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### BROADBAND OPTICAL WIRELESS LOCAL AREA NETWORKS AND REMOTE SENSING SENSORS

With the increasing popularity of multimedia services supplied over the fixed network (such as Web browsing, video conferencing, and video on demand), it is certainly only a matter of time before users will demand higher bandwidth mobile access. Advances in displays, battery technology, and processing power have made it possible for users to afford and carry laptops and palmtops. The prospects for the delivery of multimedia services to these users is, however, crucially dependent on the development of low-cost physical layer delivery mechanisms. The market needs to consolidate the data into one single handset.

To address the bit rate limitation problems of current wireless systems, **Mohsen Kavehrad**, W. L. Weiss Professor of Electrical Engineering, and his research team are examining the concept of adaptive rate delivery of future mobile/portable multimedia services with high bit rates (>100 Mbits/s) for localized areas. Examples of physical layer technologies are GSM, ultra-wideband, and optical wireless (OW) for the high-bandwidth islands, e.g., classrooms, hotels, homes, shopping malls, airports, train stations, planes, spacecrafts, etc. Consider the area of home networking when every home will be illuminated with bright white LED light which can also be a broadband communications carrier. We are entering a new era of always-on connectivity. The expectation from consumers for not only ubiquitous but also seamless data, voice, and video services presents a significant challenge for today's telecommunications systems.

It is commonly agreed that the next generation of wireless communication systems will not be based on a single access technique but will encompass a number of different complementary access technologies. The ultimate goal is to provide ubiquitous connectivity, integrating operations seamlessly in most common scenarios, ranging from fixed and low-mobility indoor environments to high-mobility cellular systems. Surprisingly, perhaps the largest installed base of short-range wireless communications links are optical, rather than radio frequency (RF). 'Point and shoot' links corresponding to the Infra-Red Data Association standard are installed in 100 million devices a year—mainly in digital cameras and telephones. It is argued that OW has a part to play in the wider 4G vision.

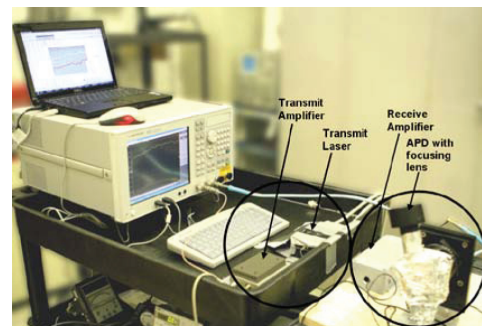
In large open environments where individual users require 100 Mbps or more, OW is a more sensible solution because of its limited cell size. Today's RF local area networks realistically cannot support more than one or perhaps two high capacity users per cell. With cell sizes of approximately 100 meters, which could accommodate tens of users, this is highly wasteful. Multiple high capacity users could only be serviced by deploying a similar number of systems, all within the same locale. This would create a situation where the cells almost completely overlap, which then raises concerns with regards to interference, carrier reuse, etc. In contrast, OW could deliver the necessary capacity to each user through multiple user-sized cells and, because of the intrinsic

cally abrupt boundary of these cells, interference would be negligible and carrier reuse would not be an issue. Indeed, OW is a future-proofed solution since additional capacity far beyond the capabilities of radio could be delivered to users as their needs increase with time. It is also a "green" technology as power consumption of optical components is smaller than RF ones.

Sensor networks are also increasingly being used for monitoring and controlling vital operations in industries, hospitals, and military installations and vehicles. Current research trends concentrate on RF technology for sensor communications. However, OW communications or visible light communications can offer a much higher data rate or higher reuse factor.

Wireless communications by infrared (IR) or visible light is inherently secure, since it is usually confined within an enclosure. It offers no interference to existing RF sensing or communication infrastructure. It is unregulated worldwide unlike RF spectrum, and small devices can be manufactured that are suitable for miniaturized sensors.

Kavehrad and his former students and postdoctoral fellows have investigated the potential of OW for indoor local area networking. With advancements in solid state optical device manufacturing and increase in availability of off-the-shelf components, OW needs to be reviewed. In a project funded by the National Science Foundation, the Kavehrad research team is designing a wireless optical communication techniques for integration into sensor networks. In the Center for Information and Communications Technology Research Laboratory, Kavehrad and doctoral student, **Jarir Fadlullah**, have built a test-bed comprised of a laser transmitter and an Avalanche Photodiode receiver, and measured the OW channel characteristics in the IR range (See figure below). The laser transmitter has an attached collimating lens, which allows one to focus a spot on the ceiling, where the IR light gets diffused. The reflected light is captured with



a focusing lens at the receiver. This set-up is termed non-directed line-of-sight, as opposed to line-of-sight and diffuse configurations. To obtain frequency responses, a network analyzer is used to modulate the constant laser drive current with RF frequencies swept in the range from 10 KHz to 1GHz.

They have demonstrated potential for transmitting several gigabits per second with this set-up. Kavehrad and Fadlullah presented a paper titled "Wideband Optical Propagation Measurement System for Characterization of Indoor Optical Wireless Channels" based on this system at Photonics West Conference in San Francisco on Jan. 27, 2010 (See news story link here: Penn State Research News). This is the widest directed non-line of sight measurement reported, using practical optical components.