PLiFi: Hybrid WiFi-VLC Networking using Power Lines

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Outline

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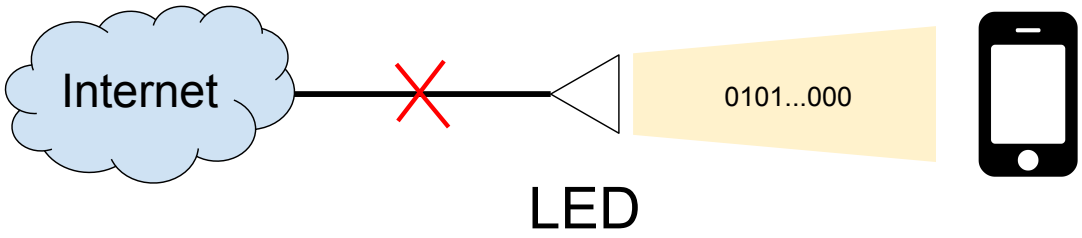
Background

- **Visible Light Communication (VLC)**
  - Unlicensed spectrum from 390 *THz* to 800 *THz* provides high achievable data rate.
  - Reuse of existing lighting infrastructure for purpose of communication make it energy efficient.
  - Unable to penetrate wall means less interference and better security
- **Power Line Communication (PLC)**
  - Utilizing existing power line network for data communication.
  - PLC devices increase 130 million by 2013 since the introduction f HomePlug AV2 standard in 2012.
  - HomePlug AV2 achieves over 1 Gbps of PHY data rate.

Challenges

- **LED to Internet Connectivity**
  Most researcher focus on LED-to-receiver without considering how the LED connecting to Internet.



- **Uplink**
  - Current VLC is limited to broadcasting.
  - Devices equipped with high power LED for communication not practical.

Challenges continued

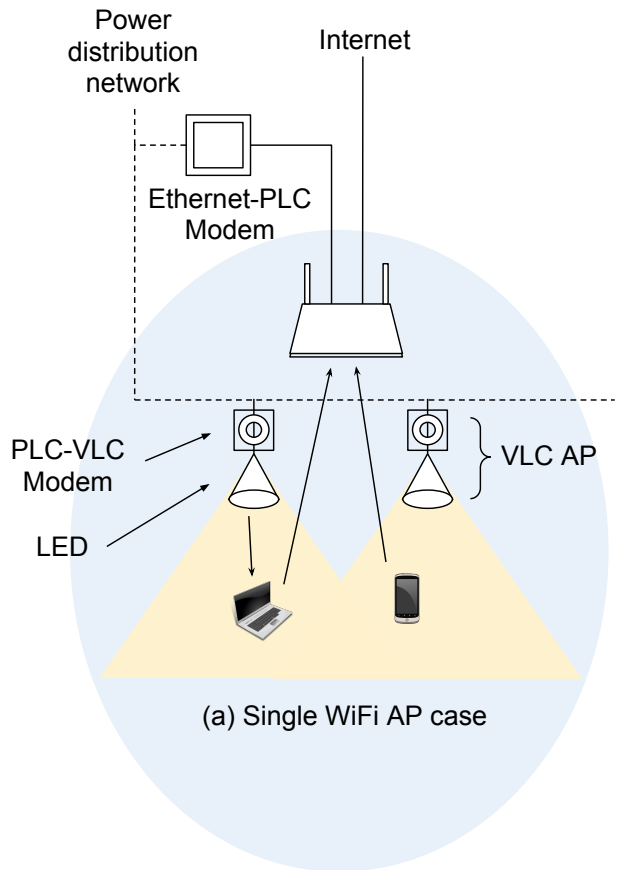
- **Device Mobility**
  - User mobility and device orientation changes can result in misalignment between transmitter and receiver.
  - Blockage between transmitter and receiver.
- **Interference**
  - Co-channel interference among multiple transmitters.
  - Absence of technique to interconnect and synchronize for Coordinated Multi-Point transmission (CoMP)

Outline

PLiFi

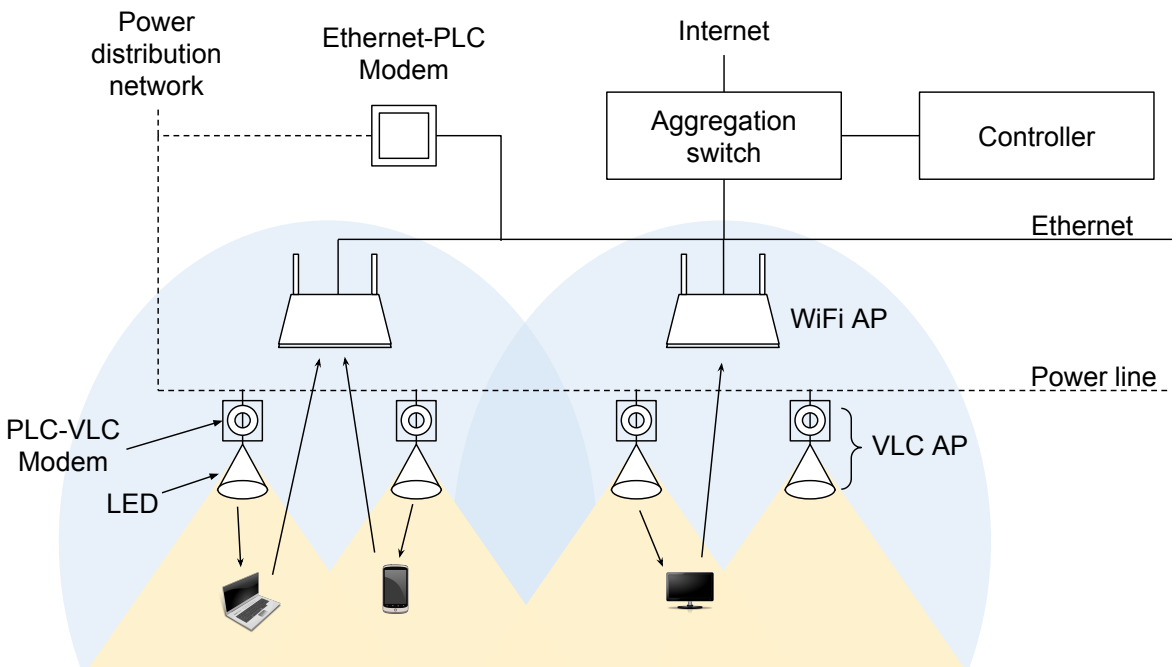
PLiFi architecture for augmenting existing WiFi networks.

- Reuse power line as backbone
- Ethernet-PLC modem as bridge between WiFi and VLC network.
- PLC network connected to VLC through PLC-VLC modem



PLiFi

- Cost-effective way of conneting LEDs.
- WiFi channel serves as uplink and takes over transmission when no VLC.
- Power line serves as backhaul for VLC coordinated transmission
- Scalability for complicated network



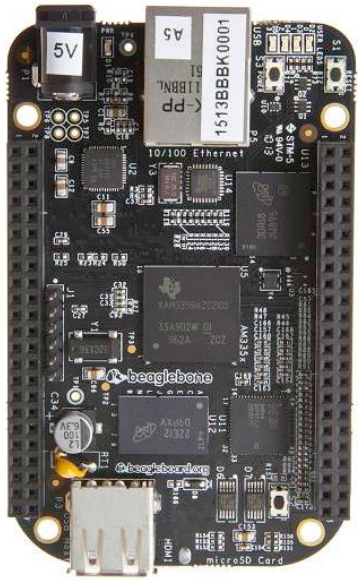
(b) Enterprise networking case

PLiFi Design

- **MAC Design**
  - Sending NACK via WiFi uplink for corrupted or lost frame
  - RTS/CTS packets for collision avoidance transmission
- **Ethernet-PLC and PLC-VLC Modems**

- HomePlug AV2
- Maximum 1.2 Gbps

ZyXEL PLA5405

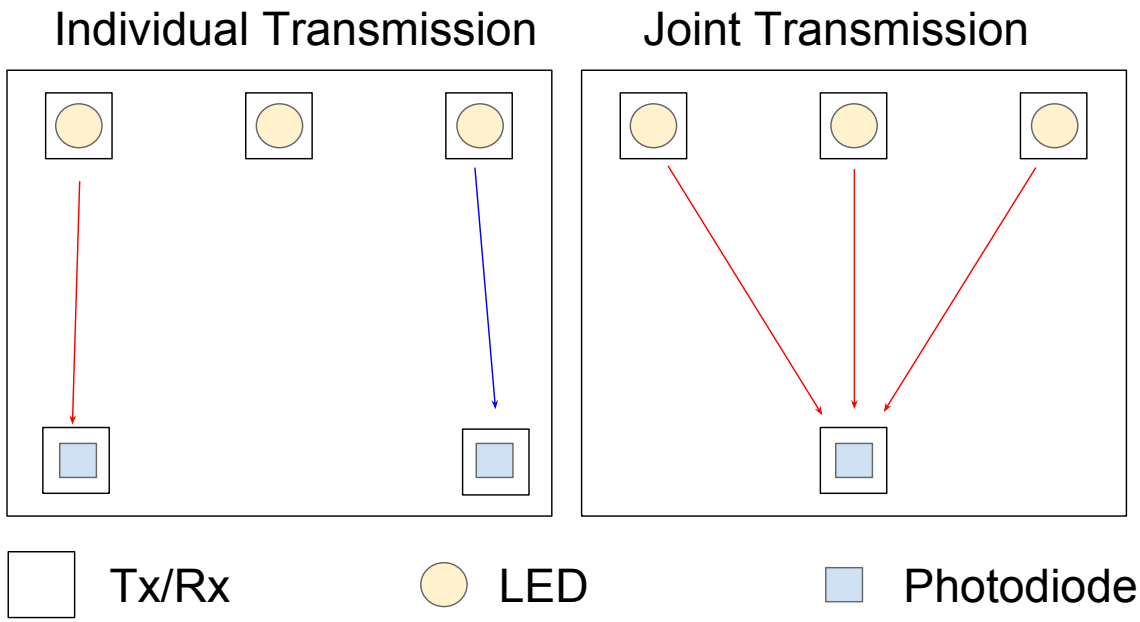


Beaglebone Black

- PLC (OFDM) to VLC (On-Off-Keying)
- 20 MSPS

PLiFi Design

- **VLC Transmission Schemes**
  - Individual Transmission: exclusive use of each LED
  - Joint Transmission: coordinated and synchronized transmission among multiple LEDs.

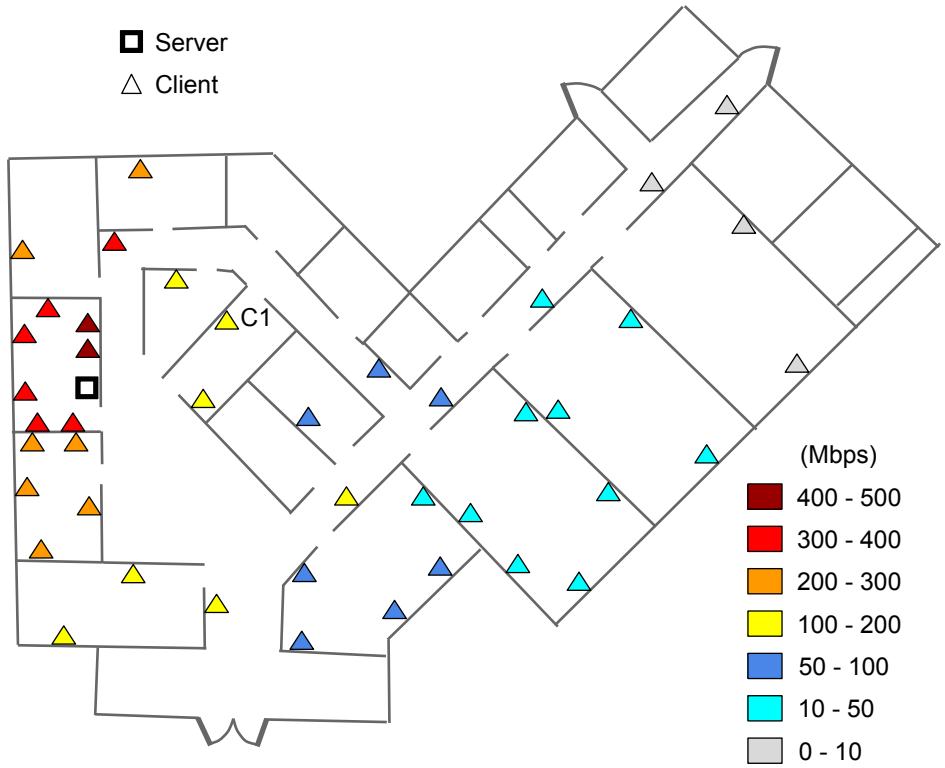


Outline

Power Line Network

Setting

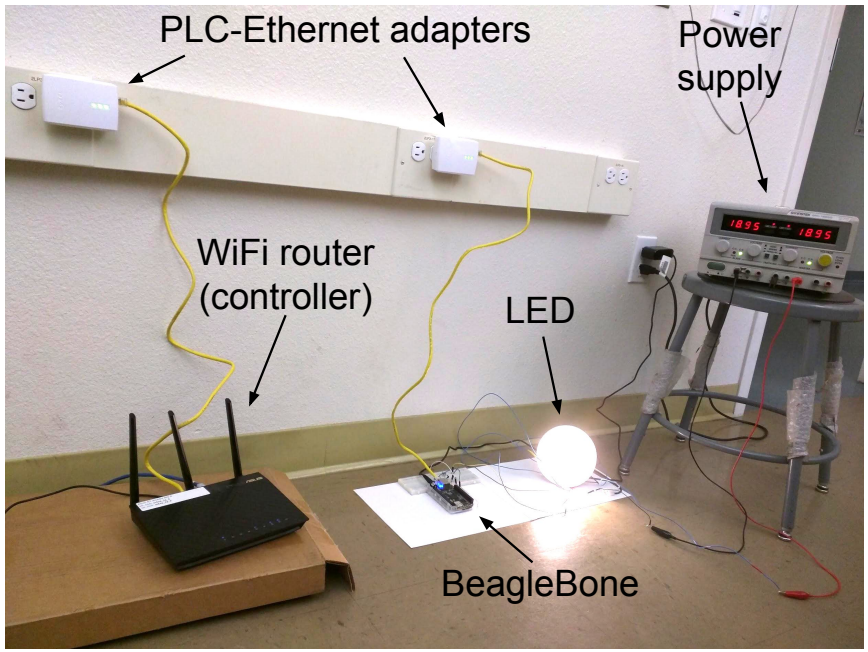
- Ethernet-PLC modem: ZyXEL PLA5405
- University building with an area of 1300 square meters.



Visible Light Mobile Network

Setting

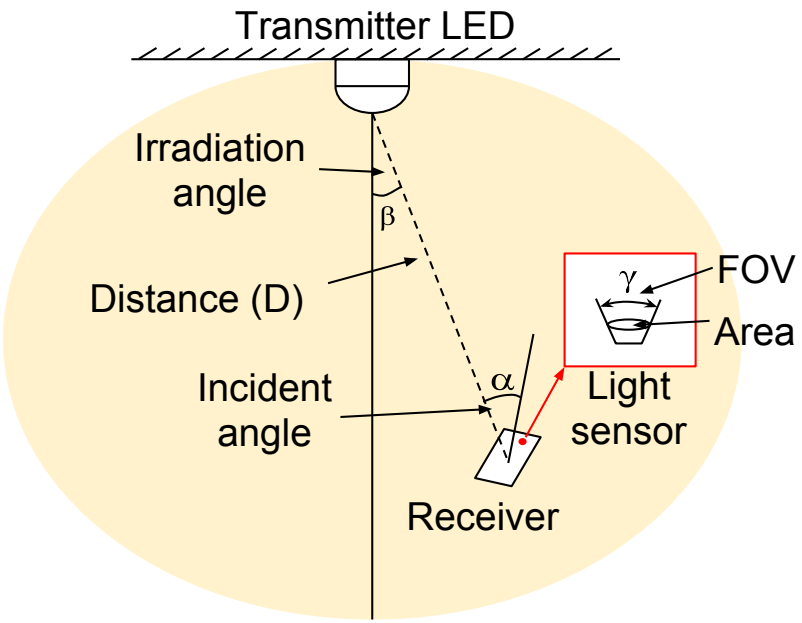
- LED: TCP RL10DR427K with 650 lumens.
- Ethernet-PLC modem: ZyXEL PLA5405
- VLC controller: Beaglebone Black linux board.
- WiFi router: Asus RT-AC68U with custom firmware



Tx and Rx

Luminous Path Loss(L_L)

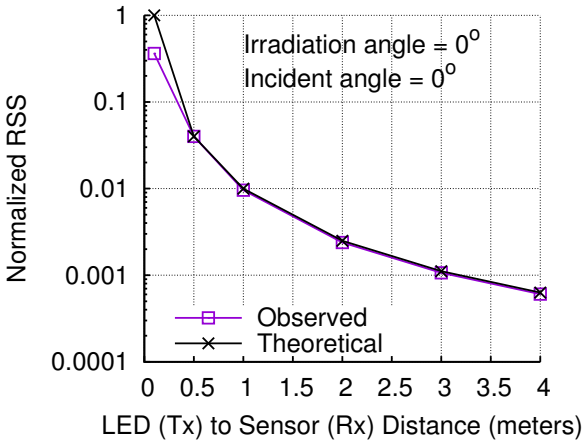
$$L_L = \frac{(m+1)A}{2\pi D^2} \cos\alpha \cos^m \beta \quad (1)$$



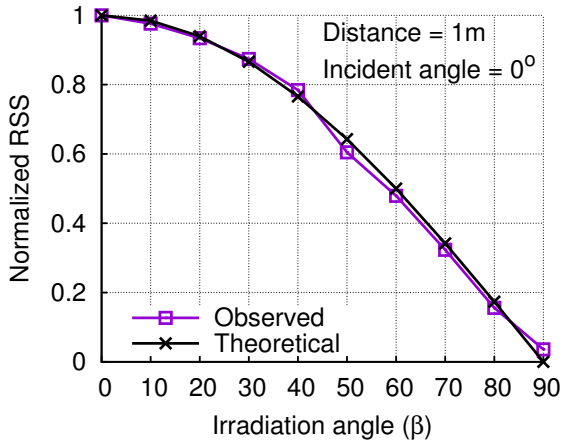
- D: distance between transmitter and receiver
- α: incident angle
- β: irradiation angle

Relative Positions of Tx and Rx

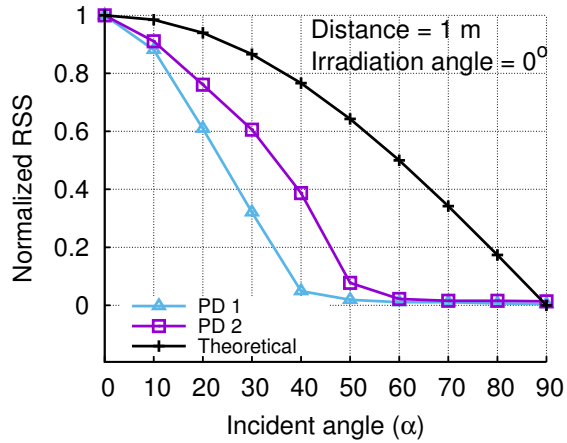
- RSS drops sharply as the distance increases
- RSS with variation in irradiation angle β following theory
- RSS with variation in incident angle α dropping faster than theory. Because of field-of-view (FOV) of receiver



(a)



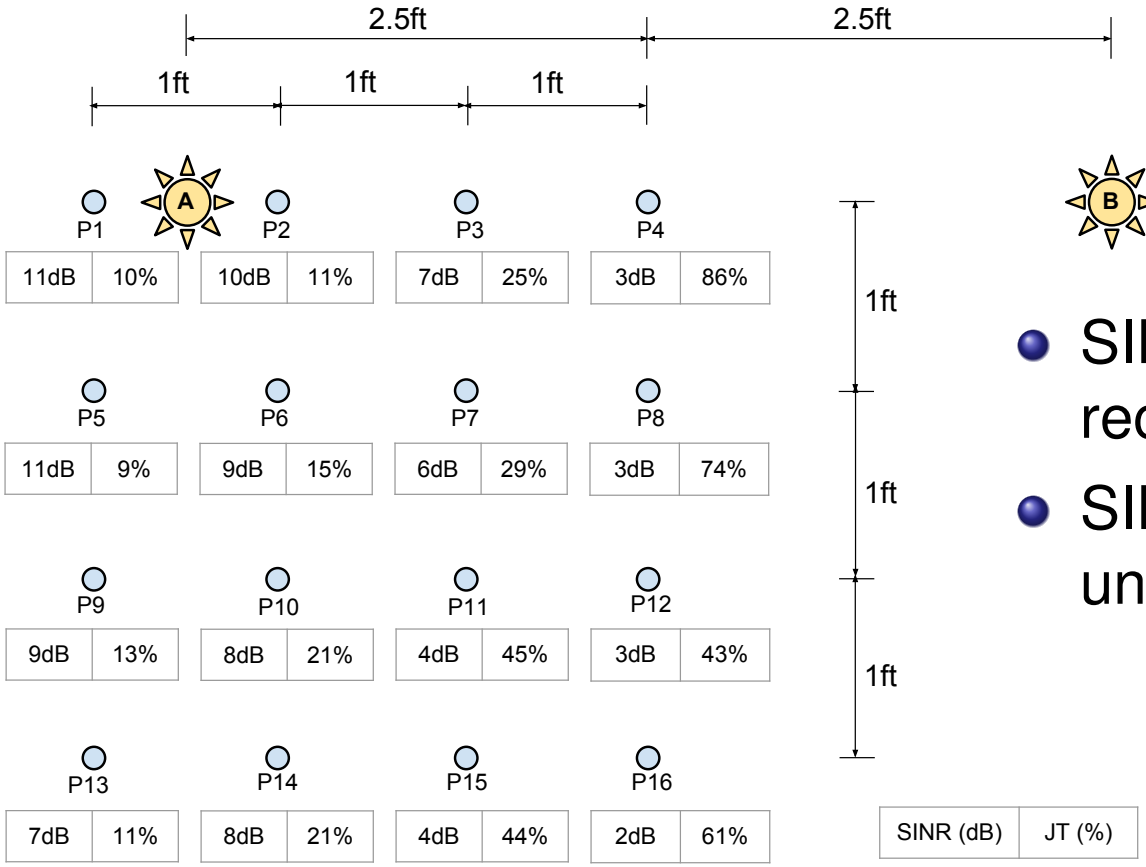
(b)



(c)

Transmission Schemes

- SINR measured at 16 locations ($4ft. \times 4ft$ grid)
- A as transmitter while B as interferer.



- SINR decreases sharply when receiver moves from A to B
- SINR increases significantly under joint transmission

Research in Progress

- Extending PLiFi to combat RSS variation and SINR degradation.
- Design of integrated PLC-VLC modem
- High-speed LED front-end with COTS

Questions?

Thank you!