

Visible Light Communication for Wireless Data Transmission

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Abstract: Visible Light Communication (VLC) technology, one of the advanced optical wireless communication technologies, in which light in the visible region (375nm-780nm) is used as a medium for data transmission is more secure and achieves high data rates as compared to conventional wireless technologies like Wi-Fi, Bluetooth, Wi-max etc., which use radio waves for communication. While using wireless internet, when more than one device is tapped into the network, then bandwidth got frustrated at the slow speeds. To overcome the shortage of bandwidth we can use light to transfer the data which can be known as “DATA THROUGH ILLUMINATION”. The idea behind is that, infra-red remote is slightly modified i.e., LED light bulb that varies in intensity which cannot be followed by the naked eye. It is possible to encode the data in the light by varying the light at which the LEDs flicker on and off to give different strings of 1s and 0s. While using mixtures of red, green and blue LEDs to alter the light frequency encoding a different data channel. If you can't see the light then you cannot access the data so the security would be snapped.

Keywords: Visible light communication (VLC), LED, Wi-Fi.

I. INTRODUCTION

Visible Light Communication (VLC) based on white Light Emitting Diodes (LEDs) is promising for realizing ubiquitous wireless networks, since LEDs would be used for both illumination [1] and wireless transmission simultaneously. There are two common approaches to produce white light illumination by using LEDs. One involves blue colored LEDs with wide-band phosphors that produce the form white light. The alternative option is by means of red, green and blue (RGB) LEDs. The RGB solution is more preferable than phosphorous-based white LED to improve the data rate, since in the latter case, the slow response of the phosphors limit the modulation bandwidth whereas the power efficiency is reduced if combined with blue filter in order to reject the phosphorescent components [4]. Moreover the RGB LEDs offer the possibility for wavelength division multiplexing (WDM) which further increases overall transmission capacity. However, in order to implement high speed wireless connectivity, the limited modulation bandwidth of the commercial LEDs (10-20 MHz) requires spectrally efficient modulation techniques, e.g. Orthogonal Frequency Division Multiplexing (OFDM) or Discrete Multi-Tone (DMT) [5]. Most recently, we demonstrated highest capacity of 2.1 Gbit/s by using WDM transmission and DMT modulation of commercial RGB LED [3]. Another gigabit experiment was reported by employing similar approach achieving data rate of 1.25 Gbit/s [6]. In this paper we present a significant increase in data rate for both single channel and WDM VLC links. The improvements in capacity have been achieved mainly by optimizing the DMT implementation and using a receiver

with appropriate bandwidth. In a this experiment, we used the RGB LED as a single channel source and we achieved 1.5 Gbit/s capacity. We used the RGB LED as a WDM source, i.e. each color carried a different signal, achieving 3.4 Gbit/s aggregate capacity.

II. EXISTING SYSTEM

VLC is a data communication medium, which uses visible light between 400 THz (780 nm) and 800 THz (375 nm) as optical carrier for data transmission and illumination. It uses fast pulses of light to transmit information wirelessly. The main components of this communication system are 1) a high brightness white LED, Which acts as a communication source and 2) a silicon photodiode which shows good response to visible wavelength region serving as the receiving element.

LED can be switched on and off to generate digital strings of 1s and 0s. Data can be encoded in the light to generate a new data stream by varying the flickering rate of the LED. To be clearer, by modulating the LED light with the data signal, the LED illumination can be used as a communication source. As the flickering rate is so fast, the LED output appears constant to the human eye. A data rate of greater than 100 Mbps is possible by using high speed LEDs with appropriate multiplexing techniques.

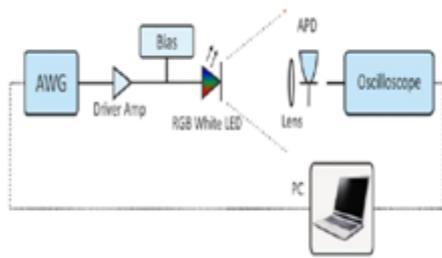


Fig. 1 Transmission of data using white LED

VLC data rate can be increased by parallel data transmission using LED arrays where each LED transmits a different data stream. There are reasons to prefer LED as the light source in VLC while a lot of other illumination devices like fluorescent lamp, incandescent bulb etc. are available.

III. PROPOSED SYSTEM

The RGB LED (Tx) was a low cost commercially available component generating a luminous flux of 6 lm at driving currents of 50 mA (with 120° full emission at half maximum intensity). Its three LED chips had the peak wavelengths of 620 nm (red), 520 nm (green) and 470 nm (blue). In the single channel experiment, the three LED chips were connected in series and modulated together by a single DMT signal consisting of $N = 512$ subcarriers within a bandwidth B of 280 MHz ($B/N = 0.546$ MHz carrier spacing). The bandwidth was chosen to fully exploit the available bandwidth and slow frequency roll off of the LED in order to increase the throughput.

In DMT modulation the single carrier signal is decomposed into a multiple subcarriers. Therefore, the finer the decomposition of the single carrier into N subcarriers, the better the DMT system can adapt to the frequency-dependent response of the channel. After an experimental analysis, presented in this work, we found that a number of 512 subcarriers was a good compromise between capacity and complexity. We preliminary estimated the signal-to-noise ratio (SNR) on each subcarrier applying BPSK modulation and evaluating the SNR from the Error Vector Magnitude (EVM) of the received constellations [8]. Bit and power loading [9] algorithm was then applied on $N-1$ subcarriers to adapt the individual carrier loading to the channel response.

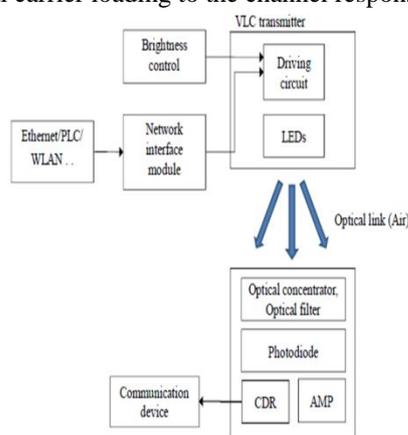


Fig. 2 Block diagram for VLC

Thus we maximized the total data rate having a homogeneous error rate on the subcarriers. The software automatically leaves un-modulated the subcarriers with $SNR < 6.2$ dB, which is the theoretical limit value for BPSK modulation (minimum bit loading).

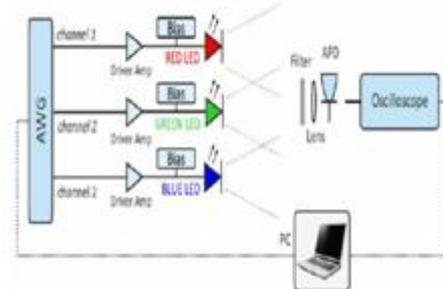


Fig. 3 Transmission of data using RGB LED's

The DMT signal also included a training sequence for synchronization and further data equalization. In our experiment, the training sequence was made of 20 DMT symbols, which was enough to average out the Gaussian noise. A cyclic prefix was added to reduce the inter-symbol interference. An oversampling factor of 16 was used to smooth the signal and overcome the arbitrary waveform generator (AWG, Agilent M8190a) step-like transitions. The total transmission length of the sequence was 1250 DMT symbols.

The output of the AWG was amplified by means of a power amplifier (Minicircuits, 25 dB gain, 29 dB minimum output power at 1-dB compression, 130 MHz 3-dB bandwidth), superimposed on a dc bias current (75 mA) and used to drive the LED. At the receiver side (Rx), a lens (Thorlabs, 25 mm diameter) was used to collect the light onto an ac-coupled analogue avalanche photodiode (Hamamatsu APD, 0.42 A/W responsivity at 620 nm and gain = 1) module having 3.14 mm² active area and an integrated transimpedance amplifier (280 MHz 3 dB bandwidth). The received signal was recorded by a real-time oscilloscope. The signal processing (SNR evaluation, DMT sequence generation, BER analysis), was performed off-line by a home-made software.

In the WDM experiment, the three LEDs were separately biased and modulated individually. The DMT signal consisted of $N = 512$ subcarriers within a bandwidth of 250 MHz (0.488 MHz carrier spacing). Two different DMT signals were generated and loaded into AWG. The first one was used to drive the LED under analysis, while the second and its inverted copy drove the others LEDs. In order to test each color separately a band-pass optical filter which select one of them was added at the Rx (peak transmission wavelengths: 629 nm, 530 nm, 452 nm; 3-dB bandwidth of 56 nm, 43 nm, 45 nm respectively).

A. Modulation Technique

SIM-OFDM is a modification of the classical OFDM modulation scheme. In OFDM a number of different frequency carriers are modulated with a signal from a scheme such as Quadrature Amplitude Modulation (QAM). The novel approach of SIM-OFDM tries to

exploit an additional “new” dimension in the OFDM frame coming from the state of each subcarrier – active or inactive. This additional dimension is employed to transmit information in an On-Off Keying (OOK) fashion. The motivation behind this concept lies in an attempt to optimize power usage, which is crucial in the current climate of “green communication systems” [2]. Each active carrier receives the energy of an M-QAM symbol and the energy of the additional bit encoded in OOK fashion. The individual performances of QAM and OOK are thus improved. Overall, this leads to performance improvement of SIM-OFDM on an energy-per-bit basis.

B. Increasing data rate

Perhaps the simplest way of mitigating the low bandwidth of the transmitter is to block the phosphor component at the receiver by using a blue filter. In [16] it is shown that this can increase the bandwidth substantially, albeit at the penalty of a small reduction in received power due to filter losses.

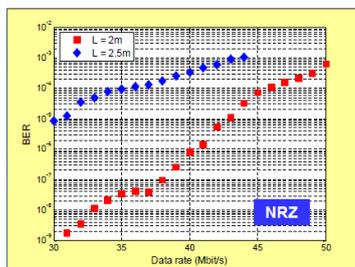


Fig. 4 Performance of BER vs. Data rate

It is also possible to improve the response by transmitter and/or receiver equalization, or the use of bandwidth-efficient modulation schemes that take advantage of the high available signal to noise ratio. In addition, for higher data rates it may be possible to use parallel data transmission from a number of LEDs.

C. Transmitter equalization

Analogue equalization techniques can be used to compensate for the rapid fall-off in response of the white LEDs at high frequencies. It is possible to use an array of LEDs, each driven using a resonant technique with a particular peak output frequency to achieve this. Careful choice of a number of different frequencies allows the overall response to be ‘tuned’ to that desired. In [17] a 16 LED array is modified to have a bandwidth of 25MHz (without blue filtering) offering a data-rate of 40Mb/s for Non-Return to Zero (NRZ) On-Off Keying (OOK). More complex equalization can also be used for single devices, and data rates of 80Mb/s (NRZ OOK) [18] have been demonstrated.

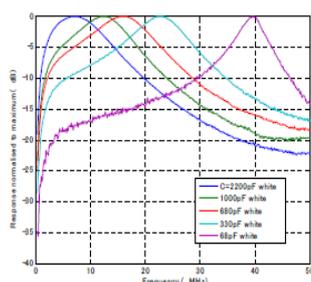


Fig. 5 Improvement of LED Bandwidth

D. Receiver equalization

Transmitter equalization has the disadvantage that the drive circuits for the LED (which often involve currents of several hundred milliamps) need modification, and in a typical coverage area there may be a number of sources, making the modifications potentially costly. In addition some of the signal energy used is not converted into light, thus reducing the energy efficiency of the emitter. Equalisation at the receiver allows complexity to be at the receiver only. A simple first-order analogue equalizer is modeled in [15], and this shows there is substantial improvement in data-rates. More complex approaches are likely to yield higher data rates.

E. Complex modulation

A high-SNR, low-bandwidth channel is typically suited to high bandwidth efficiency multilevel modulation schemes. Work in [16] shows that 100Mbit/s is possible using Discrete Multi-Tone Modulation (DMT). At present there is little work in this area, and further studies are required in order to assess the relative benefits of analogue equalization with relatively simple modulation, or complex modulation and limited channel bandwidth.

F. Parallel communication (Optical MIMO)

In most illumination applications many LEDs are used to provide the necessary lighting intensity. This offers the opportunity of transmitting different data on each device or on different groups of emitters. For this to be successful a detector array is required at the receiver, and this creates a Multi-Input Multi-Output (MIMO) system. Radio-frequency MIMO techniques can be applied to such optical transmission systems to relax the necessary alignment between the array of detectors and array of sources. Work in [19] shows that such a system can allow multi-channel data communication, without the need to align a particular detector with a corresponding source. It can be seen that there are many different methods of increasing data rates, and that a combination of these should allow data rates well in excess of 100Mb/s to be successfully transmitted.

G. Provision of an uplink

VLC using illumination sources is naturally suited to broadcast applications, and providing an uplink to the distributed transmitter structures can be problematic. Several approaches have been investigated. In [20] an infra-red uplink is used to a transmitter co-located with the VLC source, and in [21] a retro-reflecting transceiver is proposed. In this case the retro-reflector returns a proportion of the incident light to the transmitter, and this returned beam is modulated to provide a data path from the terminal to the infrastructure. This is potentially very attractive, although the data-rates that can be achieved using available modulators are low. Co-operation between VLC and RF wireless standards would also allow full connectivity for a terminal [22]. A VLC downlink can be combined with an RF uplink, and this can also reduce the load on shared RF channel, including overall network performance.

IV. FEATURES OF VLC

Li-Fi offers a number of key benefits over Wi-Fi but is inherently a complementary technology.

A. Bandwidth: The visible light spectrum is plentiful (10,000 more than RF spectrum), unlicensed.

B. Data density: Li-Fi can achieve about 1000 times the data density of Wi-Fi because visible light can be well contained in a tight illumination area whereas RF tends to spread out and cause interference.

C. High speed: Very high data rates can be achieved due to low interference, high device bandwidths and high intensity optical output.

D. Planning: Capacity planning is simple since there tends to be illumination infrastructure where people wish to communicate, and good signal strength can literally be seen.

E. Low cost: Requires fewer components than radio technology.

F. Energy: LED illumination is already efficient and the data transmission requires negligible additional power.

G. Environment: RF transmission and propagation in water is extremely difficult but Li-Fi works well in this environment.

H. Safe: Life on earth has evolved through exposure to visible light. There are no known safety or health concerns for this technology.

I. Non-hazardous: The transmission of light avoids the use of radio frequencies which can dangerously interfere with electronic circuitry in certain environments.

J. Control: Data may be directed from one device to another and the user can see where the data is going; there is no need for additional security such as pairing for RF interconnections such as Bluetooth.

V. COMPARISON BETWEEN VLC & Wi-Fi

TABLE 1 VLC Vs Wi-Fi

PARAMETER	VLC	Wi-Fi
Speed	***	***
Range	*	**
Data Density	***	*
Security	***	**
Reliability	**	**
Power available	***	*
Transmit/Receive power	***	**
Device to device connectivity	***	***
Obstacle interference	***	*

*Low ** Medium *** High

VI. APPLICATIONS OF VLC

The dramatic growth in the use of LEDs (Light Emitting Diodes) for lighting provides the opportunity to incorporate VLC technology into a plethora of LED environments.

VLC is particularly suitable for many popular internet “content consumption” applications such as video and audio downloads, live streaming, etc. These applications place heavy demands on the downlink bandwidth, but require minimal uplink capacity. In this way, the majority of the internet traffic is off-loaded from existing RF channels, thus also extending cellular and Wi-Fi capacities. There are many applications for VLC. These include:

A. RF Spectrum Relief: Excess capacity demands of cellular networks can be off-loaded to Li-Fi networks where available. This is especially effective on the downlink where bottlenecks tend to occur. Since we have ten thousand times greater than the RF spectrum the capacity has increased.

B. Smart Lighting: Any private or public lighting including street lamps can be used to provide Li-Fi hotspots and the same communications and sensor infrastructure can be used to monitor and control lighting and data.

C. Mobile Connectivity: Laptops, smart phones, tablets and other mobile devices can interconnect directly using Li-Fi. Short range links give very high data rates and also provides security.

D. Hazardous Environments: Li-Fi provides a safe alternative to electromagnetic interference from radio frequency communications in environments such as mines and petrochemical plants.

E. Hospital & Healthcare: Li-Fi emits no electromagnetic interference and so does not interfere with medical instruments, nor is it interfered with by MRI scanners.

F. Aviation: Li-Fi can be used to reduce weight and cabling and add flexibility to seating layouts in aircraft passenger cabins where LED lights are already deployed. In-flight entertainment (IFE) systems can also be supported and integrated with passengers’ own mobile devices.

G. Underwater Communications: Due to strong signal absorption in water, RF use is impractical. Acoustic waves have extremely low bandwidth and disturb marine life. Li-Fi provides a solution for short-range communications.

H. Vehicles & Transportation: LED headlights and tail-lights are being introduced. Street lamps, signage and traffic signals are also moving to LED. This can be used for vehicle-to-vehicle and vehicle-to-roadside communications. This can be applied for road safety and traffic management.

I. RF Avoidance: Some people claim they are hypersensitive to radio frequencies and are looking for an alternative. Li-Fi is a good solution to this problem.

J. Location Based Services (LBS): Highly accurate location-specific information services such as advertising and navigation that enables the recipient to receive appropriate, pertinent information in a timely manner and location.

VII. CONCLUSION

This project presents that data can be transmitted through light. If this technology is put into practical use then every bulb can be used to transmit wireless data and we will proceed through greener, cleaner and safer future. This can solve the issue like shortage of radio-frequency bandwidth and can be used in aircrafts or hospitals. Hence by using this speed of the data transmission rate can be increased where the air waves are becoming clogged due to increase in accessing of wireless internet.

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