# Power allocation algorithm under per-LED power constraint for MIMO OWC

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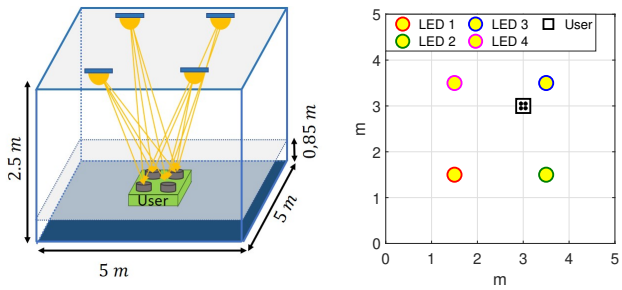
## Introduction

MIMO has been widely studied for radio frequency (RF) communication, but also appears suitable to improve the throughput and robustness of optical wireless communications (OWC). In fact, by emitting multiple spatial streams from spatially separated emitters in the ceiling, the likelihood of interruption of all optical beams simultaneously is greatly reduced. To study such systems, a key difference with radio communication is that every optical front–end has its own power limitation, rather than that the total sum of their powers is limited. This work studies to what extent this has an impact on the performance of distributed MIMO OWC links.

In this work, we consider a $N_R \times N_T$ LED-based MIMO OWC system.




(a) Room dimensions (b) Geommetric distribution

Figure 1: Illustration of a $4 \times 4$ LED-based MIMO OWC system.

Due to the its dynamic behaviour, the voltage across an LED is a non-linear function of the injected current density [1]

$$V_i \approx V_{on_i} + R_i I_i, \tag{1}$$

Unlike radio, the power consumed by an LED is not $\mathrm{E}[\mathrm{i}^2]$, but we can optimize for variance by introducing a function $g(\cdot)$ given by

$$P_{e_i} = \begin{cases} g_{DCO}(\sigma_{x_i}^2) \approx V_{on_i} z \sigma_{x_i} + R_i \sigma_{x_i}^2 (z^2+1), & \text{for DCO-OFDM} \\ g_{ACO}(\sigma_{x_i}^2) \approx \frac{V_{on_i}}{\sqrt{2\pi}} \sigma_{x_i} + R_i \frac{\sigma_{x_i}^2}{2}, & \text{for ACO-OFDM} \end{cases} \tag{2}$$

Then, we can write the total power allocated over OFDM subcarriers in the $i$-th LED, with a constraint on the variance of the time domain signal

$$\sum_{k=0}^{N-1} \mathrm{E}[|X_i(k)|^2] = \mathrm{E}[x_i^2(t)] = \sigma_{x_i}^2 \leq \sigma_{x_{max_i}}^2 = g^{-1}(P_{e_i}), \tag{3}$$

In a LED-based MIMO OWC system, the received signal vector is

$$\mathbf{y}(k) = \mathbf{H}(0)h(k)\mathbf{x}(k) + \mathbf{n}(k), \tag{4}$$

where $\mathbf{H}(0)$ is a DC-gain channel matrix and $h(k)$ is a first-order low-pass coefficient [2]. The matrix $\mathbf{H}(k) = \mathbf{H}(0)h(k)$ has a special structure: opto-electrical conversion causes frequency dependancy, while multipath is not a significant effect [2, 3].

After the SVD decomposition of the DC-gain channel matrix, i.e. $\mathbf{H}(0) = \mathbf{U}^T\mathbf{D}\mathbf{V}$, we have

$$\tilde{\mathbf{y}}(k) = \mathbf{D}h(k)\tilde{\mathbf{x}}(k) + \tilde{\mathbf{n}}(k) \tag{5}$$

The sum-rate achieved by the system can be evaluated by

$$R = \Delta_B \sum_{k=1,(2),3,\ldots}^{N/2-1} \sum_{l=1}^{L} \log_2\left(1 + \frac{\lambda_l |h(k)|^2 \tilde{\sigma}_l^2(k)}{\Gamma N_0 \Delta_B}\right), \tag{6}$$

## Link budget

We define a normalized link budget to the LED 3-dB bandwidth

$$\gamma_{TX} = \frac{\sigma_{max}^2}{N_0 f_c}. \tag{7}$$

## Power loading strategies

- Uniform power loading under a Per-led power constraint.
- Maximization of (6) under a total power constraint.
- Maximization of (6) under a Per-LED power constraint.

## Simulation Results

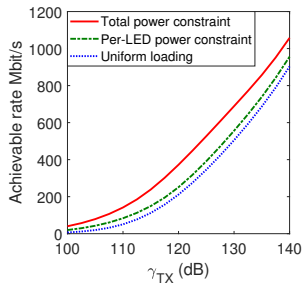



Figure 2: Achievable rate as a function of link power budget $\gamma_{TX}$.

## Conclusion

We have presented a detailed model to estimate the achievable rate of a LED-based MIMO OWC system under different power constraints. Our results have shown that, the maximization of (6) under a total power constraint achieves the highest throughput, but it is unrealistic as it can allocate more power on only one LED than its power limit. Meanwhile, the approach with uniform loading achieved the worst performance, as it is not able to adapt power over the low-pass channel. A more appropriate power constraint, which limits the amount of power on each LED was also studied. The maximization of (6) under a per-LED power constraint is then more appropriate for real systems as it makes sure that any LED will not be overloaded. In addition, it has the advantage of a better performance than a uniform loading and it allows a power-saving, with a cost of higher computational complexity.

## References

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