PERFORMANCE ANALYSIS OF IEEE 802.15.7

Visible Light Communication

Abstract

Visible light communication (VLC) is an emerging technology which deploy light to transfer data. By using a transmitter that modulates LEDs emitting light in the visible spectrum and a receiver that captures the signal through photodiodes and processes the information. IEEE by considering of this emerging technology introduced the IEEE standard 802.15.7[1].in this project MAC layer performance of IEEE802.15.7 has been analyzed.by providing random access algorithm and Markov chain model, throughput, transmission probability, delay, collision probability and packet discard probability have been presented.

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Introduction

Institute of Electrical and Electronics engineers(IEEE) by considering of this emerging technology introduced the IEEE standard 802.15.7[1] which approved in jun2011 and revised on may2018.In this standard focus is on physical (PHY) and Media access control (MAC) layers significantly deployment of VLC in short- range wireless personal area networks. [1]. Visible light communication(VLC) offers several advantages over traditional radio frequencies (RF) including approximately 300THz of license free bandwidth carried on visible wavelengths and function in a completely different spectrum than RF, immunity to electromagnetic interference so useful in medical operation and high security for use in the defence sector.

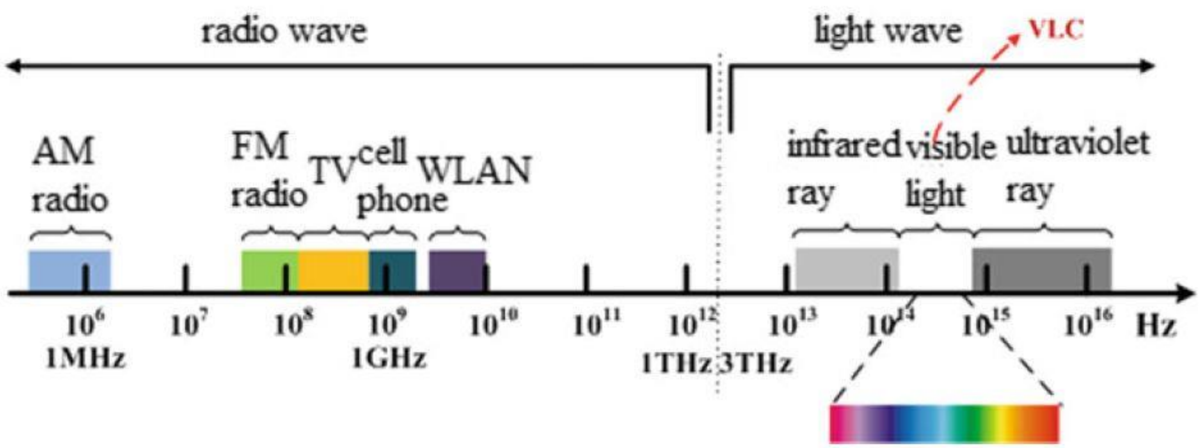

Figure1, Schematic diagram of spectrum resources

Network Topologies

By considering 3 classes of devices, infrastructure, mobile and vehicle, in optical wireless communication (OWC) can define three network topologies, Figure 2 [1,3].

Peer to peer topology which each device can communicate with any other device within its coverage area.

start topology which by using identifier for optical wireless Network (OWN) all star network can operate independently from other star networks.

Broadcast topology which without forming any network devices can send their signal to other devices with no need of destination addresses.

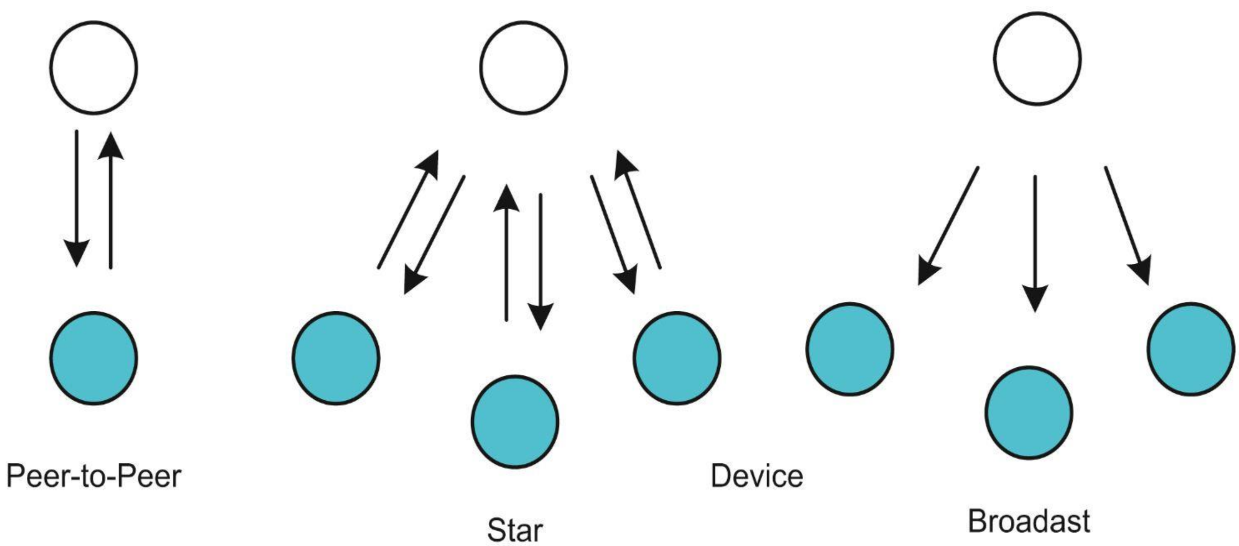

Figure 2, Network Topologies [1,3]

Superframe

Optionally we can use superframe structure. This frame is divided to equal size slots and bounded to beacons. These beacons Transmitted by coordinators periodically to announce presence of LAN network and synchronize the nodes. we can have on or off beacons but still for network discovery we need this beacon. Superframe structure have some portions such as contention access period (CAP), optional contention-free period(CFP) and beacon Period(BP).

Devices communicate during CAP with random access. [1,3,2] In this standard four random access method depends to network configuration has been defined. Unslotted random access, slotted random access, unslotted carrier sense multiple access with collision avoidance (CSMA/CA), and slotted CSMA/CA Figure 3.[1]

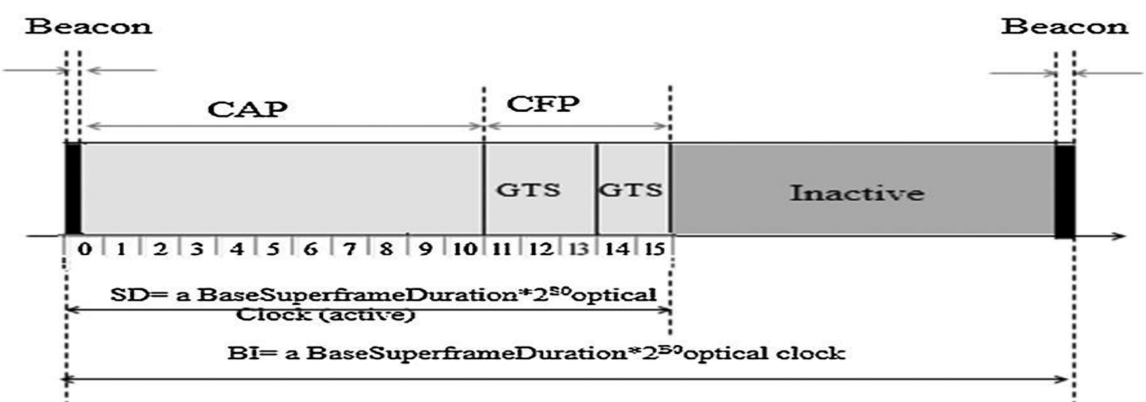

Figure 3, Superframe structure [1]

Using frame structure is helpful for minimizing the complexity of error detection specially in noisy channel. Each layer will add its own header to the structure.[1]

Performance Mechanism

In this study we consider beacon-enable slotted random access with carrier sense multiple access.

In beacon enable mode device listens to the beacon, when found the beacon device start to synchronize with superframe structure. Anytime device wants to transmit data it must be wait for a random backoff period. In carrier sense mechanism if device found channel is busy it will wait for another random backoff slots, if found channel is idle then will start transmission on the next available backoff slot.

A successful reception and validation of data or MAC command frame can be confirmed by acknowledgement. based on acknowledgement required or not originator assumed transmission was unsuccessful or successful.[1]

Random access algorithm

By presenting flowchart its s possible to study CSMA/CA mechanism with beacon enabled mode. Figure 4.

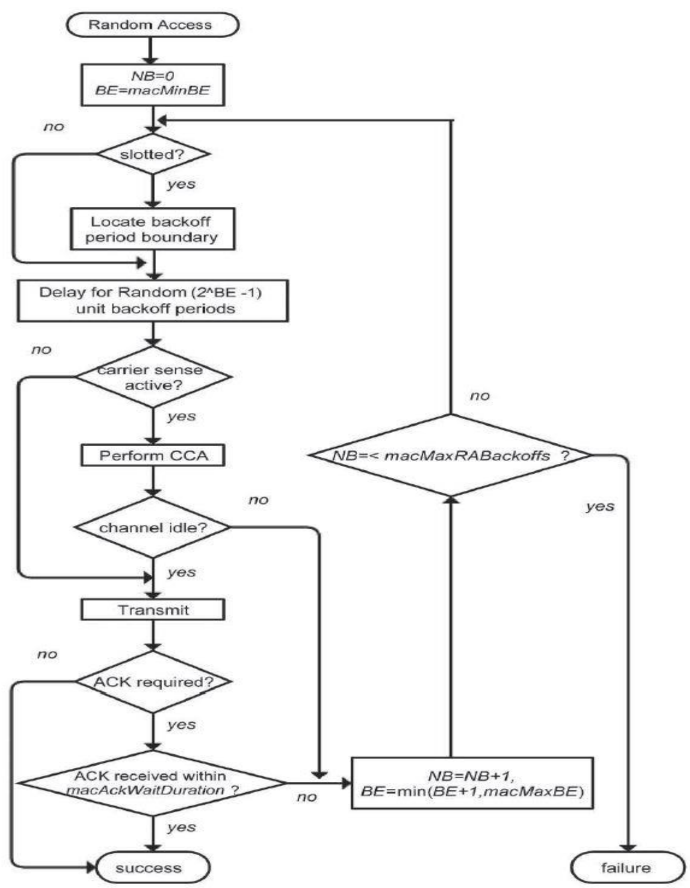

Figure 4, Access algorithm flowchart [1]

Before new packet transmission, node maintain two random variable, NB and BE.

NB is number of backoff time when channel is busy algorithm tries [2]. BE is backoff exponent that's number of backoff periods device wait before accessing to channel.[2]

In the first step these value by configuration will be set to be NB=0 and BE=MacMinBE, node will wait for a random number of backoff period specified by the backoff value, Mac layer will delay for a period of time in the range of (0, 2^{BE}-1). by performing Clear channel assessment (CCA) try to check the state of channel. If it found channel is busy going to update state value and in case state value NB reached the MaxmacBackff algorithm is terminated with failure status. Otherwise if channel is idle Mac layer will go to transmission stage. At the end, based on configuration either request for acknowledgement or not system going to request acknowledgment or going to success state. [1,2,3]

Markov Chain

For modeling MAC layer performance Markov chain have been used. For considering time parameters like packet length and backoff duration 2-D Markov chain is used. As shown in figure 4. Different state of this Markov chain has been shown in table1. [3 2]

[3]

Table I. Markov chain states.

		c(t)				
		$-L_A \dots -1$	0	$1, \dots, L_A$	$L_A+1, \dots, L_p-1$	$L_p, \dots, W_M-1$
s(t)	$0, \dots, M$	–	CCA		Backoff	
	$M+1, \dots, 2M+1$	–		Transmit		–
	$2M+2, \dots, 3M+2$	ACK not received	$c(t)$	ACK received	–	–

ACK, acknowledgement; CCA, clear channel assessment.

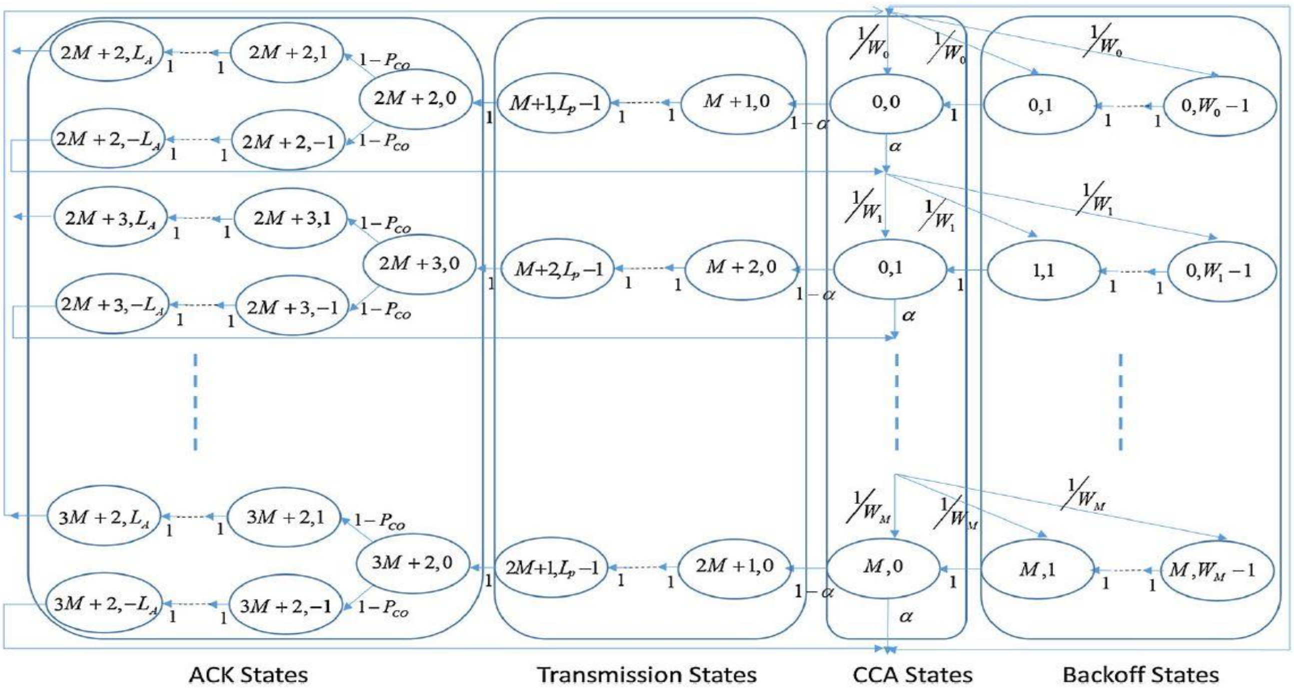

Figure5. Markov Chain [3]

In this Markov chain three stages are defined, Backoff and CCA, Transmission, Acknowledgement.

When packet arrives, node goes to the first backoff stage by choosing any value by random between (0, W_{i-1}), this W_{i-1} is the delay for random backoff period. If CCA stage successfully done and channel found it is idle, then with probability (1- α) node starts transmission. In CCA stage C(t)=0 shows node sense the channel and it is idle. Otherwise it goes to next backoff stage and wait for idle channel.

In Transmission stage C(t) determined number of slots already transmitted. And it has value between (0, L_{p-1}) where L_p indicates Packet length. After completion transmission node will switches its transceiver from transmitting to receiving and wait for acknowledgement.

In acknowledgement C(t)=0 determined switching from transmitting to receiving. in this stage two different state are possible, if $1 \leq C(t) \leq L_A$ means node is receiving acknowledgement with probability (1-P_{co}). if -$L_A \leq c(t) \leq 1$ means node is not receiving acknowledgement. And will go to next backoff stage and wait for retransmit the packet. [2,3]

Performance Metrics

In reference 2 and 3 mathematical analysis of the main network parameters (throughput, delay, power consumption, collision probability, and packet discard probability)have been done and for this study first we define each parameter and use final formula from references and then continue study network behaviour according to simulations .

Throughput

Network throughput is defined as fraction of the time one node is transmitting. [3]

$$S_{Th} = N\,(L_P + L_A)\,\varphi\,(1-\varphi)^{N-1}\,(1-\alpha) \qquad (3)$$

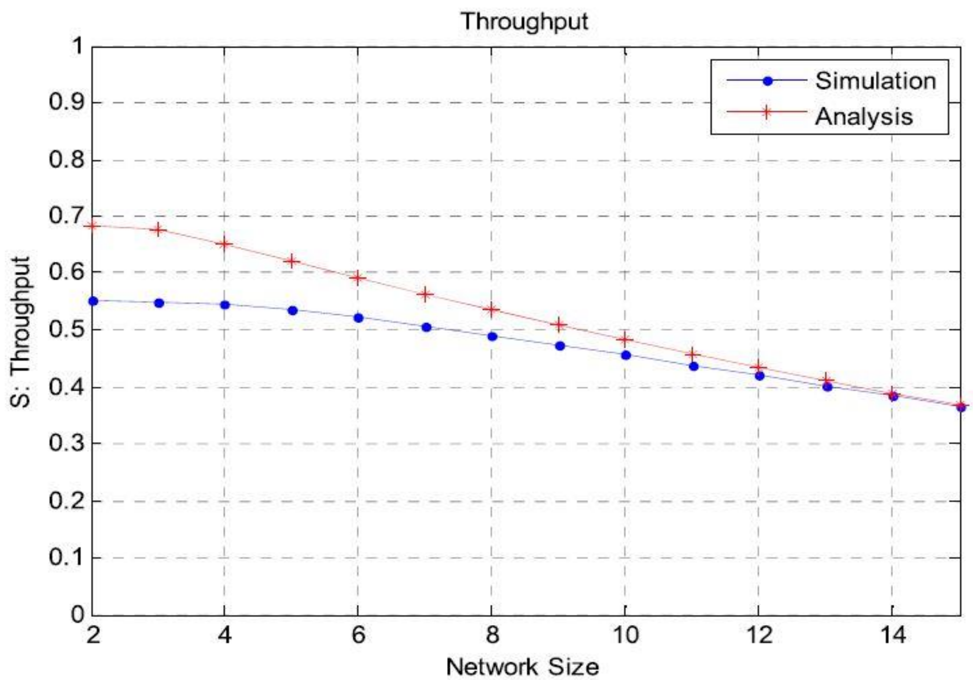

Figure 6, Network Throughput [3]

Collision Probability

Network collision probability can be defined as when one node transmit, one or more other nodes are transmitting at a given time. Or maybe these nodes perform CCA simultaneously.[3]

$$P_{co} = Pr\ \{Tx \geq 2 |\ Tx1\} = 1 - \frac{Pr\{\ Tx1 \cap Tx \geq 1\}}{Pr(\ Tx \geq 1)} \quad (3)$$

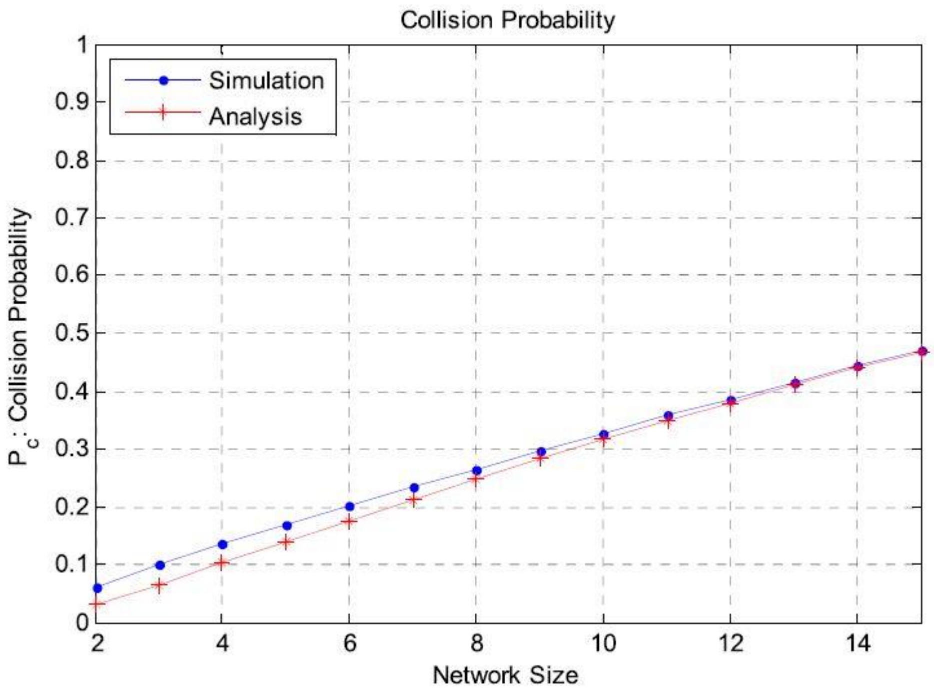

Figure7, collision Probability [3]

Transmission Probability

Transmission probability is the probability that one or more nodes are transmitting in the network including successful or unsuccessful.[3] base on Markov chain it calculated as following formula:

$$P_{tx} = (1\text{-}\alpha)\ \varphi.\ [\ L_p + (1\text{-}\ P_{c0}).\ (L_A + t_{Ack})\ ] \quad (3)$$

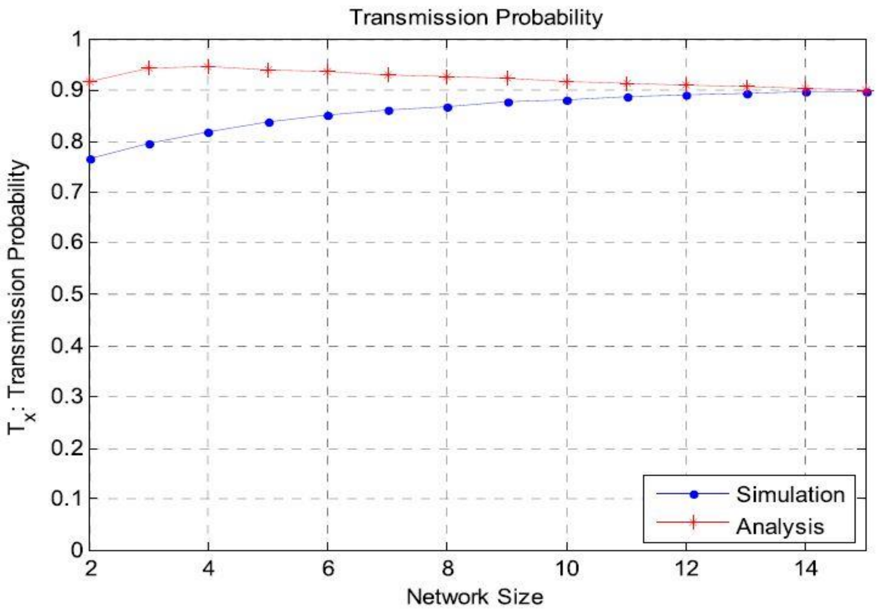

Figure8, Transmission probability for different size network [3]

In the figure 8 we see by increasing the number of nodes in network transmission probability start dropping.

Delay

Delay for a successfully transmitted packet is considered as the total number of time slots required from the time that packet reaches the head of the line until the Acknowledgement is received.[3]

$$D = \frac{1}{1-P_d}\sum_{i=0}^{M}\left\{\left[\left(\sum_{k=0}^{i}\frac{W_k-1}{2}\right)+\sum_{k=0}^{i}\binom{i}{k}((1-\alpha)P_{co})^k\alpha^{i-k}k\,(L_p+t_{ack}+L_A) + (L_p+t_{ack}+L_A)\right][(1-\alpha)(1-P_{co})\,y^i]\right\} \quad (3)$$

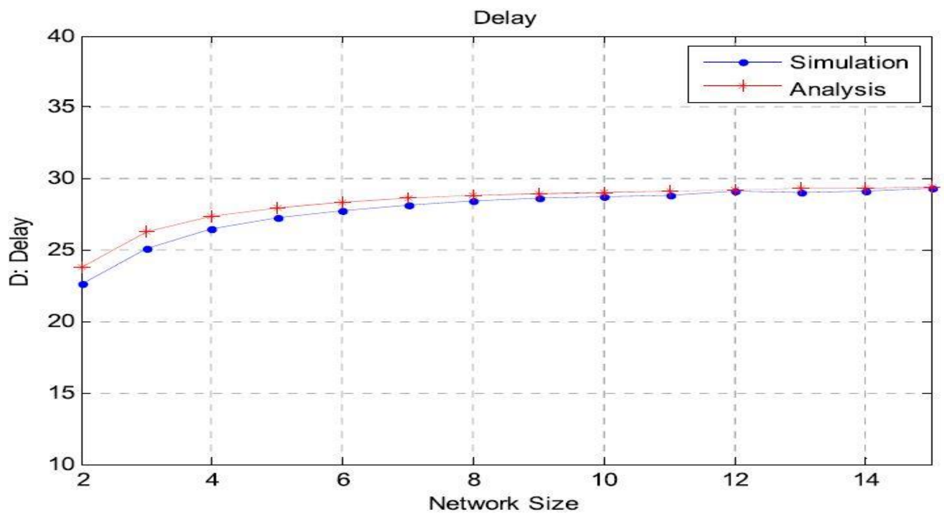

Figure 9, Network delay[3]

Packet discard probability

Packet drop probability defined as fraction of packets produced but are not transmitted successfully. It occurs for combination of channel access failure and collision in channel.

$$P_d = \sum_{i=0}^{M+1} \binom{M+1}{i} \alpha^i (P_{co}(1-\alpha))^{M+1-i} = (\alpha + (1-\alpha)P_{co})^{M+1} = y^{M+1} \quad (3)$$

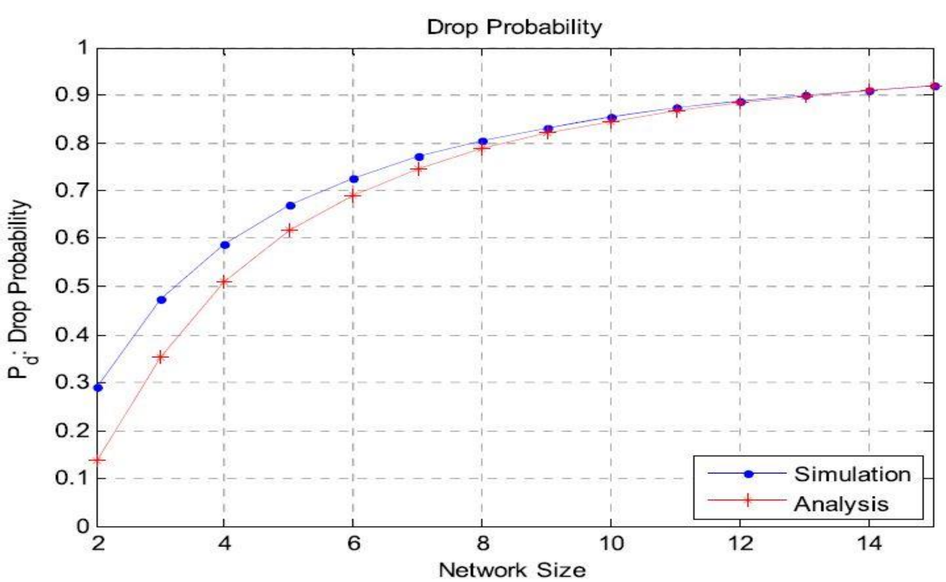

Figure 9, Packet drop probability [3]

By looking at the results from simulation and analysis formula clearly seen there is relation between network size and network metrics. Collision and packet discard probability increased by increasing in network size and in reverse transmission probability and throughput decreased.

Because all these nodes in network have shared the channel and by increasing number of nodes, they spend more time in backoff state rather than transmission state.

Beside that for designing VLC networks we need to consider some more parameter that related to physical layer. By considering characteristic of visible light sources, features of receivers, rooms model, reflection characteristics of environment can improve network responses.

Conclusion

By studying various performance metrics can see relation between number of nodes, network size, and arrival rate of traffic with Throughput, delay, transmission and collision probability.by increasing traffic, nodes spend more time in backoff state so possibility of collision increases and finally causes more delay.[3,2]

However, because of limited coverage in visible light communication there is always some hidden problems such as not detected devices, inter symbol interference (ISI) and reflections which cause physical transmission errors and this can affect MAC layer performance.

References

[1] 802.15.7-2018 - IEEE Standard for Local and metropolitan area networks--Part 15.7: Short-Range Optical Wireless Communications, ISBN: 978-1-5044-5431-5

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