## References


1. Fox News - LED Lights Send Internet Data in Minnesota
   http://www.myfoxtwincities.com/dpp/news/led-lights-internet-lvx-dec-27-2010

   By CHRIS WILLIAMS / Associated Press, Video report by Erik Runge / FOX 9 News


ST. CLOUD, Minn. - Flickering ceiling lights are usually a nuisance, but in city offices in St. Cloud, they will actually be a pathway to the Internet.

The lights will transmit data to specially equipped computers on desks below by flickering faster than the eye can see. Ultimately, the technique could ease wireless congestion by opening up new expressways for short-range communications.

The first few light fixtures built by LVX System, a local startup, will be installed Wednesday in six municipal buildings in this city of 66,000 in the snowy farm fields of central Minnesota.

The LVX system puts clusters of its light-emitting diodes, or LEDs, in a standard-sized light fixture. The LEDs transmit coded messages -- as a series of 1s and 0s in computer speak -- to special modems attached to computers.

A light on the modem talks back to the fixture overhead, where there is sensor to receive the return signal and transmit the data over the Internet. Those computers on the desks aren't connected to the Internet, except through these light signals, much as Wi-Fi allows people to connect wirelessly.

LVX takes its name from the Latin word for light, but the underlying concept is older than Rome; the ancient Greeks signaled each other over long distances using flashes of sunlight off mirrors and polished shields. The Navy uses a Morse-coded version with lamps.

The first generation of the LVX system will transmit data at speeds of about 3 megabits per second, roughly as fast as a residential DSL line.

Mohsen Kavehrad, a Penn State electrical engineering professor who has been working with optical network technology for about 10 years, said the approach could be a vital complement to the existing wireless system.

He said the radio spectrum usually used for short-range transmissions, such as Wi-Fi, is getting increasingly crowded, which can lead to slower connections.

"Light can be the way out of this mess," said Kavehrad, who is not involved in the LVX project.

But there are significant hurdles. For one, smart phones and computers already work on Wi-Fi networks that are much faster than the LVX system.

Technology analyst Craig Mathias of the Farpoint Group said the problems with wireless congestion will ease as Wi-Fi evolves, leaving LVX's light system to niche applications such as indoor advertising displays and energy management.

LVX Chief Executive Officer John Pederson said a second-generation system that will roll out in about a year will permit speeds on par with commercial Wi-Fi networks. It will also permit lights that can be programmed to change intensity and color.

For the city, the data networking capability is secondary. The main reason it paid a $10,000 installation fee for LVX is to save money on electricity down the line, thanks to the energy-efficient LEDs. Pederson said one of his LED fixtures uses about 36 watts of power to provide the same illumination that 100 watts provides with a standard fluorescent fixture.

Besides installation costs, customers such as St. Cloud will pay LVX a monthly fee that's less than their current lighting expenses. LVX plans to make money because the LED fixtures are more durable and efficient than standard lighting. At least initially, the data transmission system is essentially a bonus for customers.

Pederson said the next generation of the system should get even more efficient as fixtures become "smart" so the lights would dim when bright sunlight is coming through a window or when a conference room or hallway is empty.

Because the lights can also change color, Pederson said they could be combined with personal locators or tiny video cameras to help guide people through large buildings. The lights could show a trail of green lights to an emergency exit, for instance.

While Kavehrad and Mathias credited LVX for being the first company in the United States to bring the technology to market, Kavehrad said it trails researchers and consumer electronics companies in Japan and Korea in developing products for visible-light networks.

Pederson's previous company, 911 EP, built high-powered LED roof lights for squad cars and other emergency vehicles. He said he sold the company in 2002. He said the visible-light network grew out his interest in LEDs that goes to the mid-1990s.

The Minneapolis-St. Paul International Airport, which pays for 24-hour lighting and replacing fluorescent bulbs on high ceilings, is considering an LVX system, said Jeffrey W. Hamiel, executive director of the Metropolitan Airports Commission.

The system might include mounting cameras on the light fixtures to bolster the airport security system, but the real attraction is the savings on electricity and maintenance.

"Anything we can do to save costs is worth consideration," he said.

Michael Williams, the city administrator in St. Cloud, said the city had been considering LVX for some time.

"It's pretty wild stuff," he said. "They have been talking about it with us for couple of years, and frankly it took a while for it to sink in."

http://www.lvxsystem.com/

LVX installation video:- http://www.electrictv.net/Home.aspx?PlayID=70

2. Siemens: 500 Megabits/Second with White LED Light
   http://www.siemens.com/innovation/en/news_events/ct_pressreleases/e_research_news/2010/e_22_resnews_1002_1.htm
   Jan. 18, 2010 | Siemens researchers have improved on their own record for wireless data transfer using white LED light. In collaboration with the Heinrich Hertz Institute in Berlin, they have achieved a data transfer rate of up to 500 megabits per second (Mbit/s), significantly bettering the previous record of 200 Mbit/s. Wireless data transport by means of light paves the way for new applications in the home as well as in industry and transportation.

   Using a white light-emitting diode produced by the Siemens subsidiary Osram, the researchers from Corporate Technology in Munich succeeded in transmitting data over a distance of up to five meters of empty space. The data are directly transferred by modulating, via the power supply, the amount of light emitted by the LED. The researchers used an Ostar LED, one of the brightest LEDs on the market, which can be modulated at such a frequency that data transfer rates of up to 500 Mbit/s are possible. The resulting changes in brightness remain imperceptible to the human eye. The receiver is a photodetector which converts the light signals into electrical pulses.
   Known as VLC (Visible Light Communication), this form of data transfer has a variety of potential applications. In the home, for example, it could represent a valuable addition to established WLAN technology. Increasingly, wireless networks are compromised by the fact that in many buildings the three independent WLAN frequency bands are multiply occupied, which leads to collisions among the data packets. In a situation like this, visible light, as a currently unused and license-free medium, offers a suitable alternative. A further advantage is that this form of data transfer is impervious to interception. Only the photodetector that is positioned directly within the light cone is able receive the data. In other words, it is impossible to "tap" the data transported in the light beam. There is also a need for this type of data transfer in factory and medical environments, where in certain areas radio-borne transmission is either impossible or only a limited option. A further application is in the field of transportation, where LED stoplights or railroad signals could be used to transmit information to cars or trains.

   The researchers were also able to show that a system combining up to five LEDs is capable of transferring data over longer distances at rates as high as 100 Mbit/s. Once again, this has practical applications, since such a system could be used to transmit data via ceiling lights to a receiver mounted on a desk located anywhere within a room. The IEEE (Institute of Electrical and Electronics Engineers) has been working since 2007 to standardize activities in this field. It is hoped that this work will be completed by the end of 2010 .

3. VLCC : Visible Light Communications Using LEDs!
   http://www.cdrinfo.com/sections/news/details.aspx?newsid=10920

   As the name suggest, visible light communications are a technology for the transmission of information using light that is visible to the human eye.

   This amazing technology is rapidly approaching the practical application stage thanks to the increasingly higher performances and expanding applications of light-emitting diodes (LEDs). This Japan-original technology will be unveiled at CEATEC JAPAN 2004. Professor Masao Nakagawa (PhD), President of the Visible Light Communications Consortium (VLCC), and Professor Shinichiro Haruyama (PhD), Vice-president of the VLCC, both of whom work in the Department of Information and Computer Science at Keio University, speaks.

   Using Everyday Lighting for Communication

   These days, there's no need to explain the usefulness of wireless communications using radio waves. We take radio waves for granted, even though the human eye cannot see them. But position detection with cellular telephones and car navigation systems that use radio waves is not very accurate, as there is some difficulty in identifying the exact location of the information terminal. This drawback becomes more pronounced when equipment is used in underground shopping malls or inside buildings.

   Professor Nakagawa says, "I have spent many years researching mobile communications using radio waves. Now that the age of the ubiquitous network society is all but upon us, I have devoted a lot of thought to issues related to wireless communications. All this thinking led me to the possibility of adding data to visible light generated by equipment, including lights we use our every day, traffic signals and illuminated signs, and using the result for communication. This is where the original concept for visible light communications comes from."

   Professor Nakagawa is suggesting the creation of a new world of wireless communication, in which visible light communication is used to supplement communication not feasible using only radio waves. Several years ago, some members of the Institute of Electronics, Information and Communication Engineers (http://www.ieice.org/jpn/index/html) conducted basic research on this concept. Keeping pace with this research, rapid advances were made to raise the performance and expand the applications of LEDs, resulting in the real prospect of the practical application of visible light communications. The VLCC, with Professor Nakagawa as chairman, came into being in November 2003. With a current membership of 15 companies, the consortium is engaged in R&D aimed at the commercialization of visible light communications systems.

   Beamed to the World from CEATEC JAPAN

   Visible light communications use LEDs, which send data by flashing light at speeds undetectable to the human eye. One major advantage is that we can use the infrastructure around us without having to make any changes.

   For example, the transmission of positional information entered into individual indoor LED lighting devices and sent to a cellular telephone or similar device enables position detection that is accurate to within several meters. Theoretically, precision is possible to within several millimeters, and it is at this level that the true power of visible light communications will be realized, such as in controlling robots. To give another example, all sorts of information can be sent to cars and pedestrians using LED traffic signals.

   Visible light communications are an attractive option for the instantaneous transmission of huge quantities of data. If machines that send and receive data are placed a few centimeters apart, visible light can be used to exchange data between them. Because the light that is being used is visible to the human eye, it is obvious at a glance which pieces of equipment are communicating. This does away with mechanical verification that has been necessary up until now.

   Professor Haruyama says, "Regardless of the extent of the business potential of visible light communications, we won't know the direction that product development will take until its

applications become more clearly defined. Professor Nakagawa took up this topic in his address at CEATEC JAPAN last year. This year, however, there will be a number of actual systems on display. We are calling 2004 "Year One for Visible Light Communications," and we are very keen to see this uniquely domestic technology find a world-wide audience.

Four Exhibits Showcase the Possibilities of Visible Light

Thanks to the support of companies belonging to VLCC, there will be four exhibits at this year's CEATEC JAPAN showcasing the myriad possibilities of visible light communications in easy-to-understand formats.

Light and Sound Collaboration (Supported by Keio University, Agilent Technologies Japan, Ltd., and Sony Corporation)

Musicians each play a different instrument under red, green and blue lights. When visitors wearing headphones turn in the direction of one of these lights, they will be able to hear only the sound of the instrument receiving that particular colored light. By making the most of the visibility of this light, visitors will be able to instinctively choose the information they want to receive.

LED Traffic Signal Communication System (Supported by Nippon Signal Co., Ltd., and Nagoya Institute of Technology)

The traffic signals we see everyday are gradually being replaced by LEDs. If visible light communications are applied in this area, it will be possible to send all sorts of information from traffic signals to cars and pedestrians waiting for lights to change. Visible light communications is beginning to receive attention as a new communications medium for intelligent transport systems.

Illumination ID, Receiving Light via Mobile Terminals and Light Tags (Supported by Keio University, NEC Corporation and Matsushita Electric Works, Ltd.)

Visible light is used to send ID information from LED illumination on mobile phones and other mobile terminals. Even in places such as in underground shopping malls, where radio waves cannot easily reach, extremely accurate position information and image and text data can be transmitted instantaneously. Though LEDs are commonly used to display whether a device is on or off, light tags go further, as they can send detailed information on a device from an LED to a mobile terminal.

Visible Light Communications Applied to Cellular Telephone Displays (Supported by Cyber Solutions Laboratories, Nippon Telegraph and Telephone Corporation)

There is a form of communication, based on visible light with varying hues, that uses existing cellular telephone displays. Simply holding the handset up to a large screen transmits the telephone's ID. Also, merely pointing the phone in the direction of desired information on-screen causes the relevant information to be downloaded onto the phone. One main attraction of this technology is that it utilizes existing infrastructures, such as iAPRI.

4. [1/27/2010] Penn State University : Wireless optical transmission key to secure, safe and rapid indoor communications
   http://www.engr.psu.edu/newsevents/newsdetail.aspx?NewsID=8150&NewsDate=1/27/2010

San Francisco — Light is better than radio waves when it comes to some wireless communications, according to Penn State engineers. Optical communications systems could provide faster, more secure communications with wider bandwidth and would be suitable for restricted areas like hospitals, aircraft and factories.

Sending information via light waves either in physical light guides or wirelessly is not new, but existing wireless systems either require direct line of sight or are diffused and have low signal strength. The researchers chose to take a different approach using multi-element transmitters and multi-branch optical receivers in a quasi-diffuse configuration.

The system uses a high-powered laser diode — a device that converts electricity into light — as the optical transmitter and an avalanche photo diode — a device that converts light to electricity — as the receiver. The light bounces off the walls and is picked up by the receiver.

"Unless the walls are painted solid black, there is no need to worry about transmission within a room," said **Jarir Fadlullah**, graduate student in electrical engineering who presented the paper today (Jan. 27) at SPIE Phonotics West Conference in San Francisco, the paper will be published in the conference proceedings.

The researchers tested infrared light, but the system will also work with visible light and ultraviolet light.

"The optical system we have offers a very large bandwidth thus a very high speed," said Fadlullah. "We can send one gigabit per second or more over a gigahertz band."

The researchers, including **Mohshen Kavehrad**, professor of electrical engineering, think this looks like an ideal system. Radio frequency systems do not require line of sight transmission, but can pass through some substances and so present a security problem. Light, in a room without windows, will not escape the room, improving security, but also allowing the same frequencies to be used in adjacent rooms without interference. Multiple sensors could allow the light signal to pass from room to room or even from floor to floor. The system could also be set up to convert the signal to electricity, transfer it to another location and change it back to light.

"The safest security is physical layer security," said Mohshen Kavehrad. "If you first have to break into the building before you can attack the network it makes it very difficult."

He also notes that an optical system can operate in locations where radio frequency transmission would interfere with other equipment, especially in hospitals, aircraft and even some factories. Because this system is optical, it will not interfere with the radio frequency emissions of navigation equipment, medical devices or factory control systems.

Optical transmissions can transfer sensor data and unlike radio frequency communications, can also distribute high-resolution images.

"One application for this system would be wireless projection of high definition television," said Kavehrad.

"Currently, two high definition broadcasts exceed the bandwidth of any radio system, but with a 1.6 gigabit per second gigabit system, two HD channels could be broadcast."

While this application in conference rooms could provide mobility for presentations, applications in aircraft and medical facilities are probably more important. Currently, wireless communications are difficult in these situations because radio frequency systems can interfere with equipment using radio frequency control or communications. An optical system can operate in the same space as a radio system without interference.

"As far as I know, these are the first set of measurements for indoor optical wireless links that show the feasibility of the highest bit rates with no line-of-sight," said Kavehrad. "No radio system had comparable ability."

The researchers will continue to test optical systems, looking at visible and ultra violet light. They also believe that light emitting diode room lighting could be incorporated into the systems to provide a blanket communications network. The researchers note that this is a very green technology.

The National Science Foundation supported this work.

5. IEEE P802.15 http://www.ieee802.org/15/pub/TG7.html http://ieee802.org/802_tutorials/2008-03/15-08-0114-02-0000-VLC_Tutorial_MCO_Samsung-VLCC-Oxford_2008-03-17.pdf (Very detailed presentation).

6. i.Light: Communication Using Visible Light by G.K.H. Pang, Mechatronic Systems http://www.crcnetbase.com/doi/abs/10.1201/9780849307768.ch8