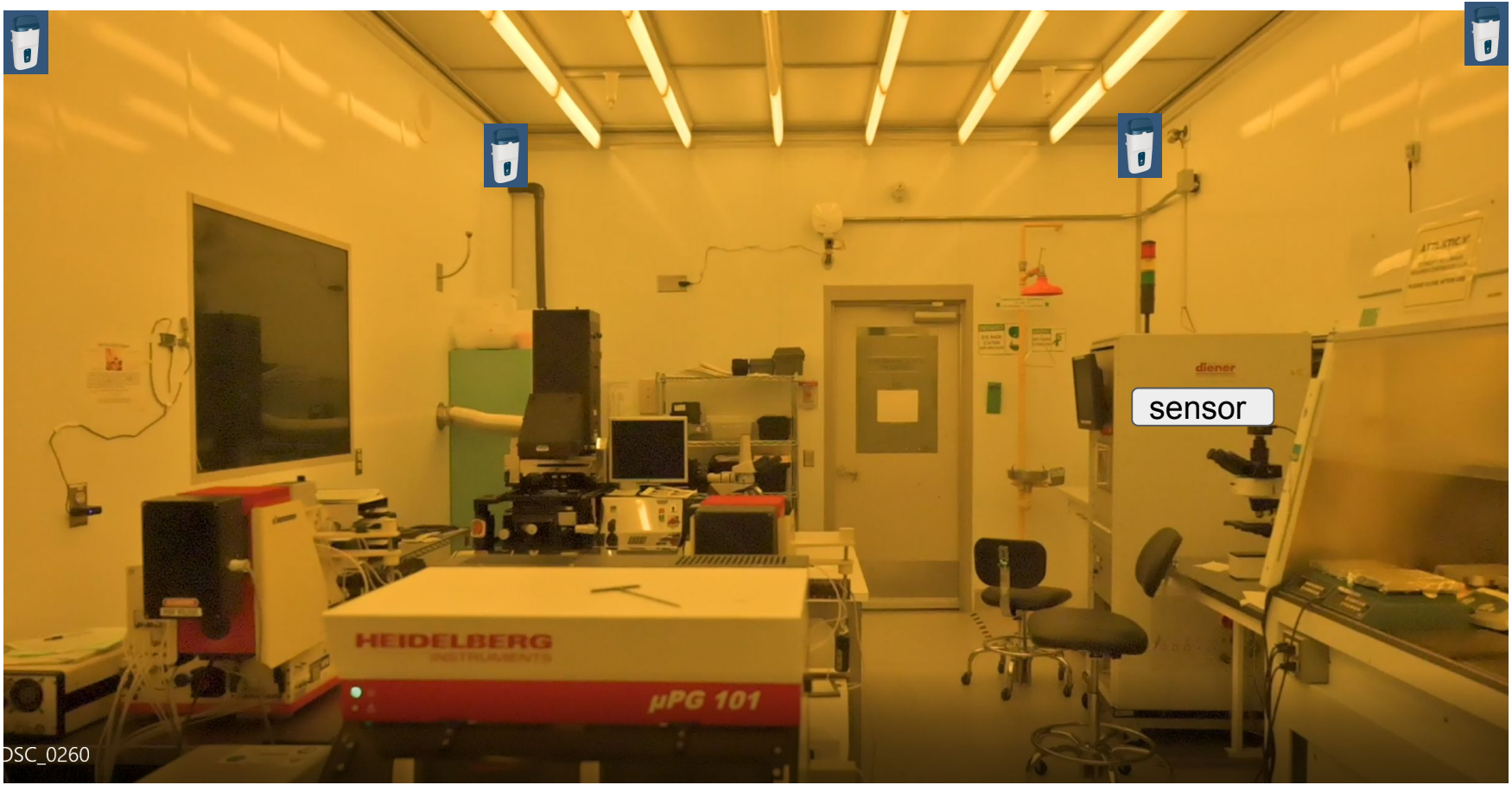
1. Indoor location system: WIFI, RFID, UWB, Bluetooth…

   Commercial UWB system can have sub-decimeter accuracy

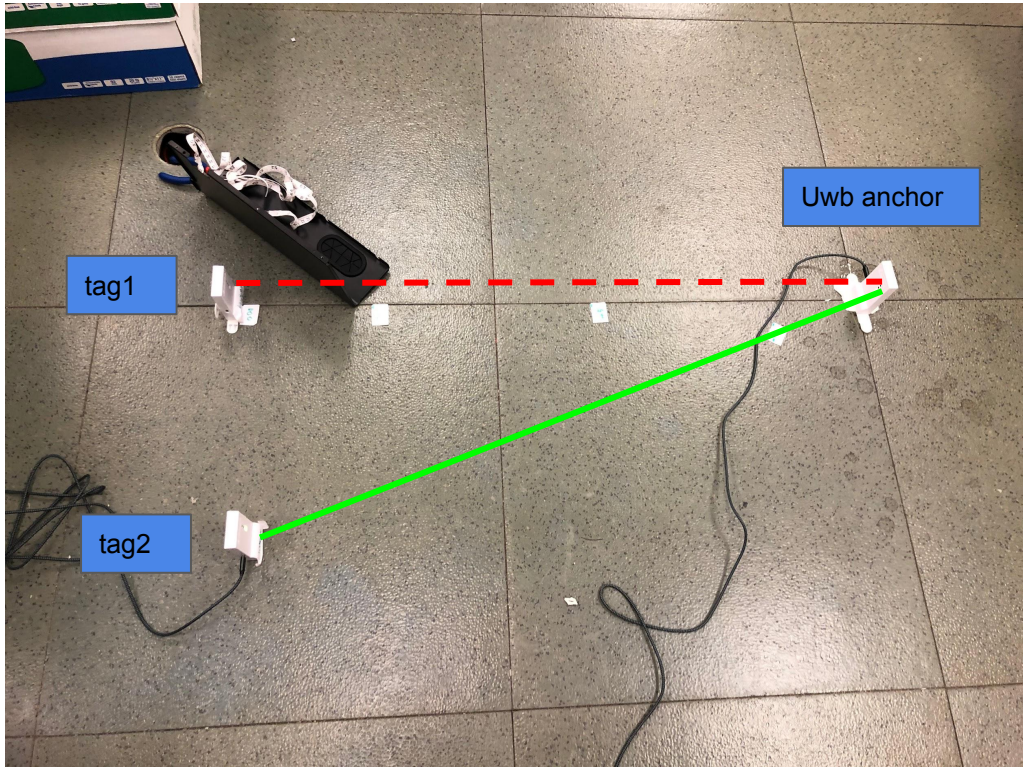
   They don’t work well in NLOS(none line of sight) condition

   They might work well for wood and paper box like obstacles.

   What about metal?


HEIDELBERG
INSTRUMENTS
µPG 101
diener
sensor
DSC_0260

Toy example



Ground truth are both 1.00m

Avg. Distance Result:

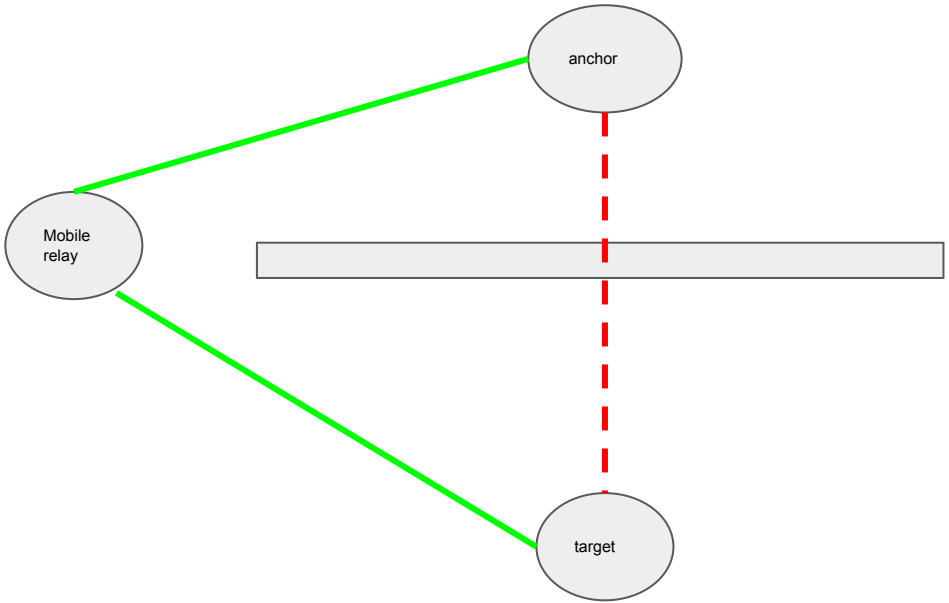
Tag1 - Anchor: 1.30m (NLOS)

Tag2 - Anchor: 1.05m (LOS)

How can we measure sensors(tags) in NLOS condition?

Our idea

Convert NLOS path into two LOS paths.



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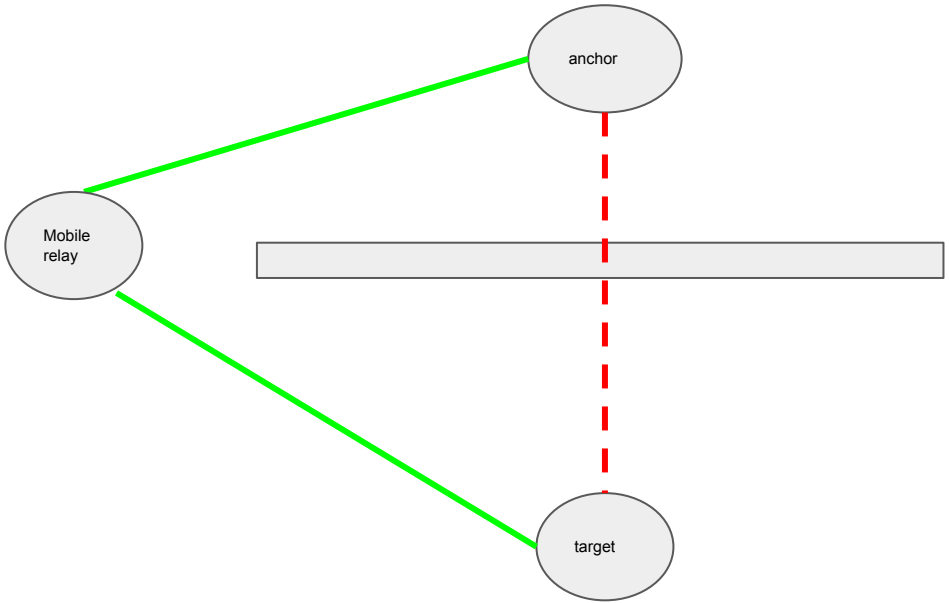
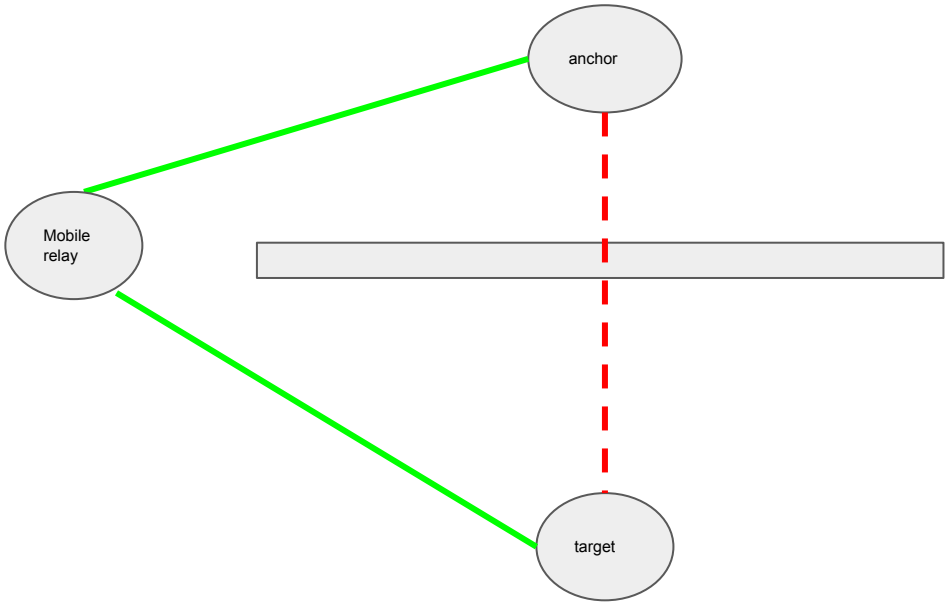


Before: We directly measure the red dash line to get the final result.

Our idea

Convert NLOS path into two LOS paths.

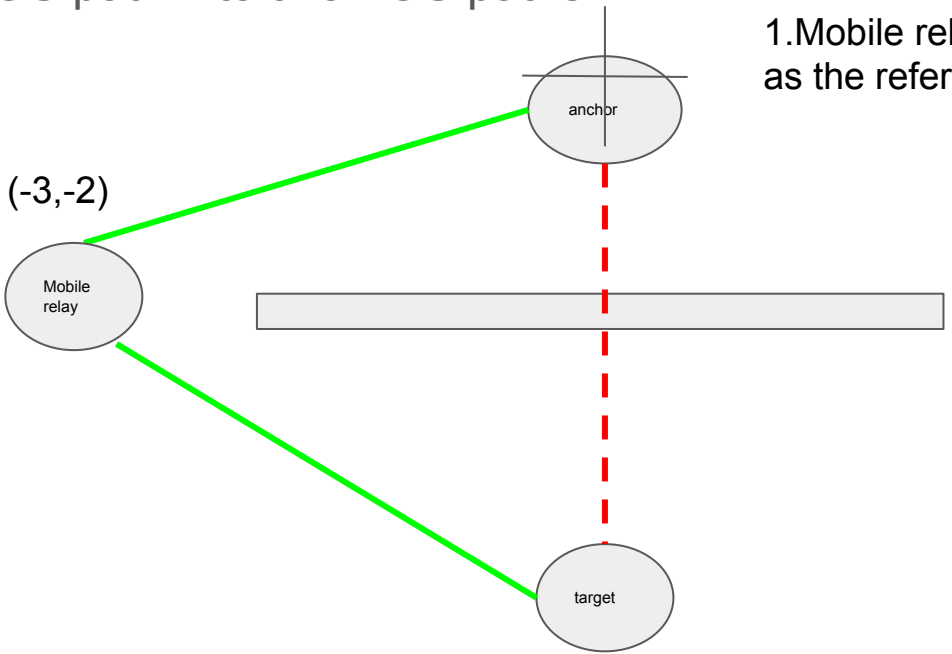


Before: We directly measure the red dash line to get the final result.

Now: We first localize the mobile relay, then from the mobile relay, we can finally localize the target.

Our idea

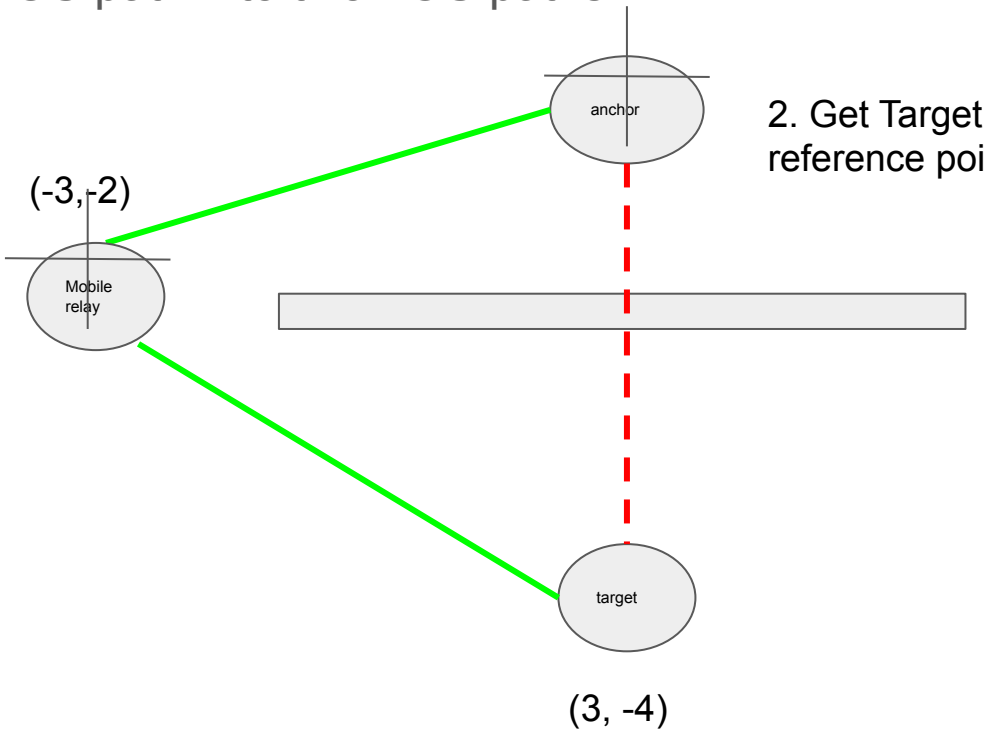
Convert NLOS path into two LOS paths.



1.Mobile relay coordinate with the anchor(room) as the reference point

Our idea

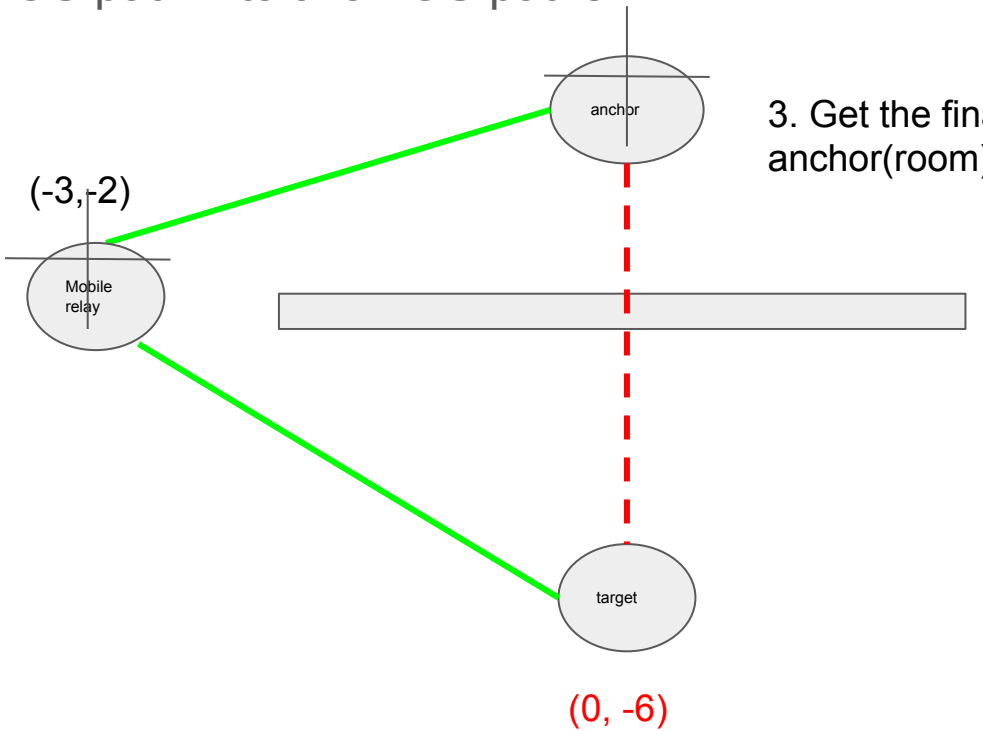
Convert NLOS path into two LOS paths.



2. Get Target coordinate with mobile relay as the reference point

Our idea

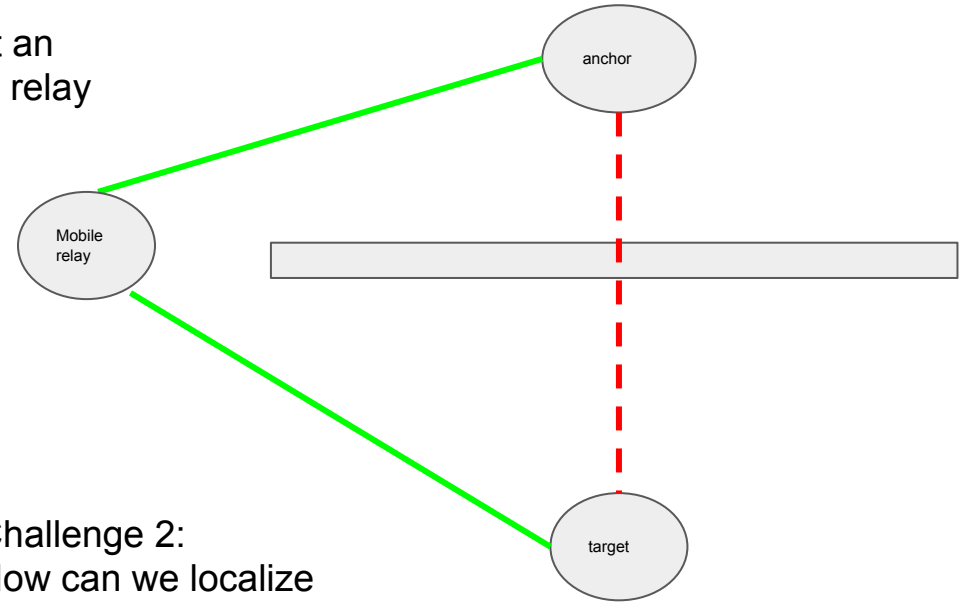
Convert NLOS path into two LOS paths.



3. Get the final target coordinate with the anchor(room) as the reference point

Challenges

Challenge 1:
How can we get an accurate mobile relay coordinate?



Challenge 2:
How can we localize target accurately from the mobile relay?

Solve challenge 1

Challenge 1:
How can we get an accurate mobile relay coordinate?

Solution:

1. We use a commercial UWB indoor location system(MDEK1001) to localize the mobile relay.
2. We embed the mobile relay on the top of a goggle to maximize the LOS probability.
   (Simple intuition, there are few obstacles between the head and anchors hanging on the ceiling)
3. To further increase the accuracy, we prepare to do some experiments and give some suggestions based on the results.
   Experiment design: Test the system accuracy with respect to
   (1) The distance between the anchor and the tag
   (2) The orientation of the tag
   (3) The variance of the result
   (4) The speed to get a stabilized result after movement

Solve challenge 1

Challenge 1:
How can we get an accurate mobile relay coordinate?

Solution:

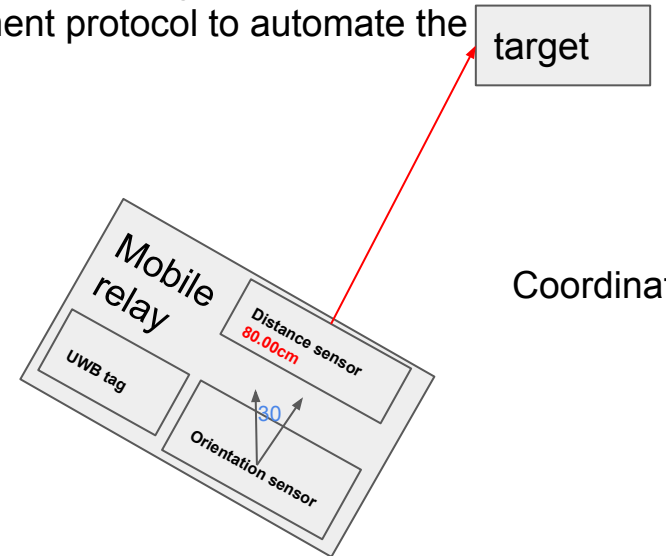
1. We use a commercial UWB indoor location system(MDEK1001) to localize the mobile relay.
2. We embed the mobile relay on the top of a goggle to maximize the LOS probability.
   (Simple intuition, there are few obstacles between the head and anchors hanging on the ceiling)

Solve challenge 2

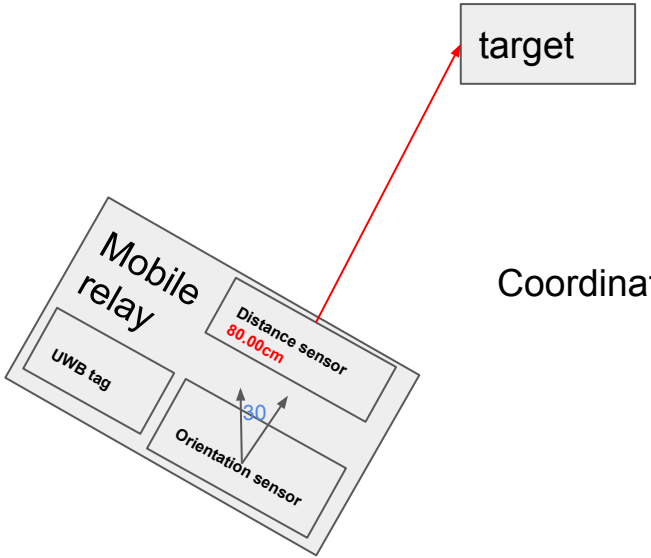
Challenge 2:
How can we localize target accurately from the mobile relay?

Solution 1:

1. We can embed an orientation sensor and a laser measurement sensor on the mobile relay to measure the relative location of the target.
2. We can design a measurement protocol to automate the Measurement process.



Coordinate = (80.00 * Sin30, 80.00 * Cos30)



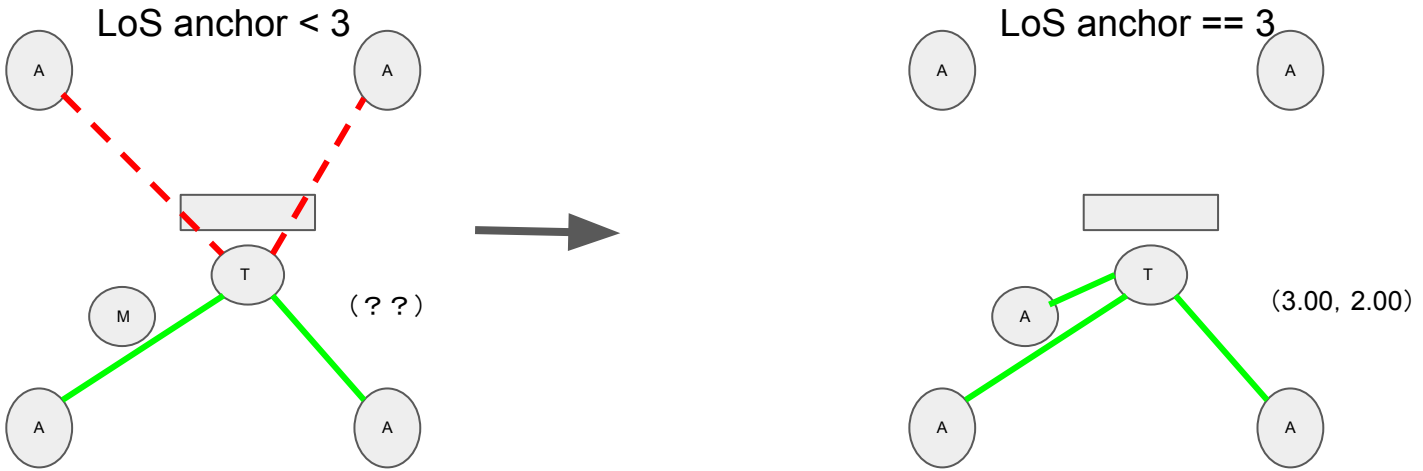
Coordinate = (80.00 * Sin 30, 80.00 * Cos 30)

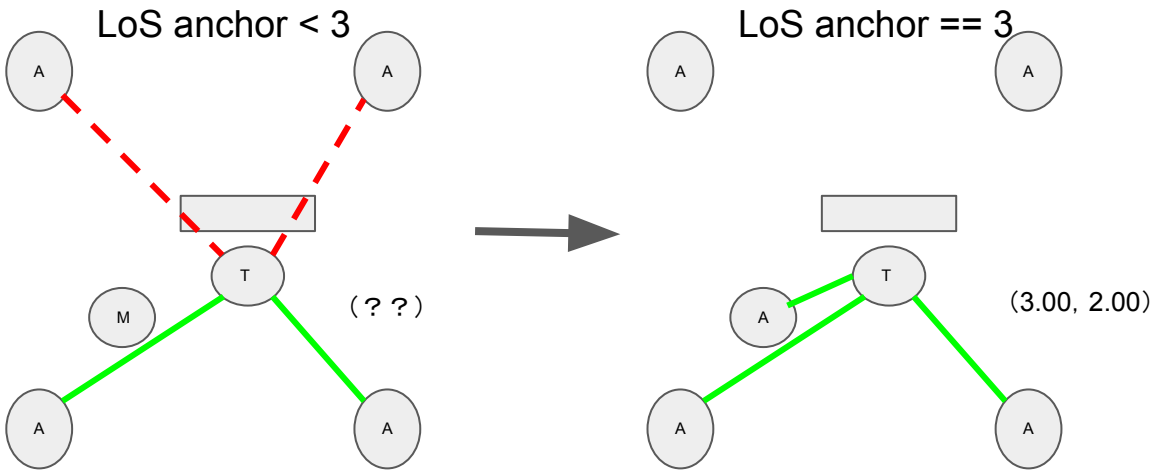
Solve challenge 2

Challenge 2:
How can we localize target accurately from the mobile relay?

Solution 2:

1. We can set the UWB tag on the mobile relay to a new anchor(LOS), and directly use the UWB system to get the coordinate of the target.




LoS anchor < 3
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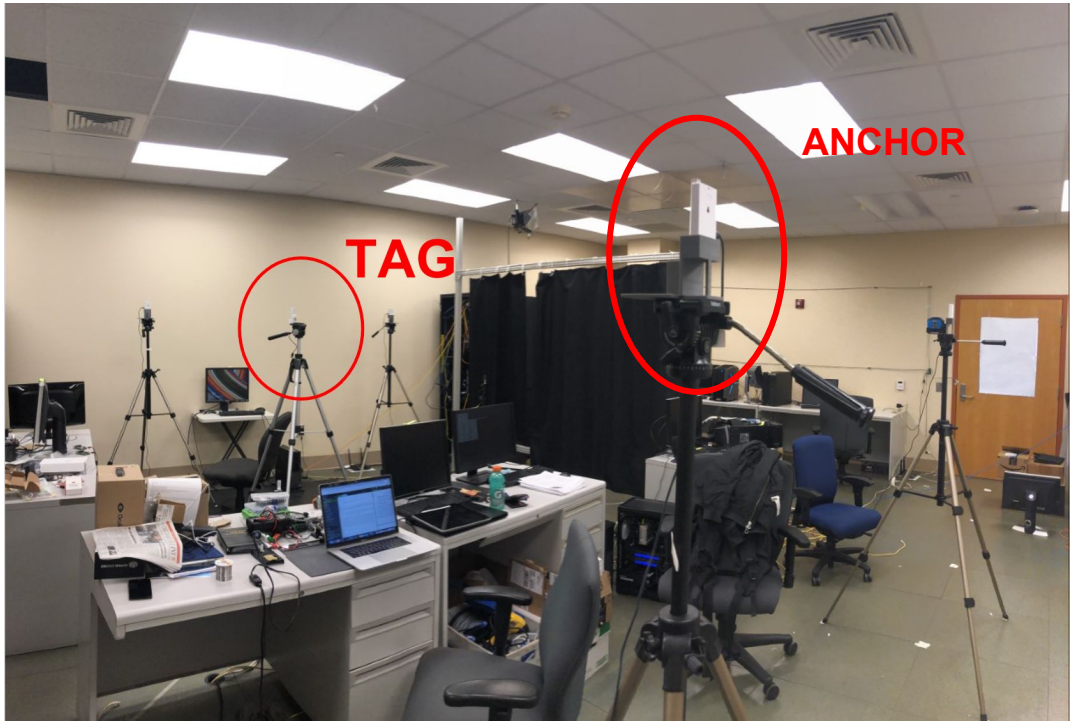
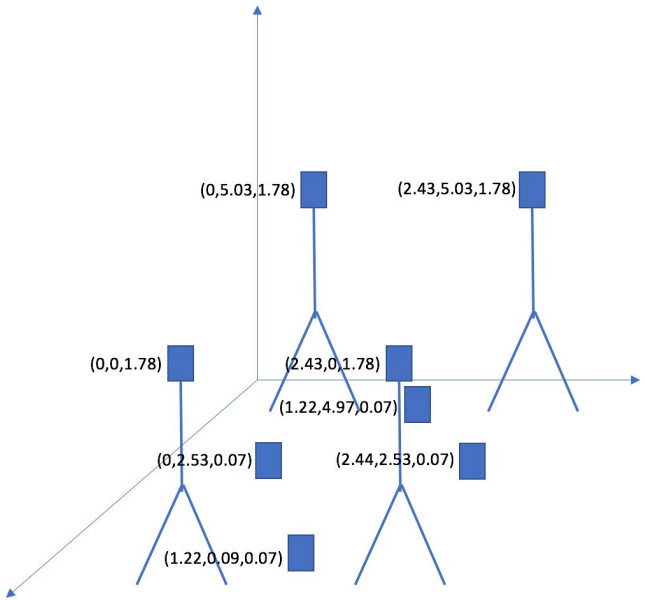
(3.00, 2.00)

Implementation

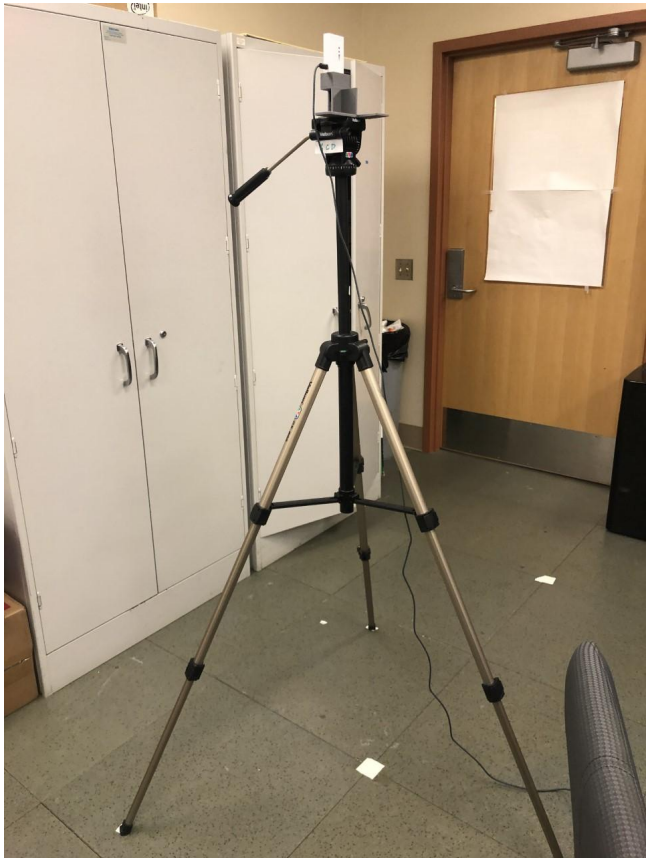
1. 3D UWB indoor location system





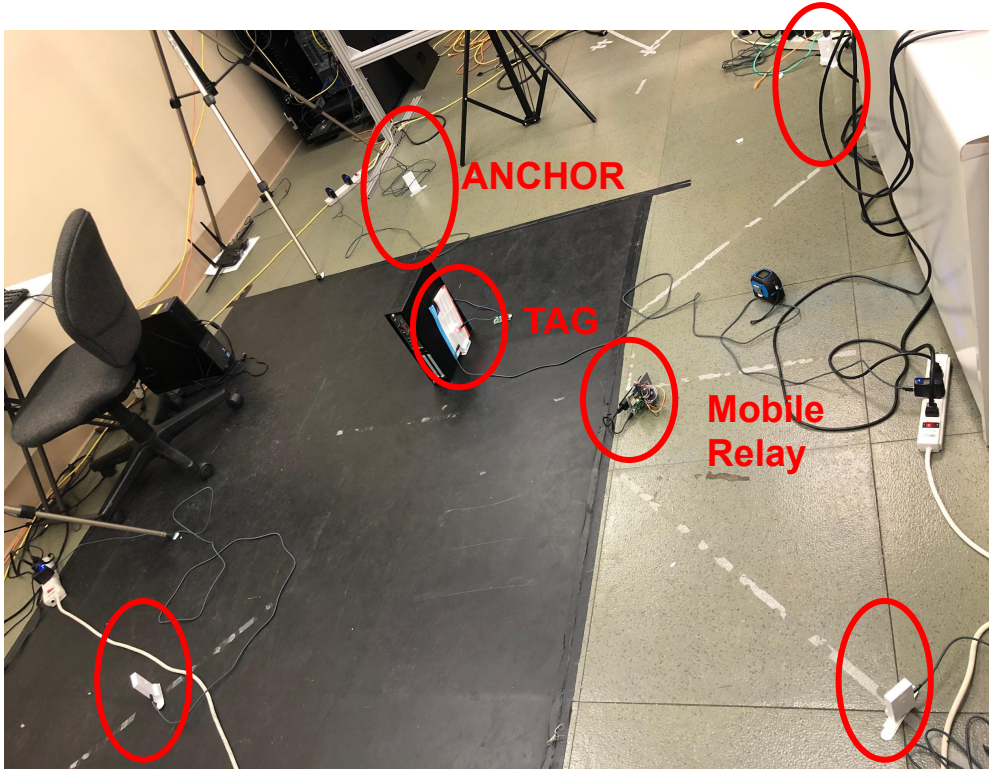
Implementation

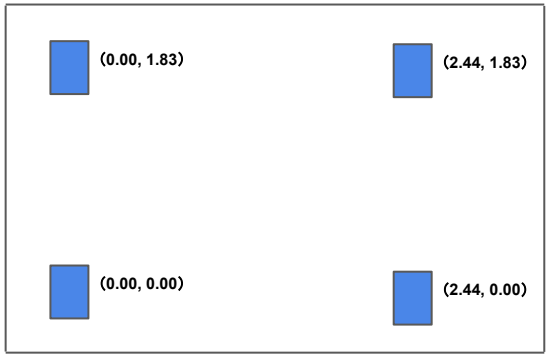
1. 3D UWB indoor location system



Implementation

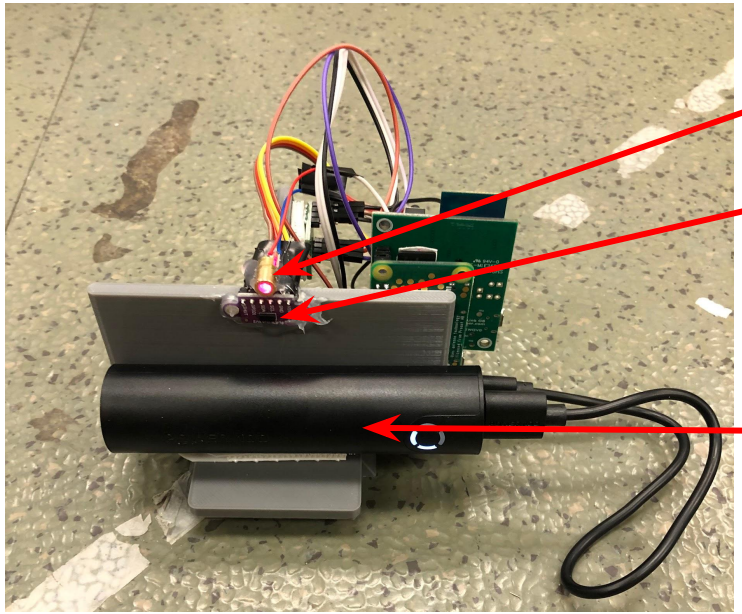
2. 2D UWB indoor location system





Implementation

3. Mobile Relay



Implementation

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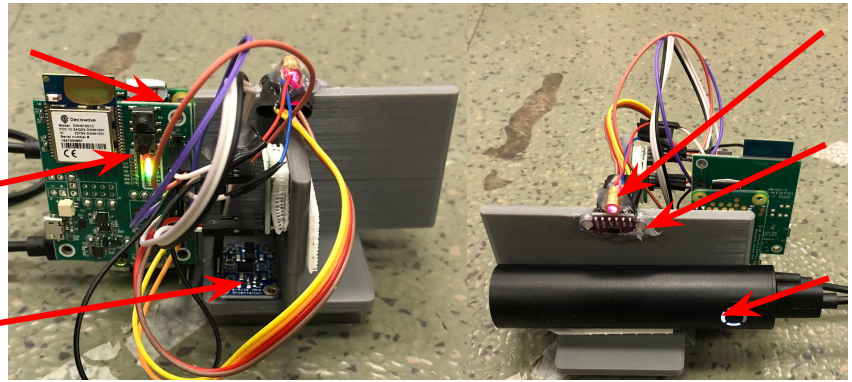
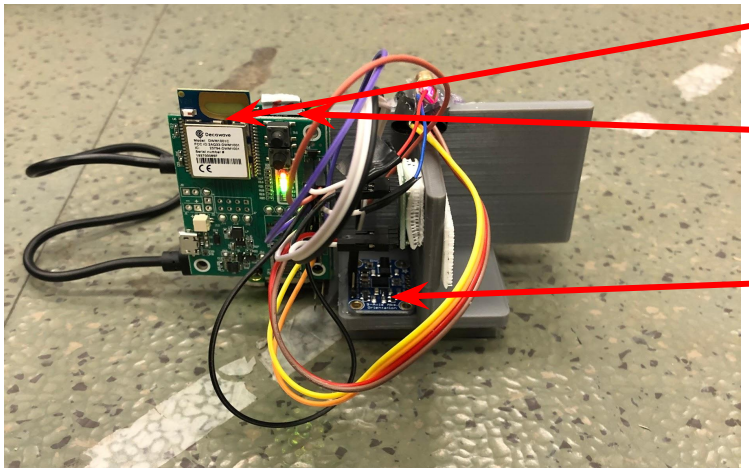


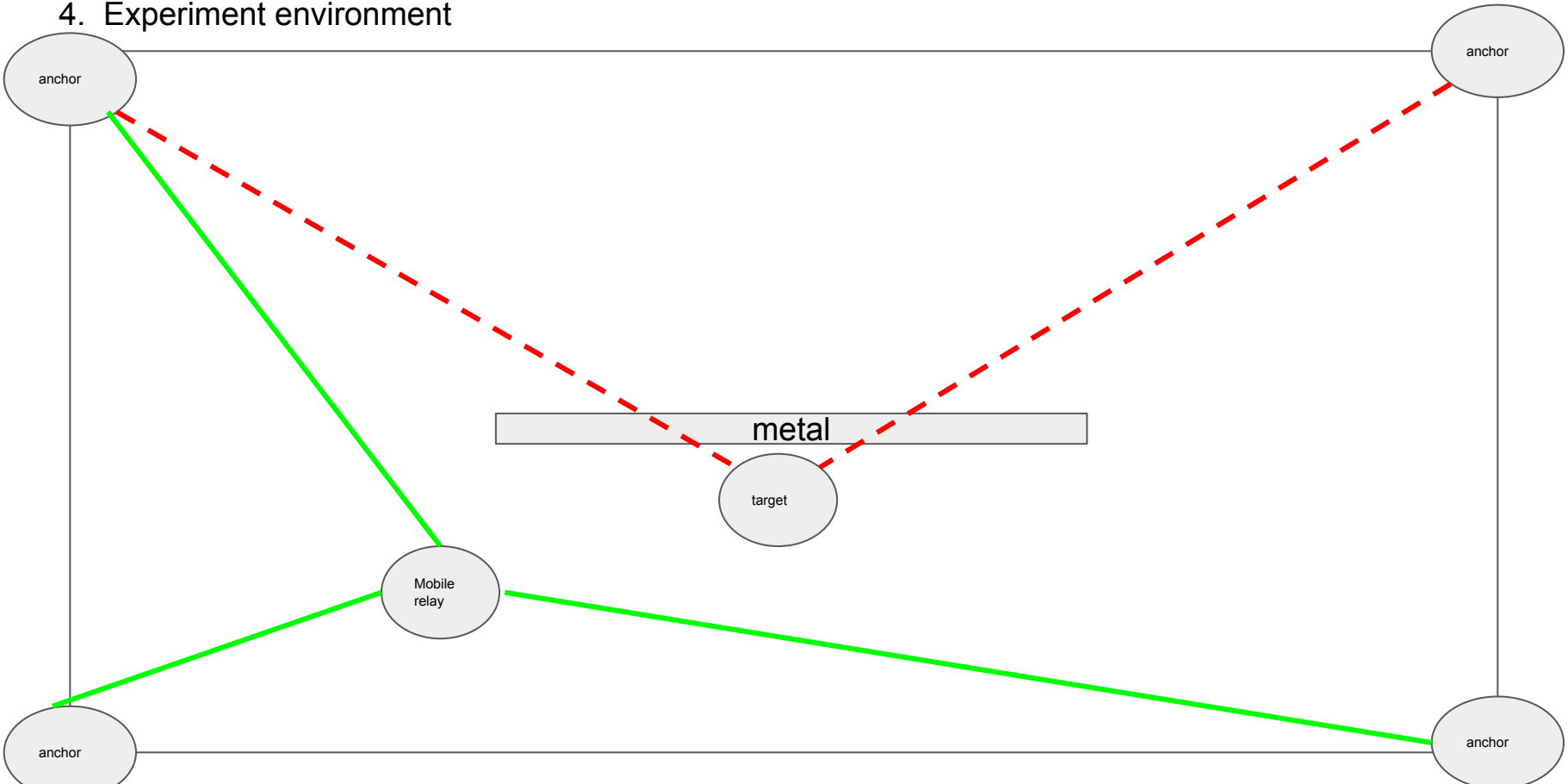
Implementation

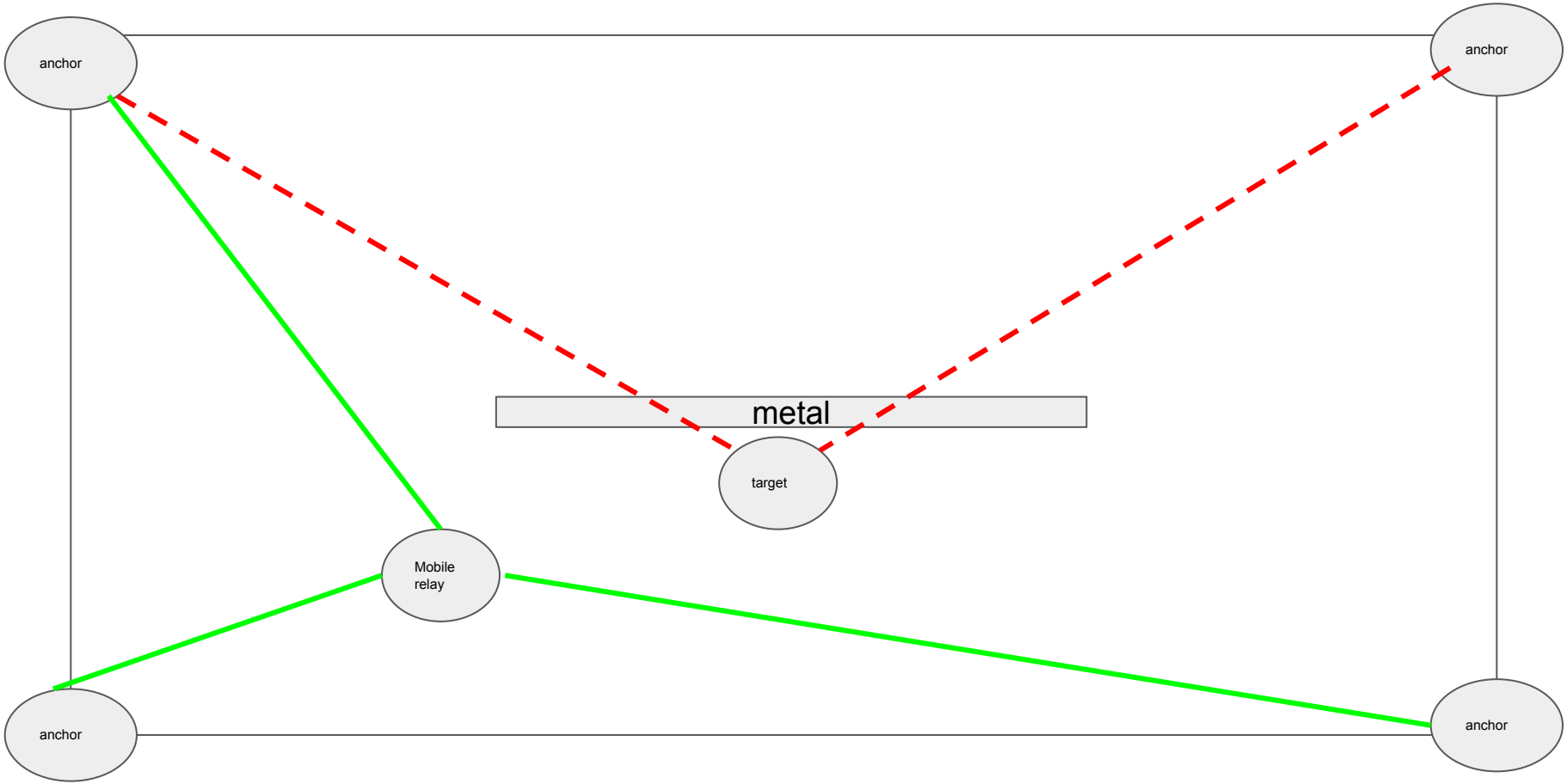
3. Mobile Relay



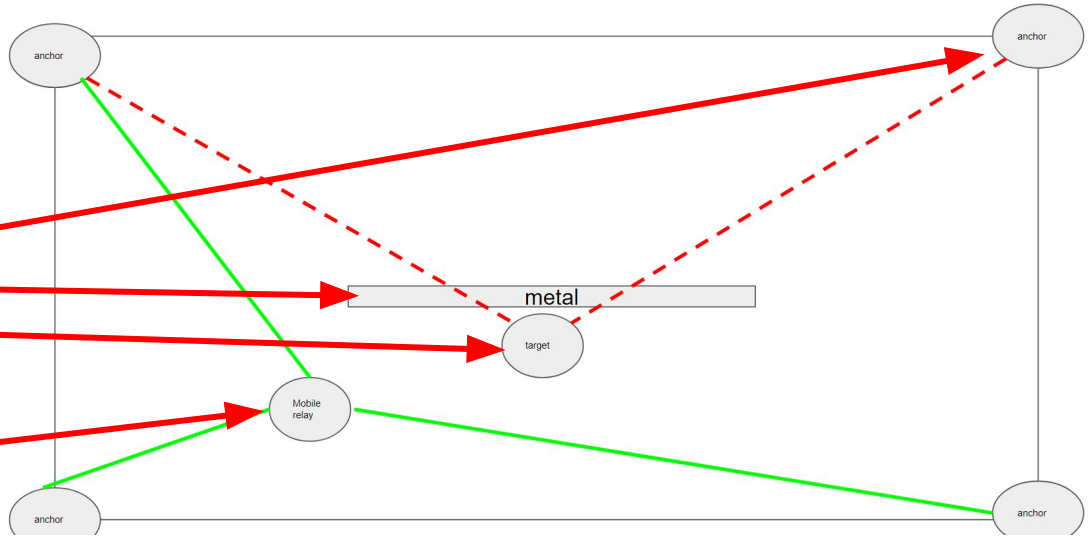
Implementation

4. Experiment environment



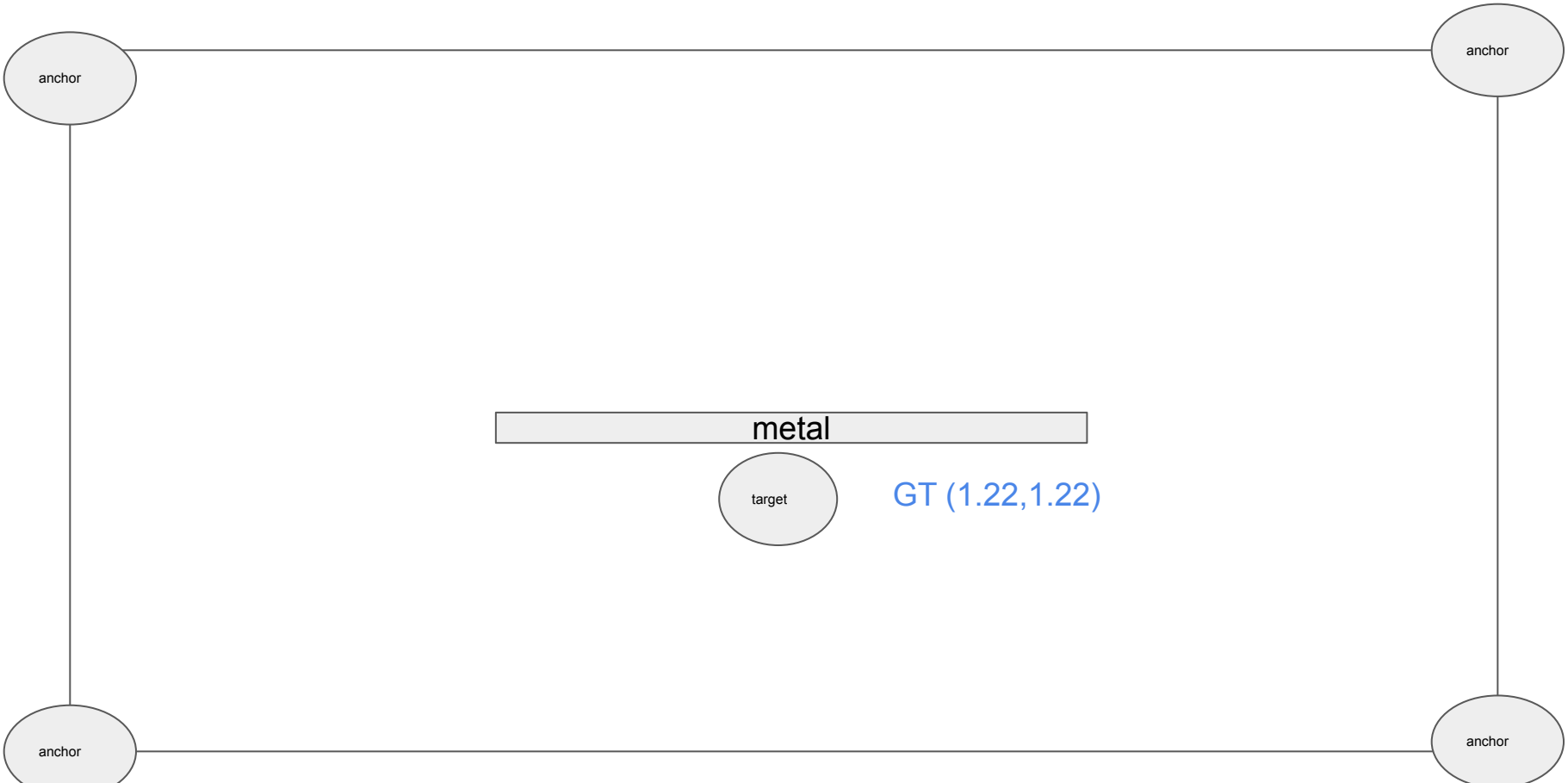

anchor
anchor
metal
target
Mobile
relay
anchor
anchor

Implementation



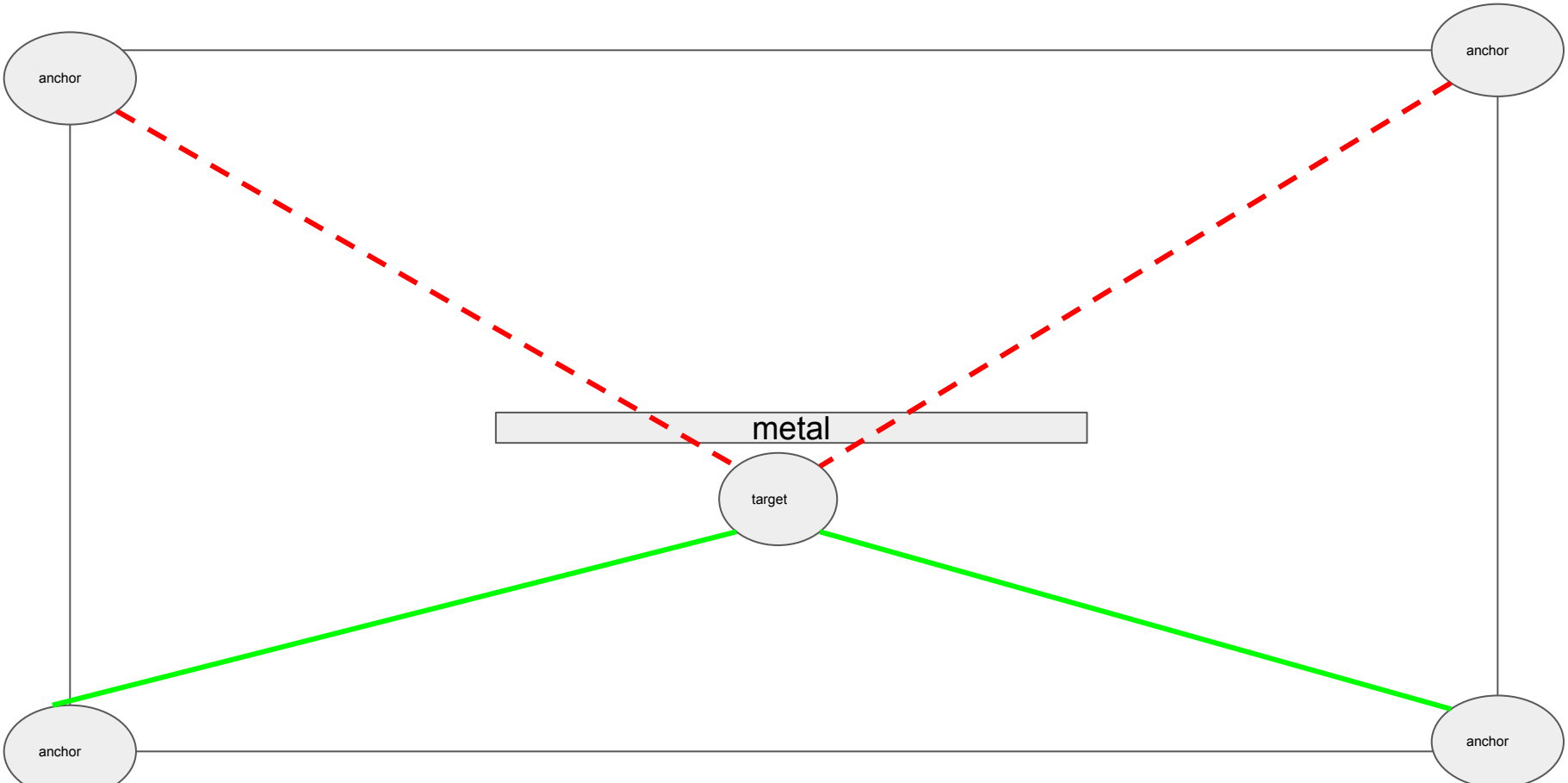
Result:

Ground truth



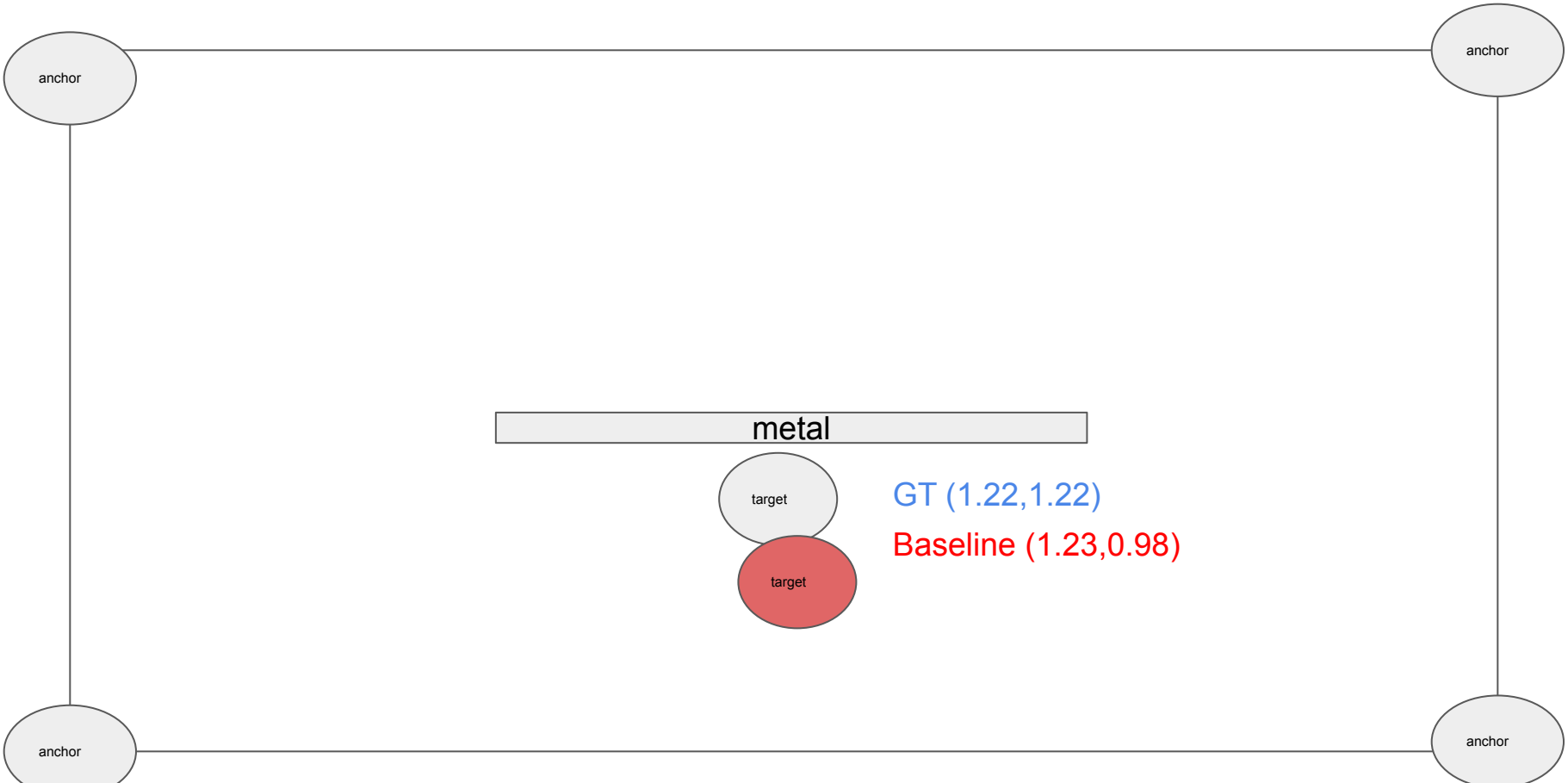
Baseline:

Directly use 4 anchors to localize the target.

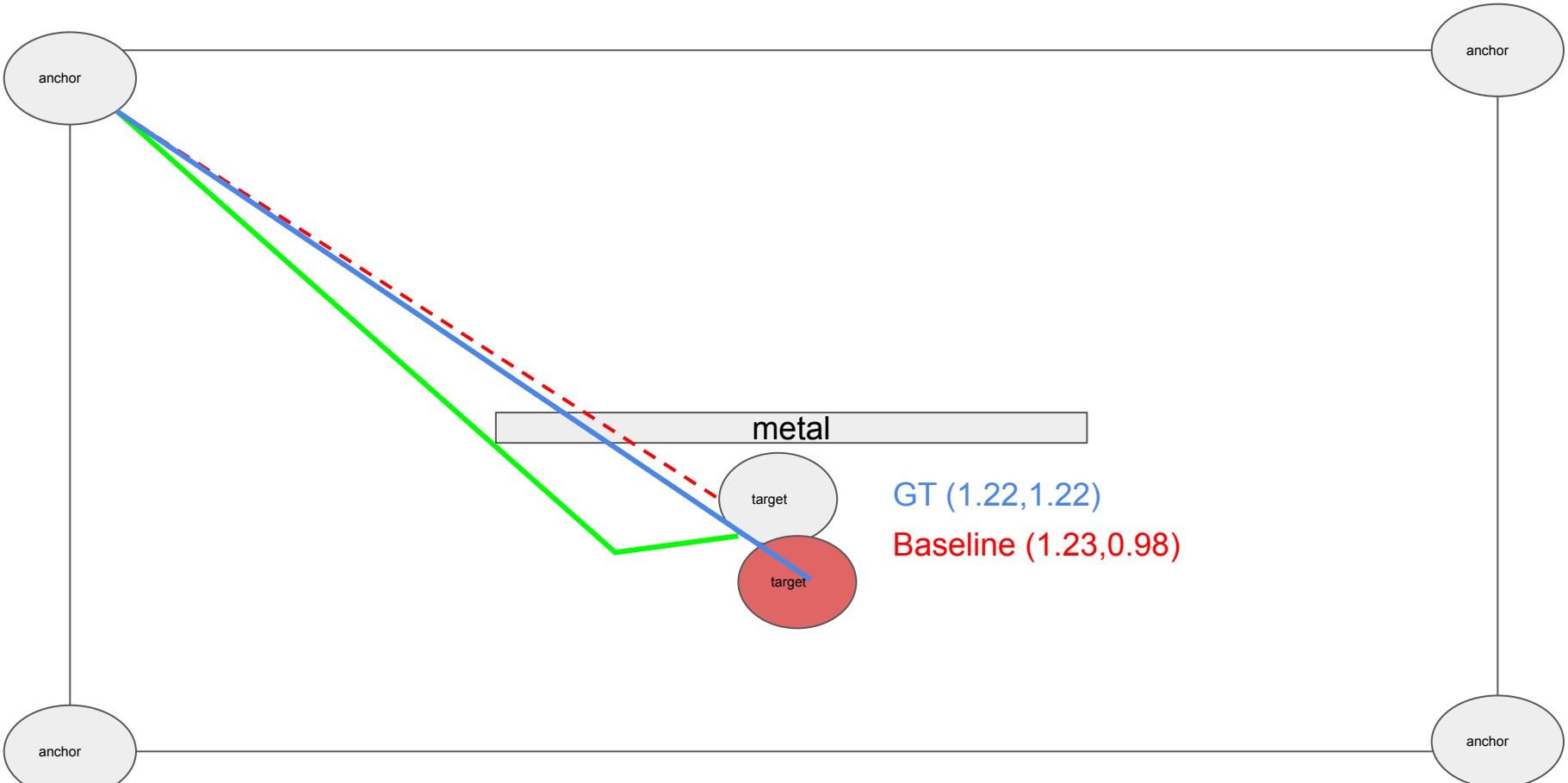


Result:

Baseline: Directly use 4 anchors to localize the target.

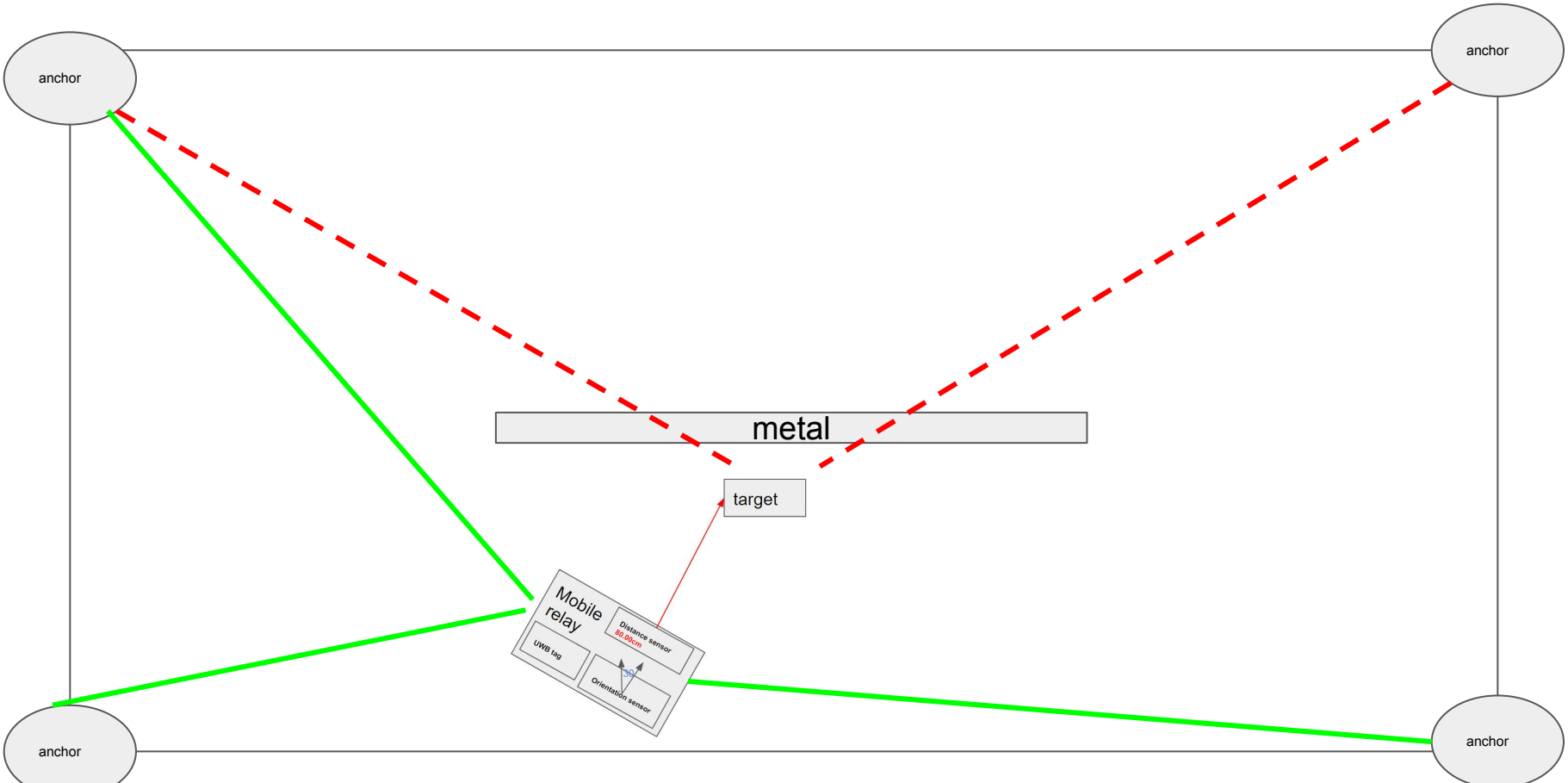


Analysis


anchor
anchor
metal
target
target
GT (1.22,1.22)
Baseline (1.23,0.98)
anchor
anchor

Method1:

Localize the mobile relay first, then use mobile relay to localize the target.



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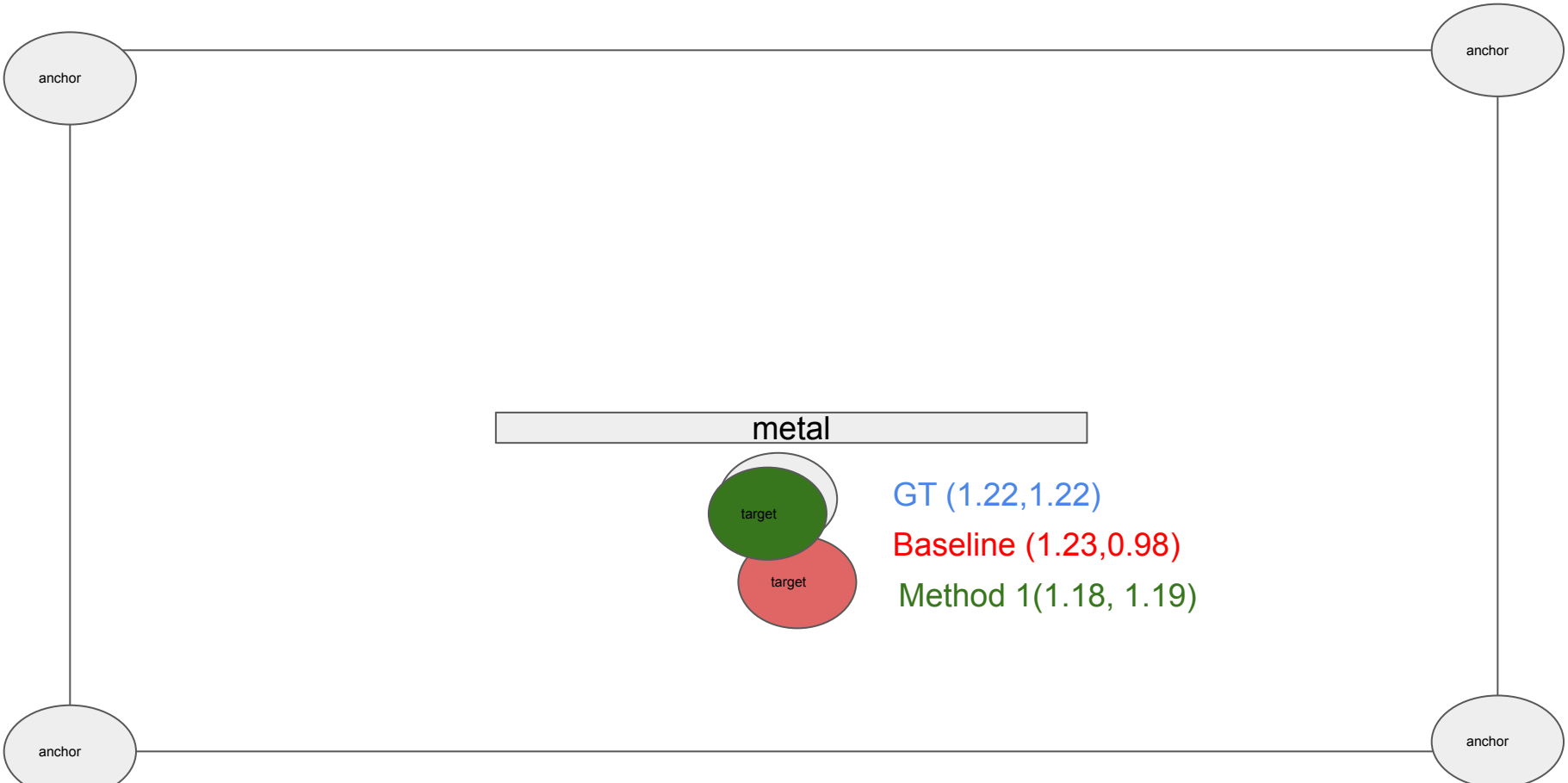

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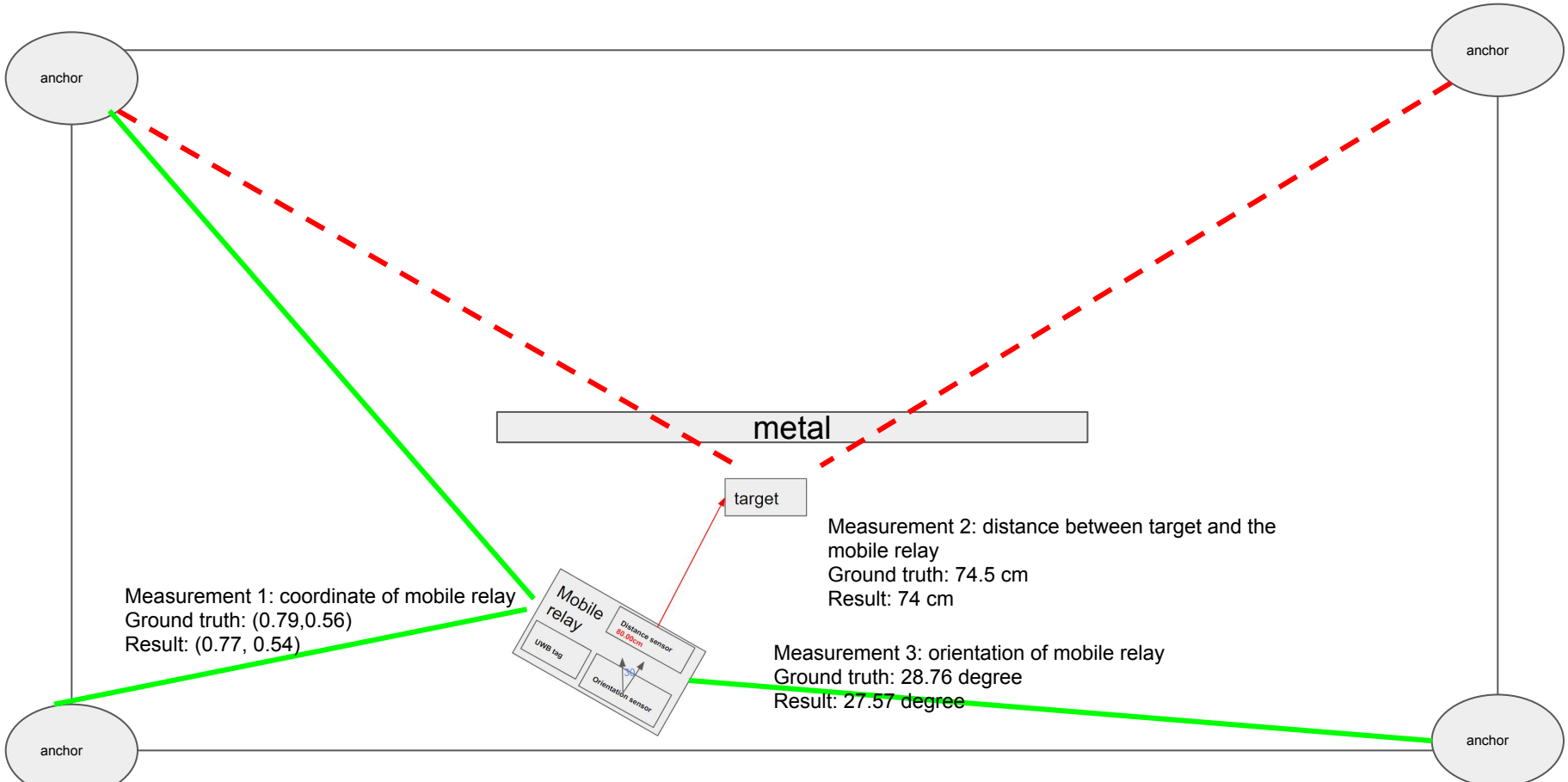
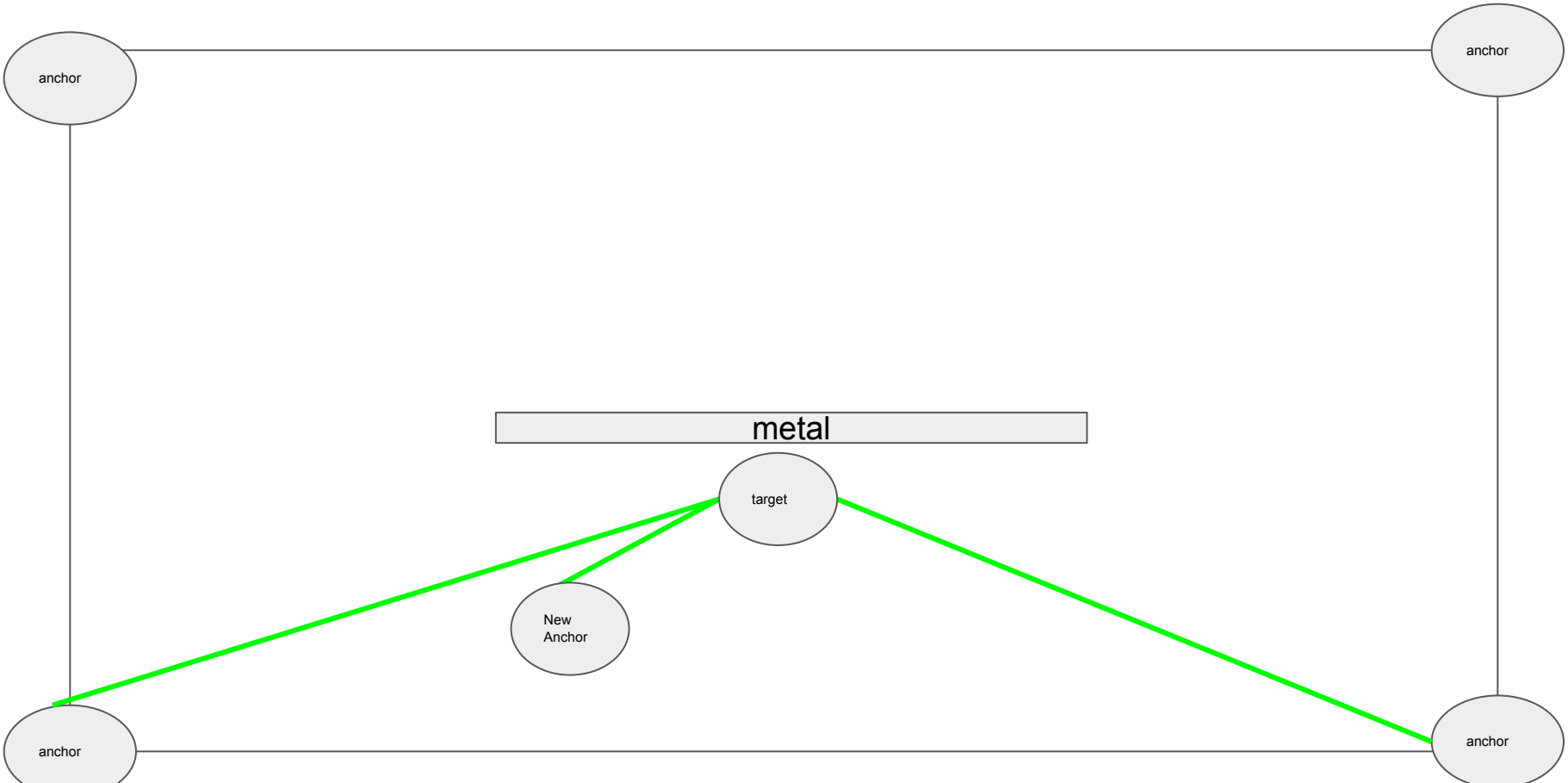


Method2:

Localize the mobile relay first, then set the mobile relay as a new anchor.



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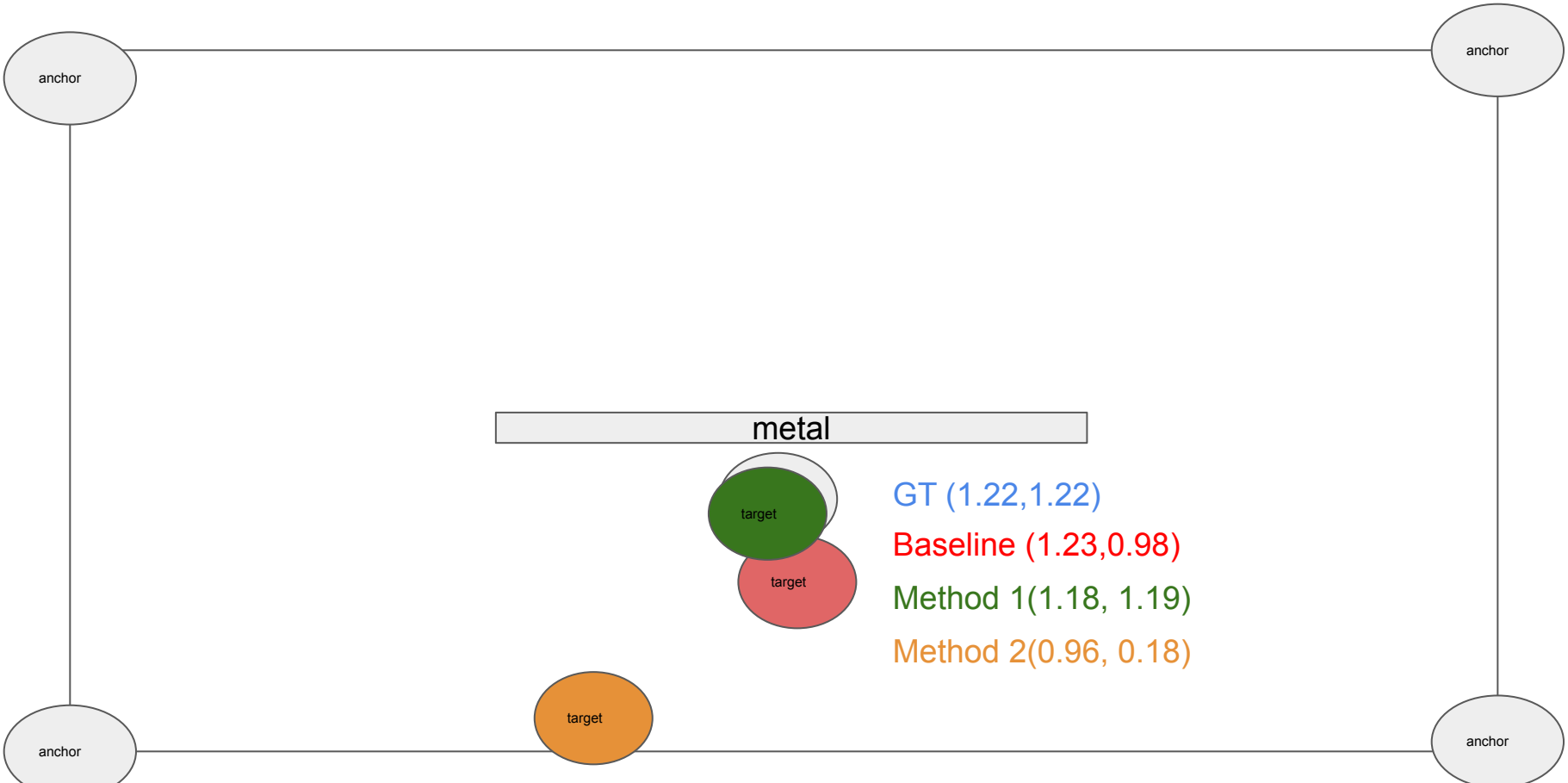

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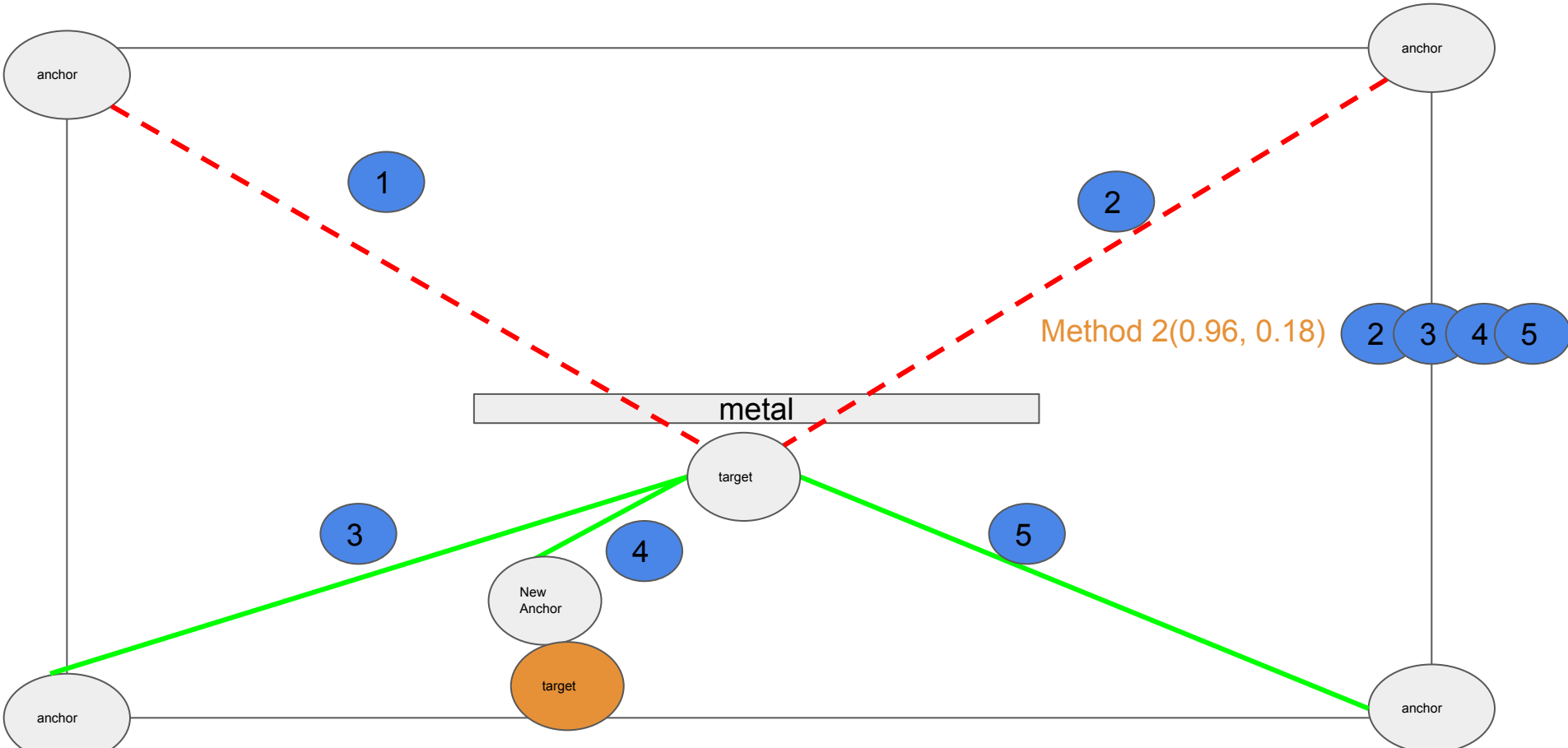

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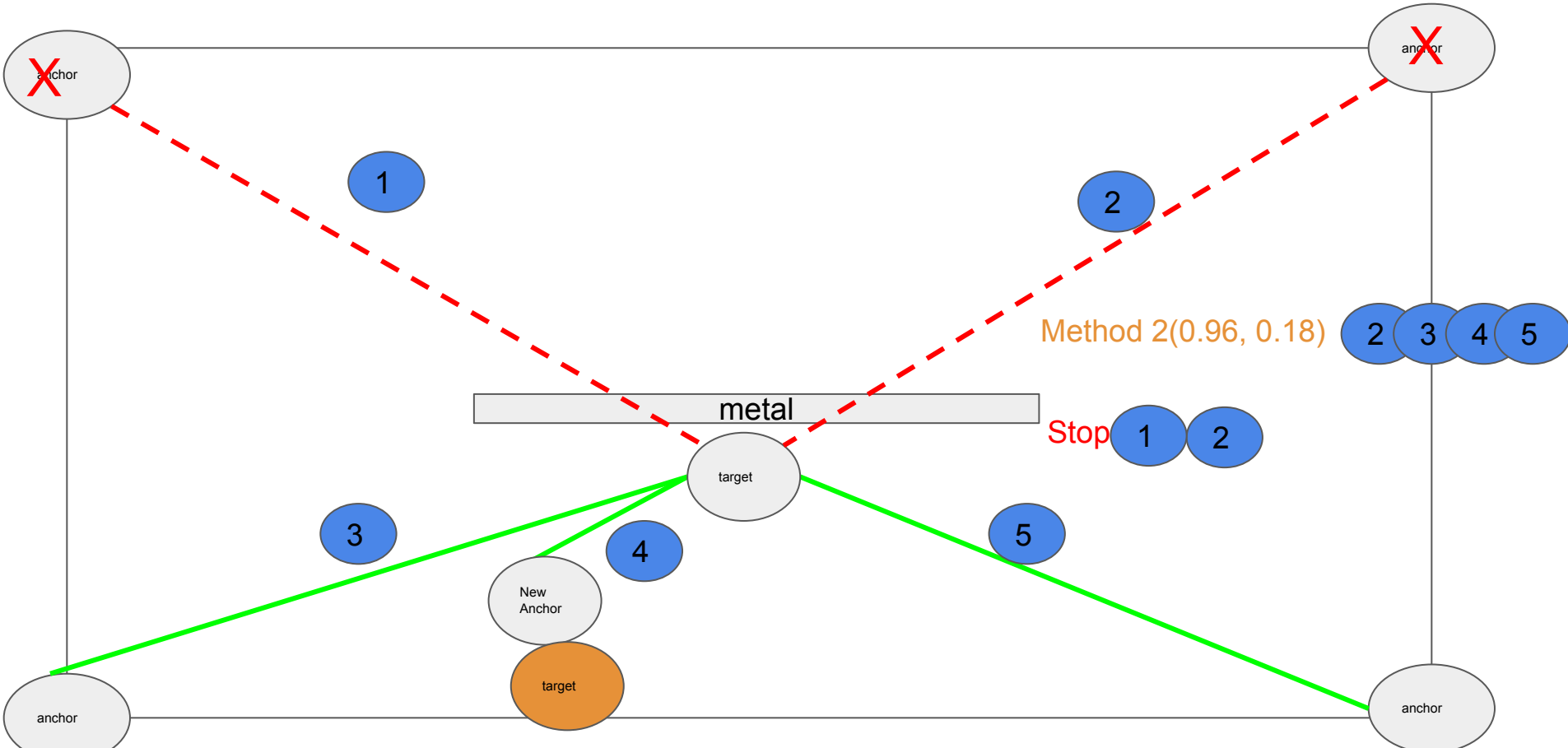

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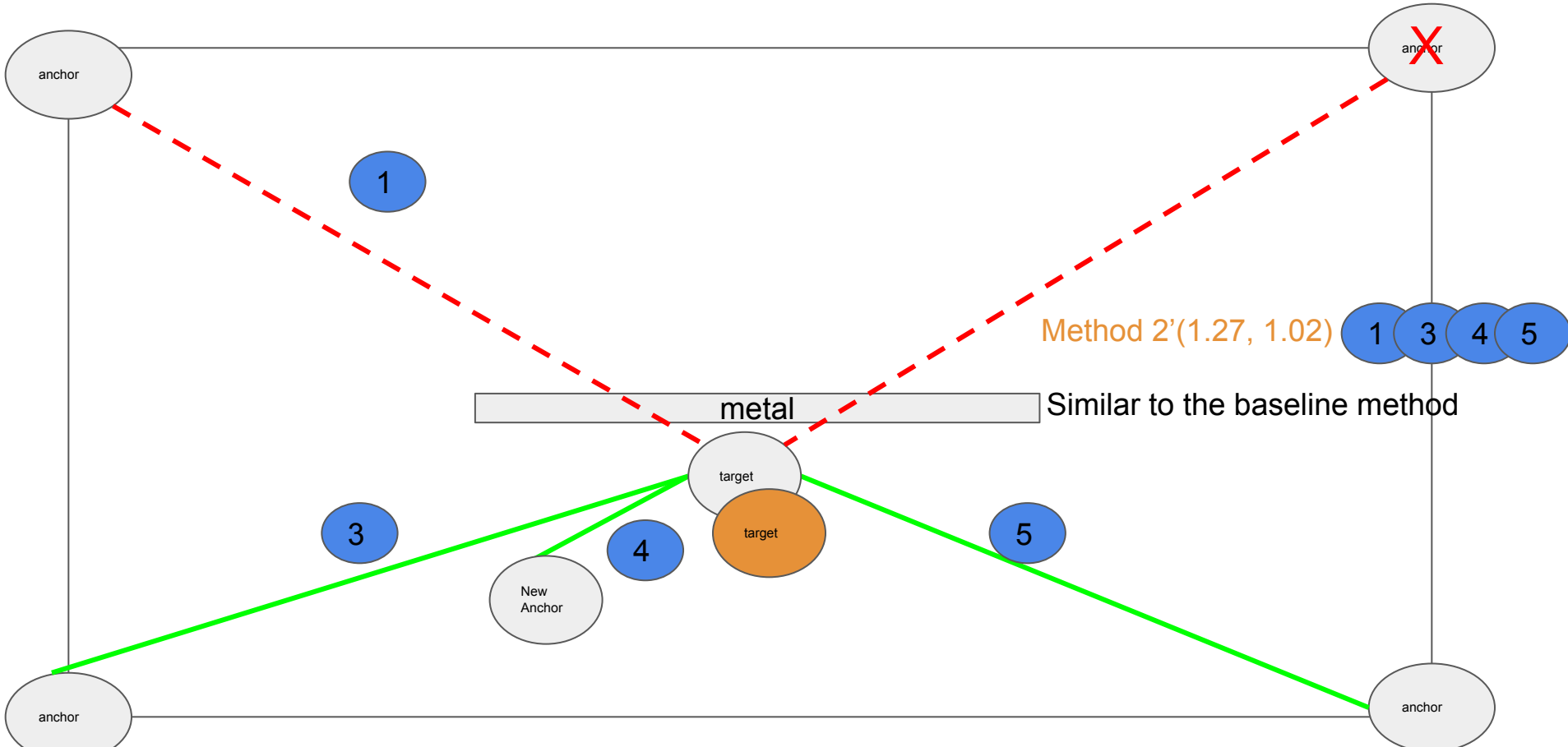

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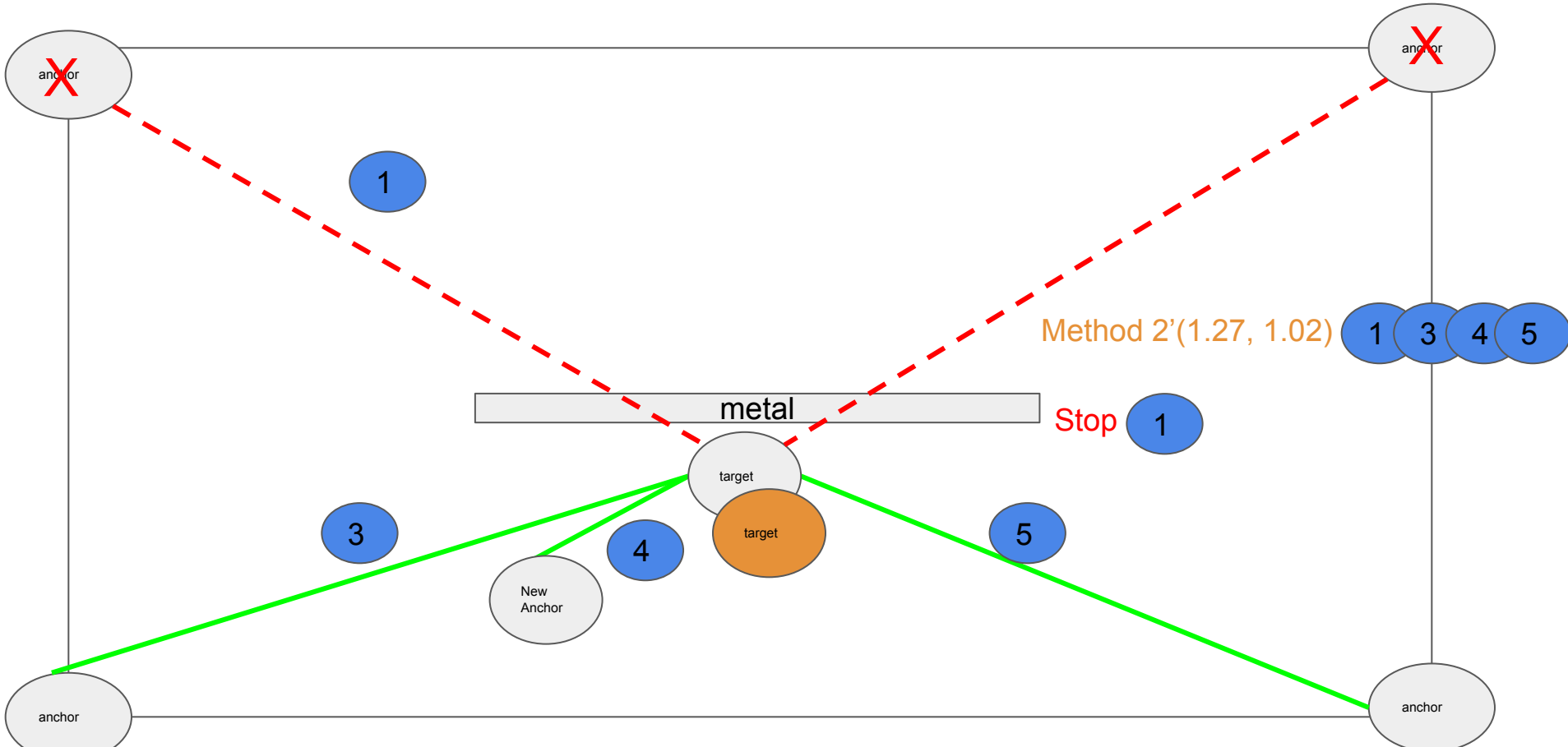

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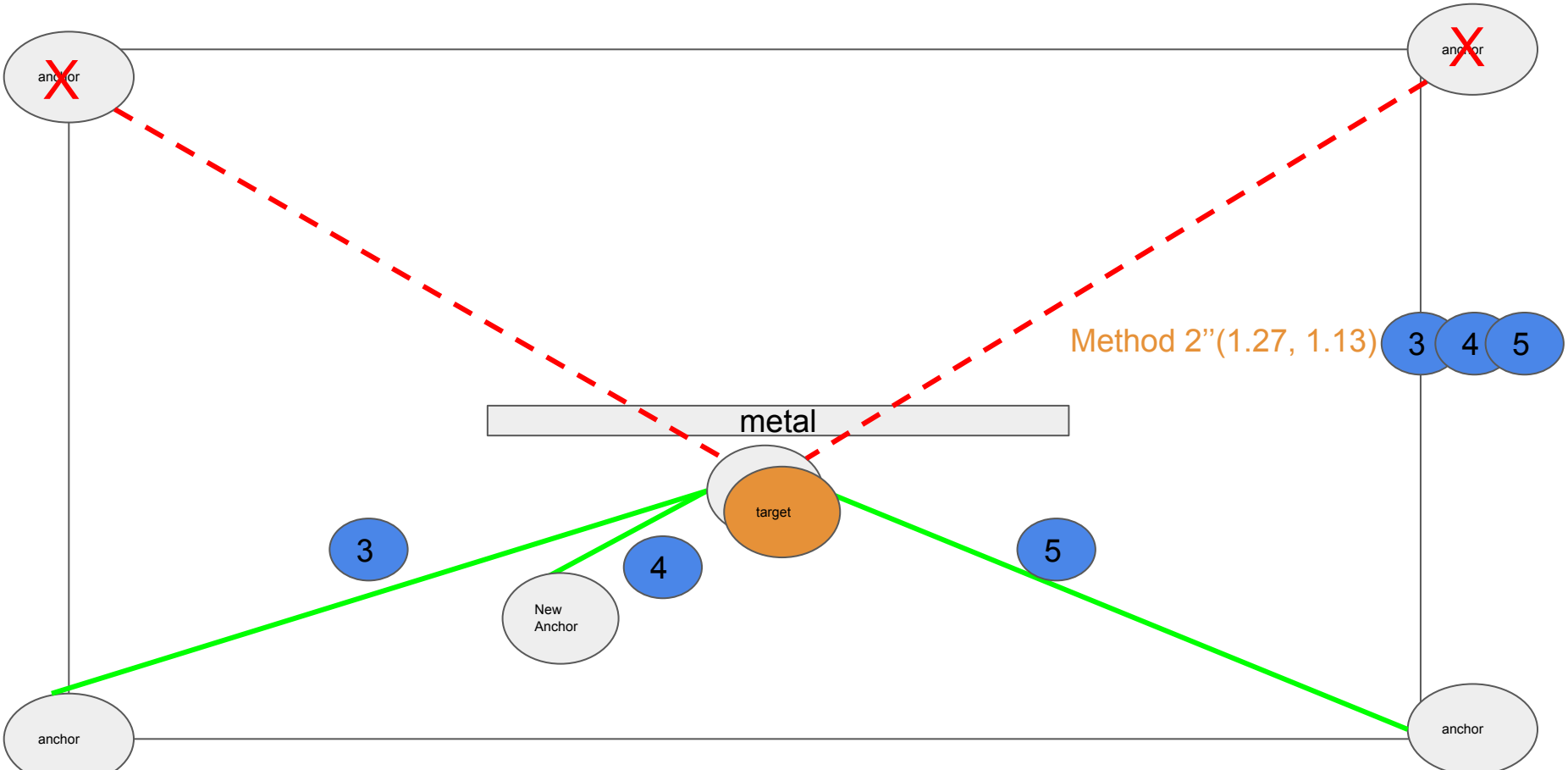

Summary

1. NLOS condition + metal obstacles will cause a poor measurement result in the UWB indoor location system.
2. We proposed two new methods to localize static targets with wireless indoor location system under NLOS condition.
3. The localization error of the mobile-relay approach is smaller than 5 cms in both X and Y axis.
4. The set-to-new-anchor approach does not work with current algorithms. We need to design a new algorithm to select right distances.

Limitation

1. We directly use the commercial UWB system. The system only supports the two way ranging result. We cannot build our algorithm from the scratch(NLOS detection etc.). In the future, we can find or build a more low-level dev platform.
2. We assume the UWB indoor location system exists. We believe in the near future, indoor location system will be a standard for public building such as supermarket, school, etc.
3. In our system, we use extra hardware to do the second phase measurement. Later, we can use the hardware such as the UWB chip, the camera etc. in the mobile phone instead.

Questions