Demo: LED-to-LED Visible Light Communication for Mobile Applications

Giorgio Corbellini, Stefan Schmid, Stefan Mangold
Disney Research
8092 Zurich, Switzerland

Thomas R. Gross
ETH Zurich
8092 Zurich, Switzerland

Armen Mkrtchyan
Disney Consumer Products
Glendale, CA 91201, U.S.A.

1. Introduction

Visible Light Communication (VLC) is a creative approach for novel mobile applications. Games, toys, location services, and augmented reality are example applications that can benefit from using visible light for communication. In the following, we address VLC applications for consumer electronics and toy networks in mobile scenarios.

2. VLC Applications

VLC is a relatively new approach for optical free space mobile networks. It has been so far mainly considered for Internet access or home networks, but more creative use cases are possible. Figure 1 illustrates the VLC toy car network scenario. Toy cars equipped with LEDs exchange short messages to trigger events. Other applications include location markers and light bulb repeaters. Since the communication is visible (as opposed to radio communication) more interactive applications become possible when using VLC. Other VLC applications include dynamic markers for augmented reality.

3. VLC Technology

In our technology, we limit the complexity of the system and the number of electronic components by avoiding the use of photo detectors for light detection: For both transmission and reception, we use LEDs as described in Dietz et.al. (2003). This approach is here referred to as LED-to-LED communication. Incoming light detection is performed as follows: An LED in reverse bias acts as a small capacitor and incoming light accelerates its discharge. By measuring the voltage at the end of a discharge cycle, light (or the absence of it) can be detected. On top of the LED-to-LED communication, we built networked devices with distributed medium access using a simplified contention-based protocol with flickering avoidance and collision detection. The protocol enables a large number of LEDs to communicate with each other (Tippenhauer et.al. 2012). Devices use low-cost 8-bit 16 MHz microcontrollers to operate the LEDs.

Nowadays, toys equipped with LEDs use light emissions mainly for artistic or decorative reasons. By integrating a micro-controller and re-using the already existing LEDs to govern light emissions, these toys can extend their capabilities to free-space optical communication so that devices can interact among each other.

4. Demo

We demonstrate a half-duplex VLC LED-to-LED communication testbed (throughput of around one kilobit per second per channel, distances in the order of meters, and distributed protocols) with various applications.

Mobile Toy Network: Short-range directional communication with a number of toys, where front- and backlights are used to exchange messages when pointed towards each other. Depending on the relative position of sender and receiver, the toys react in a different way. For example, they can mimic a discussion if they are face to face, or a race if they are located one behind the other. As result, different dynamic topologies are possible.

Magic Wand with Fashion: A magic wand with transmitting LEDs is pointed toward a princess dress and triggers light effects on the dress. Different wands convey different messages so that the resulting light effects on the dress are different.

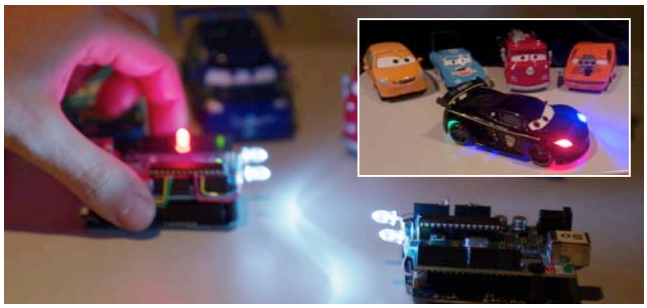

Figure 1. *Toy car scenario (Mangold 2012). Networked toys equipped with LEDs exchange messages. A communication distance of up to one meter at one kilobit per second is demonstrated.*

Light Bulb Repeaters: An LED light bulb in a desk lamp receives messages from a mobile device and broadcasts it back to the desk with higher light intensity and larger coverage. The static lamp acts as a repeater so that more devices can receive the original messages and the resulting network connectivity increases.

Location Markers and Augmented Reality (AR): LEDs embedded into toys are used to communicate to a handheld camera to enable dynamically changing AR applications. Since LEDs can simultaneously communicate among each other and send messages to the camera, new AR applications are possible.

Computer Network: Laptops with USB to LED interfaces are used to demonstrate the underlying technology and its limitations (flicker avoidance, throughput, distance, packet collisions, error handling, and hidden station problem).

5. Conclusions

The LED-to-LED communication and the contention-based medium access protocol with collision detection enable new mobile applications for entertaining and creative use cases. Compared to radio solutions like WLAN or cellular, the potential benefits of VLC are the unrestricted use of devices (the optical spectrum is unlicensed), the visibility of the connections (which can be part of the creative experience), and the fact that light sources are already all around us.

6. References

DIETZ, P. AND YERAZUNIS, W. AND LEIGH, D. 2003. *Very Low-Cost Sensing and Communication Using Bidirectional LEDs*. MERL Technical Report TR2003-35.

IEEE802 2011. *Short-Range Wireless Optical Communication Using Visible Light*. IEEE Standard for Local and Metropolitan Area Networks. Part 802.15.7.

MANGOLD, S. 2012. Visible Light Communications for Entertainment Networking. *IEEE Photonics Summer Topicals*.

SCHMID, S. AND GORLATOVA, M. AND GIUSTINIANO, D. AND VUKADINOVIC, V. AND MANGOLD, S. 2011. *Networking Smart Toys with Wireless ToyBridge and ToyTalk (Poster)*. Proc. IEEE International Conference on Computer Communications (INFOCOM).

TIPPENHAUER, N.O. AND GIUSTINIANO, D. AND MANGOLD, S. 2012. *Toys communicating with LEDs: Enabling Toy Cars Interaction (Demo)*. Proc. IEEE Consumer Communications and Networking Conference (CCNC).