A Review: Visible Light Communication using MU-MIMO-OFDM

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Abstract

Visible Light Communication (VLC) is an approach which uses LEDs (Light Emitting Diodes) for lightning as well as for providing an opening for economical higher data transfer rate setup for wireless communication, which can be used as an alternative for effective and efficient communication that can merge with the demand for higher transfer rate wireless communication. In this paper, we take an inspection of VLC and provide a wide survey on advances and research activities in VLC focusing on several aspects such as main elements of VLC systems namely MU-MIMO and OFDM, potential applications and challenges for practical utilization, combination and commercialization. In addition, importance and discussion of high-speed MU-MIMO VLC systems are considered.

Keywords: *MU-MIMO, Adaptive modulation, Orthogonal frequency division multiplexing (OFDM), Visible light communication (VLC).*

I. INTRODUCTION

Now the days, the use of LED's for human illumination is an energy efficient and environment friendly option. VLC system uses LED for illumination and data communication together which gives us an electrifying chance for a wide range of indoor applicability [13][14]. In VLC setup, the binary bits are profiled as symbol, which then modulates intenseness of the visible light produced by the LED. On the receiver side Photo Detectors (PD) are used for identifying the signals communicated through optical channels. When the Opto-electric Conversion (Optical to electrical) is done, the received signals are demodulated and the information bits are recovered.

II. VISIBLE LIGHT COMMUNICATION

Visible light communication (VLC) is a technology of wireless communication using regulated light from the visible spectrum. The light sharpness from an assimilated light source may be recognised to encrypt information. This regulated light may be recognized by a photo sensor. If the transmission rate of information is fast enough, the human eye will not be able to realize the transmitter as a varying light source [6].

VLC may be used inward inter-connected lighting control setup to establish communication network between luminaries. In this case, as the regulated light travels, the optical channel gain increases as well. This indicates that if the transferred signal is compared with the received signal, the optical channel gain may be estimated from it. These computations may permit the system setup to become flexible to environment variations.

Since optical communication is established using Intensity Modulation (IM) and Direct Detection (DD), real rather than complex signal processing is mandatory in VLC setup. By adopting the design of MIMO mechanics, In VLC setup pattern of several LED's can be engaged which not only provides necessary light levels in indoor environment but also provides a chance to develop the realizable data rates. MIMO VLC setup eliminates the bandwidth limitation of a single LED and gives an improved system throughput as well as Spectral Efficiency (SE).

In case of Radio Frequency (RF) stationed wireless communication systems, the spatial MIMO channel networks are uncorrelated if the spacing between the antennas is suitably large. Else ways, channel correlation may have non ignorable effect on the set up [15] [16]. In case of VLC, the channel gain between the LED and two closely placed PDs are usually identical. Due to the fact that LOS (Line of Sight) transmission is pre-eminent. Thus the consequential high spatial correlation of indoor VLC channel networks can severely degrade the achievable performances.

To downturn the channel correlation, measures such as increasing the distance between photo-detectors, employing power imbalance and even blocking designated channel network may be borrowed [17]. For example, power imbalanced multiple broadcast light sources are used to modify the high channel correlation executed on conventional Optical Spatial Modulation (OSM) systems [18]. Others deliberate the use of multiple PD's with distinct temperament angles on small mobile devices. Also the profits of Imaging Receiver (ImR) [17] are considered which are used to realise important signal to noise ratio (SNR) gains.

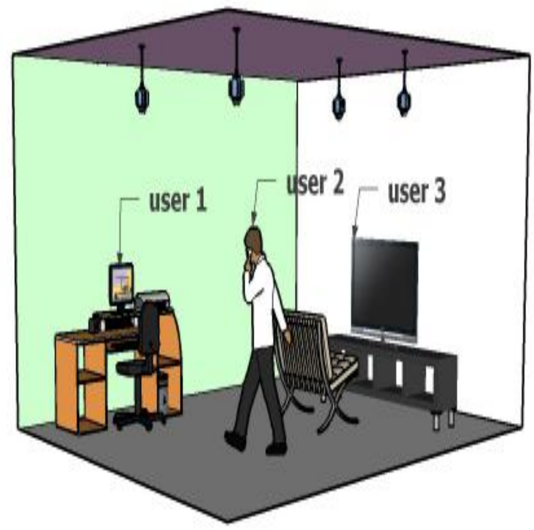

Figure 1. MU-MISO Broadcasting Scenario in Indoor visible Light Communication (Four Transmitting Units and three users) [5]

A trial indoor VLC MIMO presentation with ImR [18] and the design of hemispherical lens based ImR structure also presents the conceivableness of ImR technology in indoor MIMO VLC applications. In addition, the fisheye lenses assisted ImR may be used to give an ultra-wide field of view (FOV) [19]. It is also planned to accept an imaging angle diversity receiver to increase the system performance of indoor space division multiplexing assisted VLC set up. There has not been much research done on multiuser MISO for VLC setup which is different from radio frequency (RF) systems in two important ways.

The RF baseband signals are multiform valued where time-domain signals in the VLC system are real valued and non-negative; and ii) the foremost influence drawback for VLC is the regular optical power, rather than the normal electrical power in RF communication. Consequently, most concepts and approaches established for RF MU-MISO are not directly appropriate to visible MU-MISO.

III. MU-MIMO-OFDM

Multi-User Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MU-MIMO-OFDM) is studied for indoor VLC setups. For every subcarrier in OFDM, their respective precoding matrix is analysed in the frequency domain to remove the multi-user interference. Two different DC bias and scaling systems are measured for multiple LED's to obtain non-negative signals. Since the distances of the multiple transmitter-receiver channels are different, their time delays are also different, due to which there are subsequent phase differences. In case of wide-band systems, the phase difference should not be neglected, especially for the subcarriers with high indexes [11].

IV. MASSIVE MIMO VLC

A MU-MIMO VLC system is illustrated in Fig. 2, where a single room is assembled with multiple LED units for lightning, which also communicates data with multiple users concurrently [10].Visible Light Communication brings a conceivable affability to way of approach for 5G wireless networks. It is an energy efficient system which uses ultra wide bandwidth there by increasing the data transfer rate of communication. It helps in point-to-point LOS communications but researches been executed for NLOS (Non Line-Of-Sight) using the scattering concept and concentrate the scattered signal by the antenna and travelling towards the receiver.

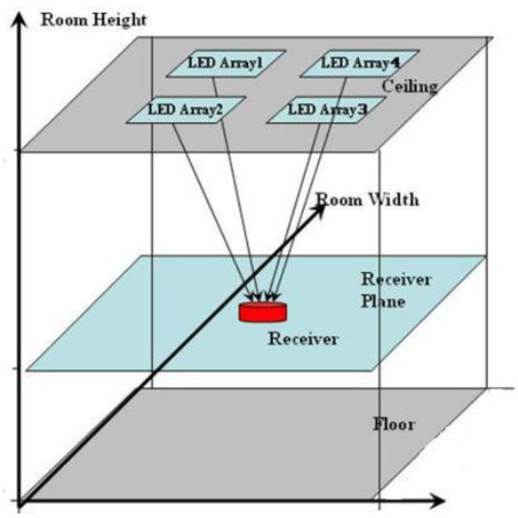

Figure 2. Massive MIMO VLC System [12]

VLC systems have high SNR and apparently sheltered network. In on-going technology higher data rate communication is highly challenging. In pursuance of communicating in this unlicensed band with increased channel capacity, massive MIMO is used with huge cluster of antennas at base trans-receivers. In this technology we use orthogonal frequency division multiplexing (OFDM) with VLC to reduce multi-user interference (MUI) and for better bit error rate (BER).

V. LITERATURE SURVEY

Qian Gao, Zhengyuan Xu **[1]** had suggested a joint constellation strategy system namely DCI-JCFM taking benefit of the wavelength, frequency, and adaptive bias varieties at the same time inside visible light communication systems. Through relating the DCI-JCFM structure, waveform symbols with a much greater MED can be attained than those from a decoupled structure with or without channel cross-talks. View works had contained a comprehensive comparison between three systems: one applying dynamic collection, one with long-term PAPR, and one with immediate PAPR control correspondingly; assessment of power efficiency of the DCI-JCFM and the general DCO/ACO OFDM systems for multi-carrier multi-Color VLC schemes; and progressive pre-coder strategy to exchange the SVD-based pre and post-equalizers were operated in this paper.

Dima Bykhovsky and Shlomi Arnon [2] recommended MA-DMT system that can considerably increases the communication throughput of a VLC communication scheme in a single room, assumed the same communication power, contingent on the scheme formation. The development is more perceptible as the sum of receivers at altered room positions increases. It is significant to note that any DMT accomplished configuration can be used for MA optimization, subsequently the goal of MA-DMT is to algorithmically improve an existing DMT-capable formation with MA ability.

Qi Wang and Zhao cheng Wang [3] deliberated MU-MIMO-OFDM for indoor VLC schemes. The distance between the multiple transmitter receiver links were calculated which were resulting phase differences in the frequency domain. Different from state-of-the-art structures, zero compelling and MMSE precoding methods were achieved on the composite channel matrices for each subcarrier, which were less interconnected when the phase differences were considered. Two DC bias and scaling systems were proposed for different sceneries. Simulation results displayed that the subcarrier with higher index attains more spectral efficiency, especially when the users were extremely associated. MMSE overtakes zero forcing when the visual power was low and more presentation gain was accomplished when the users were closer.

Rui Jiang, Zhaocheng Wang [4] presented a multi-chip LED based MU-MISO VLC scheme, where multi-chip LED works monochromatic lights to communicate independent parallel data streams. As LED is used as illumination source and receiver instantaneously, four restraints are measured in this paper i.e. luminance, chromaticity, amplitude and BER. Under these restraints, an electrical and optical power allocation system is calculated to maximize the multi-user sum-rate. When the chromaticity controlled area is defined within a Mac Adam ellipse, the communicated problem is non-convex. With polar organize alteration and loose variables, the unique problem can be reformulated as a conic optimization problem whereby optimal solutions could be found. Model result displays that higher visual power capacity do not progress the data rate due to the consistent lower electrical power. It is also determined that over a wide luminous flux range (from 70 lm to 150 lm), the variation of the multi-user sum-rate under these limitations is very small.

Z. Yu, R. J. Baxley, and G. T. Zhou [5] recommended a precoding and biasing model for multiuser multi-input single-output (MU-MISO) VLC systems with the constraint of predictable luminance level. Recently, certain works have been done in deliberation of chromaticity constraint. The communicating rate is exploited in a point-to-point VLC system under the chromaticity control as well as transmission power constraint.

Chen Hongda and a Gao Zongyu [6] analysed some of the important new developments in VLC. They validate their modern research of the 500 Mb/s real-time OOK VLC scheme grounded on phosphor-based LED at the space of 1.6 m. They also present a bi-directional 100 Mb/s VLAN or Li-Fi scheme based on OOK inflection without a blue filter. The broadcast distance is 1.9 m with an illumination near of 800 lux; both the uplink and downlink is a white light station without exploiting a blue filter. The VLC schemes they proposed are noble explanations for high-speed VLC application schemes with low-cost and low-complexity. As VLC expertise progresses, they trust that VLC technology will be developed in the prospect of wireless communication schemes. VLC knowledge displays a bright future due to its characteristic advantages and the always increasing acceptance of white LED’s.

The revolution in lighting by the acceptance of LED strategies has generated an opportunity to activity the visible range for wireless infrastructures. Energy-efficient dimming, or color power control, leftovers a key test in attaining the need for well-organized and high-speed data inflection while secondary human illumination necessities. In this object J. Gancarz, H. Elgala [7] has revised the tests to attaining this ‘dual use, with an eye in the direction of classifying approaches that will lead to effective profitable acceptance in the lighting manufacturing. With the remaining determinations on worldwide energy use decreases and prompts adoption of mobile strategies. It seems that both, the mandate for contained wireless volume and energy-efficient illumination will continue persistent.

Liqun Li, Pan Hu [8] showed the strategy, application and appraisal of Epsilon, a visible light based localization scheme that performs on LED lamps. The organization has no dependence on set-up access and can be used directly after appropriate organizing and standardizing the LED bulbs. They have recognized and overcome key mechanical challenges for precise distance dimension using light, dependable position beaconing, and robust localization where the quantity of light sources can be unnecessary or inadequate. Their assessment in distinctive office environment established the efficiency of the scheme, which achieves sub-meter correctness. The work approves the probability of visual light for high accurateness indoor localization.

The accurate indoor locating has been called a “grand challenge” for calculating. Ye-Sheng Kuo, Pat Pannuto [9] take a small step toward addressing the experiment through viewing how original smart phones and slightly-modified LED illumination can sustenance precise indoor finding with higher accuracy than previous work. Their results display that it is probable to accomplish decimetre location error and 3 location errors by basically walking under an above LED light while using one's Smartphone. When used in distinctive retail locations with above lighting, this permits a user to be precisely contained every few meters, possibly with dead calculation satisfying in the gaps. Though present method has numerous drawbacks, none perform to be important. Having established the feasibility of the basic technique, upcoming work could travel the progressing shutter channel, recover channel capability, increase image processing presentation, and reduce standing error.

VI. PRESENT CHALLENGES OF VLC SYSTEM

Indoor VLC can be categorized into two categories i.e. Line of Sight (LOS) and Non Line of Sight (NLOS) [5]. Both types of VLC suffer from interference from ambient light sources, Inter Symbol Interference (ISI) from multipath dispersion and synchronization at the receiver. SNR of an optical wireless link is proportional to the square of average receiver optical signal power which means that transmission at higher power level is required as compared to electrical channel.

VII. IMPORTANCE

In its normal setup, VLC uses light that is intensity modulated for transmitting data.

1. LEDs are economical because of their efficiency as compared to other lighting sources, LEDs appear in many applications in lighting and display including traffic lights, flat panel displays, and instrumentation. In this sense, any LED based applications fall into the category of "green" technologies.
2. In terms of communications, LEDs are "fast" so that they can be intensity modulated very quickly (order of MHz), much faster than conventional lighting. At a receiver, the signals are sensed as intensities via "Direct Detection" using a photo detector that can be very inexpensive. Modulation formats in VLC varies extensively, and their optimization under different application scenarios is an active area of research. This work is unique because unlike RF modulation, optical signals are unipolar due to the nature of the intensity-modulated signal.
3. VLC has some interesting characteristics that are unique to optical communication systems. Light-based systems are confined by opaque walls and thus improved security and enhanced reuse of the channel in densely packed cells is obtained (e.g. adjacent rooms in an office). However, this does not mean that VLC is a strict line-of-sight technology; it has been shown that VLC also works when the light in a room is severely obstructed.
4. VLC does not interfere with RF; VLC can be added to an existing network without introducing new interference. Moreover, in cases of when RF signals are perceived as a hazard, for example, in hospitals, airplanes, mines, or as RF "pollution," VLC can be applied as a practical alternative. Due to its directionality and containment properties, VLC is also a good candidate for near field communications (NFC).
5. VLC is also a contender for providing "indoor" GPS. Light based positioning and localization is being explored by a variety of researchers as potentially more accurate and more easily deployed than RF or acoustic techniques.

VIII. DISCUSSION

VLC is still in its infancy. In this section, we briefly discuss potential issues and open questions in real usage.

A. *Applicability:*

To leverage the visible light, the device needs to be exposed to the light. This may limit its applicability, e.g., it is not possible when the phone is in pocket. Thus, Epsilon targets at localization with explicit needs (user awareness), rather than passive tracking scenarios [8].

The light has to stay on, which might be an issue for the sake of energy efficiency. Favourably, for most indoor environments (e.g., offices or shopping malls) where localization is desired, lights (at least a small portion) are mostly, if not always on.

B. *Device Diversity:*

Different LEDs and light sensors may have different emission power and receiving sensitivity, which would directly affect the distance measurement. Fortunately, as solid-state devices, the intrinsic characteristics of LEDs and light sensors are highly stable over time [13]. Therefore, for each LED and each light sensor, one time calibration is enough. Considering their long lifetime (say 5 years), this cost is still reasonably small. For practical use, we may reduce calibration efforts, for example by automatically calculating the LED parameters as done for Wi-Fi in [8].

C. *Shadow and Reflection:*

Similar to the multipath issue in Wi-Fi-based localization, using visible light for localization may suffer from shadowing and reflection of the light. For instance, when holding a phone in front of body, body reflection, especially in white shirt, will bring noise to localization. Sometimes, his/her body is a big obstacle, blocking the phone from lighting.

For these issues, Epsilon counts on the user's involvement. We admit that involving the user's help is burdensome. However, on the other side, we argue this is also an opportunity. The light is visible which naturally offers a feedback to the user and makes the case to easily obtain the user's help to improve the localization accuracy, unlike other invisible RF signals. [8]

D. Modelling vs. Fingerprinting:

The model-based approach in Epsilon achieves good results only when the LED and the light sensor are within each other's FoV. This limits the application scope and we may have to fall back to coverage-based localization. Fingerprinting method will not have such constraints. However, a fingerprint is highly affected by a variety of factors such as the device attitude, body blocking of light, and etc. In addition, similar to any fingerprinting-based system, it requires to construct a database, which is a challenging task. [8]

IX. CONCLUSION

A big limitation of existing visible light communication (VLC) setup is the limited modulation bandwidth of light-emitting diodes used in such setups. By Using adaptive modulation for expanding the spectral efficiency for wireless communications has been well deliberated. For VLC with numerous physical layer systems, though, how adaptive modulation works is not well understood yet. The goal of this paper is to provide an in-depth overview of the achievable spectral efficiency of adaptive modulation for three different systems for high speed VLC: orthogonal frequency division multiplexing (OFDM), multiple inputs and multiple output OFDM (MIMO-OFDM), and Multi-user MIMO (MU-MIMO).

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