International Journal of Industrial Electronics and Control.
ISSN 0974-2220 Volume 7, Number 1 (2015), pp. 13-21

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A Survey Of Technology Trends For The Futuristic Visible Light Communication (VLC)

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ABSTRACT

VLC is an energy efficient and green technology. VLC technique uses frequencies other than radio, these are unrestricted and license free. VLC refers to short range optical wireless communication using visible light spectrum from 380-780 nm. VLC has a dual function that it is used for illumination and data communication purpose. However, many challenges like dimming, LED nonlinearity, fading, shadowing, flicker control etc. are faced by visible light communication. In this paper, the challenges are pertaining to PHY layer that includes signaling techniques illumination control, indoor channel, on user, and on LED have been discussed. The literature related to mitigation techniques to overcome these challenges has also been surveyed to provide the future direction for an energy efficient futuristic visible light communication

Keywords: Visible light communication, LED, Modulation techniques, Cognitive MAC

I. INTRODUCTION:

Visible light communication using a light emitting diode (LED) is used for two purposes that is for wireless communications and lighting. VLC is the technology it utilizes the visible light source as transmitter, the photodiode as a signal receiving component. In VLC, Change in amplitude is so small for a naked human eye that it is un-noticeable. As LED illumination device is existed everywhere in the environment

Visible light is preferred over infrared (IR) communications because it offer a compact, dual-use, energy saving solution. In section II, Various Signaling techniques are presented. In section III, various challenges are presented.

II. SIGNALING SCHEMES OF VLC:

A. Single – Carrier Pulsed modulation

High average power efficiency can be achieved by employing single-carrier (SC) pulsed modulation techniques in which the time-dependent characteristics of the optical pulse is used to convey information.

On-off keying (OOK): In this method, data is conveyed by switching the LED on and off. OOK is one the oldest formats and is the simplest in terms of hardware implementation and integration. it also exhibits a good compromise between complexity and performance.

Colourshift keying (CSK): In CSK, the different colours of light are combined of RGB type LEDs, the data at the output can be carried by the colour itself. The demerit of CSK is that both transmitter and receiver are having the complexity in the transmitter and receiver.

Pulse width modulation (PWM): In this method, information is encoded into the duration of pulses. But in PWM have longer pulses for transmission than OOK, so it has no great advantage to use this scheme.

OOK-NRZ (OOK-Non Return to Zero): OOK-NRZ is a simple and low-cost approach for VLC system. The bandwidth achieved is 50 MHz (25 times wider than un equalized LED bandwidth). The advantage of this scheme is that it is very simple to implement. In this data transmitted at rate 100Mbps and with low BER. This is used in data broadcasting.

Pulse position based modulation: Pulse-position based modulation techniques are traditionally the most popular option for modulating LEDs. They are not affected by the LED nonlinearity, but suffer from the slow rise-time.

PPM (pulse-position modulation): In PPM, the symbol duration is divided into Q equal time-slots and a single pulse is transmitted in time-slot. Hence, the symbols are identified by the position of the pulse. But its spectral efficiency is less.

MPPM: (Multipulse PPM): has been proposed to increase the spectral-efficiency of PPM by transmitting multiple pulses in each symbol-time. This modulation technique has the potential to achieve spectral efficiencies close to one. The difficulty in MPPM is that good bit-to-symbol mapping a random mapping is usually implemented to avoid complexity.

EPPM: (Expurgated PPM): EPPM can be used in VLC requiring a dimming feature by changing the length of the symbols (Q) and the number of pulses per symbol (K), setting the PAPR to any desired value while maintaining the large minimum distance property. Yet EPPM still suffers from the same low spectral efficiency as PPM. An additional advantage of EPPM over PPM is its potential to mitigate flicker since it transmits multiple pulses over a symbol period instead of one. By increasing the number of time-slots in each symbol, their duration becomes smaller.

OOK	CSK	PWM	PPM
Data is conveyed by switching the LED.	By combining the different colors of light, The output data can be carried by the color itself.	Information Is encoded In to the duration of pulses.	Data is encoded using the position of pulse with in A frame.
Simple to implement.	Complex implementation	Simple implementation.	More complex.
No control In illumination And throughput.	No efficient than OOK.	They have longer pulses than OOK.	Duration of frame must be longer than for single OOK bit.

Fig 1 Comparison of single carrier pulse modulation

	Support Dimming	Susceptibility to fading & shadowing	Susceptibility to ISI
PPM	Yes	Low	High
MPPM	Yes	Low	Medium
EPPM	Yes	Low	High
MEPPM	Yes	medium	Low

Fig 2 Comparison of PPM modulation

Multilevel EPPM: The above modulation schemes all have spectral-efficiency less than unity because they are two-level. As mentioned earlier, increasing the spectral efficiency requires exploiting the one dimension available to IM systems, the intensity. MEPPM are constructed as linear combinations of N EPPM symbols (or their complements). Similar to EPPM, multilevel EPPM (MEPPM) is able to support a wide range of PAPRs, and can transmit high speed data even in highly dimmed scenario. But MEPPM has presence of multiple light levels per symbol are present. By increasing the number of levels and decreasing the duration of time slots the illumination variations become imperceptible to the eye.

B. Multiple – Subcarrier Modulation

OFDM (Orthogonal frequency division multiplex): This is widely used in the digital TV and radio and also for Wi-Fi. OFDM uses a set of sub-carriers each at different but harmonically related frequencies. OFDM has good spectral efficiency. LED nonlinearity is another challenge in OFDM.

ACO-OFDM (asymmetrically clipped optical OFDM): it is more efficient in terms of optical power than conventional optical modulation techniques then PPM and OOK. ACO-OFDM has many practical advantages including its tolerance to multipath distortion. It has also improved demodulation scheme for better power efficiency in an AWGN channel.

DCO-OFDM (DC biased optical OFDM): As the LEDs in VLC can only convey unipolar signals in light intensity. The issue can be solved by introducing a DC-bias, which increases the power requirement of the system. But a ACO-OFDM is a power efficient alternative than DCO-OFDM.

ADO-OFDM (Asymmetrically clipped DC biased optical OFDM) ADO-OFDM is a combination of two techniques which are which ACO-OFDM and DCO-OFDM. ACO-OFDM is on odd subcarriers. DCO-OFDMA are on the even subcarriers. The even Subcarriers are demodulated using a form of interference cancellation. ADO-OFDM is more optically power efficient than conventional ACO-OFDM and DCO-OFDM for some bit rate/ normalized bandwidth. and also that by varying the proportion of optical power on the ACO-OFDM component, the DC bias level of DCO-OFDM and constellations sent on the odd and even subcarriers, the optical power efficiency of ADO-OFDM can be changed.

C. VIRTUAL COGNITIVE MAC

Cognitive Radio technique exploits underutilized licensed spectrums to improve its bandwidth availability. It is an intelligent radio and network technology that can automatically detect available channels in wireless spectrum and change transmission parameters enabling more communication to run concurrently and also improve radio operating behavior. Through this proposed system, we can reduce the blocking probability and improve the system performance.

D. MULTIPLE ACCESS TECHNIQUES

Multiple access techniques are performed in the physical layer to allow several users to get access simultaneously to the available network services. In a single cell topology per user, each user has a dedicated AP and all resources are available. This topology is practical, for example, when the existing reading lamps on top of each seat in airplanes, trains, and buses are used in VLC.

Electrical Multiplexing Techniques

TDMA (Time division multiple access): it is a synchronous technique where users cannot communicate independently and simultaneously. TDMA provides high power efficiency, which is the most important metric for OW systems while reducing the transmission capacity per user

FDMA (Frequency division multiple access): allows multiple users to transmit simultaneously using different frequencies within a single cell per room topology. In general, power efficiency is the main drawback of FDMA and worsens as the number of subcarriers increases.

CDMA (Code division multiple access): techniques rely on direct sequence spreading where users can access the same channel using optical orthogonal codes (OOCs). This means flexibility of adding users and asynchronous access capability. Users are able to transmit at overlapping times and wavelengths. Therefore, it is also possible to implement hybrid optical systems such as WDMA/CDMA or TDMA/CDMA.

Optical Multiplexing Techniques

WDMA (Wavelength division multiple access): In WDMA a number of users transmit simultaneously using different wavelengths. Each user has an independent wavelength together with an optical tunable reception filter. It is quiet expensive and has simple structure hence, not desirable.

SDMA (**space division multiple access):** it reduces co-channel interference (CCI) between channels in the same cell. The potential disadvantage of this technique is increased complexity.

DMT (**DISCRETEMULTITONEMODULATION):** DMT is split the available bandwidth into a large number of sub channels. DMT is able to allocate data so that the throughput of every single sub channel is maximized. There is an optimized use of bandwidth by turning off the sub channel if that channel is not carry any data. DMT uses the fast FFT algorithm for modulation and demodulation. In this frequency spectrum is divided in to multiple channels. A 513 Mbps transmission is achieved by this modulation scheme.

E. OPTICAL MIMO

MIMO – OFDM (Multiple input multiple output): MIMO-OFDM is used for high transmission rates that for 1Gbps. In This technique system consists of multiple-inputs and multiple-outputs link each of 4. and each transmitting signals at 250 Mb/s using orthogonal frequency division multiplexing modulation. A nine-channel diversity receiver is used.

MIMO USING SPATIAL MODULATION (SM) it increases the data transmission rate by using multiple physically-separated transmitters and multiple physically-separated receivers. SM can either be used as a stand-alone modulation or be considered as a form of multiple-input multiple-output (MIMO) that can be combined with other modulation schemes to increase the bit-rate. SM is attractive as it increases the spectral efficiency without requiring additional bandwidth. SM is also helpful in supporting simultaneous access in multiuser VLC network. But there is greater effect of shadowing and multipath interference. In a highly dispersive indoor channel, the signals received via different paths can cause severe interference between transmissions at the receivers. VLC transceivers, the size of the devices needs to be fairly small, and a SM receiver requiring multiple detectors may not be practical.

III. CHALLENGES

A. ILLUMINATION CONTROL:

DIMMING: One challenge in VLC is how to communicate when lights are “off”. However, during daytime, people tend to switch off the room lights. That technique may be used which reduce the LED brightness to a level low enough so that people will accept that the light is “off”. To support dimming, a practical VLC system should be able to operate at various optical peak to average power ratios (PAPR). Continuous current reduction (CCR) and pulse-width modulation (PWM) are two techniques that have been proposed for dimming in indoor VLC systems. But these techniques require the large bandwidths and further work is required to develop potential

techniques and compare alternatives.

FLICKER: Flicker is a fluctuation of the illumination that can be perceived by human eyes and must be avoided. Flicker can be harmful to the eye and affect eyesight. In VLC systems, since the lighting is integrated with the communication system, an inappropriate modulation scheme can cause variations in the average transmitted power, and impose fluctuations on the brightness of the LEDs. Even though the IEEE802. 15. 7 standard has devised some techniques to alleviate flicker in VLC, suitable modulation schemes are still required to have a constant average power over several symbols.

B. White LEDs

LEDs are the most likely optical sources for a dual-use lighting and communication application, and thus form the central component of the VLC system transmitter. They are preferred over other lighting sources, because it can respond to faster modulations and support higher data-rates. LEDs are preferred over laser diodes (LD) due to safety regulations, as LDs in the visible range can be harmful to the eyes. There are two type of LEDs. In the first technique, an LED emitting blue light is embedded in a layer of yellow phosphor that converts some of the light to longer wavelengths, yellow and red; the result is seen as white light to the human eye. The another type is a trichromatic LED, which integrates green, blue and red LEDS in a single device to emit white light.

LED MODULATION BANDWIDTH: For VLC systems, the performance is limited by the modulation bandwidth of the blue-chip LEDs. It is shown by Grubor et al. in 2007 that the long response time of the phosphor limits the available modulation bandwidth to several megahertz. By using a simple color filter to detect only the blue peak of the emission spectrum, the resulting modulation bandwidth is approximately an order of magnitude larger. The maximum reported bandwidth achieved through this approach is around 20MHz. A transmitter equalization approach is an alternative solution proposed by Le-Minh et al. in 2008 where the frequency response of each LED in an array is set with a simple resonant circuit (i. e., each LED has a different frequency response). An experimental demonstration using multiple LEDs that is 16 LEDs (2. 5 MHz unequalized bandwidth)and a total of 25 MHz total bandwidth. Multiple resonant equalization of a single LED is presented again by Le-Minh et al. in 2008 and a 45 MHz net bandwidth was reported.

LED NON LINEARITY: As LED is a major source of nonlinearity in optical system. In OFDM modulating signal this nonlinear behavior is important. For example, as in DCO-OFDM due to non linear behavior, clipping of the lower peaks, and clipping of the upper peaks occurs. So control this effect an optimum DC operating point and optimal OFDM signal power to modulate the LED intensity is required, which simply means that to operate the LED in a quasi-linear segment of its characteristic around the chosen DC operating point. So to select an LED with high AC/pulsed current level enhances the performance. A pre distorter that uses the LED inverse characteristics as nonlinear distortion compensator is proposed by Elgala et al. in 2009.

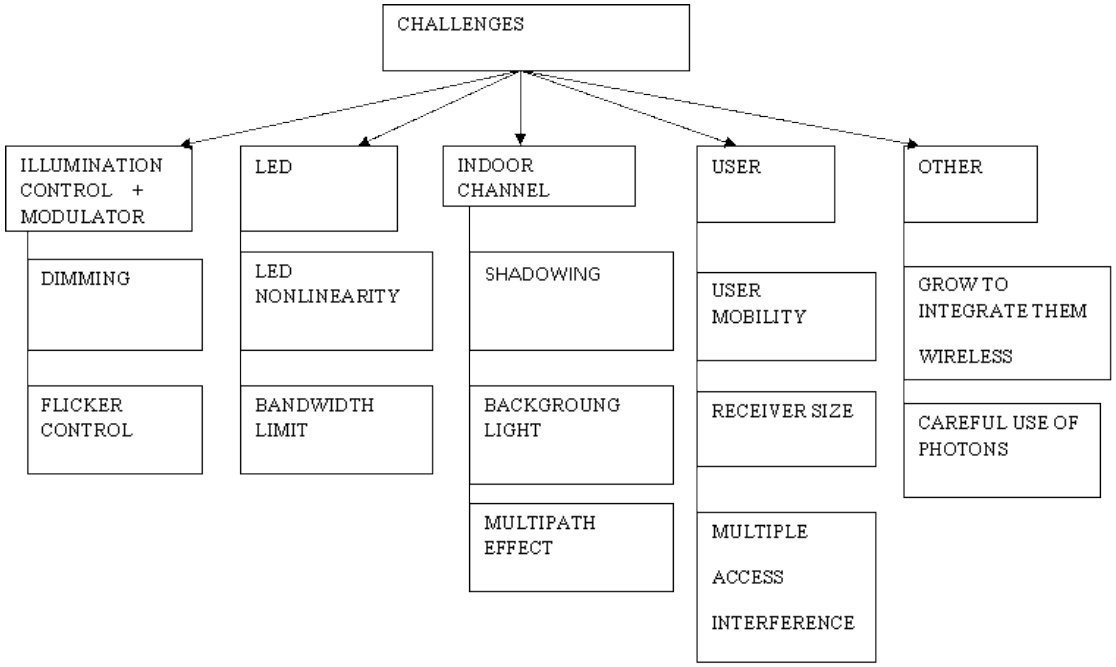

Fig 3 Challenges for a VLC system

C. Indoor VLC Channel:

In VLC, The channel impulse response is composed of two parts: a line-of-sight (LOS) part in which the response received from the direct path to the closest light source, and a non-line-of-sight (NLOS) part that is the response received after reflection from walls and other objects. This broad response causes an inter symbol interference (ISI) effect on a high-speed transmitted data stream and degrades the quality of the received signal. Hence, that modulation scheme is used which are have less ISI effect. Another important channel effect in VLC is shadowing, which is a blocking of the direct path from the lighting source to the photo detector. In VLC systems, the LOS part has a high blocking probability because visible light radiation does not penetrate opaque objects. In the indoor environment or by making the channel-varying shadowing effect can be caused.

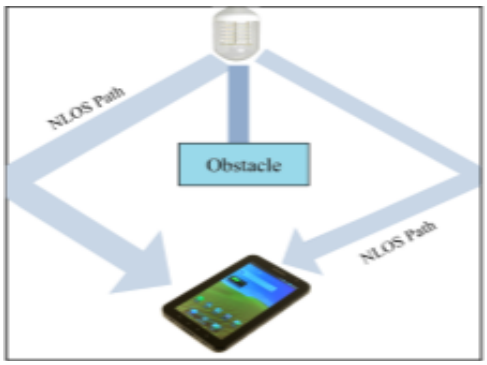

Fig 4 Shadowing effect in VLC [1]

LOS and NLOS path causes the fading. The last problem in VLC, is strong background light. Illumination levels are strong enough that in the absence of background light the SNR is quite high. As the background light increases the shot noise of the system.

V. FUTURE TRENDS OF VLC

As VLC uses frequencies other than radio, they are unrestricted and license free**.** It is accepted that VLC technology is used in future as In, VLC-based indoor positioning system will be used. and VLCs can be used for providing security. and alsoOrganic LEDs (OLED) will be used as optical transceivers to build up VLC communication links up to 10 Mbps.

VI. CONCLUSION

A Survey on technology trends has been presented. As LED is used for illumination and data transfer communication. For future short range applications, VLC present a viable and promising supplemental technology to radio and infrared wireless communication. A high transmission data rate can be established of range Gbps in VLC. Array of LEDs and lamps are used in future for transmission of video. There are various challenges in VLC but this technique is a promising technique in the future.

REFERENCES

[1] Mohammad noshad and maitebrandt –pearce, "Can Visible Light communication provide Gb/s service?, '' arXiv: 1308. 3217v1 [cs. IT] 14 Aug 2013.

[2] Jacqueline j. george, Mohammad haydermustafa, Nada mahjouboman, nuhahashimahmed, Da'admohammedHamed, "A Survey on visible light communication, '' International Journal Of Engineering And Computer Science ISSN: 2319-7242 Volume 3 Issue 2, February 2014.

[3] Nam –tuan Le and Yeong Min Jang, "Virtual Cognitive MAC for Visible Light Communication System, " International Journal of Smart Home Vol. 6, No. 2, April, 2012.

[4] Ahmad helmiazhar, Tuan-anhtran and Dominic o'brien, "A Gigabit/s Indoor Wireless Transmission Using MIMO-OFDM Visible Light Communication, " IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 25, NO. 2, JANUARY 15, 2013.

[5] Hanyelgala, Raedmesleh, Harald Haas, " Indoor Optical Wireless Communication: Potential and State-of – the-Art, " IEEE Communications Magazine • September 2011.

[6] HanyElgala, RaedMesleh and Harald Haas, " Novel Unipolar Orthogonal Division Multiplexing (U-OFDM) for Optical Wireless, : " 2012 IEEE

[7] HanyElgala, RaedMesleh and Harald Haas, " Indoor Broadcasting via White LEDs and OFDM, " 2009 IEEE.

[8] Hoa Le Minh, Dominic O'Brien, Grahame Faulkner, LubinZeng, Kyungwoo Lee, Daekwang Jung, YunJe Oh, and Eun Tae Won, " 100-Mb/s NRZ Visible Light Communication Using a Post equalized White LED, " IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 21, NO. 15, AUGUST 1, 2009.

[9] Xia Li, R. Mardling and J. Armstrong, "Channel Capacity of IM/DD Optical Communication Systems and of ACO-OFDM, " 2007 IEEE.

[10] Toshihiko Komineand Masao Nakagawa, "Fundamental Analysis for Visible-Light Communication System using LED Lights, " 2004 IEEE

[11] Mostafa Z. Afgani, Harald Haas, HanyElgala, and DietmarKnipp, ". Visible Light Communication Using OFDM, " 2006 IEEE.

[12] Dominic C. O'Brien, LubinZeng, Hoa Le-Minh, Grahame Faulkner, Joachim W. Walewski, Sebastian Randel, "Visible Light Communications: challenges and possibilities, " 2008 IEEE.

[13] Sridhar Rajagopal, Samsung Electronics Richard D. Roberts, Intel Sang-Kyu Lim, ETRI, "IEEE 802. 15. 7 Visible Light Communication: Modulation Schemes and Dimming Support, " 2012 IEEE.

[14] RaedMesleh, HanyElgala, and Harald Haas, "On the Performance of Different OFDM Based Optical Wireless Communication Systems, " 2011 Optical Society of America.

[15] Toshihiko Kominaand Masao Nakagawa, "Fundamental Analysis for Visible-Light Communication System using LED Lights, " 2004 IEEE.