Journal of Advanced Research in Signal Processing and Applications
Volume 6, Print Issue 1 - 2024, Pg. No. 1-6
Peer Reviewed Journal

Research Article

Integration of Cognitive Radio with Wireless Sensor Networks for Spectrum Sensing

Puneet Kalsi[1], Vikrant Sharma[2]

[1,2]Assistant Professor, Professor, GNA University.

INFO

Corresponding Author:
Kalsi P. GNA University.
E-mail Id:
puneet.kalsi@gnauniversity.edu.in
Orcid Id:
https://orcid.org/0009-0009-1375-1034
How to cite this article:
Kalsi P, Sharma V. Integration of Cognitive Radio with Wireless Sensor Networks for Spectrum Sensing. *J Adv Res Sig Proc Appl* 2024; 6(1): 1-6.

Date of Submission: 2024-02-17
Date of Acceptance: 2024-03-23

ABSTRACT

People's daily lives are altering as a result of recent innovations, IoT network growth, and implementation. Due to the growing demands of Internet of Things (IoT) and wireless sensor networks (WSNs), The utilization of wireless systems has surged recently and is expected to grew significantly in the near future. In wireless cognitive sensor networks, spectrum sharing allows networks to function together by sharing some of the available spectrum, particularly when there is an extra band that is not being used. Additionally, a creative framework for the smooth integration of Visible Light Communication (VLC) and Cognitive Radio Sensor Network (CRSN) technologies is presented, offering a novel solution to difficulties related to spectrum shortages and increasing network efficiency. The difficulties of the upcoming generation of Internet of Things networks are still to increase throughput whil e maintaining reliability and decrease total network latency. This paper makes a contribution to wireless sensor networks and cognitive radio combined technologies to provide spectrum availability, data bandwidth and benefits of using CR with Wireless Sensor networks.

Keywords: WSN, Cognitive Radio, Visible Light Communication

Introduction

Further spectrum resources are needed to ensure the quality of service (QoS) of future wirelessnetworks due to the widespread deployment of IoT devices. Nonetheless, there is a significantbarrier to solving this issue. diminution of the spectrum. Many strategies are used to share or reuse the spectrum among several users without causing the system's performance to deteriorate.[1] Technology is developing at a rate that has never been seen before to make devices more energy-efficient. The act of regularly observing a particular frequency band withthe goal of determining if primary users are present or absent is known as spectrum sensing, whereas the cooperative usage of shared spectrum by several users is known as spectrum sharing. One resource sharing network that is particularly useful for sharing spectrum is the Cognitive Radio (CR) network. These networks can be used in tandem to improve system performance and throughput by utilizing the idea of identifying unoccupied spectrum and requesting usage of it across different operators. In order to extend the device life and, by extension, the network lifetime, it is also perfect for wireless devices with low power.[2] Wireless sensor networks (WSN) can leverage CRN technology to boost throughput in the event of a network congestion. One of the practical ways to boost spectrum reusability and revenue for service providers is to lease spectrum from main users (PU) to secondary users (SU).

To increase network capacity, most researchers nowadays take into account the sharing idea and heterogeneity process in wireless communication. Due to the increasing demand for wireless applications, the sharing concept has emerged in contemporary wireless communication research the rise of mobile devices over the past few decades, which has increased radio access utilization.[3] The cost-effective design of radio access technology is seen to be crucial for increasing system capacity. In order to give mobile devices, the freedom to access all nearby radio resources, 5G networks support three different types of resource sharing: spectrum sharing, access sharing, and infrastructure sharing.[4] The latter two involvethe use of the Radio Resource Sharing (RRS) scheme between various mobile infrastructures .[5]

Review of the Literature

Advances in radio frequency (RF) and visible light communication (VLC) technologies havea major role in the creation and expansion of wireless sensor networks (WSNs). The goal of this work is to provide an extensive overview of the current state of the art for cognitive hybridRF-VLC systems for WSNs highlighting how important it is to integrate Cognitive Radio Sensor Networks (CRSNs) and VLC technologies in a smooth manner. The main issue that needs to be addressed is the complicated environment of this integration, which is marked by significant trade-offs between complexity and performance that get worse as more devices anddata rates are added. This review examines the core concepts of CRSNs and VLC, emphasizingimportant areas such as Energy Harvesting, Industrial Scenarios, and Resource Allocation. It also considers the potential benefits of combining these two technologies in a synergistic wayto improve network performance and spectrum utilization. Through exploring the fusion of cognitive radio technology and visible light, this research provides insightful information on the possibilities for creative uses of wireless communication, offering a fair summary of the state-of-the-art and future directions in the field of cognitive hybrid RF/VLC systems.[6]

In the review literature, wireless sensor nodes are employed to send data to the target quickly and effectively. It saves energy and expands the network's transmission capacity. Secondary source (SS), secondary relay (SR), secondary destination (SD), and principal destination (PD)nodes make up the network. A cooperative phase steering (CPS) method with duty cycling waspresented by Lee et al.[7] in an effort to increase energy efficiency and optimize spectrum sharing. They used in-depth mathematical simulations to test the plan after first performing a mathematical evaluation of the CPS. The outcomes demonstrate increased efficiency in termsof throughput and outage probability when compared to the conventional relay selection technique. Achieving spectrum efficiency among CR IoT requires optimizing network resources.

It becomes a very difficult problem to answer when several characteristics are considered at once, such as transmission power, latency, and transmission rate. By taking into account eachof these variables collectively, Muwonge et al.[8] suggested an ideal solution in the presence of interference and bit error rate (BER). They looked into the effects of packet size, network size, BER, and interference on total power, rate, and delay. To solve this problem, they employed the branch-and-cut polyhedral technique.

They noticed that power, interference, and transmission delay increase with increasing packetsize and amount of SUs.It consequently has an impact on the transmission rate and, subseque ntly, the BER performance. It is interesting to compare the suggested scheme with related onesin order to observe how well the system is improved overall.

Cognitive Approach in WSN

Cognitive approaches have been applied recently in wireless networks to get over the restrictions put in place by traditional WSNs. One contender for the upcoming generation of wireless communications systems is cognitive radio (CR). The method of knowing through perception, planning, reasoning, action, and constant updating and upgrading with a prior learning history is known as the cognitive technique. Cognitive radio can overcome the many obstacles faced by modern WSNs if it can be combined with wireless sensors. CR can identifyunderutilized spectrum in both licensed and unlicensed spectrum bands and make opportunistic use of it. The spectrum may be used at any time by the incumbents, or main users (PU), but secondary users (SU) are only permitted to use it when the PU is not utilizing it.

Table 1.Lists the requirements for a wireless sensor with a Cognitive Radio[9]

Function	Action
Cognitive capabilities	
Spectrum sensing	Detect unused spaces (white spaces) by the incumbents inthe spectrum bands.
Spectrum sharing	Use the unused white spaces of incumbents and share thewhite space information with cognitive users.
Prediction	Predict the arrival of incumbents on the channel.
Fairness	Distribution of spectrum utilization opportunities fairlyamong cognitive users.
Routing	Route the packet to the destination efficiently consideringthe network life span, load balancing, shortest route and delay in multi-hop CR-WSNs
Reconfiguration capability	Reconfigure and adjust according to the environmentoutcomes.

Environment sensing	Sensing the environmental factors as in conventionalwireless sensors
Trust and security	Building a trustable environment and secure networks.
Power control	Control transmission power considering the legal boundaries and requirements

Unlicensed users can opportunistically access numerous licensed channels through CR. Due toCR's nature, WSNs may benefit from increased communication dependability and improved energy efficiency. Researchers and industry have exciting new potential to develop algorithms,hardware, and software that can overcome the limits imposed by current wireless sensor designmethodologies when cognitive wireless sensor nodes are added to a whole network. With the help of technological advancements in sensor technology and the recent liberalizationof the FCC's spectrum utilization guideline, wireless sensors with CR can improve network performance and lessen the problem of spectrum inefficiency.

Benefits of Using CR in WSNs

In Wireless Sensor networks, CR-WSN is a novel paradigm that effectively uses spectrum resources for spikes in traffic. The system can reduce packet loss, reduce power consumption,control buffers to a high degree, and improve communication quality. The benefits of implementing cognitive radio in WSNs are covered in this section.

Effective Spectrum Use and Areas for Emerging Technologies

Although there is a limit to the number of usable spectrum bands that are available, they can be utilized more effectively. White spaces are unoccupied frequencies that cognitive radio wireless sensors can use without bothering license holders.[10] Since unlicensed users can utilize such bands for low cost, more technologies can be created specifically for these bands.

Multiple Channels Utilization

The majority of conventional WSNs communicate over a single channel. In WSNs, sensor nodes produce packet burst traffic when they identify an event. In densely deployed WSNs, numerous wireless sensor nodes in the event region compete with one another to simultaneously try and acquire the same channel. Due to packet losses and increased collisionlikelihood, this results in excessive power consumption and packet delay. It also reduces overall communication reliability. To mitigate this possible issue, CR-WSNs opportunistically accessnumerous channels.

Energy Efficiency

Due to packet losses, there is a significant amount of power waste in WSNs from packet retransmission. It's possible for CR wireless sensors to adjust their operational parameters in response to channel circumstances. As a result, energy usage from packet collisions and retransmissions can be reduced.

Global Operability

Every nation has its own laws governing spectrum regulation. It is possible that a band that is available in one nation might not be in another. When manufactured wireless sensors are deployed in different places, traditional wireless sensors with a predefined working frequencymay not function.[11] However, nodes that possess cognitive radio capacity can get around the issue of spectrum incompatibility by switching the communication frequency range they use. Consequently, it is possible to use CR wireless sensors practically anywhere throughout the world.

Application Specific Spectrum Band Utilization

The quantity of wireless sensors being used for various purposes has grown at the moment. Data flow in WSNs is typically coupled both spatially and temporally. WSNs produce packet bursts in response to any event, and they are silent in the absence of an event. The design problem of the communication protocols for WSN is increased by these temporal and spatial correlations. It is possible that wireless sensors deployed for the same purpose in spatially overlapping regions use different incumbents' spectrum thanks to the clever communication protocols in CR-WSN. Cooperative communication between SUs makes this possible and, of course, reduces interference problems.

Dynamic Spectrum Sensing

Certain systems are intended to use the radio frequency ranges of the electromagnetic spectrum.A CR network with an appropriate spectrum sensing approach can be used to more efficientlyutilize the available radio frequency bands. It is well known that these CR networks will increase the data transmission rate in upcoming wireless networks. Cognitive radio technology-based dynamic spectrum access schemes have the potential to reduce spectrum management overhead and increase spectrum efficiency.[12] CRN encompasses a wide range of study areasand draws a lot of research activity. Using CRNs presents a number of difficulties, these include adaptive hardware design, sensing algorithms, security, dissemination, intelligence, and implementation. Numerous spectra sensing methods have been developed over time and are categorized as follows:

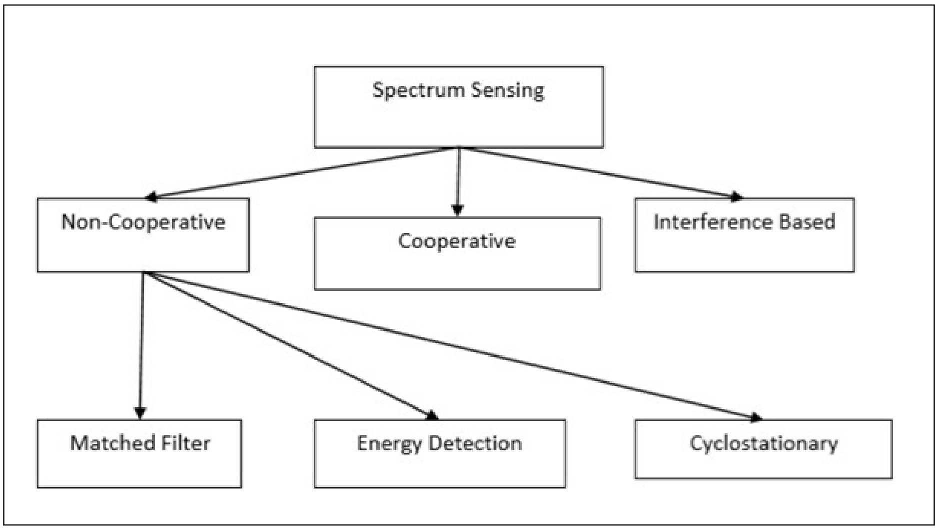

Figure 1.Spectrum Sensing Classification[12]

Cooperative sensing, one of the various methods utilized to carry out spectrum sensing, is oneof the subjects we have concentrated on. By collecting and combining the sensing data and outcomes from individual CR users, cooperative spectrum sensing contributes to the enhancement of the CR Network's overall sensing capacity. When CR users work together, theycan make decisions that are more accurate when taken as a whole. There are three primary factors that influence cooperative sensing:

1. Our methodology for cooperative sensing.
2. The sensing method's representational models and
3. Difficulties encountered in applying this sensing technique.

Three distinct methodologies are used in cooperative sensing: centralized, distributed, and relay-based. The Game Theoretical model, Parallel Fusion, Machine Learning approach, Particle Swarm Optimization, and Random Matrix Theory are some of the models that are usedto explain how cooperative sensing functions.[13] Additionally, channel uncertainty, cooperation overhead, decision fusion, interference temperature measurement, coalition formation, and mobility present obstacles when using cooperative sensing. The primary goal isto impart knowledge about Cognitive Radio Networks and all of its foundations.

Cognitive Radio Sensor Networks

The adaptability of wireless sensor networks (WSNs) in a range of industries, including healthcare, industrial automation, and urban intelligence, has attracted significant interest . There is currently a severe lack of Radio Frequency (RF) spectra because to the soaring demandfor wireless communication services. Certain frequency bands have been underutilized for extended periods of time due to improper exploitation of the old spectrum allocation procedures. Cognitive Radio (CR), which enables effective and dynamic spectrum usage, has emerged as a viable solution to this problem.[14] CR technology is extended further by Cognitive Radio Sensor Networks (CRSNs), which combine CR with sensor networks to navigate complex, dynamic wireless environments.

By fusing the intelligence and adaptability of CRs with the sensing power of sensor networks,CRSNs optimize spectrum utilization, boost network efficiency, and promote effective data transfer. With the help of real-time observations and application needs, sensor nodes equippedwith CR capabilities in CRSNs automatically perceive, analyze, and adapt to the wireless environment.

CRSNs create intelligent and adaptive wireless sensor networks inside a network of sensor nodes. CR's cognitive functions let it to adjust to and absorb information from its surroundings.By utilizing software-defined radio technology, CRs may be reconfigured and reprogrammed in real-time, which makes it easier to sense, analyze, and react to changes in the radio frequencyspectrum.

Characteristics of CRSNs

CRSNs function in complex physical contexts where their ability to control multiple physical domains effectively is essential to their operation. Spectrum resources, time resources, power resources, and space resources are the essential physical domains of CRSN.

Spectrum resources: In CRSNs, the spectrum of electromagnetic frequencies used for wireless communication is crucial. The spectrum is strictly restricted since it accommodates many vital applications. CR stands out because to its capacity to dynamically access and makeuse of "white spaces" or "spectrum holes," which are unused portions of the spectrum.[6] Coexisting with other wireless systems is made possible by CR's capacity to adaptively adjust spectrum utilization and automatically detect unoccupied communication channels.

Time resources: Time synchronization is essential to CRSNs because it makes it easier for sensor nodes to coordinate and allocate resources optimally. By precisely aligning time, CRSNsprevent collisions and guarantee effective communication.

Power resources: Because sensor nodes have limited energy resources, power management is essential in CRSNs. CR maximizes energy efficiency, extends network lifetime, and optimizes energy usage by dynamically modifying routing pathways and transmission power.

Space resources: To maximize resource allocation and interference control, CRSNs take advantage of the spatial features of the wireless environment. Optimizing spectrum utilization and improving network performance are made possible by the deliberate placement of sensor nodes according to their actual locations.

To maximize their performance in dynamic wireless environments, CRSNs might mix severalresource management algorithms. Spectrum management, a tactic made up of methods for facilitating effective spectrum allocation and use, is the foundation of CR.

Some Key Elements are Listed Below

Spectrum sensing: CR equipment finds underutilized or unused frequency bands;
Spectrum decision: CR devices choose the best frequency bands for transmission basedon measured spectra;
Spectrum sharing: PUs and SUs share and manage the spectrum through underlay,overlay, and hybrid spectrum sharing schemes;
Interference mitigation: methods for reducing interference include adaptivemodulation, coding schemes, and power control mechanisms;
Spectrum mobility: In dynamic spectrum situations, CR devices make effective use ofthe available spectrum resources by employing spectrum mobility strategies;
Spectrum management database: a centralized source of information regarding the useof spectrum that provides details on the resources that are available.
Dynamic spectrum access: this feature enables CR devices to adjust frequencyconsumption in real-time in response to available spectrum;

Enforcement and regular monitoring of the spectrum is necessary to preserve itsintegrity and guarantee its equitable and effective usage.

An illustration of how some of the primary CR approaches interact is shown in Figure 2. Thisis just one of many possible instances of the CR cycle, or CR structure, which aids in determining how adaptively cognitive capacity operates.

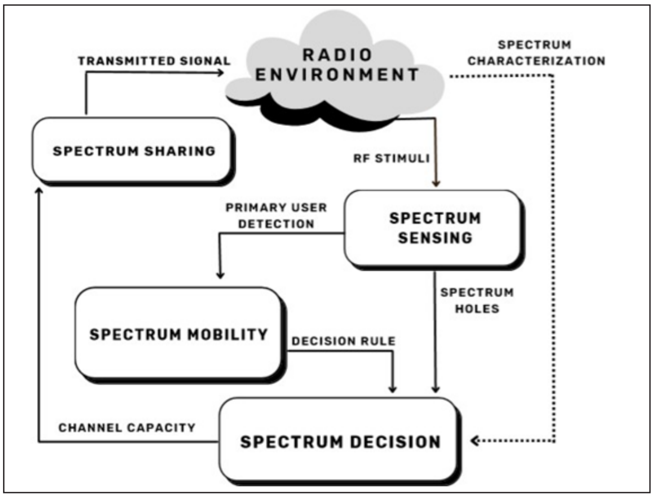

Figure 2.Cognitive radio cycle[14]

These methods seek to maximize spectrum efficiency, share resources among many users, ensure equitable and interference-free coexistence, and optimize spectrum use. They stand fora variety of facets of radio spectrum management, including efficient access and utilization.

Since comparable techniques may be used to the visible light spectrum, they are essential for hybrid communication systems that combine VLC and RF. In the field of hybrid RF/VLC systems, performance evaluation and comprehension are critical. While there are certain benefits to combining RF and VLC technologies, there are drawbacks as well that need to be carefully considered. Performance metrics direct the design and optimization of these intricatenetworks by offering crucial insights into the effectiveness, dependability, and quality of the system.

Basics of Visible Light Communication (VLC)

VLC is a visible light communication technique that operates in the 400–800 nm frequency range of the visible light spectrum. The main enablers of VLC, LEDs are widely used in homes,offices, and public areas. They provide data transmission and illumination at the same time.

One important benefit of VLC is that it does not rely on the more crowded electromagnetic spectrum, making it a good option for systems, especially in light of the rapidly expanding number of wireless communication devices. To encode data, the VLC modulates the LED lights' intensity. The human eye is incapable of perceiving this high frequency modulation. Thismodulated light is detected by a photodiode at the receiving end, which then transforms the variations in light intensity into an electrical current that is then converted back into a binary data stream. The essential difference between the principle of operation and data transmissionusing optical fibers is that VLC uses open space for data transfer.[15]

Despite being widely used, traditional radio frequency systems have many difficulties. Due tothe scarcity and licensing of RF spectrum resources, interference problems and congestion arise. RF-based systems can be expensive to deploy, and they sometimes lack intrinsic securitycapabilities that are required for some applications. Additionally, RF systems require a significant amount of energy, which may have an impact on the environment.

There are various advantages to integrating CR networks—which are distinguished by their capacity to adjust dynamically to the spectrum environment—into hybrid RF/VLC systems.[16] Intelligent radios in CR networks allow them to dynamically use the available spectrum resources. Through the integration of RF and VLC technologies, carrier relay networks (CRs)are able to adaptively choose the best channel based on the current situation. This results in increased network capacity, better quality of service, and effective spectrum utilization.

Conclusion

This paper depicts the frequency bands that are currently available to us are being used rather inefficiently and not to their full potential. With the help of Cognitive Radio technology theseinefficiencies can be addressed and improve spectrum utilization efficiency. The benefits of cognitive radio wireless sensor networks are discussed in this research. It provides an extensiveoverview of the developments and future directions in the field of CRSNs with VLC technology. Sensing techniques appropriate for circumstances using cognitive radio wireless sensor networks are examined. The study showcases that cutting edge research in the areas ofwireless sensor networks and cognitive radio networks for the Internet of Things.

References

1. Heejung Yu and Yousaf Bin Zikria “Cognitive Radio Networks for Internet of Things andWireless Sensor Networks” Sensors 2020, 20, 5288; doi:10.3390/s20185288
2. Ostovar,A.;Zikria,Y.B.;Kim,H.S.;Ali,R. Optimization of Resource Allocation Model With Energy-Efficient Cooperative Sensing in Green Cognitive Radio Networks. IEEE Access 2020,8, 141594–141610
3. Mohammed Ayad Saad, Mustafa S. T, Mohammed Hussein Ali, M. M. Hashim, MahamodBin Ismail1, Adnan H. Ali, “Spectrum sensing and energy detection in cognitive networks”, Indonesian Journal of Electrical Engineering and Computer Science Vol. 17, No. 1, January 2020, pp. 465~472 ISSN: 2502-4752, DOI: 10.11591/ijeecs.v17.i1
4. A. Benjebbour, Y. Saito, Y. Kishiyama, A. Li, A. Harada and T. Nakamura, “Concept andpractical considerations of non-orthogonal multiple access (NOMA) for future radio access,” 2013 International Symposium on Intelligent Signal Processing and Communication Systems, Naha, 2013, pp. 770-774.
5. Adnan H. Ali,.; Farhood, A.D. “Design and Performance Analysis of the WDM Schemes for Radio over Fiber System With Different Fiber Propagation Losses.” Fibers 2019, 7, 19.
6. Rodrigo Fuchs Miranda, Carlos Henrique Barriquello “A Review of Cognitive Hybrid Radio Frequency/Visible Light Communication Systems for Wireless Sensor Networks” Sensors 2023, 23, 7815. https://doi.org/10.3390/s23187815
7. Lee,S.;Yoon,J.;Jung,B.C., “A Cooperative Phase-Steering Technique with On-Off Power Control for Spectrum Sharing-Based Wireless Sensor Networks. Sensors 2020, 20, 1942.
8. Ssajjabbi Muwonge, B.; Pei, T.; Sansa Otim, J.; Mayambala, F. A Joint Power, Delay andRate Optimization Model for Secondary Users in Cognitive Radio Sensor Networks. Sensors2020,20,4907.
9. Gyanendra Prasad Joshi, Seung Yeob Nam and Sung Won Kim,“Cognitive Radio WirelessSensor Networks: Applications, Challenges and Research Trends”, Sensors 2013, 13, 11196- 11228; doi:10.3390/s130911196
10. Zhou, G.; Stankovic, J.A.; Son, S. Crowded Spectrum in Wireless Sensor Networks. In Proceedings of the Third Workshop on Embedded Networked Sensors (EmNets 2006), Cambridge, MA, USA, 30–31 May 2006.
11. Borms, J.; Steenhaut, K.; Lemmens, B. Low-Overhead Dynamic Multi-Channel MAC forWireless Sensor Networks. In Proceedings of the Seventh European Conference on Wireless Sensor Networks (EWSN’10), Coimbra, Portugal, 17–19 February 2010; pp. 81–96.
12. Preet Talajiya, Aniket Gangurde, U Ragavendran, Hariharan Murali, “Cognitive Radio Networks and Spectrum Sensing A Review”, http://www.i-joe.org
13. M. Sharma, P. Chauhan, and N. Sarma, “A brief review of cooperative spectrum sensing:Issues and challenges,” 2016 International Conference on Accessibility to Digital World (ICADW), Guwahati, pp. 113-116, December 2016. https://doi.org/10.1109/icadw.2016. 7942523
14. Gardaševic´, G.; Katzis, K.; Bajic´, D.; Berbakov, L. Emerging Wireless Sensor Networksand Internet of Things Technologies—Foundations of Smart Healthcare. Sensors 2020, 20, 3619. [CrossRef] [PubMed]
15. Teixeira,L.;Loose,F.;Barriquello,C.H.;Reguera,V.A.;Costa,M.A.D.;Alonso,J.M.nEnergy Efficiency of Visible Light Communication Systems. IEEE J. Emerg. Sel. Top. PowerElectron. 2021,9,6396–6407.
16. Chen,C.(Ed.)VisibleLightCommunication(VLC);MDPI:Basel,Switzerland, 2022.