

On the design of multi-user multi-cell visible light communication networks

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Nov. 15, 2023

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Visible Light Communication

❖ Wireless data transmission using visible light emitted from light-emitting diodes (LEDs).



- ❖ Dual functionality
 - Illumination (primary)
 - Communication (secondary)
- ❖ Immunity to interference from other electromagnetic sources
- ❖ Environment friendly
 - Hospital
 - Airplane

❖ Large-scale VLC network is expected to support multiple mobile users in large public areas.



The implementation of multi-cell, where each cell is composed of multiple LEDs transmitters, will be crucial for accommodating multiple mobile users.

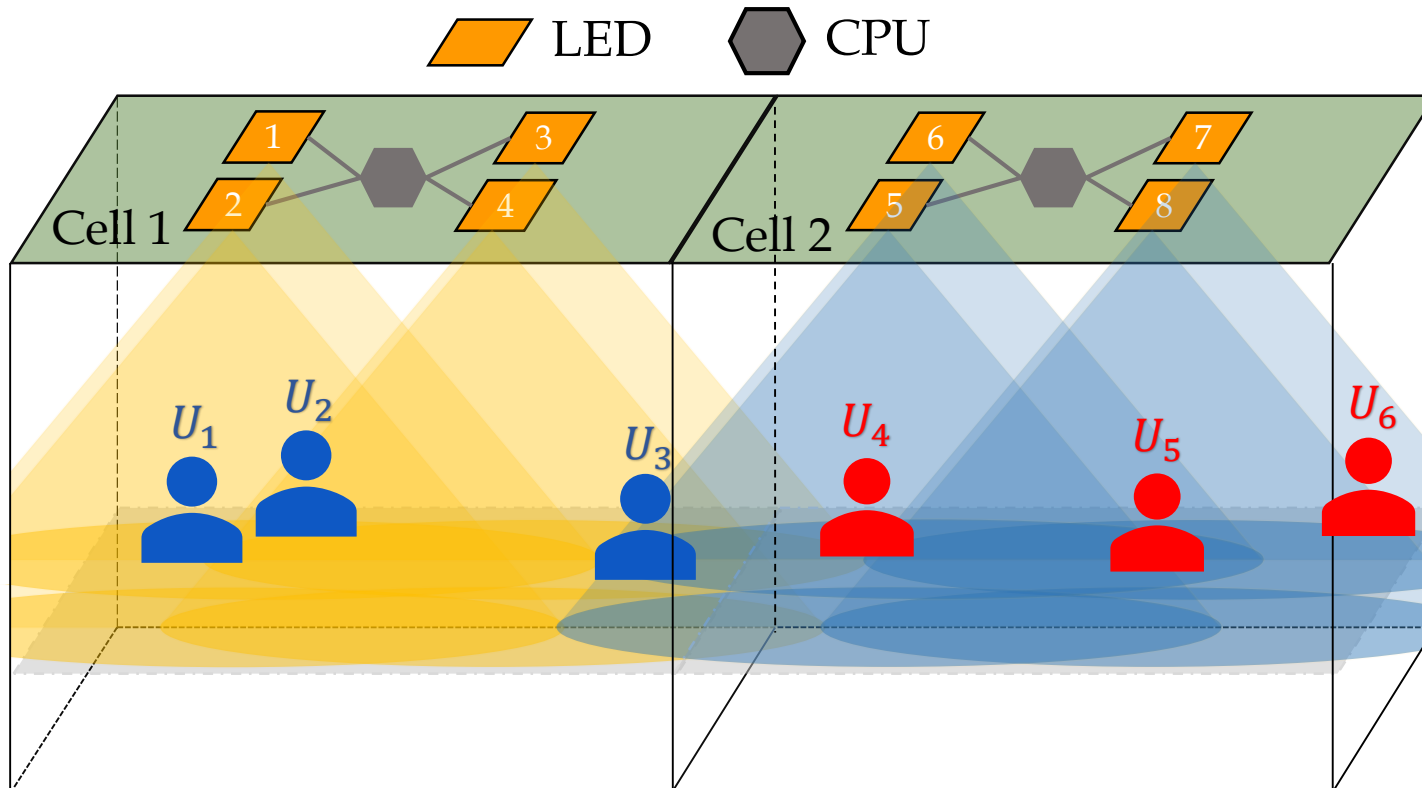


Multi-user multi-cell VLC network

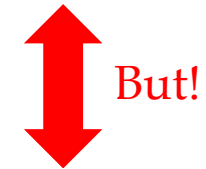
Multi-User Multi-Cell VLC

- Each cell is formed by N_T LEDs and simultaneously serve K users
- Each user is equipped with a single-photodiode (PD) receiver

→ Each cell can be regarded as a multi-user multi input single output (MU-MISO) broadcast system



- ❖ Large illumination coverage
- ❖ Support more users



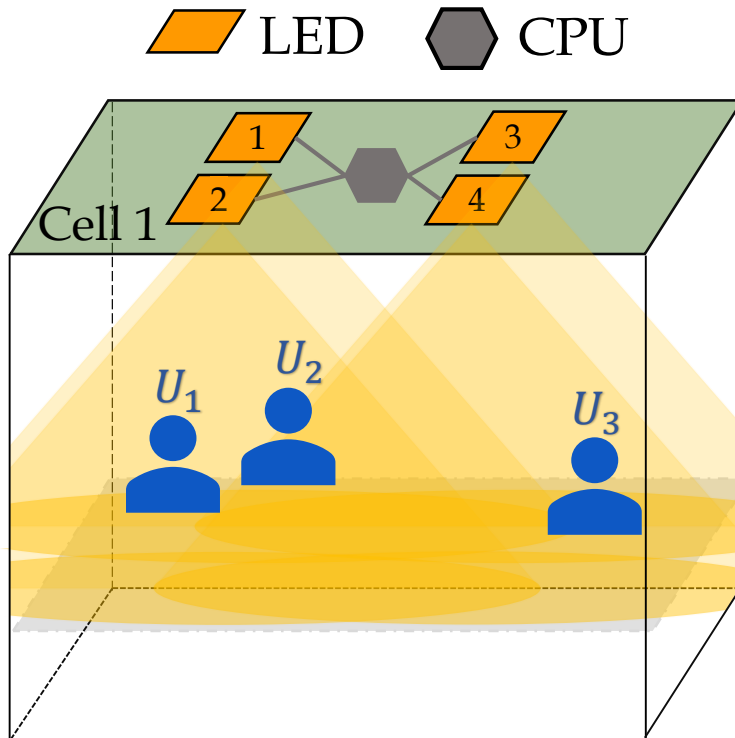
Challenges:

- Intra-cell interference
- Channel similarity
- Inter-cell interference

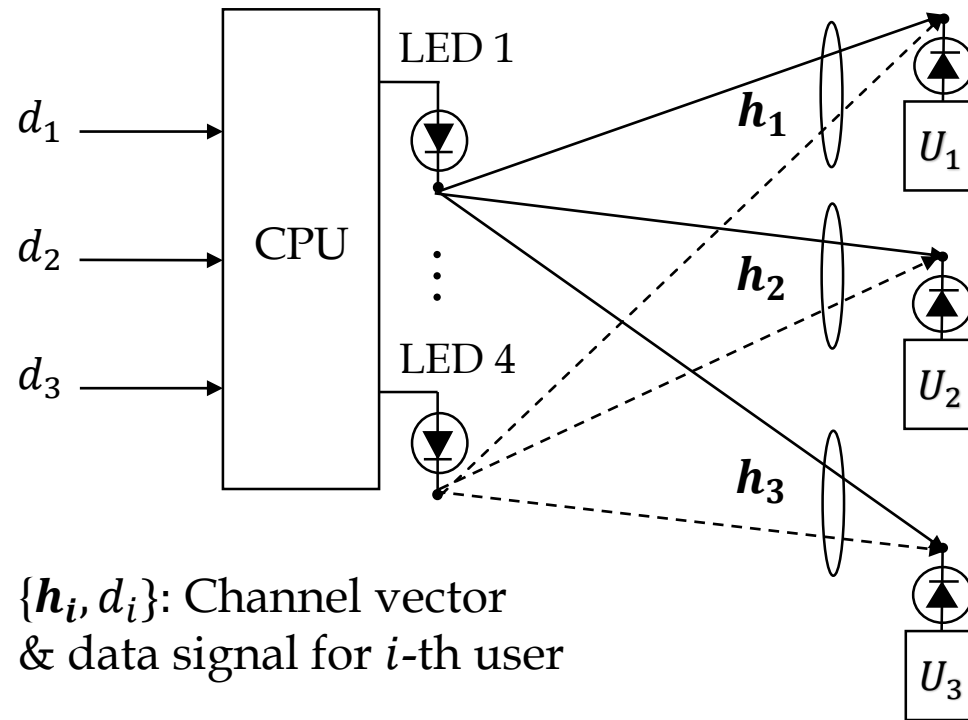
→ Degrade the system performance:
sum-rate, energy efficiency

Multi-User Multi-Cell VLC - Challenging Issues

- Intra-cell interference** : interference from multi-user signal in same cell



MU-MISO broadcast system



$\{h_i, d_i\}$: Channel vector
& data signal for i -th user

Receiver signal at i -th user: y_i

$$y_1 = f(h_1, d_1, d_2, d_3)$$

$$y_2 = f(h_2, d_2, d_1, d_3)$$

$$y_3 = f(h_3, d_3, d_1, d_2)$$

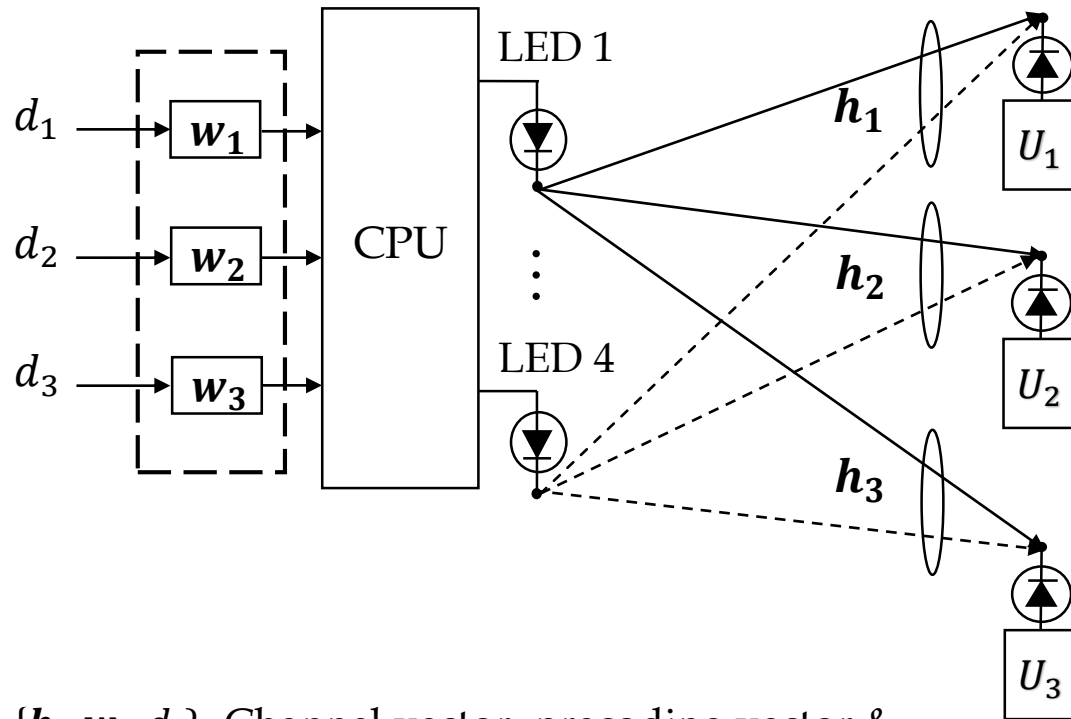
Intra-cell interference

➔ How to reduce intra-cell interference ?

Multi-User Multi-Cell VLC - Challenging Issues

➔ How to reduce intra-cell interference ?

❖ **Precoding technique:** Linearly encoding d_i by a vector w_i to reduce the effect of interference at received signal



$\{h_i, w_i, d_i\}$: Channel vector, precoding vector & data signal for i -th user

□ Received signal at the i -th user

$$y_i = h_i w_i d_i + h_i \sum_{j=1, j \neq i}^K w_j d_j + n_i$$

↓
Intra-cell interference

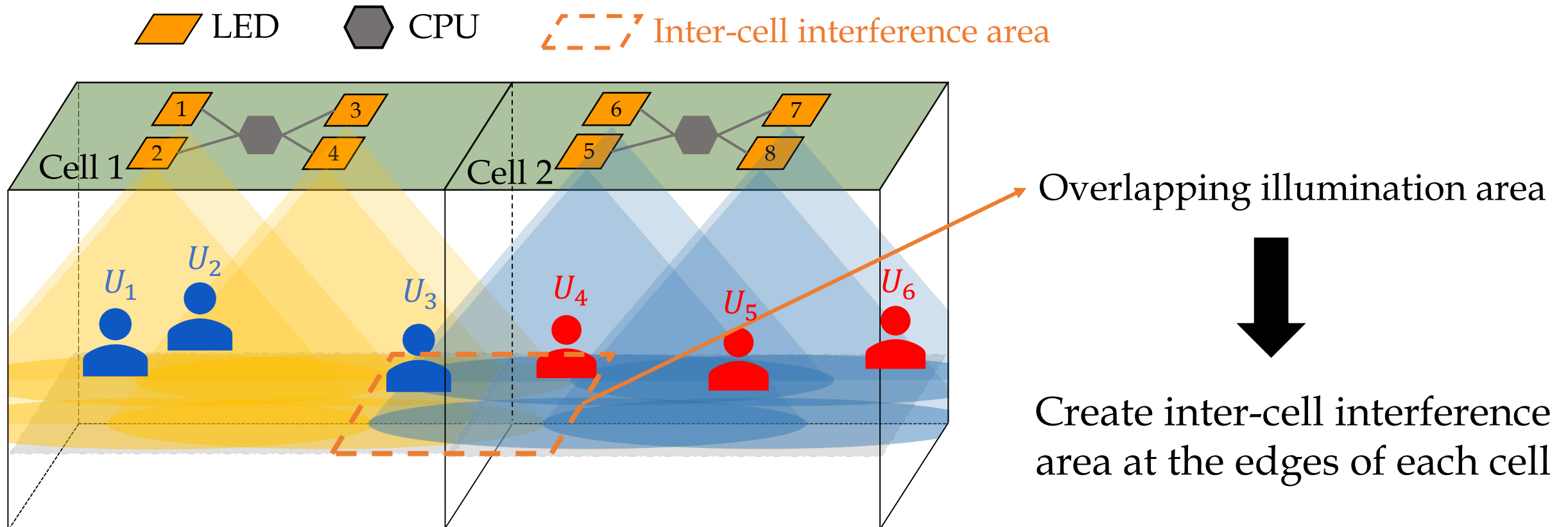
➔ By generate precoding vector w based on the users' CSI, the intra-cell interference can be eliminated

□ But when users' channel vectors are similar, similar precoding vectors for different users, resulting in ineffective interference cancelation

➔ **Channel similarity problem**

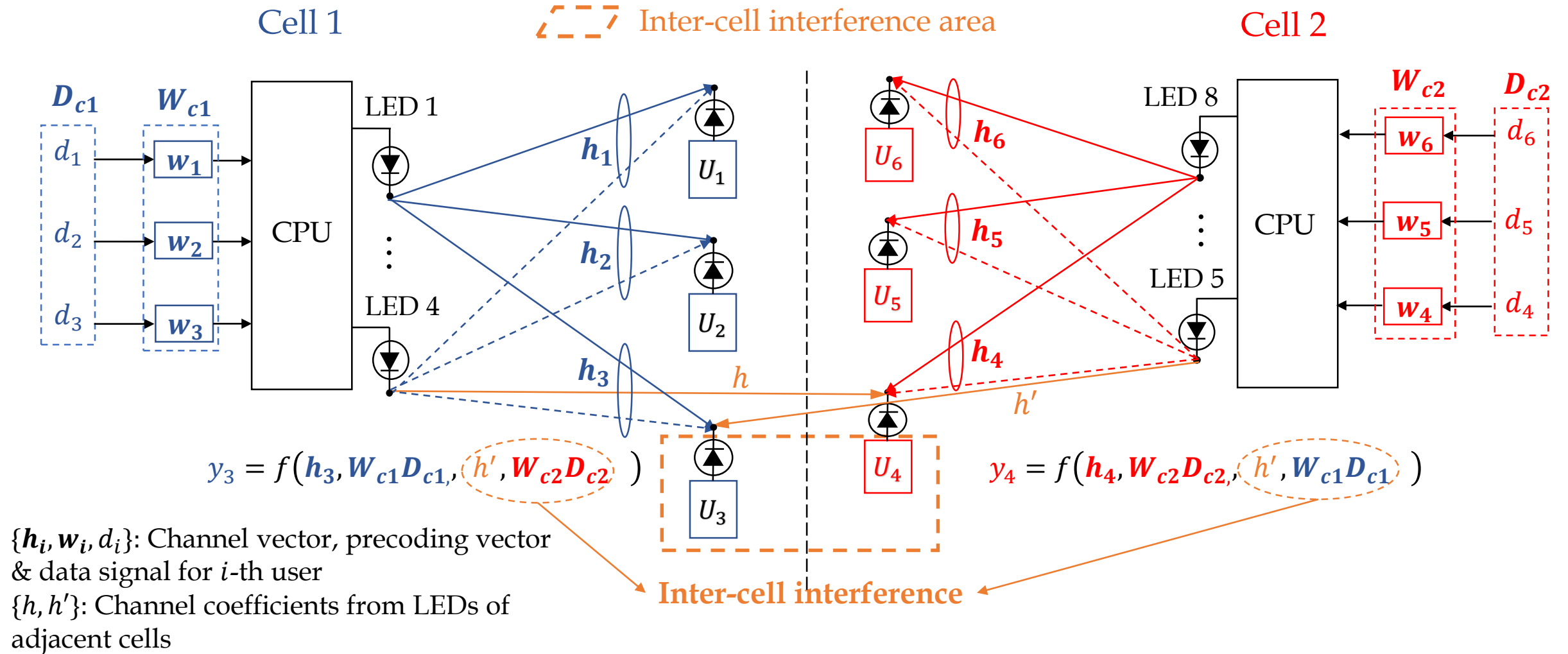
Multi-User Multi-Cell VLC - Challenging Issues

- **Inter-cell interference:** interference from multi-user signal of adjacent cells



Multi-User Multi-Cell VLC - Challenging Issues

- Inter-cell interference:** interference from multi-user signal of adjacent cells



Current approaches

Reference	Main Contributions
[1] - 2015	Propose precoding design for the multi-user coordinated atto-cells* VLC networks
[2] - 2018	Propose beamforming design with channel uncertainty for the downlink transmission of coordinated atto-cell* VLC networks
[3] - 2019	Propose coordination/cooperation strategies and precoding design for multi-users multi-cell VLC networks

- Limitations** {
- **Fixed-shape cell design:** cell formation is fixed independently of user distribution
 - **Negative impact of channel similarity** is not considered

➔ Current designs are not effective in **a large-scale dynamic networks** with **multiple mobile users**

*Atto-cell is a small-scale cell that is illuminated by one LED array

[1] H. Ma, L. Lampe and S. Hranilovic, "Coordinated Broadcasting for Multiuser Indoor Visible Light Communication Systems," in *IEEE Transactions on Communications*, vol. 63, no. 9, pp. 3313-3324, Sept. 2015, doi: 10.1109/TCOMM.2015.2452254.

[2] H. Ma, A. Mostafa, L. Lampe and S. Hranilovic, "Coordinated Beamforming for Downlink Visible Light Communication Networks," in *IEEE Transactions on Communications*, vol. 66, no. 8, pp. 3571-3582, Aug. 2018, doi: 10.1109/TCOMM.2018.2817222.

[3] T. V. Pham and A. T. Pham, "Coordination/Cooperation Strategies and Optimal Zero-Forcing Precoding Design for Multi-User Multi-Cell VLC Networks," in *IEEE Transactions on Communications*, vol. 67, no. 6, pp. 4240-4251, June 2019, doi: 10.1109/TCOMM.2019.2900675.

Our approaches

- ➔ **Adaptive shape cell design** {
- Cells are constructed without a clear cell boundary
 - Cells are updated based on the users position, movement and traffic requirements

★ User

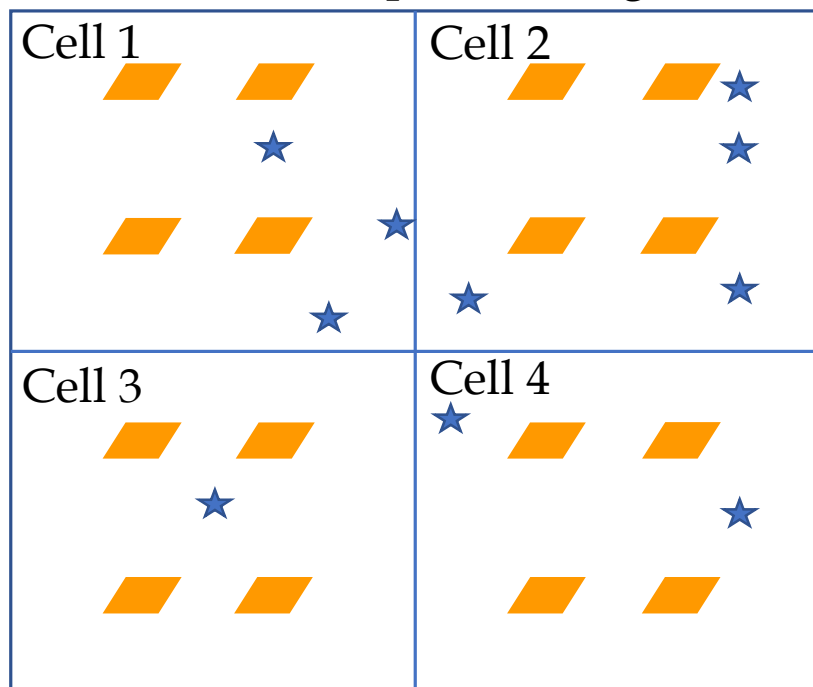


Active LED

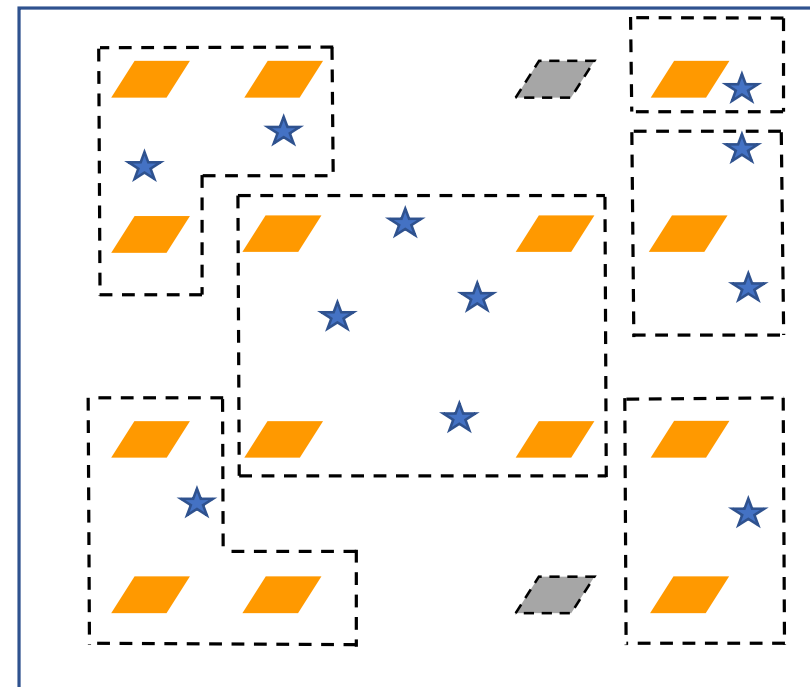


Idle LED

Fixed-shape cell design

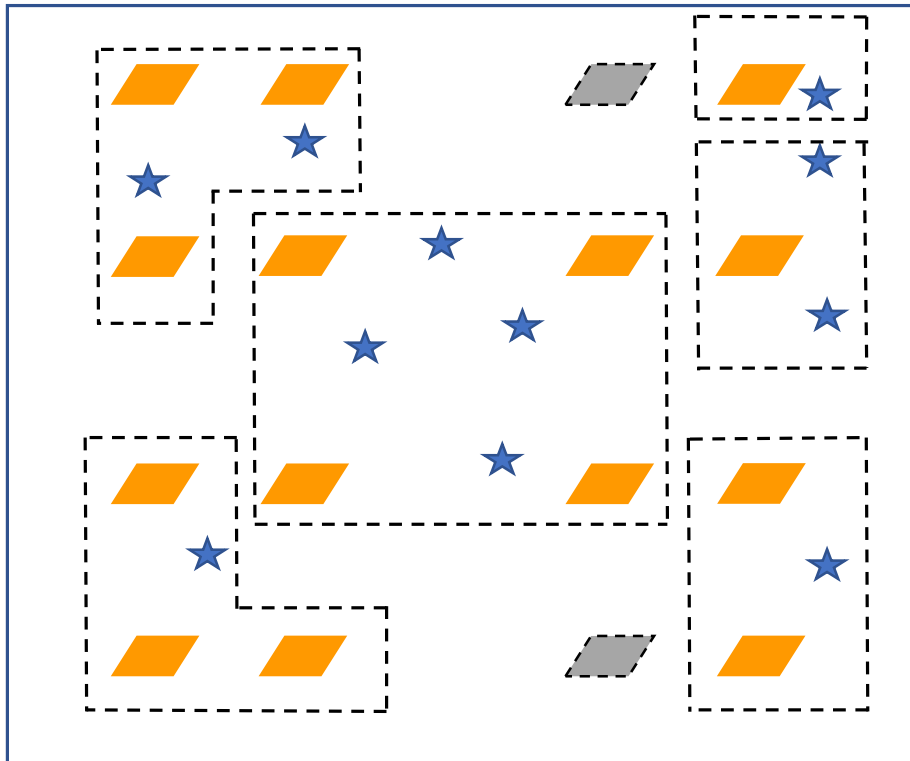


Adaptive shape cell design



Our approaches

Active LED Idle LED



Adaptive shape cell design

- ❖ More effective than the fix shape cell design in a dynamic networks with multiple mobile users
- ❖ Proper cell design based on users position and movement can guarantee reliable and continuous services with high achievable rate.
- ❖ Joint adaptive shape cell design and precoding technique can effectively reduce the effects of intra-cell, inter-cell interference and channel similarity

Goal and Schedule

1. Research Goal

- ❖ Introduce the **adaptive shape cell design** for dynamic multi-user multi-cell VLC mobile networks
- ❖ Propose **robust precoding design** to adaptively reduce the negative effect of channel similarity, inter-cell and intra-cell interference

2. Research Schedule

No.	Task	Period
1	Survey and formulate the problems	Q4-M1
2	Propose the concept of adaptive shape cell design and corresponding precoding design to overcome the problems	Q1, Q2 - M1 Q3, Q4 - M2
3	Test the proposed design via simulation	
4	Establish theory based on repeated validation of results	
5	Thesis and paper writing	Q1,Q2 - M2

Thank you for listening!

Q & A