

Research In Optical Free-Space Communications

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Advances in photonic device technologies have yielded deployable low-cost and low-power LED lighting that is commercially available today. This technology is expected to completely replace lighting systems as we know them within the next 15 years. Energy savings from this replacement are no less than incredible. Not as obvious is the unique opportunity this transformation presents in the form of new ways to enable the data networking of a vast array of physical objects.

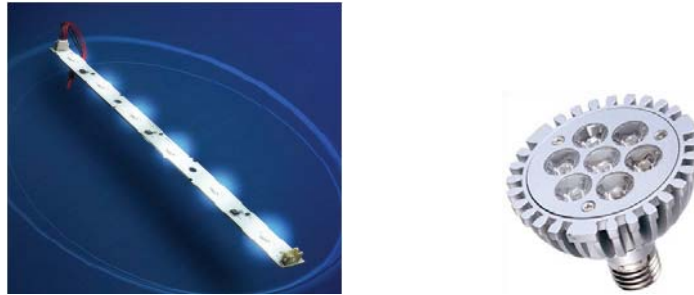


Figure 1: LED Replacement for Florescent and Incandescent Bulbs

These objects include people and their personal communicators (PDAs), automobiles, machinery in the physical plant (e.g., motors and actuators), inventory (e.g., pallets, boxes, individual items), sensor systems (e.g., surveillance, ecological monitoring), as well as more exotic applications including bioinstrumentation (biometric clothing), property management (e.g., tracking of chairs, tables, etc.), and smart spaces (e.g., rooms that adapt to occupants' preferences). Because LEDs can be digitally modulated, future lighting systems can play a large role in their feasibility.

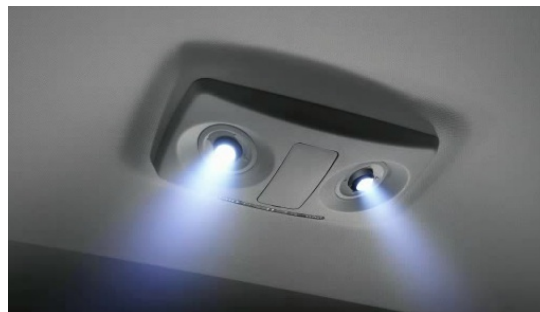


Figure 2: Modulated LED Light for Communications

Each of these scenarios requires ubiquitous localized communications supporting data networking. The applications are characterized by various degrees of symmetry – the need for data exchange in from the core network to devices and vice versa; and in the required bandwidth and latency needs. For example, many industrial automation applications are achieved with very low bit

rates whereas streaming HD media to seats in a passenger aircraft requires very high data rates. In fact, the ‘bandwidth density’ of free-space visible light communications makes it very attractive for this scenario. Vehicular communications, such as active braking in vehicle-to-vehicle scenarios, are safety-critical, and thus have more strict latency and delivery requirements.



Figure 2: High Bandwidth Density: HD Media Per Seat

LED lighting promises to cover the ‘air gap’ between fixed data networking infrastructure and objects in the physical world that are at arbitrary locations. This is only possible with a critical density of networking. Thus, the deployment of future lighting can play a central role establishing connectivity with enabling broad-based “cyber-physical” systems – the connecting of the physical world with the Internet. Under this vision Radio Frequency (RF) and optical free-space communication will coexist, each serving complementary and in some cases, competitive services. Here, for example in the urban setting of Boston, a wireless mesh network (WMN) consisting of interconnected gateways (typically RF) provide large-footprint coverage to localized access points while complementary optical and RF-based technologies serve to communicate with end-devices. Such a system leverages the ubiquity of future LED deployment and exposes a multitude of opportunities for networking applications.

In our research program in FSO communications we are engaging in fundamental research addressing the aforementioned topics. In addition, we plan to construct two networking testbeds suitable for experimentation with potential indoor and outdoor scenarios and for both line-of-site and diffractive lighting. The indoor testbed will be comprised of a room equipped with optical access points designed to support interchangeable LED technologies to permit investigation of a variety of modulation schemes as emerging from the core research. End devices will be achieved with low-cost sensor nodes and PDAs equipped with photodiodes matching the modulation schemes. This scenario will allow investigation of high-bandwidth density applications of streaming HD media delivery (such as video delivery per seat in a passenger aircraft) and room and device tagging and localization (low bandwidth applications such as industrial automation).

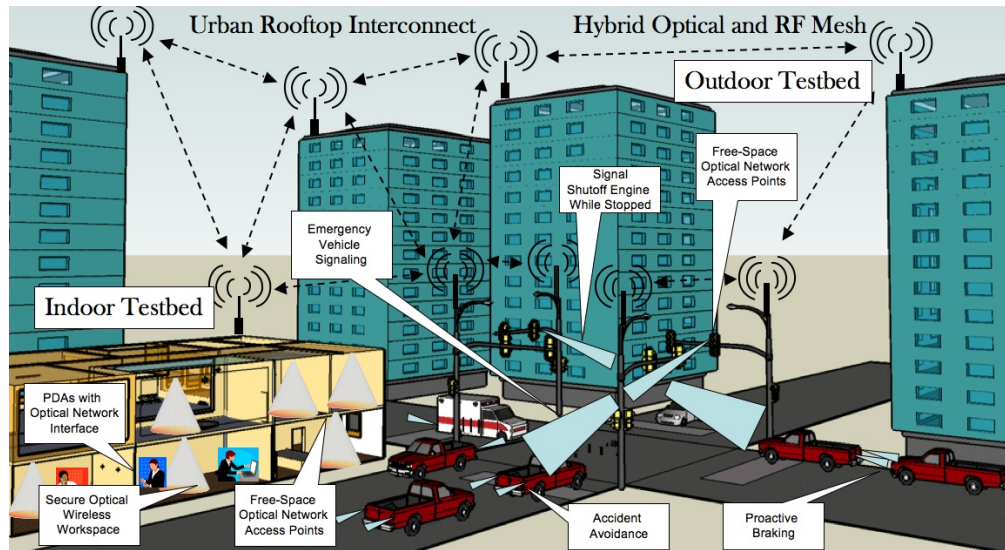


Figure 3: Outdoor Scenario and Testbed

The outdoor testbed will be realized by collaboration with Boston’s municipal wireless broadband initiative which can provide backhaul (to the Internet) connectivity and RF spectrum to serve our custom access points that will be strategically located on signage and light poles to comprise the outdoor testbed. Such a testbed is intended to support the investigation of hybrid RF-optical and all optical modes of networking in vehicular communications. The testbed will enable piloting real systems and validation of research and will also stimulate the discovery of unanticipated phenomena.

Ongoing research activity includes the development of prototype LED-based communications with off-the-shelf components. For example, we are investigating the use of LED-based flashlights for illumination and communication, effectively achieving the function of an optical network with USB connections on each side (illustrated below).

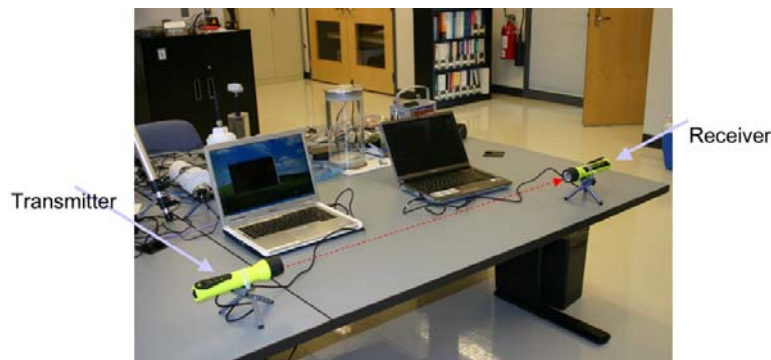


Figure 4: Prototype LED FSO System with Flashlights

As an enabler, FSO networking is complementary to our work in supporting network applications in healthcare. For example, a body-worn sensing device, as illustrated below benefits greatly from localization – knowing its location – within a building. By coupling location information with personal activity monitoring is an essential tool in novel diagnostic and therapeutic methodologies. FSO ‘tags’ as coded light emanating from room lighting is a practical solution for localization and the support of many safety problems.



Figure 5: Supporting Wireless Healthcare Monitoring

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