Towards a Visible Light Network Architecture for Continuous Communication and Localization

Jialiang Zhang, Chi Zhang, Xinyu Zhang, Suman Banerjee
University of Wisconsin - Madison

VLCS'16

Landmarks of VL Communication Technology

- 2000
  - Early research in VLC
  - 802.11 standard for infrared communication
- 2011
  - 802.15.7 standard for VLC, 96 Mbps
- State-of-the-art
  - Gbps, single-link, short range
  - Centimeter-precision localization

Challenges for reliable, ubiquitous VLC

- Prior work mainly focused on
  - Point-to-point communication
  - Static scenario

- Challenges towards ubiquitous VLC
  - Lack of multipath diversity reduces reliability
  - Human blockage/shadowing often reduces link rate to 0

Challenges for reliable, ubiquitous VLC

- Poor reliability also compromises VL localization
  - Prior VL localization only focused on small scale localization
  - Blockage/shadowing/movement causes service interrution

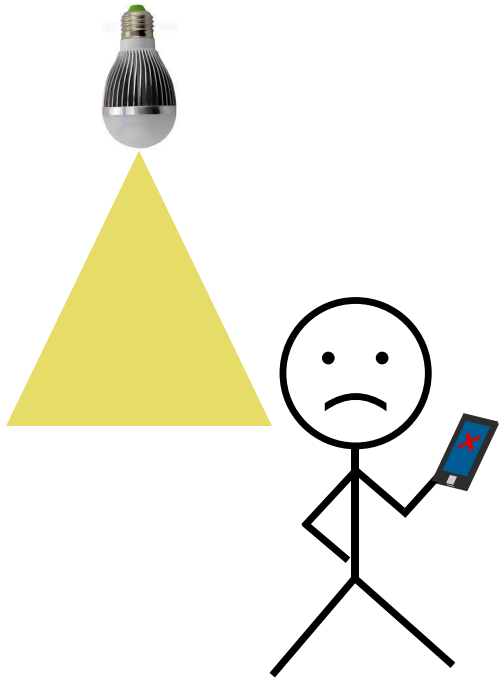
Challenges for reliable, ubiquitous VLC

- A usable communication/localization scheme should be transparent to users
  - Ubiquitous, seamless connectivity
  - Always available without user intervention

- VLC is not such a technology yet!
  - PHY communication cannot solve the issue
  - Need new network architecture!

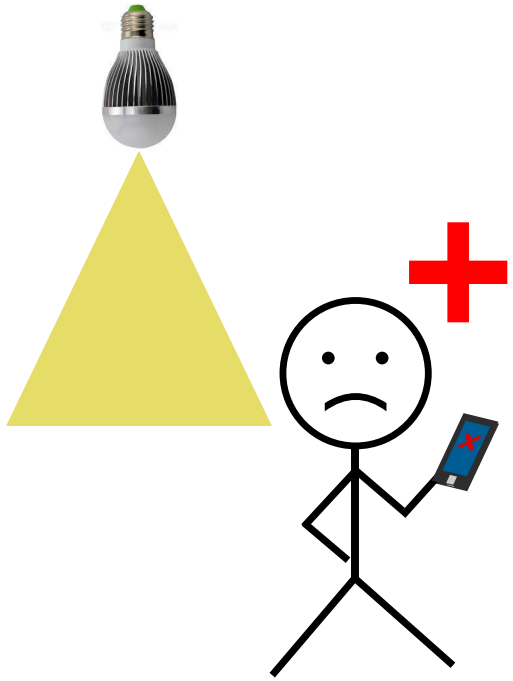
From VLC to VLN

From VLC



From VLC to VLN

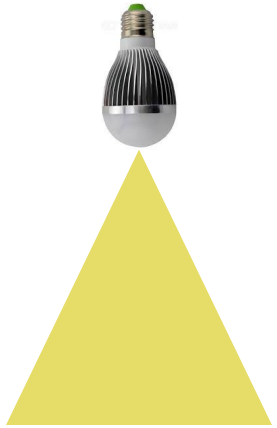
From VLC



Architecture for connectivity management

From VLC to VLN

From VLC



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Architecture for connectivity management

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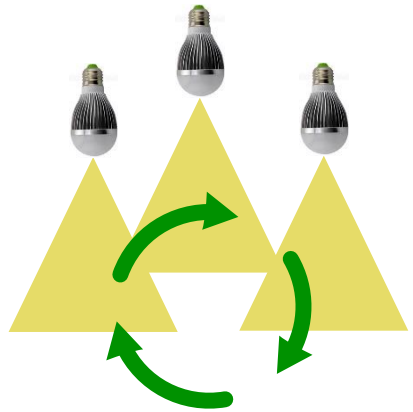
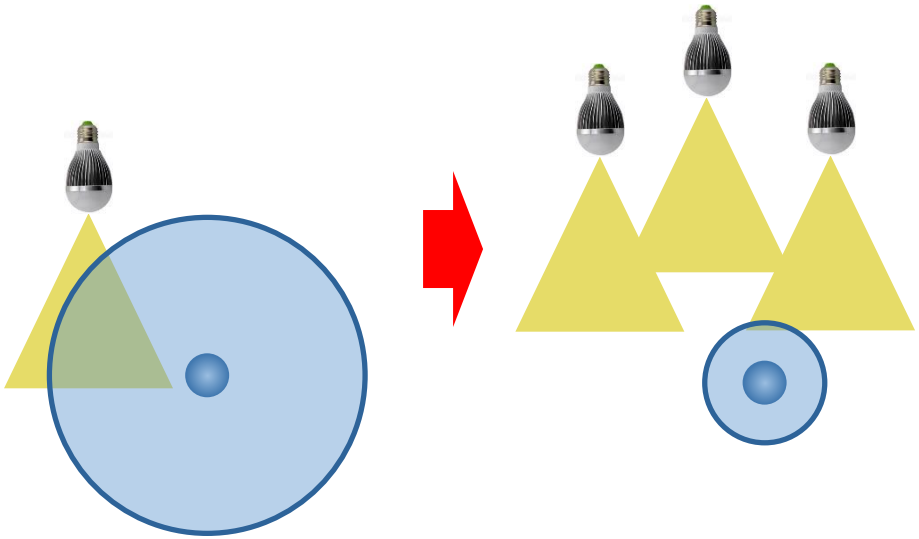
Goals

- **Continuous communication**
  - Seamless roaming
  - Uninterrupted service

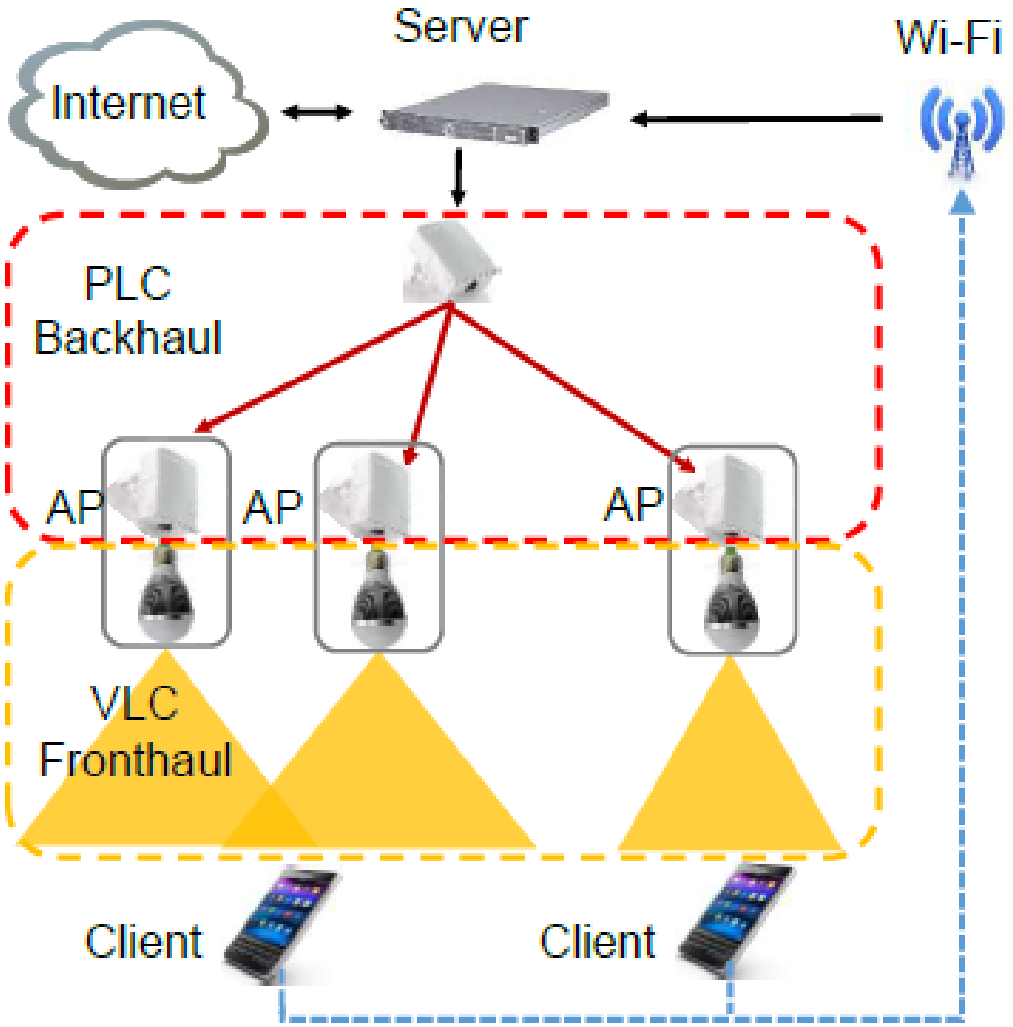


- **Realtime localization**
  - More landmarks, better accuracy



Components of VLN

- **Front-haul**
  - Clusters of APs like "distributed antennas"
  - Tight PHY cooperation
- **Back-haul**
  - Connecting APs to central server
- **Central server**
  - Centralized MAC to maximize throughput and minimize outage



Front-haul

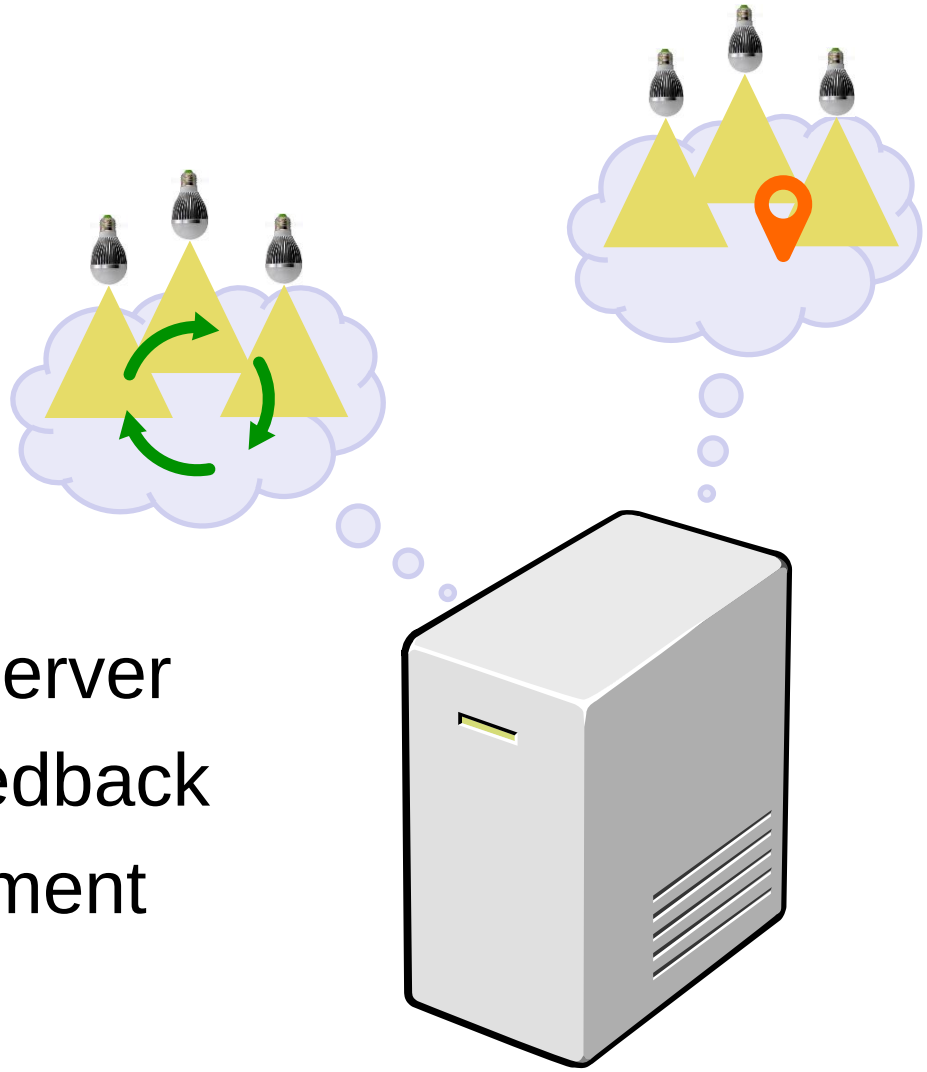
- **Downlink AP with smart LED**
  - Sync and cooperate at symbol-level
  - Balancing diversity and spatial reuse
- **Uplink via Wi-Fi**
  - A critical feedback channel with high reliability
  - Reusing current infrastructure simplifies deployment

Back-haul

- **Power Line Communication (PLC)**
  - Dual role front-haul: lighting and communication
  - Back-haul uses PLC adapters to facilitate these 2 roles
  - No need for new wiring

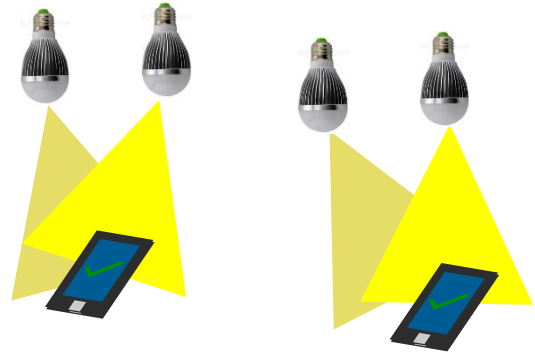
Central server

- **Connectivity management**
  - Coordinates APs
  - Collects channel feedback from clients
- **Realtime localization**
  - Spatial relations of APs are known to server
  - Reliably localizes a client based on feedback
  - Facilitates active connectivity management

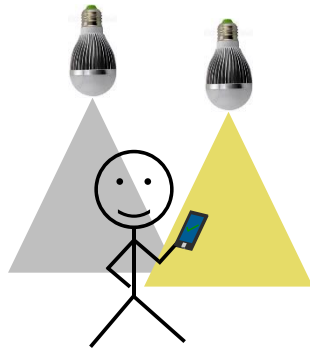


Connectivity Management

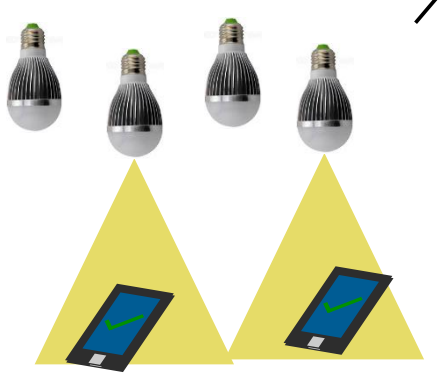
- **Dynamic clustering**
  - Increases SNR, expands range



- **Soft binding**
  - All APs form a single virtual AP
  - No reassociation needed for roaming

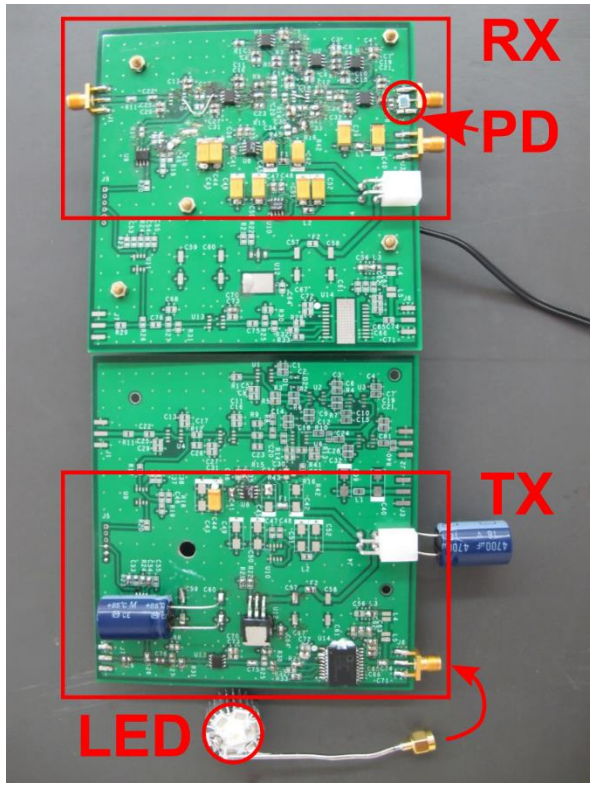


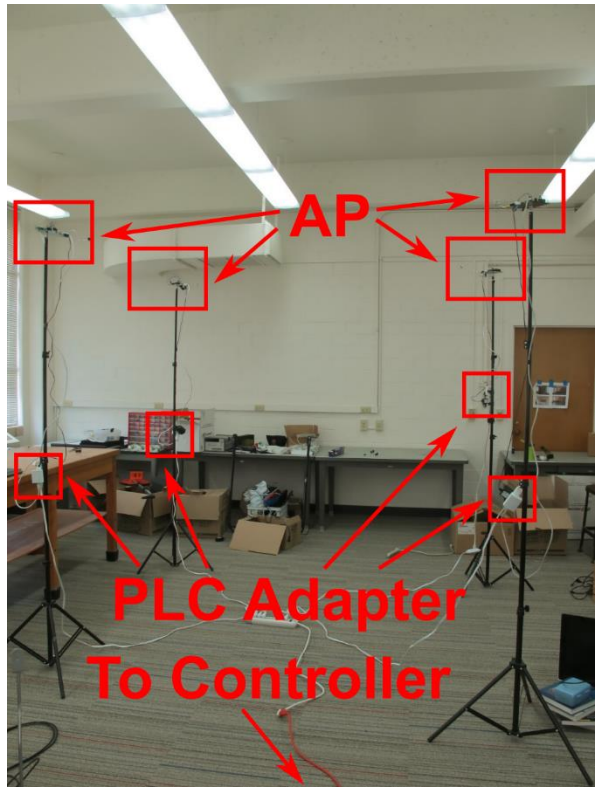
- **Centralized MAC**
  - Frame based scheduling:
    Balancing spatial reuse, coverage and SNR



Implementation

- **End-to-end implementation**
  - Customized smart LED driver; 4 AP network
  - TCP/UDP stack atop customized MAC/PHY
  - Embedded baseband processor





Performance

- **Basic performance**
  - PDR > 95 % coverage: 1.5m @ 2W Tx power
  - Symbol-level sync among APs: 90% sync error < 10us
  - Bitrate: 10 kbps (limited by synchronization and processing)
  - Total latency: 200-300ms, with 100-200ms from uplink

Performance

- **Connectivity management based on AP cooperation**
  - Much less sensitive to device rotation
  - PDR doubles at network edge
  - Capacity is scalable with number of APs

Summary

- Ubiquitous VL communication/localization
  - Achieving seamless connectivity
  - Achieving uninterrupted localization

- A new VLN architecture imitating “distributed antennas”
  - Tight PHY cooperation between APs to remove blind spots
  - Centralized scheduling to balance coverage and capacity

Thanks!