unless there are some changes to current wireless technology, this situation will get worse and worse as more cell phones, iPads, and other portable wireless devices are brought into your home and the homes of your neighbors. Like in our analogy of a group of people speaking, the more devices that are close to each other, the more likely they are to interfere. Additionally, there are also government regulations and licenses associated with radio frequency devices. Thus in developing new technologies all these issues should be addressed.

So is there a way to improve this current situation? In order to answer the question, let us return to our analogy where a group of people were all talking at once. It becomes easier to distinguish them if their voices have different pitches (i.e., one has a high pitch voice and another low). So is there a way to adapt this analogy to address some of the issues current wireless technology has? Of course, one solution would be to use higher radio frequencies, but current government licensing in many countries makes this difficult. Instead we can use light to communicate between wireless devices! This is known as optical wireless communications and the modern concept dates back to 1880 when Alexander Graham Bell presented his photophone. It was not until the late 1970s that this field picked up interest again when Gfeller and Bapst demonstrated that infrared light could be used to fill a room and communicate with devices. Since then it has been an area of active research and development. Light has a much higher frequency (pitch in our analogy) and it does not interfere with the current devices operating at the much lower radio frequencies. Unlike current wireless technology, light is easily confined (i.e., does not travel through walls) so it will not interfere with devices in other rooms. This drastically reduces the amount of interference that can happen. Additionally, this makes optical wireless more secure since someone cannot steal your medical records or internet connection without you being able to spot them, whereas using current wireless technology your neighbors can detect your wireless network since it travels through walls. Of course that might mean you have more people sitting outside your windows trying to steal the internet, but at least now you can see them to chase them off! This is easily fixed though since there are coatings you can put on windows to prevent the optical wireless connection from leaking out into the street.

The use of higher frequencies would enable you to transfer your videos and pictures much quicker between our portable devices. It will definitely be a lot faster (more than 10 times) than Bluetooth or your current wireless adapter meaning you have to spend less time waiting to transfer your files. Additionally, this also addresses the issue of government regulations since optical wireless communication is highly confined, less regulation is needed. This does not mean that optical wireless communication will completely replace radio frequency wireless technology, since the current technology does have the advantage of covering large areas since it can travel through walls and other obstructions. In the future, these two technologies will exist side by side working together to make more secure and reliable wireless networks. Let us now take a closer look into the field of optical wireless communications.

https://doi.org/10.33178/boolean.2012.13

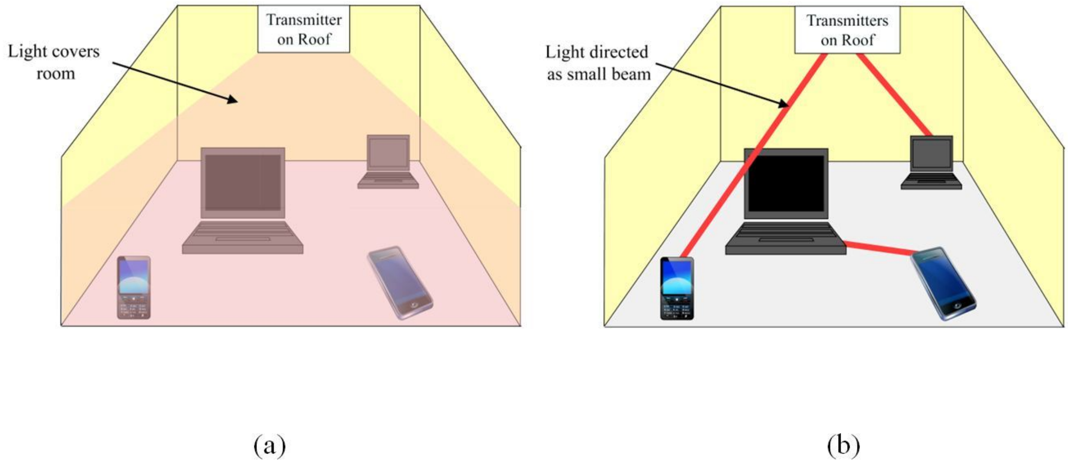

Figure 2: Examples of two optical wireless communication methods. In (a) Diffuse Optical Communication is shown. Here light from the source is shown spreading throughout the room, whereas (b) shows Line-of-Sight Optical Communication where the light is directed i

How does optical wireless work?

One common method of sending data optically is to change the brightness of the source based upon the information that needs to be sent. The receiving device detects the changes in brightness and translates these changes into something that it can understand. Now you may ask, "How would this affect lighting in the room?" Luckily for us, the eye operates quite slowly. Think about watching a movie or TV where it seems that there is fluid motion. However, most movies and shows have less than 72 images per second! The rates that the brightness changes happen in optical wireless communication are at least 100,000 faster than this, so your eye does not have the capability to notice this. To your eye there will be a constant brightness level.

Optical wireless technology is classified based upon how much the light spreads out or how much space the light covers in a room and whether it reflects off objects as seen in Figure 2. Here we will discuss the two extreme cases of light spreading. The first method (Figure 2 (a)) is to spread light throughout the whole room and reflecting off the walls. This is known as diffuse optical communication and in many cases a light emitting diode (LED) is used as the source. You may be familiar with LEDs in car headlights, traffic signals or Christmas tree lights replacing traditional light bulbs due to being more energy efficient. The other method uses small beams of light to communicate with one specific device. This method is known as line-of-sight communication and commonly uses a laser as the source of light. In this method it is extremely important to direct the beam towards the device it needs to communicate with as seen in Figure 2(b).

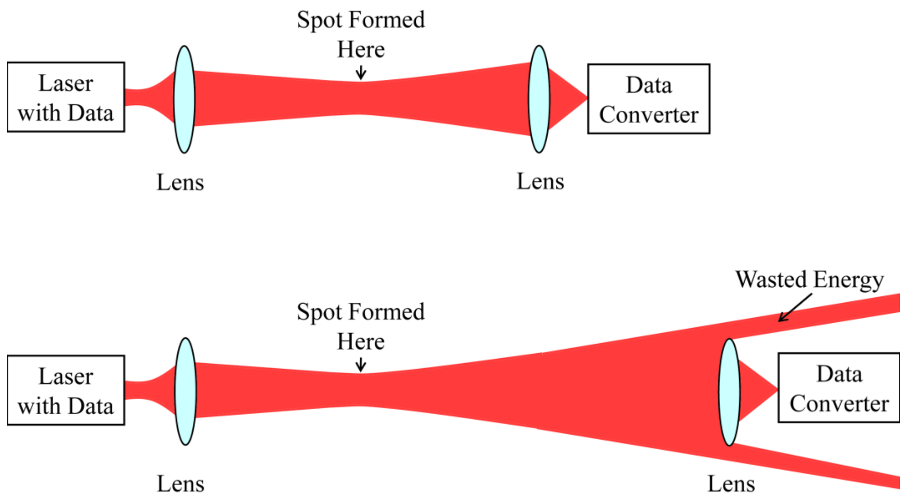

Figure 3: Optical wireless link using a fixed lens. The lens fixes the distance that the laser beam spot forms. The top picture shows the link operating at its designed range, whereas in the bottom picture that range is exceeded and energy is wasted.

Smart Optical Wireless

Focusing on the Line-of-Sight method, we need to make sure that the light can travel the whole distance to the device (e.g. laptop or cell phone). If you have played with a laser or flashlight you know there is only a certain distance that they can go. So how can we change this distance? Now most of us played with a magnifying glass when we were young and noticed that there was a specific distance that would allow you to see text at a bigger size. The more adventurous of you found out that there was an optimal distance to use the magnifying glass for burning leaves or other things. If you used magnifying glasses of different strengths you found this would happen at a different distances based upon their strength. Similarly, in Line-of-Sight optical wireless communications the lens will set the distance that the laser beam focuses at as seen in Figure 3. After this spot, it starts expanding again. This can cause a problem if you continue further than your original design range since not all of the light will be picked up by your laptop or cell phone receiver, causing less power to be received. This reduces the quality of the connection since many important factors (e.g. error rate) that determine quality all rely on the amount of power received. Additionally, it is very energy inefficient and thus this design will not reduce long term energy cost. Hence, in developing optical wireless technology we want to develop a system that is able to capture as much of the transmitted light as possible.

My work has focused on trying to do this. I have worked on designing smart optical wireless transmitters that capture all the transmitted light. The idea is to design a lens that has the ability to change its focusing power. The lenses I have been working with are controlled by changing the amount of electrical power you apply to them. By changing the focusing ability of the lens, the laser beam will focus at a different spot. Ideally, you want to make this spot smaller than the receiver on your laptop or cell phone so that all

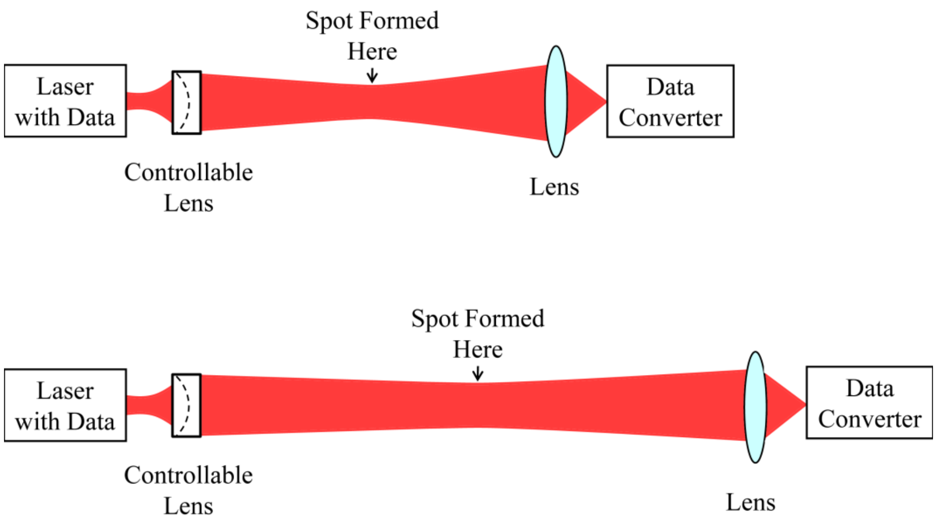

Figure 4: Using a controllable lens when the distance between your mobile device and the computer transmitter changes the lens changes its focusing power so that all light is captured by the lens. Shown here are two different distances and how when the lens focus

light sent out is captured. More captured light leads to a better quality connection and to the use of less laser or LED power being required. In turn, this also leads to better energy efficiency. This concept has been demonstrated for indoor environments, but it can be extended to outdoor and undersea scenarios with some modifications. Using this method, the amount of optical power loss was more than halved at a distance of 4 m from the transmitter when compared to the non-smart wireless system (Marraccini and Riza 2011).

Wireless technology in the future

Over the next few years, wireless technology will need to adapt to address issues that have developed. Part of the solution will be the use of optical wireless networks. Optical wireless will be used in situations where increased speed and security are required, whereas radio frequency networks will be used to cover large areas. These two technologies are complementary. Optical wireless technology will become more common in the home and work environment since it will be needed to meet the increasing demand for faster speeds due to the large amounts of data being uploaded and downloaded. Smart designs are needed since they will lead to better quality, reliability, and energy efficiency.

I would like to thank my supervisor Prof. Nabeel A. Riza for his advice, guidance, and support.

Further Reading

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