Position Paper

# Ubiquitous Networking for Human Containers

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## Vision

Our vision in this context is for pervasive *networking*: networking that is universally available to interconnect devices that come and go in human-occupied spaces.

As more and more humans become counted as parts of urban environments, we find ourselves in a 'containered' world in which we live, work, and play. In these containers there is a unique opportunity to introduce ubiquitous networking through the manipulation of light as the communications medium. This concept was originally an opportunistic approach – as we replace conventional lighting with LEDs for substantial energy savings we would embed free space optical communications; however, we have uncovered many other important reasons to more explicitly exploit 'full-spectrum' light for these contexts. Once light is controllable, any device – sensor, actuator, camera, or mobile – can become a participant in the optical field generated and maintained as part of the container.

## Potential for advances in the field, and impact

Consider the following:

- Most mobile device use is in the home or workplace; yet this is also the location of weakest performance
- Mobile device use is skyrocketing due to the success of smart phones and tablets
- By 2013, predictions show that there will be more wireless devices attached to the internet than conventional computers with keyboards [1]
- Efforts to achieve energy independence, green technology to support the power grid and consumer-side energy management will drive the adoption of millions of new wireless devices interconnected in human occupied indoor spaces for supporting smart grid applications
- Low-power CMOS cameras are now embeddable in most phones and in many sensor networking platforms; the use and interpretation of the visual field is becoming the norm for many sensing applications
- The nature of internet traffic is transforming with the adoption of high-data rate rich media such as HTML 5 and video

The result of these trends is recognition that indoor-spaces will become a first-class destination for, devices, data, and their interconnection to each other and the Internet cloud. We believe initiatives that exploit locality, especially transmission power control, spectrum reuse, and innovative adaptation of cognitive radio will be ideal for these containers, and are pursuing solutions in this set. With such an approach, the wireless channel bottlenecks that exist today, and the opportunity to support a wide range of pervasive devices operating at different energy levels and capability, will be mitigated, supporting a rich new set of use cases and applications.

**Existing work**
Through efforts of the NSF Smart Lighting ERC [4] we are developing technologies that manipulate light for supporting a wide range of human needs. These include (1) synthesizing light for the purpose of capturing and sustaining normal circadian rhythms, (2) developing non-contact sensing systems for migrating biohazards, and (3) modulating light for local network access while balancing lighting color control and energy efficiency requirements [2-3].

This latter work is yielding a prototype "light bulb" capable of streaming data in indoor, short-range applications while simultaneously providing illumination. These devices are capable of high-density channel reuse of the carrier due to the limited crosstalk in spot down-lighting scenarios. We are currently developing this technology to support a femtocell access model used by some carriers to solve the mobile bandwidth crisis. We simultaneously provide illumination, consumer-side energy management control, and address the highly-energy-inefficient installed base of incandescent down-lights (> 800M units installed in the US alone).

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**References**
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3. J. Chau, K. Matarese, and T.D.C. Little, "IP-Enabled LED Lighting Supporting Indoor Mobile and Wireless Communications," Poster and Demo, MobiSys 2010, San Francisco, CA, June 2010.
4. Smartlighting.bu.edu

**Background and experience of the participant**
Thomas Little is a professor of Electrical and Computer Engineering at Boston University where he has been involved in research in multimedia computing, mobile ad hoc computing and networking, sensor networking, and at present, developing pervasive networking technology using lighting as a substrate. He is Associate Director of the NSF Smart Lighting ERC (RPI, UNM, BU). See http://hulk.bu.edu for recent publications.