LI – FI

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***Abstract-* The aim of this paper is to make you understand "li-fi is bidirectional, high speed and fully networked wireless communications, like *Wi-Fi*, using visible light. Li-Fi is a subset of visible light communications (VLC) and can be a complement to RF communication (Wi-Fi or Cellular network), or a replacement in contexts of data broadcasting. It is wireless and uses visible light communication (instead of radio frequency waves), part of wireless communications technology, which carries much more information, and has been proposed as a solution to the RF-bandwidth limitations.A complete solution includes an industry led standardization process.**

***Index Terms-* Signal modulation in owc,multiple access,uplink,the li-fi autocell,the cellular network.**

I. INTRODUCTION

Thirty years after the introduction of the first commercially-available mobile communication systems, wireless connectivity has evolved into a fundamental commodity like gas and electricity. The exponential increase in mobile data traffic during the past two decades has led to the massive deployment of wireless systems. As a consequence, the limited available RF spectrum is subject to an aggressive spatial reuse and co-channel inter-ference has become a major capacity limiting factor. Therefore, there have been many independent warnings of a looming "RF spectrum crisis"1as the mobile data demands continue to increase while the network spectral efficiency saturates despite newly-introduced standards and great technological advancements in the field. It is estimated that by 2017, more than 11 exabytes of data traffic will have to be transferred through mobile networks every month. Most recently, VLC has been identified as a potential solution for mitigating the looming RF spectrum crisis.

Over the past decade, significant research efforts have been directed towards exploring alternative parts of the electromagnetic spectrum_ that could potentially offload a large portion of the network traffic from the overcrowded RF domain. Very interesting results have recently been reported from the use of millimetre wave (mmWave) communication in the 28 GHz region as well as from the use of infrared and visible light. The latter is particularly enticing as lighting is a commodity that has been integrated in virtually every inhabited environment and sophisticated infrastructures already exist. The use of the visible light spectrum for high speed data communication is enabled by the emergence of the light emitting diode (LED) which at the same time is at the heart of the next wave of energy-efficient illumination. In that sense, the concept of combining the functions of illumination and communication offers the potential for tremendous cost savings and carbon footprint reductions. First, the deployment of VLC access points (APs) becomes straightforward as the existing lighting infrastructure can be reused, and there exist off-the-shelf technologies such as power-line communication (PLC) and power- over-Ethernet (PoE) as viable backhaul solutions for retrofit installations, and new installations respectively. Second, because lighting is on most of the time in indoor environments even during day time, the energy used for communication would practically be zero as a result of the piggy-backing of data on illumination. However, even if illumination is not required energy efficient intensity modulation (IM) techniques exist that would allow data communication even if the lights are visually off. These are already compelling benefits, but the case does not end there. The visible light spectrum includes 100s of THz of license free bandwidth, 10,000 times more than the entire RF spectrum up to 30 GHz, including the mmWave spectrum. Optical radiation, in general, does not interfere with other radio waves or with the operation of sensitive electronic equipment. Therefore, it is ideal for providing wireless coverage in areas which are sensitive to electromagnetic radiation – some examples include: hospitals, airplanes, petrochemical and nuclear power plants, etc. Furthermore, the inability of light to propagate through walls offers an inherent level of network security. The same feature can be exploited to eliminate interference between neighboring cells.

II. SIGNAL MODULATION IN OWC

A seamless all-optical wireless network would require ubiquitous coverage provided by the optical front-end elements. This necessitates the usage of a large amount of Li-Fi enabled lighting units. The most likely candidates for front-end devices in VLC are incoherent solid-state lighting LEDs due to their low cost. Due to the physical properties of these components, information can only be encoded in the intensity of the emitted light, while the actual phase and amplitude of the light wave cannot be modulated. This significantly differentiates VLC from RF communications. VLC can only be realized as an IM/DD system, which means that the modulation signal has to be both real valued and unipolar. This limits the application of the well-researched and developed modulation schemes from the field of RF communications. Techniques such as on-off keying (OOK), pulse-position modulation (PPM), pulse-width modulation (PWM) and unipolar M-ary pulse-amplitude modulation (M-PAM) can be applied in a relatively straightforward fashion. As the modulation speeds are increased, however, these particular modulation schemes begin to suffer from the undesired effects of intersymbol interference (ISI) due to the non-flat frequency response of the OWC channel. Hence, a more resilient technique such as OFDM is required. OFDM allows adaptive bit and energy loading of different frequency sub-bands according to the communication channel properties.This leads to optimal utilization of the available resources. OFDM achieves the throughput capacity in a non-flat communication channel even in the presence of nonlinear distortion.Such channel conditions are introduced by the transfer characteristic of an off-the-shelf LED that has a maximum 3 dB modulation bandwidth in the order of 20 MHz.4, 5 In fact, the record-breaking results presented in4–6 have all been achieved using OFDM with, to the best of the authors' knowledge, the first experimental OFDM results for VLC reported in.Further benefits of this modulation scheme include simple equalization with single-tap equalizers in the frequency domain as well as the ability to avoid low-frequency distortion caused by flickering background radiation and the baseline wander effect in electrical circuits.

III. MULTIPLE ACCESS

A networking solution cannot be realized without a suitable multiple access scheme that allows multiple users to share the communication resources without any mutual cross-talk. Multiple access schemes used in RF communications can be adapted for OWC as long as the necessary modifications related to the IM/DD nature of the modulation signals are performed. OFDM comes with a natural extension for multiple access – OFDMA. Single-carrier modulation schemes such as M-PAM, OOK and PWM require an additional multiple access technique such as frequency division multiple access (FDMA), time division multiple access (TDMA) and/or
code division multiple access (CDMA).

IV. UPLINK

Up until now, research has primarily focused on maximizing the transmission speeds over a single unidirectional link.However, for a complete Li-Fi communication system, full duplex communication is required, i.e., an uplink connection from the mobile terminals to the optical AP has to be provided. Existing duplex techniques used in RF such time division duplexing (TDD) and frequency division duplexing (FDD) could be considered, where the downlink and the uplink are separated by different time slots, or different frequency bands respectively.

However, FDD is more difficult to realize due to the limited bandwidth of the front-end devices, and because superheterodyning is not used in IM/DD systems. TDD provides a viable option, but imposes precise timing and synchronization constraints which is needed for data decoding, anyway. However, plain TDD assumes that both the uplink and the downlink transmissions are performed over the same physical wavelength. This could often be impractical as visible light emitted by the user terminal may not be desirable.Therefore, the most suitable duplex technique in Li-Fi is wavelength division duplexing (WDD), where the two communication channels are established over different electromagnetic wavelengths. Using infrared (IR) transmission is one viable option for establishing an uplink communication channel.A first commercially-available full duplex Li-Fi modem using IR light for the uplink channel has recently been announced by pureLiFi.There is also the option to use RF communication for the uplink. In this configuration, Li-Fi may be used to do the "heavy lifting" and off-load data traffic from the RF network, and thereby providing significant RF spectrum relief. This is particularly relevant since there is a traffic imbalance in favor of the downlink in current wireless communication systems.

V. THE LI-FI AUTOCELL

In the past, wireless cellular communications has significantly benefited from reducing the inter-site distance of cellular base stations. By reducing the cell size, the network spectral efficiency has been increased by two orders of magnitude in the last 25 years. More recently, different cell layers composed of microcells, picocells and femto cells have been introduced. These networks are referred to as heterogeneous networks.Femtocells are short range, low transmission power, low cost, plug-and-play base stations (BSs) that are targeted at indoor deployment in order to enhance coverage. They use either cable Internet or broadband digital subscriber line (DSL) to backhaul to the core network of the operator. The deployment of femtocells increases the frequency reuse, and hence throughput per unit area within the system since they usually share the same bandwidth with the macrocellular network. However, the uncoordinated and random deployment of small cells also causes additional inter- and intra-cell interference which imposes a limit on how dense these small RF can be deployed before interference starts offsetting all frequency reuse gains. The small cell concept, however, can easily be extended to VLC in order to overcome the high interference generated by the close reuse of radio frequency spectrum in heterogeneous networks. The optical AP is referred to as an attocell.Since it operates in the visible light spectrum, the optical attocell does not interfere with the macrocellular network. The optical attocell not only improves indoor coverage, but since it does not generate any additional interference, it is able to enhance the capacity of the RF wireless networks. Li-Fi attocells allow for extremely dense bandwidth reuse due to the inherent properties of light waves. The coverage of each single attocell is very limited, and walls prevent the system from suffering from co-channel interference between rooms. This precipitates in the need to deploy multiple access points to cover a given space. However, due to the requirement for illumination indoors, the infrastructure already exists, and this type of cell deployment results in the aforementioned very high, practically interference-free bandwidth reuse. A byproduct of this is also a reduction in bandwidth dilution over the area of each access point, which leads to an increase in the capacity available per user. The user data rate in attocell networks can be improved by up to three orders of magnitude. They do not cause any additional interference to RF macro- and picocells, and can, hence, be deployed within RF macro-, pico- and even femtocell environments. This allows the system to vertically hand-off users between the RF and Li-Fi sub-networks, which enables both free user mobility and high data throughput. Such network structure is capable of providing truly ubiquitous wireless network access.

VI. THE CELLULAR NETWORK

The deployment of multiple Li-Fi attocells provides ubiquitous data coverage in a room in addition to providing nearly uniform illuminance. This means that a room contains many attocells forming a very dense cellular attocell network. A network of such density, however, requires methods for intra-room interference mitigation while there is no inter-room interference if the rooms are separated by concrete walls. Interference mitigation techniques used in RF cellular networks such as the busy burst technique, static resource partitioning, or fractional frequency reuse have been considered. The unique properties of optical radiation, however, offer specific opportunities for enhanced interference mitigation in optical attocell networks. Particularly important is the inability of light to penetrate solid objects, which allows interference to be managed in a more effective manner than in RF communication. According to example, the VLC interference mitigation caused by solid objects in a typical indoor environment leads to a tremendous increase in area spectral efficiency (ASE) over an RF femtocell network deployment in same LTE indoor office environment. The presented results highlight that the improvement with respect to ASE can reach a factor of up to 1000 in certain scenarios. Essential techniques for increasing wireless system capacity such as beamforming are relatively straightforward to use in VLC as the beamforming characteristic is an inherent, device specific property related to the field of view (FOV), and no computationally complex algorithms and multiple transmitting elements are required.

VII. CONCLUSION

Research in VLC over the past ten years has primarily been focussed on finding an optimum modulation scheme for IM/DD assuming point-to-point VLC links by taking into account that VLC may serve two simultaneous functions: (a) illumination, and (b) gigabit wireless communication. The predominate sources for signal dis- tortion are frequency dependent in such systems. This constitutes one key reason why there is now a general understanding that OFDM is the most suitable choice as a digital modulation scheme for Li-Fi, and there are good technical reasons to reconsider the IEEE 802.15.7 VLC standard. The straightforward multiple access tech- nique that OFDMA provides at almost no additional complexity and its compatibility to state-of-the art wireless standards like LTE and IEEE 802.11 further favor the selection of this modulation/multiple access scheme. The realization of a bidirectional connection also seems to have been addressed successfully to an extent that the first commercial bidirectional point-to-point Li-Fi systems are available. The most practical solutions to the uplink channel realization is to consider the IR or RF spectrum. The confidence brought by encouraging recent research results and by the successful VLC link-level demonstrations, has now shifted the focus towards an entire Li-Fi attocell networking solution. The unique physical properties of light promise to deliver very densely-packed high-speed network connections resulting in orders of magnitude improved user data rates. Based on these very promising results, it seems that Li-Fi is rapidly emerging as a powerful wireless networking solution to the looming RF spectrum crisis, and an enabling technology for the future Internet-of-Everything. Based on past experience that the number of wireless applications increases by the square of the number of available physical connections, Li-Fi could be at the heart of an entire new industry for the next wave of wireless communications.

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