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Guest Editorial

Optical wireless communication systems

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ABSTRACT

The emerging field of optical wireless communication (OWC) systems is seen as potential complementary technology to the radio frequency wireless communications in certain applications. It is deemed as a possible technology in the future 5th Generation communication networks to address the spectrum congestion and improve the system's capacity. More research and developments in OWC is still needed in order for it to be adopted in current and future communication systems. This special issue brings together research papers on OWC covering free space optic, visible communications and ultraviolet communications.

1. Introduction

The world of wireless communications has gone through tremendous changes in the last three decades. In the last few years, we have seen a surge in the number of mobile subscribers requiring access to high-speed wireless services at any time and any place. Currently, there are over 7.2 billion gadgets, and the annual mobile traffic is expected to reach ~3 Zetabyte by 2019 [1]. This growth (in speed and applications) has motivated both mobile operators, researchers and the standardization bodies to continuously develop new transmission technologies, protocols, network infrastructure solutions and standards to enhance the minimum technical system performance requirements outlined in Table 1 [2]. Future technologies that will require reliable high-speed wireless connections include sensor networks, delay tolerant networks, vehicular communications networks, cognitive networks, manufacturing, medicine, mega data centers etc. [3–7]. The wireless technologies will also benefit from a number of techniques including advanced signal processing algorithms at the physical layer, novel environment-aware applications, wireless network coding, physical-layer security and interference alignment among others.

In wireless communications network throughput (bit/s in an area) is a function of three main parameters of the cell density (cells/area), the available frequency spectrum (Hz), and the spectrum efficiency (bits/Hz/cell). Current 4th generation (4G) communication networks are mainly optimized for a peak data rate of a few 100 Mbps. This is expected to increase to 1 Gbps or beyond in the future 5th generation (5G) networks, which should be able to cater for the Internet of things (IoT) [8]. The deployment of IoT is a major challenge for future communications networks, which will be extensively deployed in smart

Table 1
Technical system performance requirements.

Parameter	Value
Peak data rate	20 for Downlink – based on 5G IMT
Average spectral efficiency	9 bps/Hz – Downlink indoor ~8 bps/Hz – Downlink urban ~3 bps/Hz – Downlink rural
Traffic capacity	10 Mbps/m^2 – Downlink
Latency (user)	Low – 4 ms for enhanced mobile broadband
Energy efficiency	High – Lowe average power with long sleep period
Bandwidth	Minimum of 100 MHz, increasing up to 1 GHz @ frequencies >6 GHz
Mobility	High – Up to 500 km/s

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environments, smart building buildings, security and safety, agriculture, manufacturing, device-to-device communications etc. [9].

The frequency spectrum is a precious and costly resource, and its scarcity is the main challenge as the number of users is continuously growing at an exponential rate. Addressing this challenge requires innovation in many areas including novel ways for spectrum sensing, sharing, borrowing and reuse, reduced the cell size and increase cell density (i.e., more complexity), improving the frequency reuse strategy, reducing the interference (i.e., lower transmit power levels), advanced modulation and coding schemes, parallel transmission (e.g., massive multiple input multiple output (MIMO), and more efficient protocols. In addition, to reduce the pressure on wireless networks using the licensed spectrum and improve the network capacity, the emphasis is to use wireless technologies (typically low power and shorter range), which operates in the unlicensed spectrum i.e., ultra-wideband, 60-GHz, near-field communications, TV white space, WiFi, Bluetooth, etc.

2. Optical wireless communications

An alternative and a complementary option would be to adopt the optical wireless communications (OWC) technology, which covers the ultraviolet, infrared and visible bands (from 350 to 1550 nm). OWC offers a huge unregulated bandwidth (orders of magnitude higher than RF) and can deliver data rates compatible with the optical fiber communications in the infrared band [10–13]. OWC offer a number of advantages including (i) fast deployment in difficult terrain, and situations; (ii) relatively low cost compared to RF; (iii) free from RF interference; (iv) inherent security (light can be confined within opaque walls); and (v) high energy efficiency.

In future wireless communication networks, co-existence and co-use of OWC, cellular and WiFi (with over 500 MHz of available bandwidth in the unlicensed bands of 2.4 GHz and 5 GHz) systems could be considered as one possible option to the spectrum management and easing of the spectrum congestion [14]. In 5G, a combination across all frequency bands could be important, which could be achieved by allocating lower frequencies for wide area coverage, higher frequency bands (i.e., millimetre (20–100 GHz) and OWC for access networks and personal area communications as well as short range indoor links. The latter is best suited for the visible band (390–700 nm), which is commonly referred to as visible light communications (VLC). VLC has seen a growing research activities in recent years. VLC takes a full advantage of visible light emitting diodes (LEDs) for the dual purpose of illumination and wireless data communications at very high speeds.

Many of the current wireless communication technologies share key technological similarities, and this is also likely to be the case in future wireless systems. The key technology requirements outlined in Table 1, which are mostly intended for the RF technologies, are very challenging. The peak rate, which is for the ideal conditions, determine the maximum offered bandwidth, coding and modulation schemes that could be supported by the access technology, whereas low latency requirement points to the use of small cells (nano—and femto-cells) in both indoor and outdoor environments with low transmit time interval. The high-energy efficiency requirement sets the tone for low power consumption and highly intelligent power management system. The OWC system, seen as a complementary technology to the RF, can address these requirements, and therefore could be adopted in multitude of applications including [11,12]:

- Broadband internet in rural areas [15] – Mostly FSO and ultraviolet systems that can replace optical fiber access technologies such as fiber to the home (FTTH) in order to provide connectivity between in-building networks and to broadband and backbone data networks.
- Inter-building connectivity and electronic commerce [16] – FSO and visible light communications (VLC), which provide speed, flexibility and high security.
- Audio and video streaming [13] – For live broadcasting of sporting events, in emergency situation, indoor entertainment etc.
- Unmanned aerial vehicle and underwater vehicles [16,17] – FSO, and VLC systems can be used in military surveillance, monitoring traffic and disaster areas, or broadcasting vital data.
- Space to ground and inter-satellite links to transfer extremely higher amount of data by FSO technology then in RF domain [18].
- High-secure quantum key distribution based OWC for long haul systems – satellite to ground [19].
- OWC based secure codifying techniques – Optical orbital angular momentum – for mobile and IoT scenarios [20].
- Intelligent transportation system [11] – Mostly VLC in vehicle-to-vehicle and vehicle-to-infrastructure safety communications, and entertainment within vehicles.
- Inter- and intra-chip communications [21].
- Medical and manufacturing [22] – Wearable medical devices with wireless transmission capabilities are a key technology for monitor health and wellbeing of people. OWC is seen as a potential candidate for medical wireless body area networks with high data rates capabilities.
- Wireless sensor network [23] – Sensor data is extremely important to in underwater, manufacturing etc. for condition-based monitoring, machine diagnosis and process adaptation to new requirements etc.