Networking Smart Toys
with Wireless ToyBridge and ToyTalk

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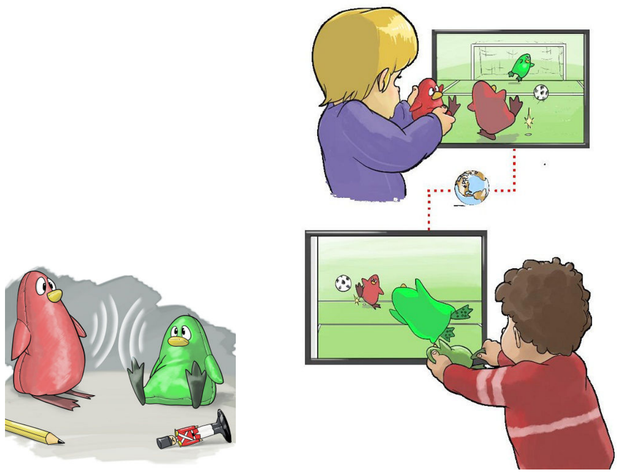
***Abstract*—In this submission, emerging research challenges of *smart toy networking* are identified and discussed. We present a *ToyBridge* middleware platform that was developed to integrate physical-world smart toys with online activities, and a *Visible Light Communications ToyTalk* platform we developed for simple toy communications. Videos of *ToyBridge* and *ToyTalk* showcases accompanying this submission can be accessed at [1].**

I. Smart Toys as a Pervasive System

This submission identifies research opportunities and scenarios for future communications, networking, and mobile computing applications in *smart toy networking*. The complexity of today's toys is increasing, and toys that have various wireless communication capabilities, as well as different sensors and actuators, are becoming common. At home or in smart environments (for example, in entertainment theme parks), networked wireless toys, interacting with each other, computers, mobile phones, smart objects, and online communities, offer opportunities for unique entertainment experiences [2].

In smart toys networking, future wireless *Internet of Things* will merge with *online gaming and social networking*. For example, social networking sites designed specifically for children (i.e., [3]) can be integrated with physical-world smart toys, as illustrated in Fig. 1. Toy behavior in the physical world and toy interactions with each other and with other objects can be based on online experiences of toy owners. Toys that are carried by children and share experiences in an entertainment park can, through wireless physical-world contact, become "friends", and later continue their friendship and interactions online. Toys may react differently to each other depending on how frequently they interact, or how long they have not interacted, online or in the physical world. Additionally, authenticating online social network contacts using physical-world toys can make online interactions safer for children. In this submission we present the Wireless *ToyBridge* platform that can be used as a starting point for integrating physical-world smart toys with online activities.

Engaging, entertaining realizations of smart toy networking require numerous research challenges to be addressed. Enriching user experiences with mobile toys requires low-power feature-rich *toy context awareness* and *self-localization*, as well as low-cost low-power identification and classification of toy interactions (i.e., distinguishing toys that are actively interacting from toys that are simply positioned next to each other). Pervasive wireless toys networks may exacerbate some parents' fears over exposing their children to RF radiation. To address these concerns, *visible light communications* (VLC) may be used as a low-power low-cost non-radiating alternative to traditional short-range wireless RF communications, as illustrated in Fig. 2. In this submission we describe the VLC *ToyTalk* platform we have developed, where light-emitting diodes are used as *bi-directional transmitters and receivers*. Videos demonstrating *ToyBridge* and *ToyTalk* platforms are available at [1].



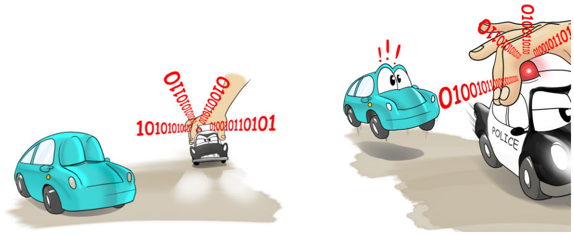
(a) (b)

Fig. 1. In smart toy networking, future *Internet of Things* will merge with *online gaming and social networking*: (a) toys wirelessly interacting with each other, and (b) smart toys integrated with online gaming and social networking.

Additional research opportunities in smart toy networking include enabling advanced capabilities in inexpensive toys via *toy-to-computer and toy-to-toy complexity offloading*, designing and developing communications for *green toys* that operate using energy harvested from the environment, investigation and analysis of toy mobility patterns, and taking advantage of opportunistic delay-tolerant toy networking made possible by toy contacts with each other and other devices.

II. Wireless ToyBridge: Cyber-Physical Social Networking

To integrate physical-world toys with online activities, a *Wireless ToyBridge* middleware layer is used, as shown schematically in Fig. 3. Since browser applications do not have permissions to control hardware (i.e., to write to or to read from external devices), the applications use sockets to talk to the ToyBridge OS service, which contains hardware modules



(a) (b)

Fig. 2. Visible Light Communications (VLC) in smart toy networking. VLC allows for low-power low-cost secure toy-to-toy wireless interactions.

responsible for controlling the toys. The ToyBridge-to-toy interface depends on the type of toy used. Lego Mindstorms NXT toys, for example, are connected via a standard Bluetooth interface. Buzz Lightyear remote controlled robots, on the other hand, rely on proprietary infrared communication protocols which cannot be implemented using standard infrared (IrDA) hardware and libraries. As part of Wireless ToyBridge development, we *reverse-engineered* the infrared signalling schemes used by two different versions of Buzz Lightyear robots, and implemented them as custom ToyBridge infrared (IR) communication modules. We also created a mini IR interface device, where the control sequences generated by the ToyBridge custom IR module are written to a buffer using an FTDI USB-to-serial converter with a RS232 chip, and buffer's output is used to toggle an infrared light-emitting diode (LED). Browser-to-toy functionality for Lego Mindstorms and for one model of Buzz Lightyear robots is demonstrated in the accompanying video [1].

Seamless toy-to-browser interface, as well as the possibility to shift toy complexity to the computer, enable easy creation of innovative applications that can make full use of smart toys' radios, sensors, and actuators. The associated challenges, some of which we are currently addressing using the wireless ToyBridge platform, include *online user authentication and identity management using physical-world toys* (i.e., using the approach described in [4]), and enabling advanced capabilities in inexpensive toys by *offloading complexity* from a toy to a computer (i.e., a toy with an inexpensive processor implements voice recognition and similar resource-intensive operations by forwarding its sensors' data to a ToyBridge-running computer).

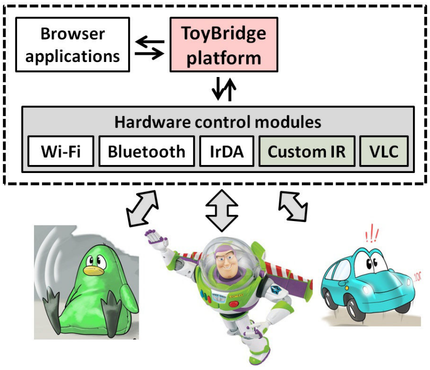


Fig. 3. *Wireless ToyBridge* middleware. Browser applications communicate with ToyBridge, which includes modules for communicating with physical-world toys.

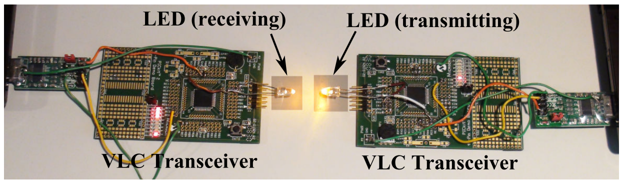


Fig. 4. Wireless *ToyTalk* Visible Light Communications (VLC) testbed. In *ToyTalk* VLC transceivers, *the same LED is used as a transmitter and a receiver*.

III. Wireless ToyTalk: Low-Cost Low-Power Smart Toys Communications using Visible Light

For close-range toy communications, a compelling technology is *Visible Light Communications (VLC)*, where the information is transmitted using simple ubiquitous *Light Emitting Diodes (LEDs)*. LEDs have long been used in toys due to their small size, low cost, and low energy consumption. Moreover, VLC is secure, does not generally raise concerns about radiated energy, and makes it easier to detect purposeful contact between toys. VLC standardization efforts are currently underway in the IEEE 802.15.7 Task Force.

In this submission we present the "LED-to-LED" VLC *ToyTalk* platform we developed. A photo of the ToyTalk platform is shown in Fig. 4. In a VLC system where an LED is used to transmit information (i.e., an LED is turned on and off), a photodiode may be used to detect LED transmissions. However, in the ToyTalk platform designed for toy communications, to save the costs and to reduce energy consumption and complexity, we *use an LED as a transmitter and a receiver* [5]. We programmed Microchip PIC16F887 cards to toggle the LEDs (to send information), and to read LED capacitance discharge times (to receive information). Currently, the platform implements a simple framing scheme with preamble-based transceiver synchronization, and achieves bit rates of 0.8-0.9 kb/s, which is sufficient for many low-cost toy communication scenarios. A video showcasing the ToyTalk platform is provided at [1]. Smart toy networking VLC-related research challenges include designing, developing and evaluating VLC MAC protocols suitable for low-power toy communications. Using the developed platform, we are currently evaluating the tradeoffs of LED-to-LED VLC (i.e., reduced power consumption versus achievable bit rates). Our future work includes *integrating ToyTalk with ToyBridge*.

References

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