IoRL: 5G-VLC localization protocol and algorithm

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Background and motivation (1/2)

- **Location-based services (LBS) :**

- **From outdoor to indoor**

➢ The total mobile data traffic: ~ 77 Exabytes per month by 2020

➢ 70% to 90% of the overall data traffic occurs indoor environment

- **Positioning accuracy requirement proposed in 5G forum white paper:**

➢ With accuracy from 10 m to less than1 m on 80% of occasions, and better than 1 m for indoors.

Background and motivation (2/2)

Table I: Current widely used indoor positioning technologies

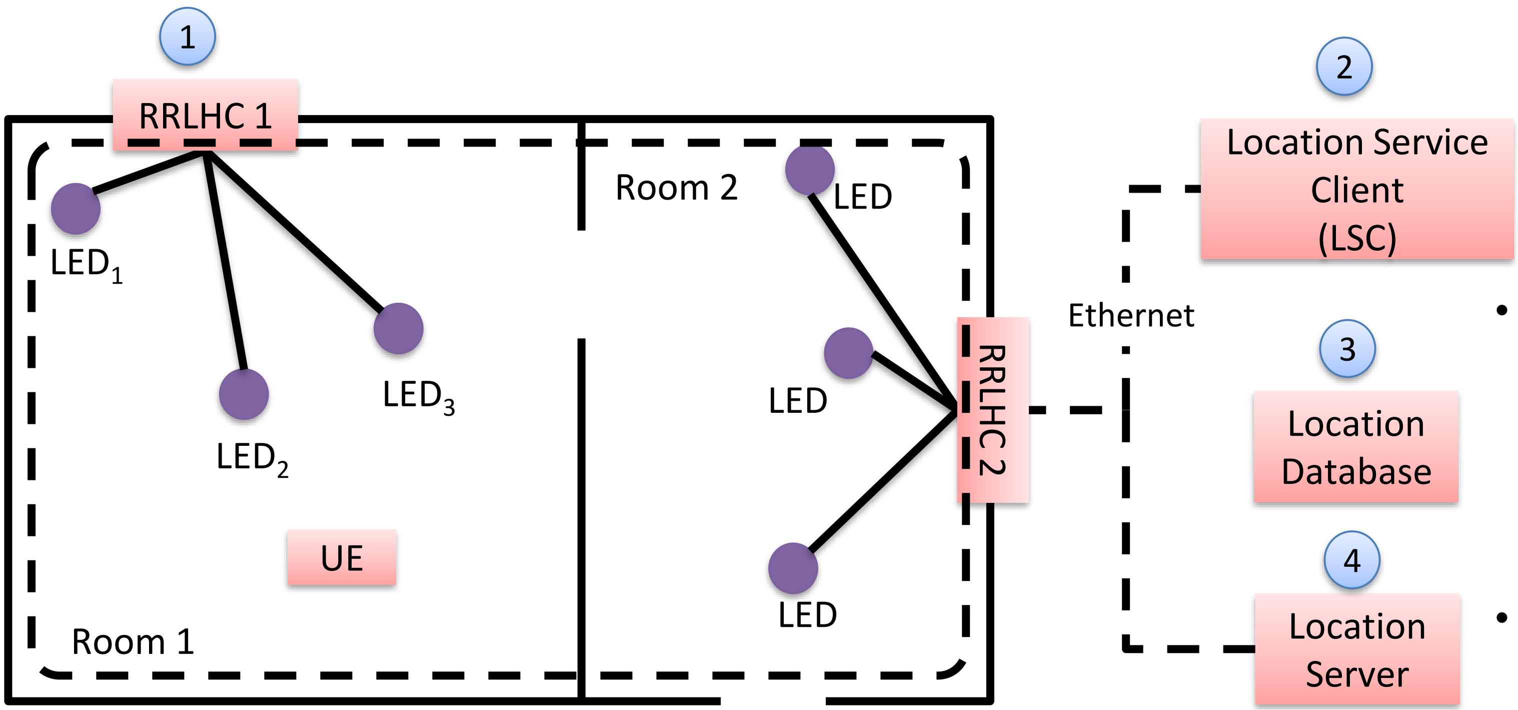
Positioning technologies	Accuracy	Cost	Power consumption
VLC	0.01	Low	Low
RFID	1-2m	Low	Low
Bluetooth	1-5m	Low	Low
Zigbee	1-10m	Low	Low
UWB	0.01-1m	High	Low
Wi-Fi	1-5m	Medium	High
Cellular networks	2.5-20m	Medium	High
GPS	6-20m	High	High

Requirements of indoor positioning technologies in 5G network:

- High positioning accuracy
- Low-cost
- Low power consumption

The most promising candidate: VLC for 5G indoor networks

VLC based positioning framework in IoRL



- Received signal strength of the positioning signal by UE
- Estimated coordinates of UE
- Coordinates of all LEDs and floor plans

RRLHC: Remote Radio Light Head Controller
UE: User Equipment

Location database in IoRL

Measured location relevant parameters in the SDN location database

	UE ID	RRLH ID	mmW parameters			VLC parameters			Timestamp
			pToA_A1	...	pToA_An	RSS_L1	...	RSS_Ln	
Nr. of bits	8	8	8	8	8	8	8	8	13
Interval	[0,255]	[0,255]	[0,255]	[0,255]	[0,255]	[0,255]	[0,255]	[0,255]	MM/dd/yyyy hh:mm:ss a zzz

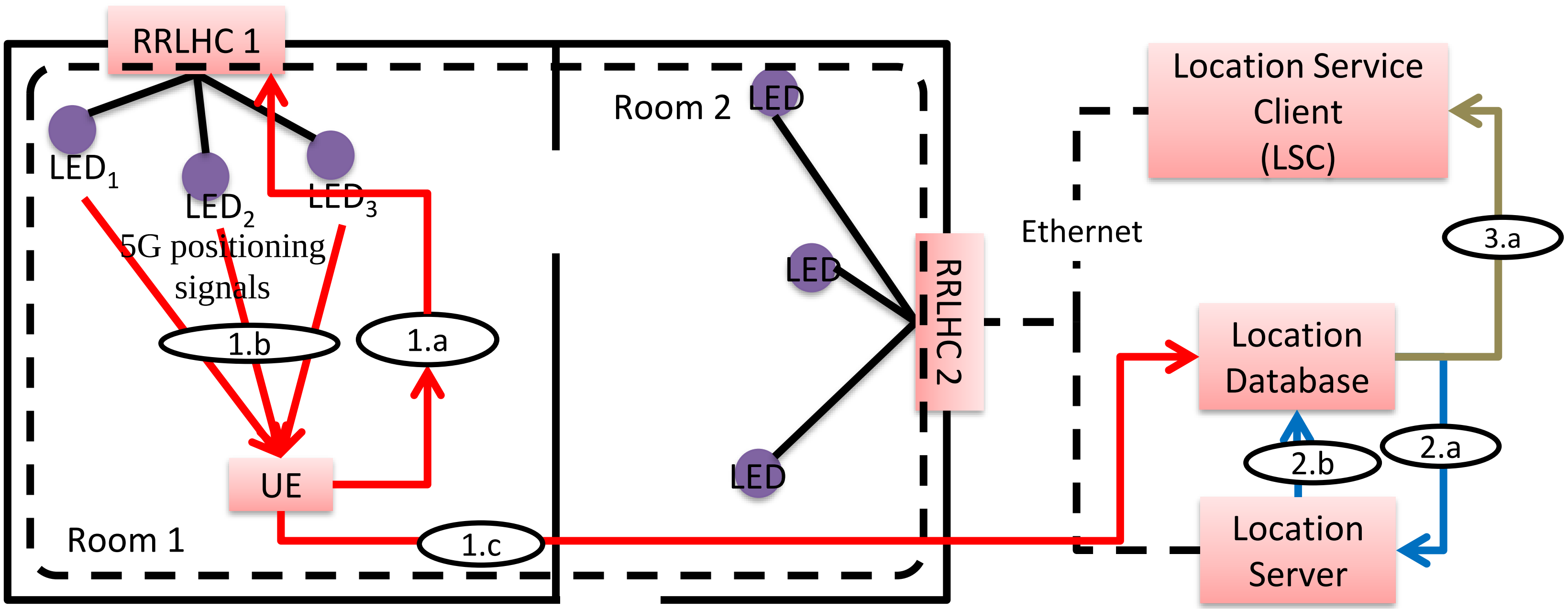
Antenna and LED coordinates in the SDN location database

	RRLHC ID	RRLH ID	Antenna Coordinates			LED Coordinates			LED Tx Power
			X	Y	Z	X	Y	Z	
Number of bits	8	8	8	8	8	8	8	8	8
Interval	[0,255]	[0,255]	[0,255]	[0,255]	[0,255]	[0,255]	[0,255]	[0,255]	[0,255]

Estimated UE coordinates in the SDN location database

	UE ID	UE coordinate			Timestamp
		X	Y	Z	
Number of bits	8	8	8	8	13
Interval	[0,255]	[0,255]	[0,255]	[0,255]	MM/dd/yyyy hh:mm:ss a zzz

VLC based positioning procedure in IoRL



Positioning procedure:

Step 1: Measurement of location relevant parameters

Step 2: Location estimation

Step 3: Exploitation of location estimation

RSS based positioning algorithm

$$H_{LOS}(0) = \begin{cases} \frac{A_r(m+1)}{2\pi d^2} cos^m(\phi) T_s(\psi) co\,s(\psi)\,, 0 \le \psi \le \psi_{FOV} \\ 0 \; elsewhere \end{cases}$$

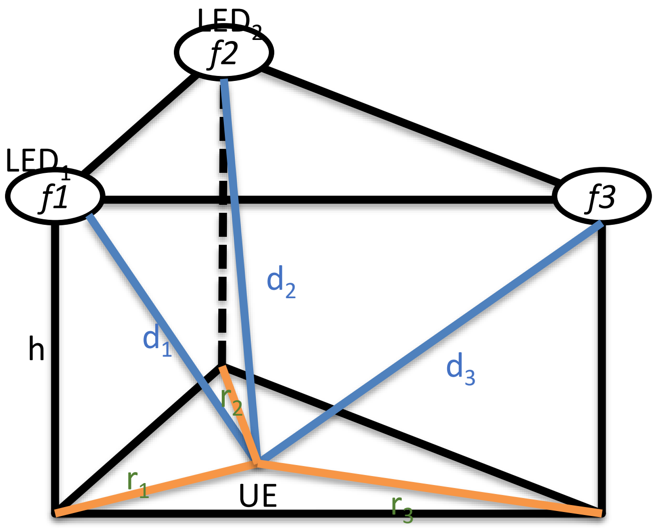
- *Received power* P_R: $P_R = G * H_{LOS}(0) * P_T$

$$d = \sqrt[m+3]{\left(\frac{G \cdot A_r(m+1)h^{(m+1)}}{2\pi}\right)\frac{P_T}{P_R}}$$

- *Projection distance r* : $r = \sqrt{d^2 - h^2}$

- *Coordinates of UE* (x_e, y_e) :

$$\begin{cases} (x_e - x_1)^2 + (y_e - y_1)^2 = r_1^2 \\ (x_e - x_2)^2 + (y_e - y_2)^2 = r_2^2 \\ (x_e - x_3)^2 + (y_e - y_3)^2 = r_3^2 \end{cases}$$



It is difficult to obtain VLC model parameters in various complex indoor environments,
and further significantly impact on positioning accuracy

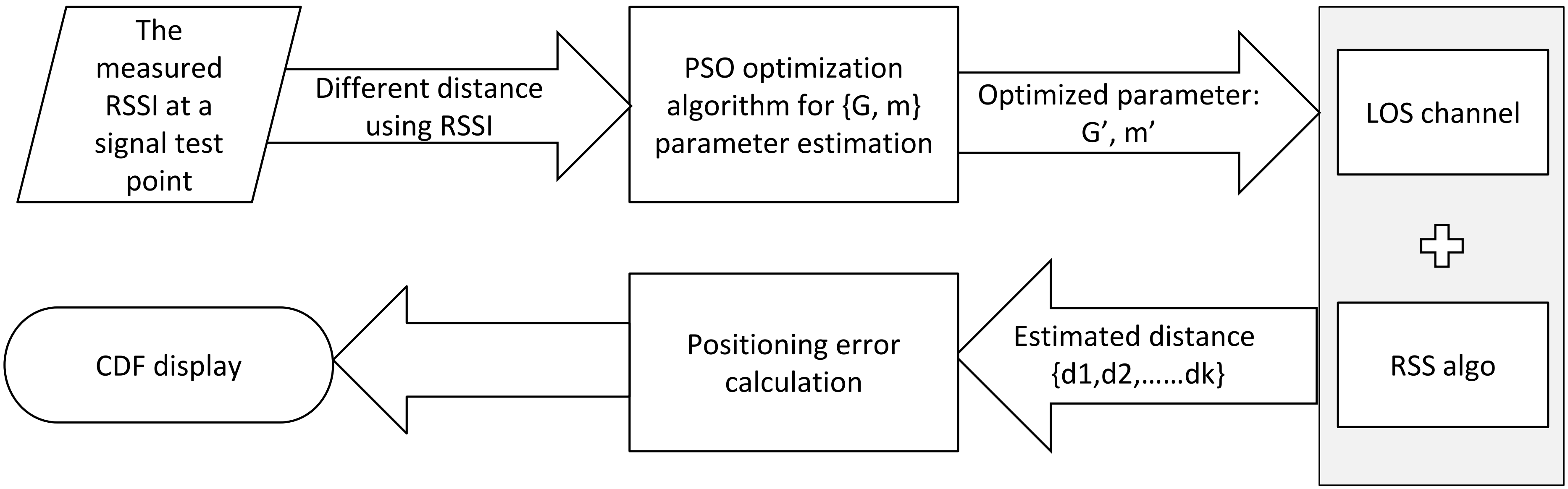
Particle swarm optimization (PSO) method is proposed to simulate the parameter estimation in the practical indoor environment

RSSI ranging parameters estimation with PSO method

Particle swarm optimization (PSO) is an artificial intelligence (AI) technique that can be used to find approximate solutions to extremely difficult or impossible numeric maximization and minimization problems.

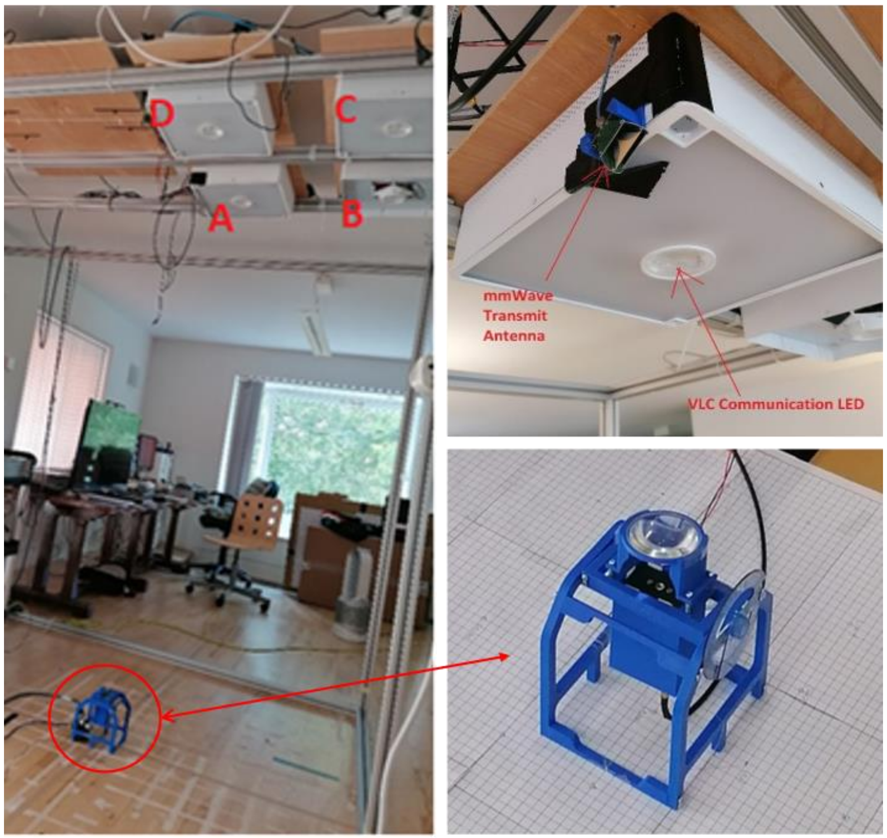
We apply it to estimate the VLC channel parameters from received RSS measurement.

RSSI ranging parameters estimation with PSO method



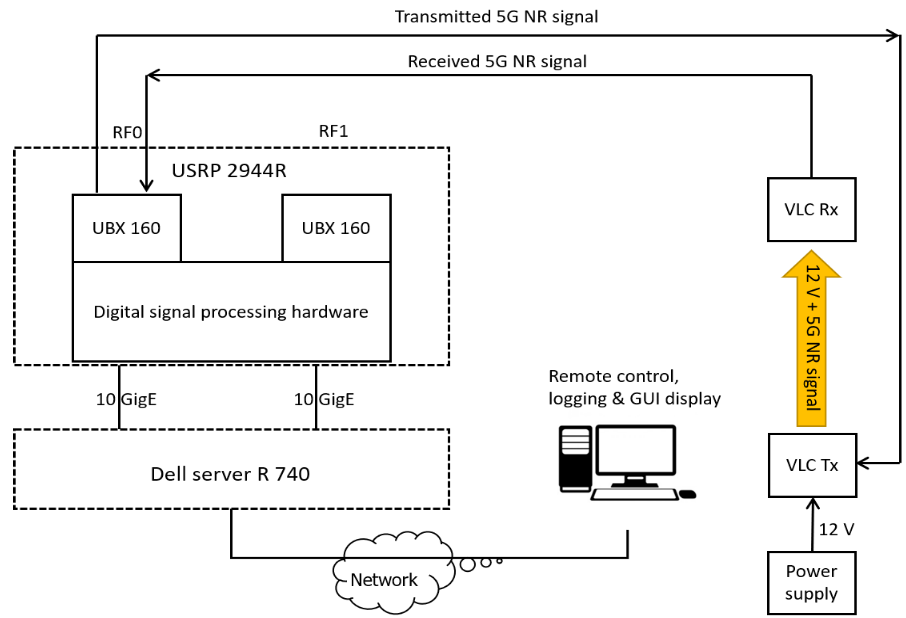
Experimental testbed specifics

➢ The laboratory environment setup



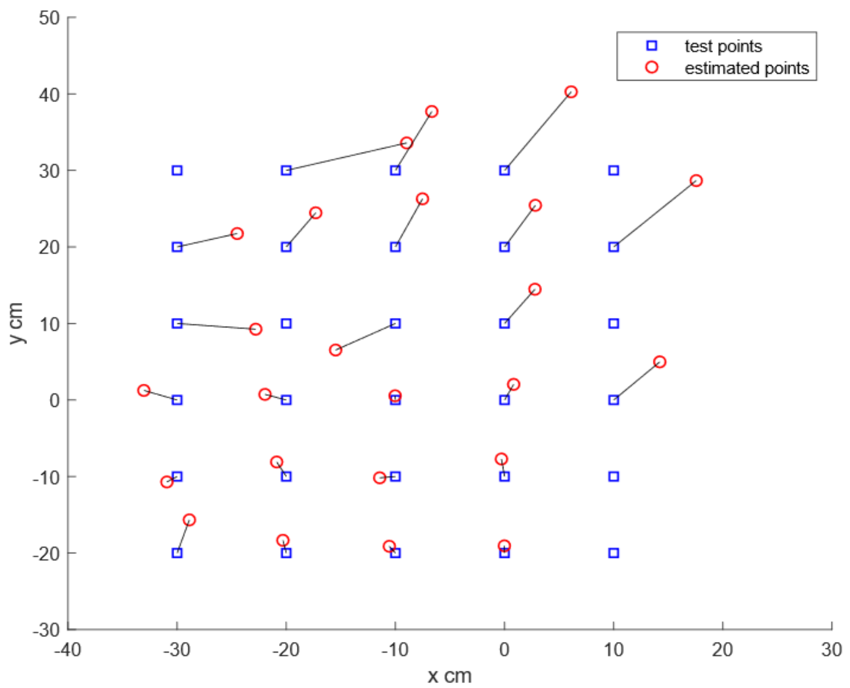
- 40cm x 50cm positioning area
- 30 (5*6) uniform distributed test points

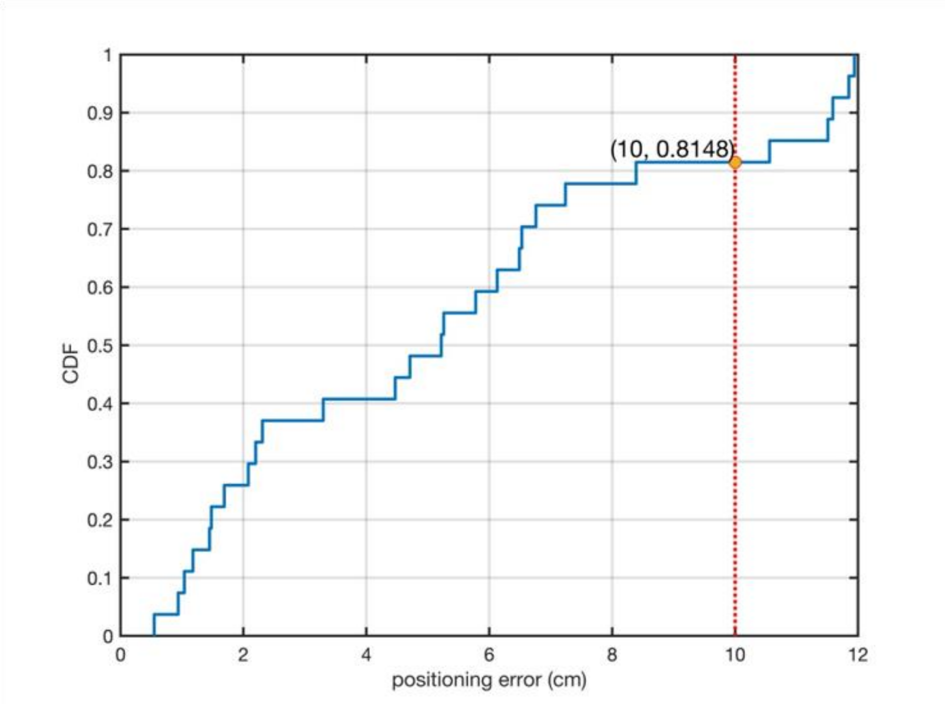
➢ System configuration diagram



VLC TX	LED A	LED B	LED C	LED D
Subcarrier index	1	3	5	7
Frequency (kHz)	60	120	180	240

Experimental results





- 30 (5*6) uniform distributed test points
- 25 valid points and 5 invalid points
- Each reference point measured 50 times
  - 1500 (5*6*50) estimated points in total

- Among 25 valid test points:
  - the min PE = 0.55 cm
  - the max PE = 11.94 cm
  - mean PE = 5.28 cm
- Cumulative distribution function (CDF) :

A positioning accuracy of 10 cm at the confidence of 81.48 %.

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Thank you for your attention

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