# Indoor Positioning Systems Based on Visible Light Communication: State of the Art

## Introduction

For outdoor scenarios, GPS is used extensively. However the positioning accuracy is several meters which is unaccaptably large for indoor scenarios. Outdoor positioning tech thus cannot be used indoors.

Two features make light available for positioning:

1. The light strength varies according to differenet light sources, which can be readily detected by light sensors embedded
2. The light strength is stable at different times of a day, avoiding site-survey and database maintenance.

* Received Light Strenght of the light source can be used for localization

VLC-based IPS advantages:

* Can be used in RF sensitive areas like hospitals…
* LED offers a narrow beamwidth: more precise AOA information
* VLC has little influence from multipath interference (primary energy comes from line of sight link)
* Can be installed inexpensively since they utilize existing lightingsystems.
* Higher precision than traditional positioning

## Indoor Positioning technologies and VLC

### Various indoor positioning technologies

Different techniques: frequency modulation, cellular networks, zigbee, Wi-Fi, Infrared, Ultrasound, Bluetooth, RFID and UWB?

### VLC

RF-bandwidths are failing to meet requirements

* VLC is promising alternative

High speed response characteristics of White-LED devices , at the same time of lighting, LEDs can send information. VLC has the following advantages:

* Cost efficiency: VLC uses existed lighting infrastructure to communicate
* Broad Bandwidth: between 385 and 800 THz
* Energy efficiency: LED’s are energy efficient and use it’s energy to communicate at the same time
* Communication Security: Visible light can not penetrate most objects and walls, and links can be kept confedential

## VLC-based-IPSs

### VLC-based Indoor Positioning techniques

* The device-free-IPS analyses how a human body changes the pattern of received signal strength to detect and locate human in an indoor environment.
* VLC-based-IPSs with high precision (up to a few centimeters)
* VLC-based positioning systems: Eplison, Luxapose, LIPS, PIXEL

1. LED Technology:
   * White-LEDs (Blue led with phosphor or RGB combination)

Blue led is commonly used for easy implementation and lower cost. Second method can use Colour Shift Keying (CSK) to modulate the data: better performance in comms

* + RGB-LED (slightly higher modulation bandwidth data rates and lower response time than white leds  
    can transmit data by modulating RED, GREEN and BLUE separately.

1. Modulation Method: the modulation method for VLC should achieve not only the data rate but also to meet the demand of illumination: dimming control and flicker control
   * On-Off Keying (OOK): just turning the LED on and off, no dimming or flicker control
   * Pulse Position Modulation (PPM): the position of the transmitted pulse identifies the transmitted symbol. This method is Simpler but with lower spectral efficiency and a lower data rate. (therefor lots of different PPM’s are proposed)
   * Orthogonal Frequency Division Multiplexing (OFDM)
   * Color Shift Keying (CSK)
   * Carrier-less Amplitude and Phase (CAP)
2. Types of Receivers: two classes (Photodiode (PD) and image sensors)
   * Photodiode: easy, high data rate, most likely to choose the method of RSS, TOA and TDOA algorithms.
   * Image Sensors: less expensive, camera based

### Taxonomy of the VLC-based IPSs

Decisions on 3 key features: mathematical method, sensor-assisted method, and positioning optimization method.

### Mathematical Method

1. Proximity