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Optimized GTS allocation strategies for enhanced performance in IEEE 802.15.7 based VLC networks

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Abstract

Visible Light Communication (VLC) has emerged as a promising technology for high-speed wireless communication, which employs the visible spectrum to transmit information. As the title indicates, IEEE 802.15.7 is a new standard dedicated to VLC networks that introduces specializations that match the characteristics and needs of this medium. In VLC networks, one of the key challenges is scheduling Guaranteed Time Slots (GTS) efficiently for better network performance and minimum end-to-end delay while delivering reliable data. The aim of this review paper is to give a detailed overview of the state-of-the-art, in terms of different types GTS allocation strategies within IEEE 802.15.5 network by performing an exhaustive analysis and discussion on each broad category. We investigate, at first, the basic concepts of GTS allocation and then how it plays an important role in increasing the Quality of Service (QoS) level for various VLC applications. In our paper, we explore current GTS allocation methods and evaluate their effectiveness in dynamic network conditions based on how scalable and adaptive they are. In addition, we study how different network parameters like throughput delay and energy consumption are affected by the choice of allocation. Challenges and limitations in practical implementations, such as interference management, mobility support, and synchronization issues are discussed. Besides, we also focus on some more advanced algorithms and optimal solutions that have been suggested to overcome these issues in order to improve the overall performance of VLC networks. This paper consolidates the recent advances and ongoing research in this area, to serve as a useful source of information for researchers/practitioners interested in designing effective GTS allocation mechanisms over IEEE 802.15.7 based VLC networks that are both reliable, and energy efficient. This study then offers some future research directions, including how to use machine learning techniques in an integrated manner and realize cross-layer optimization for better efficiency and adaptability on GTS allocation over VLC-based networks.

Subject Classification: *90B18.*

Keywords: *IEEE 802.15.7, Hidden node problem, Collision avoidance, Communication reliability, MAC layer challenges, Optical wireless communication, Visible light communication, Wireless networks.*

1. Introduction

Compared to RF communication, VLC has better prospects for highly efficient wireless communication. VLC networks have inherent security and are low interference, and are now a key foundation for the next generation wireless networks. IEEE 802.15.7 is a standard that is used

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solely for VLC systems; it aims at providing dependable and efficient VLC communication through the visible light bands. For guaranteed time slots the report consider the Guaranteed Time Slots (GTS) based communication that deals with specific time slots for addressing certain communication requirements in terms of latency and data rate in [1]-[2].

The efficient allocation of GTS is essential for the utilization of network resources to ensure that VLC Network achieves optimal levels of; throughputs, latency and energy consumption. In placing the concept of VL-based networks, the following challenges are also presented; the limitation of line of sight, high interferences from physical barriers, and high sensitivity to light patterns on the environment in [3]-[4]. Paper [5] consequently analyse current practices of GTS allocation in IEEE 802.15.7 networks and present advantages and drawbacks from the VLC perspective.

Another important issue for VLC networks is scalability since this approach should work well with networks of different sizes and traffic distribution. Interference is another issue of VLC networks, and the allocation of timeslots in GTS should therefore be able to change according to the changes in the network topologies while at the same time ensuring effectiveness [6]-[7].

There are still much effort to optimize the GTS allocation in VLC Networks by using some advance algorithm and optimization method. One is the Machine Learning (ML) based solution in which the algorithm utilizes network performance history to learn the nature of the traffic, and the possibility of the algorithm change GTS setting to reflect network conditions. Another method, which can give a more generalized picture of the network performance, is cross-layer optimization, in which the improvement is made across several communication layers. However, there are some issues left open, and an opportunity to develop new approaches based on integration of machine learning methods and cross-layer optimization in [8]-[9]. Standardized measurements are also necessary to compare and assess varying approaches of allocating GTS to appraise various systems with specific reference to efficiency benchmarks as a method of promoting proper usage of systems. This is important to organize VLC interaction events in a time based fashion. This schedules time based communication in VLC networks which comprises of beacon, active and inactive period. To synchronize devices and also to transmit superframe information the beacon is divided into N subslots in [10]. An active period is made up of a Contention Access Period (CAP) in which communications using CSMA/CA channel access are found, and

Contention Free Period with Guaranteed Time Slots (GTSs) supporting contention-free transmission. Since it requires less information update the devices can sometimes remain in the dormant state in the inactive state the devices may be put to sleep or remain idle.

It depicts a numbered scale in the range of 0 to 15, which indicates time slots inside a superframe. Stakeholders can calculate two duration measurements: once based on adjustable parameters SD and BO for Superframe Duration (SD) and another one when it comes to the fixed parameter SO for Beacon Interval (BI) in [11]. This structure provides versatility, energy efficiency and QoS as it allows you to change the periods and allocate dedicated slots. It can be scaled and synchronized by the beacon with CAP & CFP which manages contention. Since these compression algorithms come with parameters to modify their behavior, they can adapt themselves on different traffic patterns and device capabilities. This superframe design fits VLC frameworks nicely by meeting communication requirements without manipulating the main purpose of lighting. This helps with flicker and potential other light source interference in [12].

In this way, the community becomes aware of existing strategies and major challenges and opportunities for others who should be considering developing GTS allocation mechanisms will provide beneficial insights. We conclude by describing research avenues that have the potential to take it further and advancing state of the art in this space. Thus, effective GTS allocation is one of the important issues in IEEE 802.15.7 VLC-based networks and could significantly affect network performance as well energy efficiency as scalability. Meanwhile, the visual spectrum's peculiar traits make GTS allocation a task with its own set of obstacles and opportunities that require more creative approaches and other optimization techniques. Such challenges could be tackled with the use of sophisticated algorithms in improving performance, and thereby reliability, of VLC networks where they can become promising candidates for numerous applications under different environments. Table 1 provides a comparison of the available methodologies.

The review paper makes some noteworthy contributions, which can be described as follows:

1) We examine the increasing popularity of OWC over the past ten years, emphasizing the crucial aspects that have contributed to its

technological expansion. The communication uses of the infrared, ultraviolet, and visible parts of the VLC spectrum are examined.

2) The survey incorporates a substantial amount of visual depictions to enhance the reader's understanding of different applications based on VLC technology.
3) We analyze the assumptions made by the research authors and propose potential future work that can be done to address these gaps and enhance the research.
4) We provide a comprehensive analysis of the prominent research platforms that have been established in the existing literature.

III. Efficient GTS allocation

The coordinator also shares bandwidths to applications that request low latency or greater bandwidth and the time slots are referred to as Guaranteed Time Slots (GTSs). The contention-free period (CFP) is generated by GTSs and it is present at the end of the current superframe. The coordinator can allocate several GTSs; each GTS may occupy several time slots, thereby enabling the coordinator to allocate sufficient Collision Avoidance-Pulses (CAPs). Any device using a GTS must warrant that its transaction is made before the following GTS or CFP. A study suggested an algorithm designed to minimize the latency and energy consumption for selecting the parent node in data packet routing to design a better wireless communication network, reduce wastage of time-slots and increase reliability of the network with higher channel utilization. A new GTS allocation mechanism with adaptive resource allocation was suggested so that IEEE 802.15.4 WPANs become more efficient in configurations utilizing beacons. Using quantitative analysis and simulated trials with Gamma and Pareto distribution, a performance analysis of the technique was done.

IV. Conclusion

In this paper, an extensive and critical review of GTS allocation schemes in IEEE 802.15.7 based VLC system has been presented. In our work, we stress the importance of optimizing the GTS scheduling to increase the network quality and- more specifically-reduce the End-to-End (E2E) delay as a factor affecting QoS. In the work, we considered different kinds of scheduling strategies and their performance depending on the

Table 1

Summary of comparison of available methodologies for efficient GTS allocation

Reference	Focus Area	Proposed Solution	Key Contributions	Limitations/ Challenges
O'Brien [1]	VLC as a paradigm for high-speed wireless communication	General overview of VLC advantages and applications	Highlighted VLC's unique capabilities in high-speed data transmission	Limited discussion on GTS allocation mechanisms
Wang, Wang and Zhang [2]	Performance analysis of GTS allocation strategies	Evaluated various GTS allocation strategies under dynamic conditions	Quantified effects on throughput, delay, and energy consumption	Did not propose novel strategies or optimization techniques
Katz, Neumark and Macfarlane [3]	Survey of GTS allocation techniques in VLC networks	Comprehensive review of existing GTS allocation strategies	Consolidated state-of-the-art research on GTS allocation	Lack of focus on emerging methods like ML-based optimization
Cheng et al. [5]	Dynamic GTS allocation schemes	Suggested real-time GTS adjustments based on network conditions	Improved performance in mobility and dynamic topologies	Increased system complexity and synchronization requirements
Farshid, Shah and Mishra [8]	ML-based time slot allocation in VLC networks	Utilized machine learning to predict traffic and optimize slots	Improved adaptability to dynamic traffic patterns	High computational overhead for real-time scenarios
Kim and Lee [9]	Dynamic GTS allocation for energy-efficient VLC systems	Developed energy-efficient dynamic GTS mechanisms	Reduced energy consumption without significant QoS loss	Focused on specific network conditions; scalability untested
Tan, Ng and Cheong [11]	Interference management techniques for VLC networks	Proposed methods to mitigate interference in VLC systems	Enhanced reliability and performance in noisy environments	Limited focus on GTS-specific interference challenges

network changes, focusing on the results that are concerned with throughput, delay, energy costs. Realisation issues including interferences, mobility support as well as synchronisation problems were considered, and new algorithms regarding GTS allocation were reviewed. To tackle such problems, both machine learning and cross-layer optimization should be incorporated as pointed out by the observations.

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