# Study on VLC Channel Model Based on Poisson Stochastic Network Theory

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Presentation
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June 11, 2021

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# VLC?

- Message signals die out over longer distances
- Requirement of Carriers
- Modem to Place message on a Carrier

Figure 1: Source:Internet

# Block Diagram of VLC Architecture

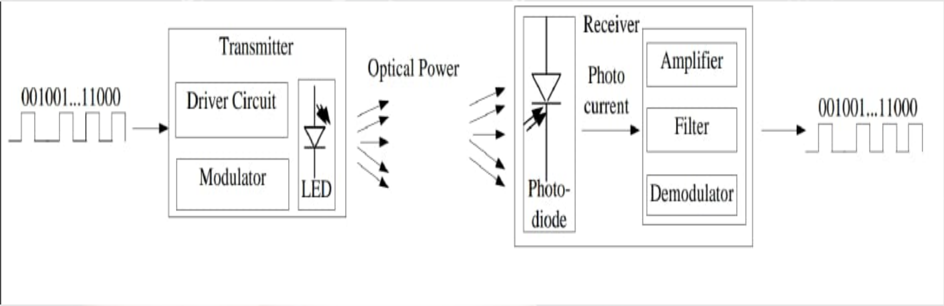



Figure 2: Source:Conference Paper[2]

# Transmitter

- LD and LED dual-functional
- Plank's Theory: $E_g = hf$
- Modulation

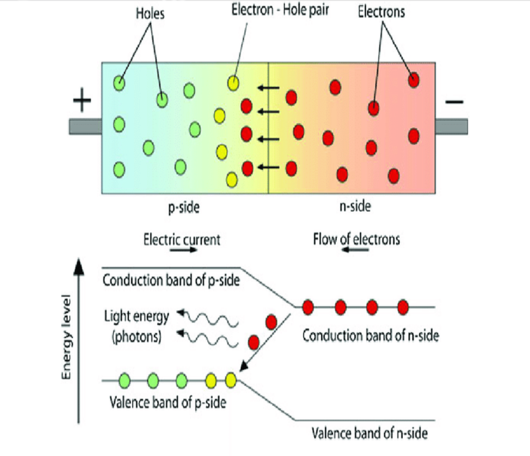



Figure 3: Source:Internet

# Receiver

- Light2Electric Signal Conversion by Photo-detector
- $R = \dfrac{e \times \eta}{h \times \nu}$ : Ratio of output current to Input Optical Power.

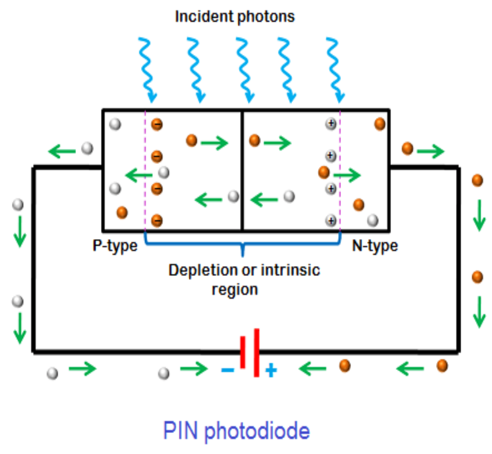



Figure 4: Source:Internet

# Channel

- Multi-Path Reflections
- $\lambda_{VL} < \lambda_{RW}$
- VL interference

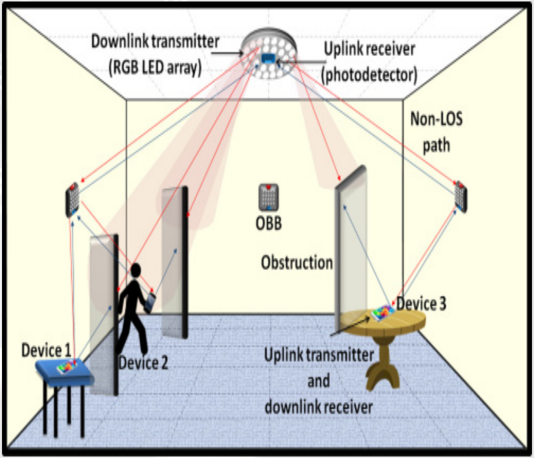



Figure 5: Source:Internet

# Types of Channel

- LoS and NLoS
- Directed,Non-Directed and Hybrid Channels

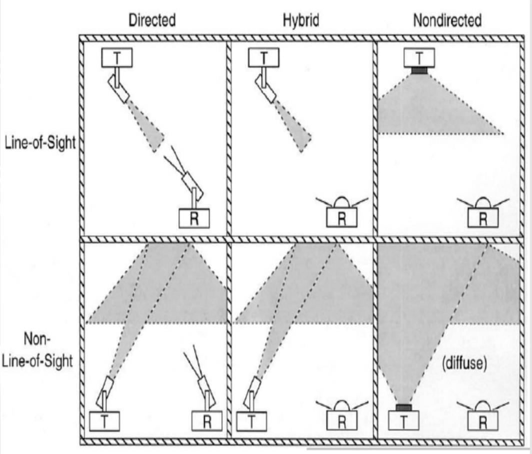



Figure 6: Source:Conference Paper[1]

## Study of Channel

- Appropriate Rxd power level is desired in any communication System
- Interference may deteriorate Rxd power
- Increasing Txd power, Optimizing the LED Layout and decreasing FOV of Rx are remedies
- Study of Channel is needed to Compute Rxd power
- To study the Channel random distribution of RPs is needed
- Finding the best Layout of LED is the Motto of this paper

# Homogeneous Poisson Point Process

- Several RPs in space obey Poisson Distribution,so that the Network can be modelled as Poisson Stochastic Process
- Due to several properties HPPP can well approximate the actual reflection environment

**Poisson Distribution:**

$$P(X = x) = \frac{e^{-\lambda}\lambda^{x}}{x!} \tag{1}$$

**Poisson Point Process:**

$$P(\phi(A)) = n) = \frac{e^{\lambda|A|}\lambda|A|^{n}}{n!} \tag{2}$$

# Properties of HPPP

- If points in Space forms PP
- Subset of points is a rv with a Poisson Distribution
- Complete Independence
- Number of points in set A is a Poisson Rv with Parameter $\lambda|A|$

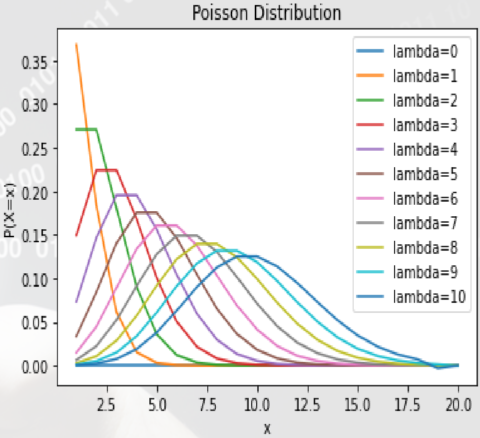



Figure 7: Source:Python Simulation

# SINR as Quality metric

- Optical signals are highly Incoherent
- Reflections are regarded as interference
- SINR to describe the quality of signal reception
- PPP is Translation Invariant so Rx at different positions is moved to origin

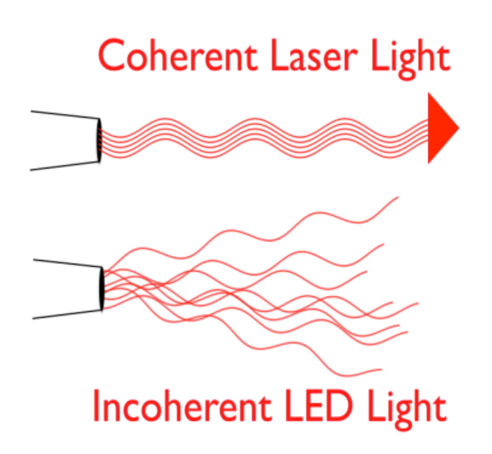



Figure 8: Source:internet

# Signal to Interference+Noise Ratio

- SINR for a specific sender

$$SINR_x(n) = \frac{P_x S_x(n)/l(|x|)}{N + I - P_x S_x(n)/l(|x|)} \quad (3)$$

$$I = \sum_{x \in \phi} P_x S_x(n)/l(|x|) \quad (4)$$

- $|x|$ : distance from each sending end to receiving end
- $P_x$ : Transmitted power
- $S_x$ : Gain of each reflection point
- $N$ : Noise power
- $I$ : Total power received at Rx
- The path loss function

$$l(|x|) = (K|x|)^{\beta} \quad (5)$$

- $K > 0$ and $4.5 > \beta > 2$

# Path Loss Function

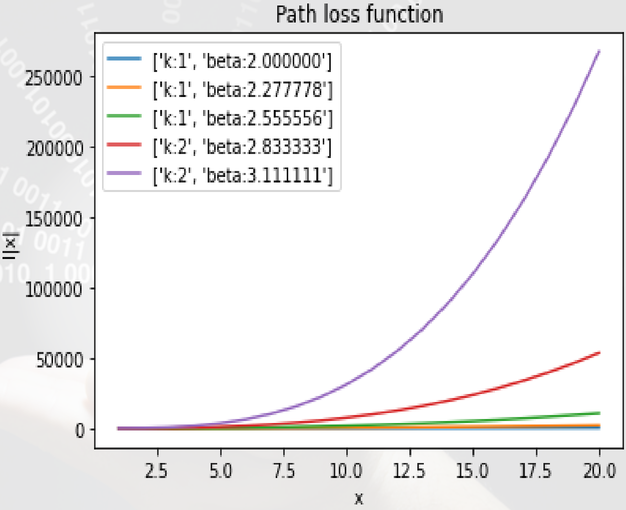



Figure 9: Source:python simulation

# Transmission Model

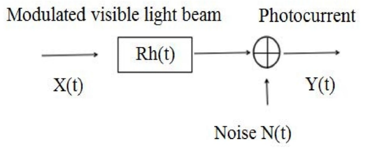



Figure 10: Source:conference paper[1]

- At the Tx end Photo-current signal $Y(t)$ can be expressed as:

$$Y(t) = RX(t) \circledast h(t) + N(t) \tag{6}$$

- $R$ : Responsivity

$$R = \frac{I_{out}}{P_{in}} \tag{7}$$

$$R = \frac{e \times \eta}{h \times \nu} \tag{8}$$

- $X(t)$ : light signal emitted by LED
- $h(t)$ : Channel shock effect
- $N(t)$ : AWGN noise

# Light Source Model

- Lambertian model is used to simulate the emission of Light source
- Light intensity distribution of an LED can be expressed as:

$$I(\theta) = I(0)cos^m(\theta), \theta \in (0, \frac{\pi}{2}) \tag{9}$$

- $\theta$ is the beam exit angle
- $m$ is Lambert coefficient can be expressed as:

$$m = -\frac{\ln 2}{\ln cos\theta_{1/2}} \tag{10}$$

- $\theta_{1/2}$ is the half power angle
- $I(0)$ is the central light intensity and can be expressed as:

$$I(0) = \frac{m+1}{2\pi} P_s \tag{11}$$

- $P_s$ is the Txing power of light source

# Light Source Model simulation

# Impulse Response

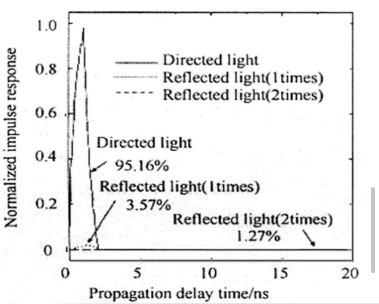
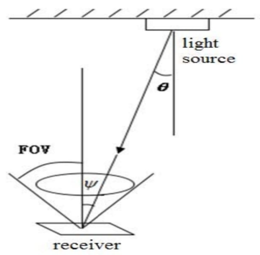



Figure 11: Source:conference paper[1]

- Channel Impulse response=sum of Impulse responses of single Tx and Rx set.
- Impulse response consisting single LED and Rx is expressed as:

$$h(t;S,R) = h^0(t;S,R) + \sum_{k=1}^{\infty} h^k(t;S,R) \tag{12}$$

# Impulse Response



Positional relationship between the light source, receiver and reflective surface

Figure 12: Source:conference paper[1]

- Impulse response of the direct-view channel:

$$h^0(t;S,R) = \frac{m+1}{2\pi} cos^m(\theta) d\Omega rect(\frac{\Psi}{FOV})\delta(t-\frac{d}{c}) \quad (13)$$

- Solid angle of the Rx : $d\Omega = cos\frac{A}{d^2}$
- $\Psi$ : receiving angle
- $d$ : distance between LED and Rx

# Received power

- Continuous data connection in all the places in the room
- Improper placing of LEDs and too small FOV of Rx lead to blind spots.
- Received power of LED light source can be expressed as :

$$P_r = H(0)P_t \tag{14}$$

- $P_r$ : Received power
- $P_t$ : Average transmitted power

# DC channel gain $(H(0))$

- DC channel gain from impact responce can be obtained as :

$$H(0) = \begin{cases} cos(\Psi)cos^m\Psi T_s(\Psi)g(\Psi)\dfrac{A(m+1)}{2\pi d^2}, & 0 \leq \Psi \leq \Psi_c \\ 0, & \Psi > \Psi_c \end{cases} \tag{15}$$

- $T_s(\Psi)$ : optical filter gain
- $g(\Psi)$ : optical concentrator

$$g(\Psi) = \begin{cases} \dfrac{n^2}{sin^2\Psi_c}, & 0 \leq \Psi \leq \Psi_c \\ 0, & \Psi > \psi_c \end{cases} \tag{16}$$

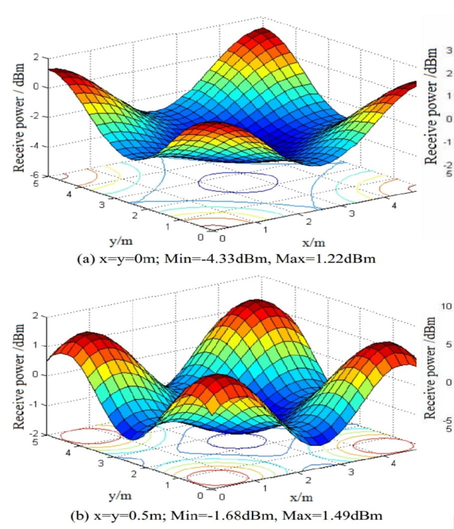
- $n$ is refractive index

# Variance of power distribution

$$D = \frac{1}{S}\iint_L [P_r(x,y) - \overline{P_r}]^2 dxdy = \frac{1}{S}\sum_{i=1}^{N}\iint_L [P_t f(u_i, v_i; x, y) - \overline{P_r}]^2 dxdy \qquad (17)$$

- Simulations for power fluctuation is performed for different layouts of LEDs
- 4-LED are symmetrically distributed
- Room dimensions:$5m \times 5m \times 3$
- Rx is placed on a plane at a height h from the floor.

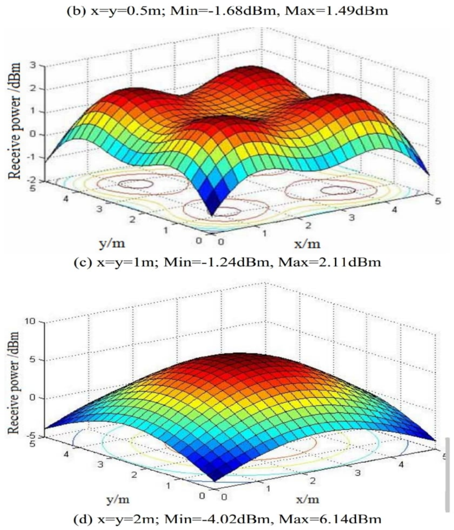
# Impulse Response




(a) x=y=0m; Min=-4.33dBm, Max=1.22dBm

(b) x=y=0.5m; Min=-1.68dBm, Max=1.49dBm

Figure 13: Source:conference paper[1]




(b) x=y=0.5m; Min=-1.68dBm, Max=1.49dBm

(c) x=y=1m; Min=-1.24dBm, Max=2.11dBm

(d) x=y=2m; Min=-4.02dBm, Max=6.14dBm

Figure 14: Source:conference paper[1]

# Applications

- By locating RPs Easedropping can be mitigated to add more security.
- Effective channel modelling results in reducing the effect of Interference which increases the SINR or quality of signal reception.

# Conclusion

The scheme proposed in this paper can be used to obtain the optimal layout of LED lamp in visible light communication system.

# Thank You!