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| TGbb: Analytical channel and blockage model |
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Abstract

This document describes an analytical channel and blocking model which reduce simulation complexity for system-level simulation and enable a predefined occurrence of blocking objects.

# Introduction

The channel impulse response between an optical wireless communication (OWC) transmitter and receiver pair can be calculated with high accuracy via the ray tracing method. However, due to the high computational effort, this method is unsuitable for the calculation of large numbers of different transmitter-receiver constellations and resulting channel realizations.

In system-level simulation, protocol-procedures and mobility of a potentially many transmitters and receivers must be considered. Even for short scenarios with a duration in the order of few seconds, there may be a high number of simulated time instants and respective channel realizations that impact the higher layer behavior. Avoiding the complexity of calculating all link level details with very high accuracy, simple link level models are applied in order to enable system level simulation with reasonable performance. This makes it feasible to evaluate arbitrary protocol sequences and assess the performance on the higher layers.

For the system level it is only important at which receivers the transmission can successfully be decoded and at which ones not.

Reception?

Transmission

OFE

model

PHY model

Received power

Optical transmit signal power

MAC model

Blocking model

System level Link level

Channel model

# Channel model

Justified by the low influence of the NLOS signal [], the channel model considers only the LOS impulse response in order to reduce computational complexity. Hence, for every transmission performed by a transmitter, the signal’s optical power at a given receiver with respect to the optical transmit power can be calculated using formula 1 as a propagation loss model. Here $\left|H\right|\_{LOS} [dB]$ is the optical channel DC gain. Furthermore, $m$ is the Lambertian order of the emitting LED. $A\_{PD}$denotes the area of the receiving photodiode, $d$ the distance between the emitter and receiver. $Φ$ and $ϕ$ refer to the angle of emission and incidence respectively. $ϕ\_{FOV}$ is the field of view at the receiving photodiode.

$$\left|H\right|\_{LOS}= f\left(x\right)=\left\{\begin{array}{c}\frac{\left(m+1\right)A\_{PD}}{2πd^{2}} cos^{2}\left(Φ\right)\cos(\left(ϕ\right))g\_{C}\left(ϕ\right)g\_{F} , \left|ϕ\right|\leq ϕ\_{FOV}\\0 , \left|ϕ\right|>ϕ\_{FOV}\end{array}\right.$$

Formula 1: Optical channel DC gain

Given the emitted modulated optical power at the transmitter $P\_{tx,opt}$ [dBm], the optical power $P\_{rx,opt}$ [dBm] at a receiver’s photodiode can be calculated by formula 2.

$P\_{rx,opt} = P\_{tx,opt}+10⋅log\_{10}(\left|H\right|\_{LOS}$)

Formula 2: Optical receive power

A responsivity $r$ characterizes the utilized photodiode and determines the current that is caused by the incident light. To yield the electrical signal power after the photodiode, as perceived by the digital signal processor (DSP), the optical signal current must be squared. Hence, the electrical signal power $P\_{rx,el} [dBm]$ can be calculated via formula 3.

$$P\_{rx,el} = 2⋅[P\_{rx,opt}+10⋅log\_{10}\left(r\right)]$$

Formula 3: Electrical signal power at the receiving DSP

[Due to the pure LOS channel being considered, the channel impulse response is flat. However, in real hardware the OFE adds frequency-dependent signal loss. This effect can be modeled by applying the OFE model, as described in document number 1574, to the frequency-dependent SNR if it is important to the physical layer.]

The calculation of noise power $P\_{n} [dBm]$ depends on the used photodiode. The observed noise from positive-intrinsic-negative photodiodes is primarily thermal noise and can be modeled as AWGN [] with a given power spectral density (PSD).

Based on the electrical signal and noise powers, an effective $SNR [dB]$ can be calculated via formula 4.

$$SNR \left[dB\right]= P\_{rx,el}-P\_{n}$$

Formula 4: SNR at the receiver DSP

## Propagation delay

The delay between transmission and reception of the signal can be calculated using the distance between transmitter and receiver as well as assuming light speed propagation.

# Physical layer model

## Capture model

The capture model determines whether the SNR of a reception is high enough during the preamble to trigger the receiver’s DSP. Furthermore, it may model the effect of multiple overlapping / interfering receptions, i.e. which reception, if any, is captured.

## Error model

For a given captured reception, the interesting result for the system level is whether the frame is received successfully or lost. This can be derived from the theoretical packet error rate (FER) of the reception. It is sufficient to drop the reception with a probability equaling the FER.

The FER can be calculated by each PHY model based on the used modulation and coding as well as the receive S(I)NR.

# Calibration and accuracy assessment

[TODO]

# Geometric blocking model

In contrast to blocking in the RF-channel, blocking in the LC-channel introduces mainly severe shadowing for most materials. The shadowing loss is typically very high and prevents any signal from propagating through the blocking object. Hence, blocking in LC is hard to characterize generally due to the dependence on the individual surroundings in each scenario.

A simple way of representing blocking objects is to insert non-opaque spheres into the simulated space. The spheres can be described by the center point’s position and a radius. Subsequently, a simple intersection testing can be used to determine whether the LOS between a transmitter and receiver is blocked by an object. Having multiple transmitters and receivers, the blocking sphere inherently provides spatial and temporal consistency. In MIMO systems, for example, this method prevents the performance from being overestimated when single LOSs are blocked independently.

## Scripted blocking

Blocking events can be scripted to happen due to a pre-specified scheme during the simulation scenario by providing a list of time durations and corresponding sphere geometries. For example, a blocking object (sphere) may reside from second 1 to second 4 at a location [4, 5, 2.2] and have a diameter of 1. Several subsequent blockages can be gathered in a list as shown in table 1.

|  |  |  |  |
| --- | --- | --- | --- |
| **Start [s]** | **End [s]** | **Center Position** | **Diameter** |
| 1 | 4 | [4, 5, 2.2] | 1 |
| 3 | 7 | [2, 2, 1.5] | 2 |
| 5 | 6.4 | [4, 5, 2.2] | 0.25 |
| 10 | 13 | [2, 6, 0.75] | 1.5 |

Table 1: Example blocking script data

The simulation logic would in that case perform book keeping about all blocking spheres at the given times.

[Insert pseudo code for the insertion and deletion of blockers]

The simulation logic must then regard for the potentially blocking sphere between a transmitter and receiver at every transmission between the given start and end time.

[Insert algorithm for intersection testing between transmitter and receiver]

## Geometric stochastic blocking model

[TODO needed?]

# References

[TODO]