ISSN 2229-5518

OPTICAL WIRELESS COMMUNICATION: A FUTURE PERSPECTIVE FOR NEXT GENERATION WIRELESS SYSTEMS

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Abstract— The next generation wireless communication systems need to be of higher standards, so as to support various Broadband wireless services- such as, Video conferencing, mobile videophones, high-speed Internet access etc. The existing wireless systems can hardly provide transmission capacity of the order of few Mbps. In recent years, interest in optical wireless (OW) promising complementary technology for RF technology has gained new momentum fueled by significant deployments in solid state lighting technology. This paper aims at reviewing and summarizing recent advancements in OW communication, with the main focus on perspective of optical wireless system for next generation wireless networks.

Index Terms— Hybrid wireless systems, Indoor infrared wireless communications, Infrared, wireless communication, local area networks, Optical wireless, Outdoor optical wireless communication.

1. INTRODUCTION

AN optical wireless (OW) communication system relies on optical radiations to convey information in free space, with wavelengths ranging from infrared (IR) to ultraviolet (UV) including the visible light spectrum. The transmitter/source converts the electrical signal to an optical signal, and the receiver/detector converts the optical power into electrical current. Light emitting diodes (LEDs) or laser diodes (LDs) can be used as optical sources and photodiodes (PDs) as detectors [1]. An optical wireless communication system is an attractive alternative to radio, primarily because of a virtually unlimited, unregulated bandwidth. The optical spectrum is a universally available resource without frequency and wavelength regulations. An optical wireless communication system has the advantage of requiring low cost and low power consumption, also. In 1990s, some practical applications using optical wireless communication become actual, and some products and their standards were completed. Optical wireless systems are classified into two categories depending on where the system is utilized.

INDOOR APPLICATION

There is a growing interest in indoor wireless networks as a consequence of the large scale utilization of personal computers and mobile communicators. Infrared is preferred as wavelength in these applications, originally. This is because essentially a large total transmission bandwidth is possible, facilitating fast transmission system due to the very high frequency involved in optical carrier. The Infrared Data Association (IrDA) specifies three infrared communication standards: IrDA-Data, IrDA Control, and a new emerging standard called AIr. Since this document focuses on IrDA-Data and its relationship to Bluetooth, for the purpose of this document, IrDA refers to the IrDA-Data standard. In general, IrDA is used to provide wireless connectivity technologies for devices that would normally use cables for connectivity. IrDA is a point to- point, narrow angle (30° cone), ad-hoc data transmission stadard designed to operate over a distance of 0 to 1 meter and at speeds of 9600 bps to 16 Mbps.

General IrDA characteristics

Characteristics include:

- Proven worldwide universal cordless connection.
- Installed base of over 50 million units.
- Wide range of supported hardware and software platforms.
- Designed for point-to-point cable replacement.
- Backward compatibility between successive standards.
- Narrow angle (30 degree) cone, point-and shoot style applications. (Non-interference with other electronics and low-level security for stationary devices.)
- High data rates; 4 Mbps currently, 16 Mbps under development.

What is IrDA Used For?

IrDA is used to transmit data by the following devices:

- Notebook, desktop, and handheld computers
- Printers
- Phones and pagers
- Modems
- Cameras
- LAN access devices
- Medical and industrial equipment
- Watches etc.

Worldwide Acceptance

With a worldwide installed base of over 150 million units and growing at 40% annually, IrDA is widely available on personal computers, peripherals, embedded systems and devices of all types. In addition, the wide use and acceptance of IrDA standards and robust solutions have accelerated adoption of the IrDA specifications by other standards organizations. The universal adoption and worldwide implementation of IrDA specifications guarantees a universal hardware port, and rapidly emerging software interoperability [2].

OUTDOOR APPLICATION

Optical wireless communication is rapidly becoming a familiar part of modern urban life. Over the last half decade, there has been a steady increase in the number of consumers using high capacity data transmissions, and their data-rate demands have risen from hundreds of megabits per second to tens of gigabits per second. These consumers include businesses, educational and recreational establishments, government offices, and utilities. Capacity-hungry communication applications range from local area network (LAN) systems to Internet and company intranet. The high data rates needed can be attained with optic fiber, which has been distributed to connect cities and continents. However, often the "last mile" from the fiber backbone to the client premises presents a significant problem. It may not be possible or practical to lay down optic fibers, and it is invariably costly and time-consuming. Optical wireless communication (UOWC) can bridge the gap (Fig. 1).

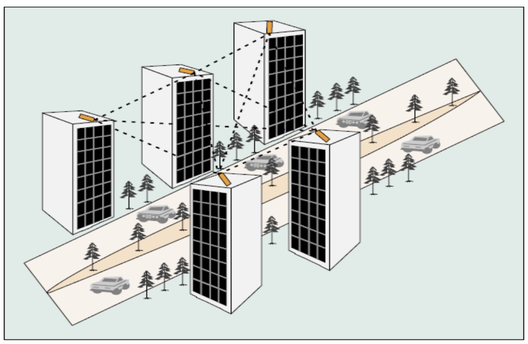


FIGURE 1. A schematic illustration of an optical wireless communication network

In fact, all modalities of wireless communication can offer solutions to the last mile problem, affording flexible and rapid connectivity. However, radio frequencies carry heavy tariffs and licensing fees. Furthermore, the beaurocracy involved in obtaining permits can take months. This is particularly troublesome when a temporary solution is sought, or an unexpected redeployment of premises calls for the provision of instant communication links. There is also growing concern about the health hazards associated with extensive exposure to radio frequency radiation. On the other hand, if eye safety hazards are allayed, optical communication is not dangerous. After all, sunlight has been harmlessly endured since time immemoria [3].

In contrast to wireless links, existing infrastructures of electrical cable can be used to bridge the last mile gap as is familiar with asynchronous digital subscriber line (ADSL) or cable television (CATV) connectivity. However, the broadband data rates offered by optical communications would be relinquished and data flow may stall. This solution is also subject to high leasing fees. In practice, the unique features offered by what is alternatively termed free space optics (FSO) or lasercom (a popular abbreviation for laser communications) have been demonstrated in the urban environment. Numerous links between high-capacity fiber backbone and end users function satisfactorily in major cities all over the world. An optical wireless communication system can provide the transmission capacities of fiber links using lightweight and compact equipment that can be installed in less than a day — and no licensing fees are necessary [4]. When installing a link, the transmitters and receivers can be placed on rooftops, lampposts, billboards, bridges, and even inside office windows, and a system can be operative within hours. A tragic example of the deployment efficiency of lasercom was witnessed following the September 11th terrorist attacks. Communication with the disaster area was operational within hours, aiding in the recovery work itself and regaining connectivity with many of the businesses and companies hit by the devastation. In some applications, the high security features of OWC is of paramount importance, as the extremely directional, narrow beam optical link makes eavesdropping and jamming nearly impossible. Even if a transient bird can momentarily block the path, unwanted interferers are thwarted. This characteristic has been exploited for many years in high security satellite-ground links, which prefer the optical communication modality because of its small "footprint." Health and safety regulations ensure that the potential threats of laser light such as eye damage are held in check. Strict adherence to these rules makes OWC a safe and secure solution for easily deployable high bandwidth communication. Furthermore, with the many advances witnessed in optical communication technology, OWC is considered to have great potential for future cost-effective data links. Much groundwork research has already been done in the field of lasercom in intersatellite links, where many of the benefits listed for UOWC are equally advantageous.

2. SYSTEM CONFIGURATIONS

The different kinds of links for indoor optical wireless communication have been classified, depending on the existence of a line of sight (LOS) path between the transmitter and the receiver, and the degree of directionality (directed, non directed or hybrid). The six basic configurations are shown in figure 2.

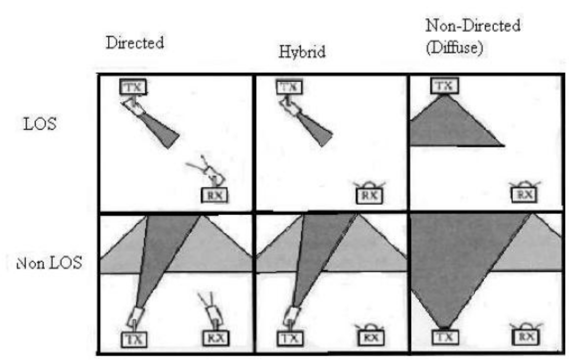


Figure 2. Indoor optical wireless link configurations

LOS link systems improve power efficiency and minimize

multipath distortion. Non LOS links, on the other hand increase link robustness as they allow the system to operate even when obstacles are placed between the transmitter and receiver, and alignment is not required.
Directed links also improve as the path loss is minimized, but this kinds of system need alignment of the transmitter, the receiver, or both, making them less convenient to use for certain applications.
Directed-LOS links also improve power efficiency because the transmitted power is concentrated into a narrow optical beam making possible the use of narrower field of view (FOV) receivers, and an improved link budget. Also this kind of system does not suffer from multipath distortion, and a predetermined maximum transmission distance can always be assured for a given optical power, independently of the reflective properties or the shape of the room, as far as the line of sight is not interrupted. Thus, the drawback of this configuration is that it is susceptible to blocking, and it requires aiming of the transmitter or receiver. A special case of this topology is the tracked system. This configuration presents the advantages of maximum power efficiency, and high coverage.
Hybrid non-LOS systems do not present the blocking problem, but suffer from multipath distortion that increases as the area is increased.
One of the most attractive configurations is the non directed non-LOS, or diffuse. Systems working under this configuration do not require a direct line of sight, or alignment, between the optical transmitter and the receiver because the optical waves are spread as uniformly as possible in the room by making use of the reflective properties of the walls and ceiling. This kind of link has the advantages that it can operate even when barrier are placed between the transmitter and the receiver. This makes it the most robust and flexible configuration. In spite of the advantages of the diffuse configuration, this kind of system suffers from multipath dispersion and higher optical losses than LOS and hybrid LOS. [1][5][12]
Outdoor system configuration is changed from indoor system. As shown in fig 3 In outdoor system the transmitter telescope collimates the beam in the direction of the receiver and determines the beam diameter. At the receiver, a telescope collects the incoming light and focuses it onto the photodetector, which then converts it to electric current.

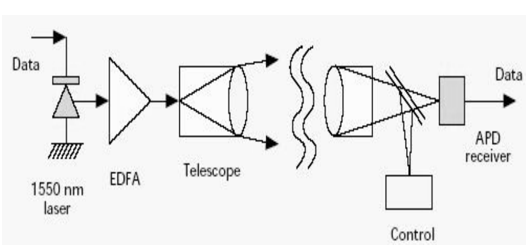


Figure 3. Outdoor optical wireless link

The electrical signal is amplified and processed. A decision making device determines the nature of the signal according to its amplitude and arrival time. The quality of reception is measured by the probability of error, expressed in terms of bit error rate (BER). The transmitter and the receiver are separated by the propagation channel, which, in the case of outdoor OWC the atmosphere. Even on an apparently clear day the atmosphere is pervaded by molecules and aerosols, which cause absorption and scattering of the light. Changes in temperature along the propagation path lead to scintillations in the received light due to the resultant due to the resultant turbulence. Line of sight is imperative for outdoor OWC, and may be maintained with the help of a tracking and pointing system. Tracking is performed in two stages, coarse tracking and fine pointing. Coarse tracking may use GPS or other a priori Knowledge. Fine pointing requires electro-optic mechanisms such as a quadrature or a matrix detector. Pointing involves a beam-steering device which may be mechanical, such as a galvo-mirror, or non-mechanical, such as acousto-optic crystals, electro-optic devices or optical phased arrays (OPAs).
The individual link between transmitter and receiver can be extended to a network topology. This allows for greater flexibility and extends the effective transmission range.

3. APPLICATIONS AREA FOR OPTICAL WIRELESS

There is little doubt that radio solutions will remain dominant for most applications, but there are several areas where OW is attractive.

Telematic applications

There is also a growing interest in optical communications between moving vehicles, and between vehicles and roadside hubs. These are being considered for telematic applications, such as road pricing and navigation, as indicated by the development of an ISO standard (ISO CALM 204) for such systems. The German government has adopted an optical communications system for its tolling system for freight vehicles [6]. Several train-operating companies are investigating FSO for communications with trains, to provide broadband 'to the seat'.

Secure wireless applications

There are a number of applications where OW can provide secure communications. The IRDA is promoting 'Financial Messaging', where a secure transaction takes place between a handheld and a retail terminal, albeit at low data rates [7]. Such a concept might be extended to retailing of high bandwidth content such as DVDs and CDs to portable players. In the future this might require several Gb/s in order to achieve reasonable download times. Theft of content would be limited by the confined nature of the optical signal, and extremely high spatial bandwidth could be achieved within the retail environment. This is relatively straightforward to achieve with a directed OW link used in a 'point and shoot' manner, or in a booth in which the link environment can be controlled.
There may also be other environments such as dealing rooms where secure wireless networks are required, and OW can easily provide this.

Ultra-high bandwidth wireless

ISSN 2229-5518

Applications such as virtual reality suites, and wireless TV studios require multi Gb/s wireless communications with very high spatial bandwidth density. The directivity available with optical links, combined with tracking makes this feasible. [11]

RF Hazardous environments

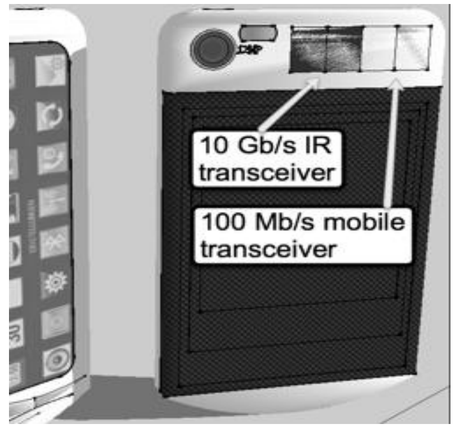
One of the major growth sectors in avionics is data and speech communications to aircraft. Satellite broadband is being added to aircraft, and many aircraft are equipped with telephone to the seat. The wireless link from the passenger to the data infrastructure is currently not possible, and OW represents perhaps the only allowable alternative. A mobile phone or PDA containing a radio and optical terminal could allow seamless communications with a local optical base station part of the aircraft infrastructure. Hospitals offer similar opportunities, both in wireless instrumentation and transmission of data. In sensitive environments, the access point or network could automatically disable the radio interface, enabling communications through the optical link.

Hybrid Wireless Systems

In broad terms optical wireless provides high bandwidth, and providing coverage is problematic, whilst for RF approaches the opposite is the case. Perhaps the key advantage of OW (in a general environment where security is unimportant) is the ease with which high bandwidth LOS channels can be provided, and the potential these have to decrease the load on the infrastructure. Hybrid systems that can allow this are therefore attractive, and fit well within the 4G vision of heterogeneous wireless systems working together to provide a seamless infrastructure. Very simple hybrid approaches combining optical and radio frequency links have been proposed recently for short-range (indoor) communications [8, 9]. Reference [10] describes protocols that use RF signalling and reallocate the optical sources under blocking conditions. Future research in this area is discussed in later sections.

4. COMMERCIAL SYSTEMS AND RESEARCH STATE OF THE ART

The Optical Mobile



In modern smart phones 3 communication channels available (RF, Mobile, Giga Speed). It Provide optical mobile communication within a RF free environment and fastest data transfer method of a mobile device. It can be Communicates optical "on the move" at 100 Mbit/s and GigaSpeed data transfer and reception 10 Gbit/s.

The Optical Memory

Optical memory is the most basic version of a wireless optical data network. Optical memory stick consist GigaSpeed mobility transceiver. It can be used for data storage and connects equipment to each other within a range of 1 m. memory stick uploads and downloads files with GigaSpeed technology and communicates with mobile device within a range of 2 m.

Traffic management

IRDA has formed The Travel Mobility Special Interest Group (IrTM) in order to develop a specification for toll payment. A standard also exists for longer-range communications (ISO TC 204 CALM). A major commercial amount of activity is by Efkon, who have won large contracts for payment systems worldwide, notably a German project for truck traffic tolling.

Much more commercial optical system being investigated that are not discussed in this paper are optical router, GigaSpeed Technology , The Optical Room Connector , Ultra-high bandwidth wireless etc.

5. CONCLUSION

This paper reviews OW communication technology; overviews research activities, and state the perspective for next generation wireless network. It is anticipated that further experimental and theoretical studies will provide enhanced foundations for important new developments in this very rapidly growing area. Future wireless standards offer a good opportunity for the wider adoption of OW. In particular, as 4G networks will be highly heterogeneous, OW based air interfaces can be incorporated to terminals in addition to the conventional RF based ones. Considerable work is still needed to fully exploit the clear advantages of the optical solutions, as well as developing low-cost subsystems and components to implement them.

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I017689