VLC-backscatter Design for Self-charging indoor IoT Devices

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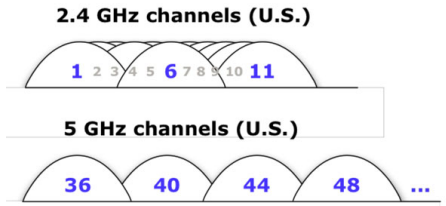
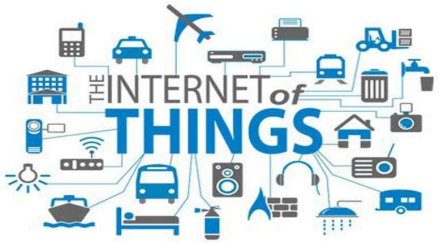
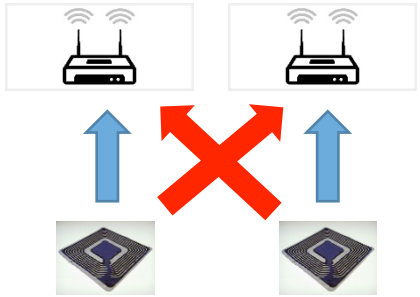
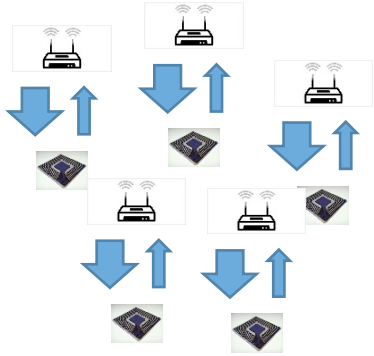
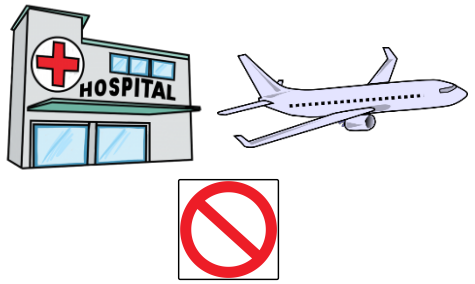
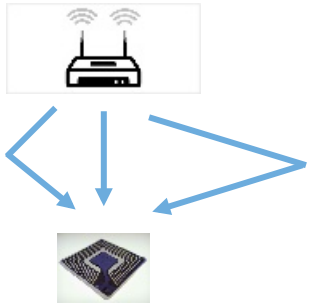
Challenges of Internet of Things and IoT localization

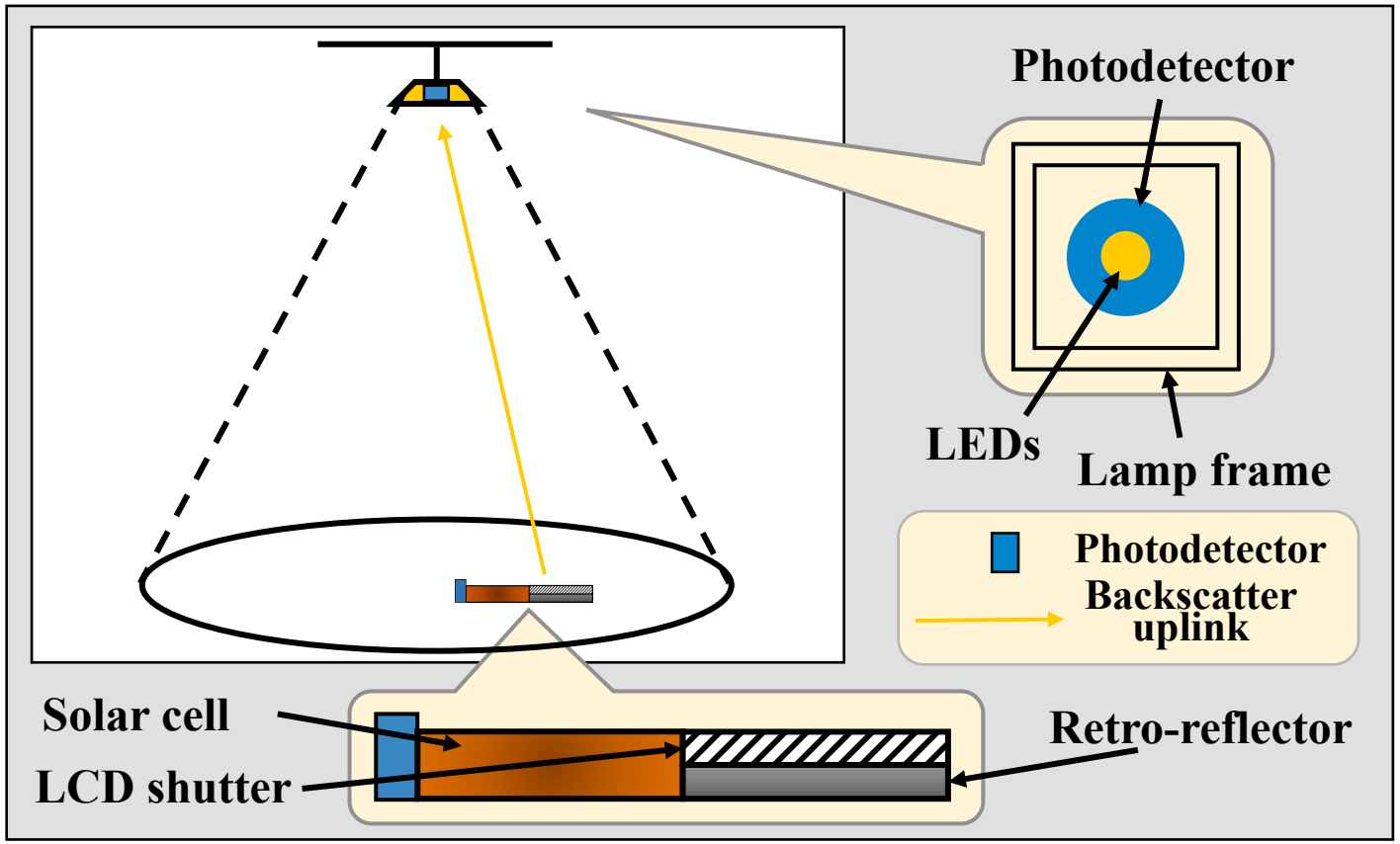
Wired connection 	*Wireless access* 	*Battery* 	*Density of devices* 
Deployment complexity makes it impractical	Compete with user's devices on allocating the spectrum	Replacing batteries is cost-inefficient	The number of communication devices and objects is huge

Limitations of RF backscatter and RF based indoor localization

				
Uplink *depends on downlink*	Uplink mutual *interference* among RF backscatters	Due to the short communication distance (2-5 meters), *infrastructure support* is expensive	Unavailable in a *RF limited* environment	*Multipath effect* reduce RSSI based localization accuracy

What is visible light backscatter?

Harvest energy from infrastructure light using solar cell and modulate the reflected light beam from retro-reflector by switching on and off the shutter (i.e. liquid crystal display shutter). Without generating light by itself, the visible light backscatter can continuously operate Rx chain and shutter driving using the amount of harvested energy.

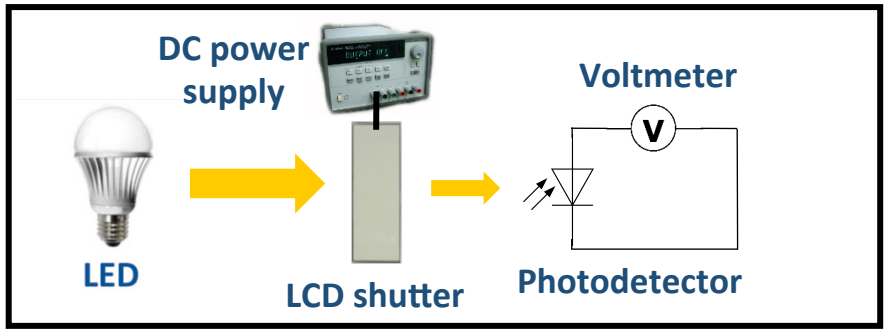


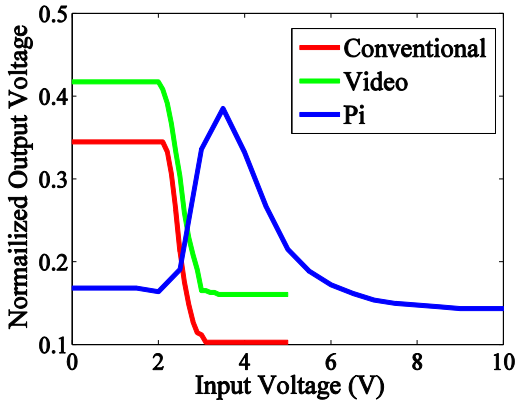
Advantages

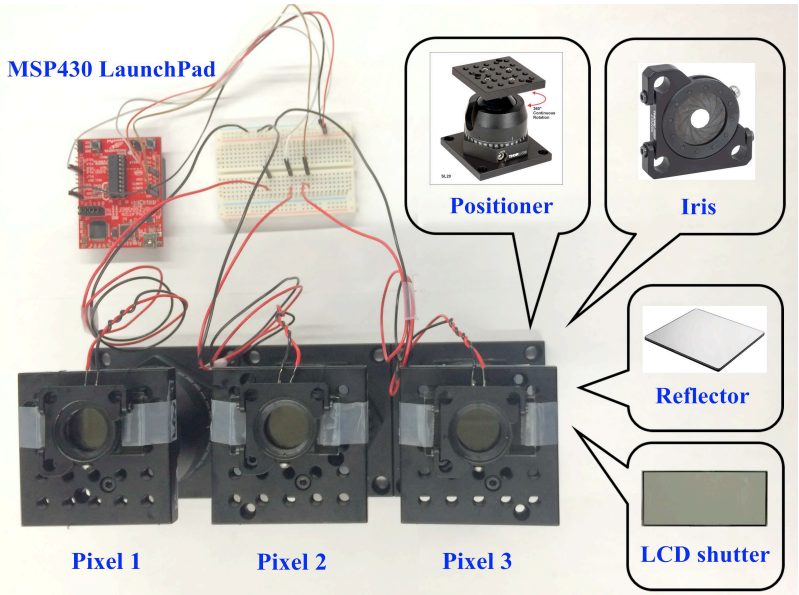
- Downlink is always available whenever illumination is needed.
- Directional uplink improves spatial reusability
- Light infrastructure enable the deployment of visible light backscatter with low cost
- Visible light backscatter can be used in most RF-limited environment
- Dominant LOS path
- Non-uniform optical power distribution increases the variation of RSS at different locations

Limitation of the state-of-the-art VLC backscatter

- Non-linearity of LCD shutters limits the dynamic range of modulation.
- The state-of-the-art VLC backscatter can only use on-off keying (OOK).

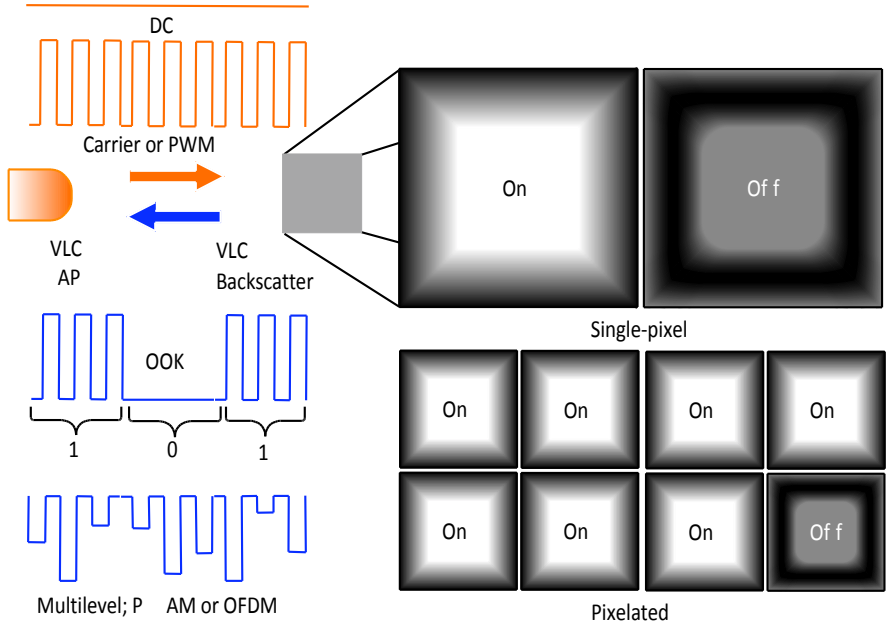


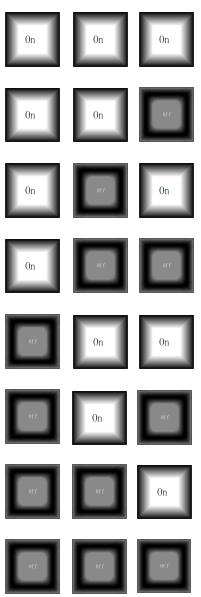


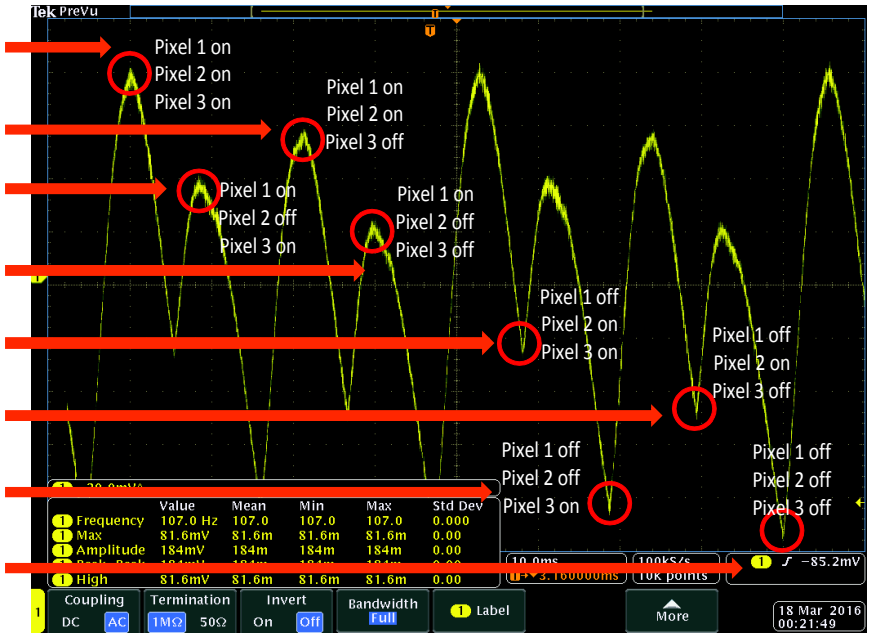


A novel pixelated visible light backscatter

- Multiple smaller reflector forms the pixelated visible light backscatter.
- Multi-level signals are enabled.
- PAM, OFDM become available

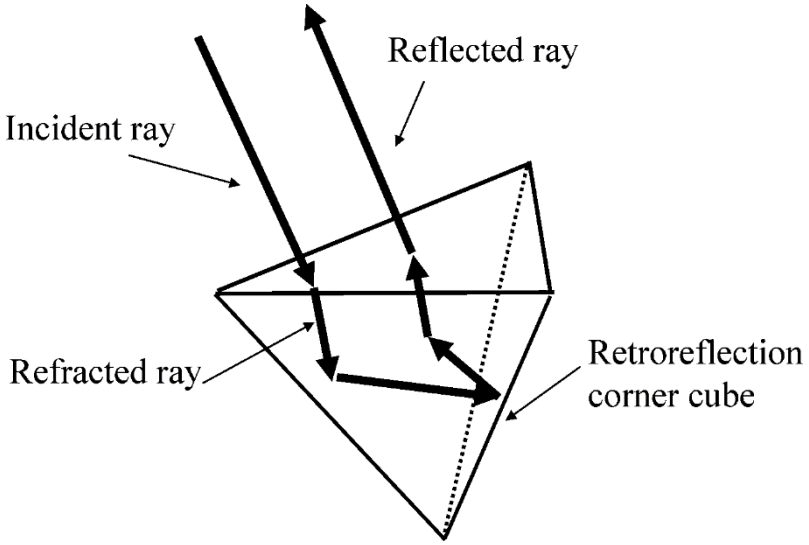


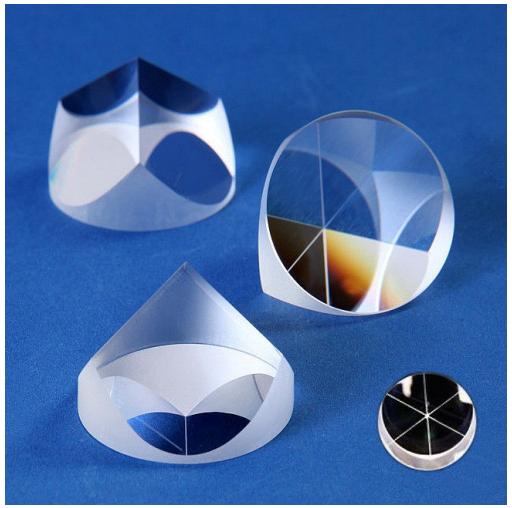


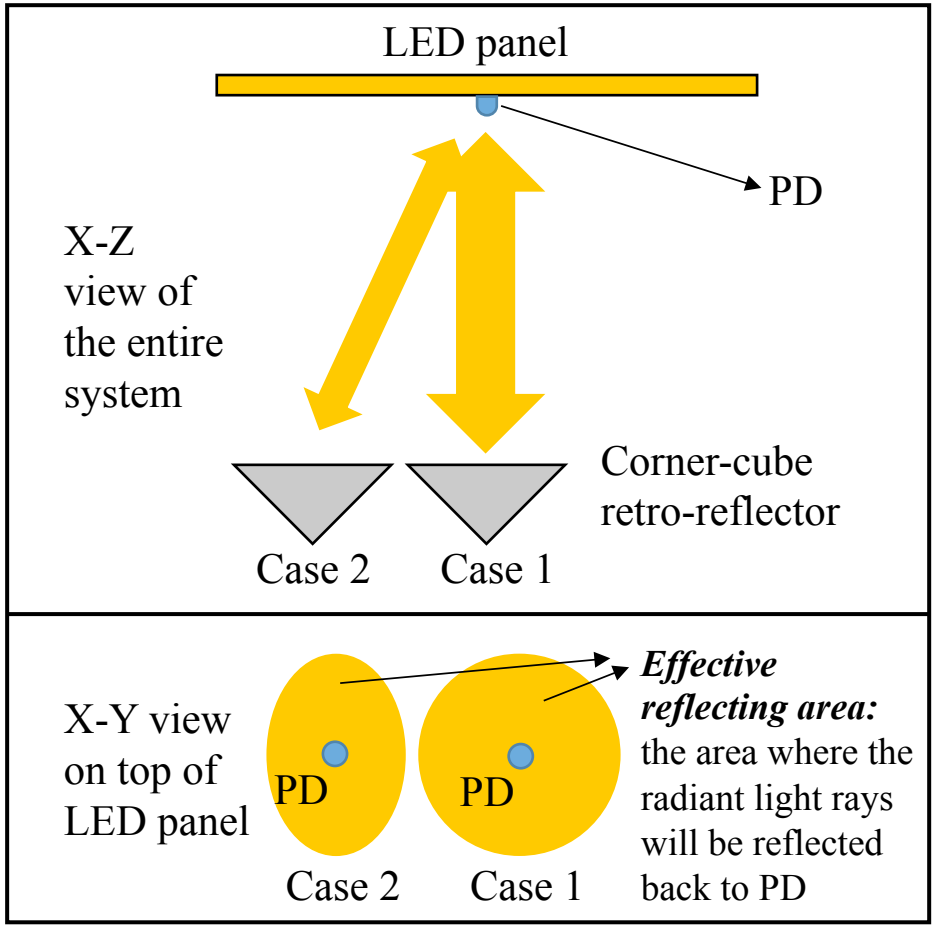


Circular corner-cube retro-reflector based visible light localization

- Localization technique – RSSI and trilateration based
  - Main idea: Photodiodes (PDs) are mounted on light source to receive the reflected light from retro-reflector. When retro-reflector changes its location and orientation, the received optical power on each PD will change.





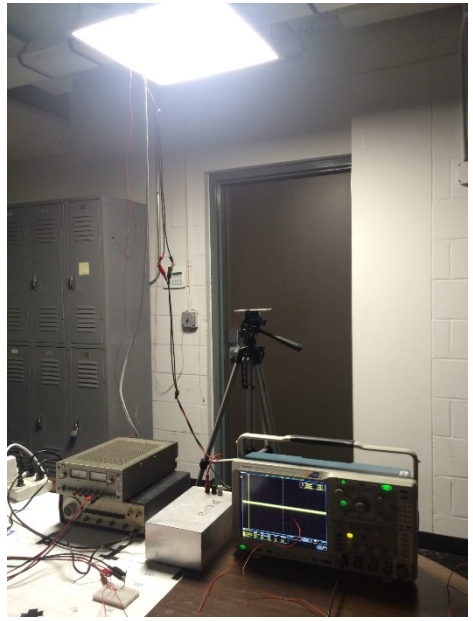


Corner cube retro-reflection: the incoming ray is reflected three times, once by each surface, which results in a reversal of direction.

Circular retro-reflector: ensure isotropic property, which is important for localization

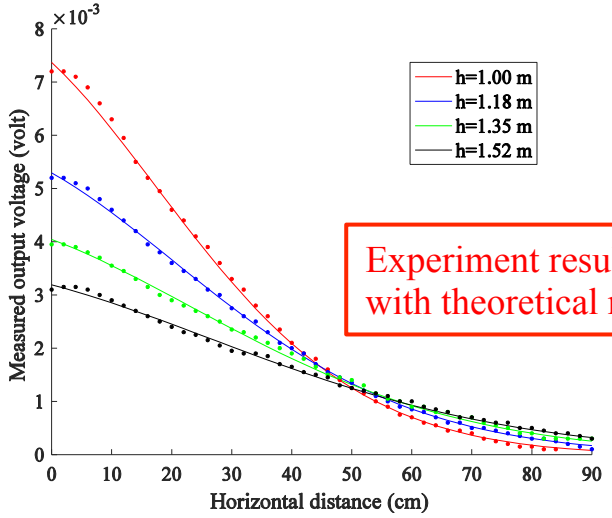
We theoretically derive the amount of light rays from light source that can be retro-reflected back to the photodiode mounted on light source.

Experiment based validation of RSSI derivation



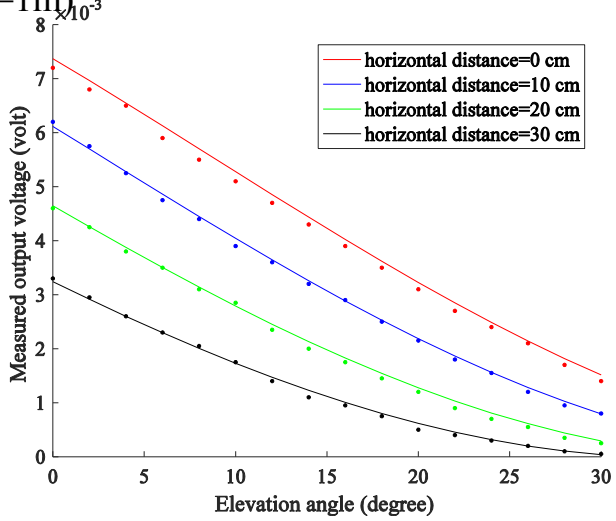
Testbed

Vary horizontal distance at 4 different heights

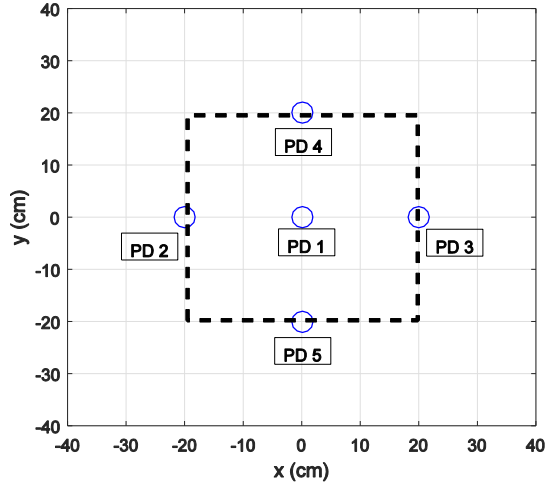


Experiment results match well with theoretical results

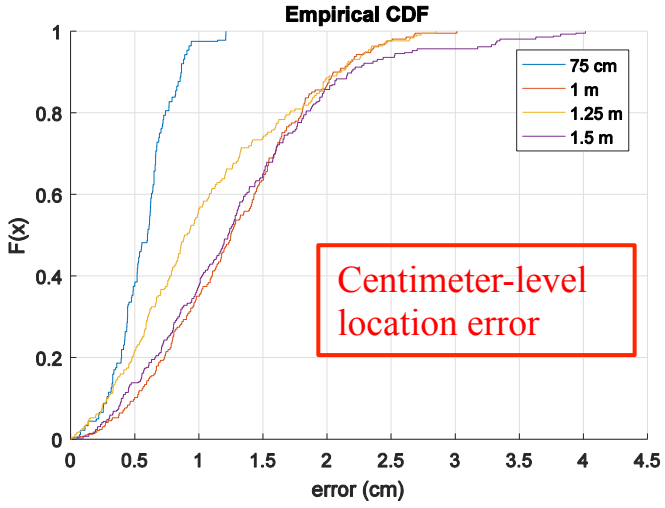
Vary orientation at 4 different locations (h=1m)



Experiment based evaluation of localization and orientation accuracy

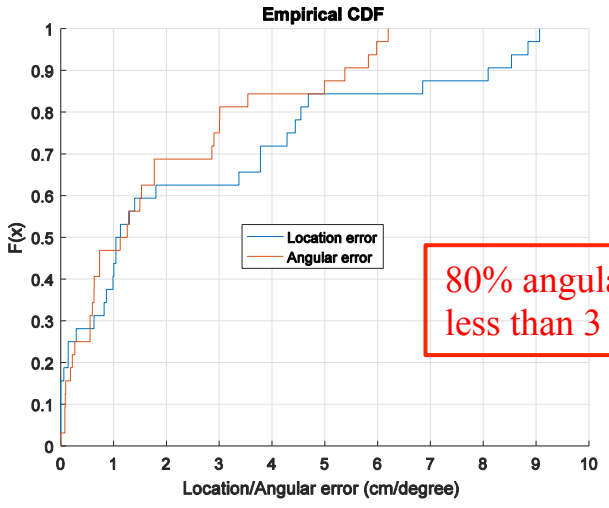


Grid structure localization system configuration



Centimeter-level location error

CDF of location error when the front face of retro-reflector is parallel to LED panel surface



80% angular error less than 3 degrees

CDF of location error and angular error