Demo: Battery-free Visible Light Sensing

Andreas Soleiman
Uppsala University
Sweden
andreas.soleiman@it.uu.se

Ambuj Varshney
Uppsala University
Sweden
ambuj.varshney@it.uu.se

Luca Mottola
Politecnico di Milano and RISE SICS
Italy and Sweden
luca@sics.se

Thiemo Voigt
Uppsala University and RISE SICS
Uppsala, Sweden
thiemo@sics.se

1 ABSTRACT

We present our efforts to design the first Visible Light Sensing (VLS) system that consumes only tens of µWs of power to sense and communicate. We achieve this by designing a sensing mechanism that uses solar cells to achieve sub-µWs of power consumption for sensing. Further, we devise an ultra-low power backscatter-based transmission mechanism we call Scatterlight that transmits digital readings without incurring the processing and computation overhead of existing sensors. We demonstrate our preliminary prototype that detects and transmits three simple hand gestures.

2 BATTERY-FREE VISIBLE LIGHT SENSING

Visible light is a ubiquitous medium that requires minimal to no additional infrastructure to provide illumination. Visible light can be sensed using simple and low-cost – photodiodes or solar cells – which requires minimal processing effort at the sensing device. Thus, visible light offers a significant advantage for sensing applications over mediums such as radio frequency (RF) signals which require complex processing and power hungry radio operating on licensed spectrum. However, despite clear advantages there have only been a few deployments (excluding vision systems) of visible light sensing (VLS) systems. The main reason for this is that these systems combine visible light sensing together with communication which significantly increases the complexity and cost of deployment. Thus, a key enabler to achieve widespread deployment of VLS systems is to use unmodulated ambient light for sensing that requires tracking of shadows cast by objects or people [2, 3].

There are two main reasons for the lack of pervasive deployment of VLS systems: First, existing VLS systems fail to take advantage of the ubiquitous nature of visible light. These systems combine visible light communication (VLC) together with sensing which requires retrofitting of the luminaries with specialized modulating circuits [1–3]. This significantly increases the cost and the complexity of deployment. Second, these systems employ conventional light sensing mechanisms to sense changes in the ambient light conditions. Such mechanisms feature sensors with components that negatively affect pervasive deployment.

We present our vision to design simple and ultra-low cost and power light sensors with the ability to sense changes in the ambient light. Such sensors can operate on small amounts of energy harvested from ambient light or other harvesting sources, and transform any well-lit surface to a sensing medium. Their low cost enables deployment at a wide scale. Hence, such sensors could make VLS systems pervasive. To enable our vision, we use unmodulated light to sense shadows by building on recent systems. We introduce the first VLS system that can sense changes in unmodulated ambient light by tracking shadows at a peak power consumption of 0.5 µW communicating these events at a peak power of 20 µW. To achieve this, we make two key contributions over existing state-of the- art systems [2, 3]: First, we design a mechanism that couples solar cells to a thresholding circuit to consume sub-µWs of power to sense shadow events. Second, we embrace the observation by Zhang et al. [5] and devise a mechanism we call *Scatterlight* that offloads processing from sensors to powerful end devices using RF backscatter without involving energy-expensive computational blocks. This enables ultra-low power and low-cost light sensors we call visible light markers (VLM).

3 DEMO

We demonstrate the ultra-low power nature of the VLM. We generate a carrier signal using a dedicated device. Next, we operate the VLM using energy harvested through a small solar cell. We perform a hand gesture over the sensor (solar cell) under unmodulated ambient light. The VLM senses the shadow event, and digitises it using its thresholding circuit. Then the VLM mirrors the digitised shadow event onto backscattered signals using the *Scatterlight* mechanism. We finally receive the backscattered transmissions from the VLM at the CC 1310 end device [4]. We sample the RSSI at the end device to receive Scatterlight transmissions in real-time, and visualise them.

REFERENCES

[1] Ye-Sheng Kuo, Pat Pannuto, Ko-Jen Hsiao, and Prabal Dutta. 2014. Luxapose: Indoor positioning with mobile phones and visible light. In *MOBICOM 2014*.
[2] Tianxing Li, Chuankai An, Zhao Tian, Andrew T. Campbell, and Xia Zhou. 2015. Human Sensing Using Visible Light Communication. In *ACM MOBICOM 2015*.
[3] Tianxing Li, Qiang Liu, and Xia Zhou. 2016. Practical Human Sensing in the Light. In *ACM MOBISYS 2016*.
[4] Ambuj Varshney et al. 2017. LoRea: A Backscatter Architecture that Achieves a Long Communication Range. In *ACM SENSYS 2017*.
[5] Pengyu Zhang et al. 2014. Ekhonet: High speed ultra low-power backscatter for next generation sensors. In *ACM MOBICOM 2014*.

VLCS'17, October 16, 2017, Snowbird, UT, USA

ACM ISBN 978-1-4503-5142-3/17/10.
https://doi.org/10.1145/3129881.3129898