Prototyping Multi-Transceiver Free-Space-Optical Communication Structures

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Motivation & Challenge

Free Space Optics (FSO) has the potential to deliver wireless communication links at optical level speeds.

Problem: Maintenance of line-of-sight (LOS) between transceivers during an ongoing transmission is an important issue since FSO transmitters are highly directional.

Our Focus & Work :

- By using multiple directional transceivers we can maintain optical wireless links with minimal disruptions that are caused by relative mobility of communicating nodes.
- We present a prototype implementation of such multi-transceiver electronically-steered communication structures which uses a simple LOS detection and establishment protocol and assigns logical data streams to appropriate physical links.

Literature

Previous Work:

- Roof-top deployments in metropolitan area, point-to-point links via powerful lasers [1]
- Indoor mobility with diffuse optics (10s of meters) [2]
- Interconnects in short distances (1-10s cm)
- Using mechanical auto-tracking or beam steering
- Previous work on swaying and vibration of buildings to tolerate disruptions
- Use gimbals, expensive tracking instruments, backup beams
- Mobility is not the main concern – Stationary nodes are assumed

Our Work:

- FSO-MANETs: FSO in the context of *mobility*
- Use FSO by means of "optical antennas" containing multiple FSO transceivers on a spherical structure, as shown in our recent work ([3]) and as illustrated in Figure 1, to achieve spatial reuse and the achievement of electronic steering via simple handshaking protocol.
- Building of a prototype of such a spherical FSO structure with multiple transceivers and show its performance.

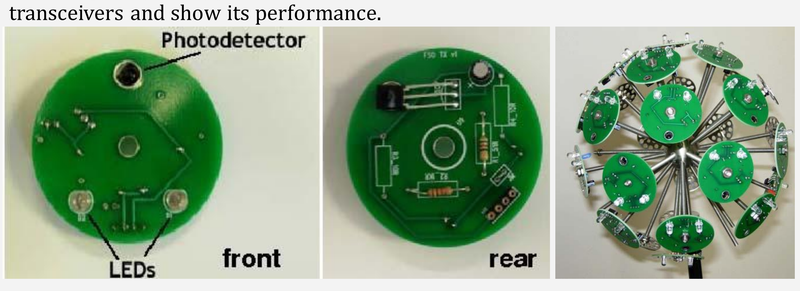

Figure 1: Transceiver circuit front and rear view and 3-D spherical prototype optical antenna

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Methodology and Approach

Introduce basic building blocks for MANETs using multi-element free-space-optical structures and demonstrate a prototype implementation of such multi-transceiver electronically-steered communication structures.

- Maintain optical wireless links with minimal disruptions caused by relative mobility of communicating nodes.
- Investigate reliability protocols as management of logical data streams through multi-interface FSO structures.

LOS Alignment Protocol

- Use a simple line-of-sight (LOS) detection and establishment protocol, dynamically assigning logical data streams to appropriate physical links.
  - A simple three-way handshake messaging method, illustrated in Figure 2, for full assurance of bi-directional alignment.
  - Periodic exchange of small frames between neighbor multi-element FSO nodes in order to identify the transceivers that are in line-of-sight of each other.

Prototype

- Prototype consists of two main parts: Transceiver circuit (Figure 1) and controller circuit (Figure 3).
- Design consists of 3 FSO transceivers connected to a circuit board with a micro-controller, which connects to a laptop computer through RS-232 serial port, and implements the alignment protocol: it routinely probes for new alignments.
- This simple prototype is duplicated for two other laptop computers for the establishment of data flows (file transfer) among the three nodes (i.e. laptops).
- Goal: Test the feasibility of an LOS alignment algorithm, and demonstrate that despite a major change in physical network topology, data phase can be effectively restored upon re-establishment of alignments.

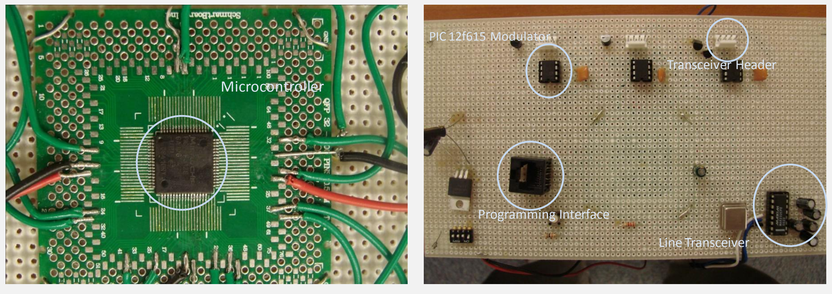

Figure 3: Controller circuit front and rear view

Experimentation

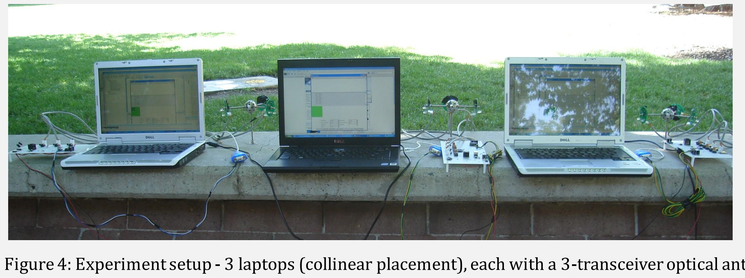

Figure 4: Experiment setup - 3 laptops (collinear placement), each with a 3-transceiver optical antenna.

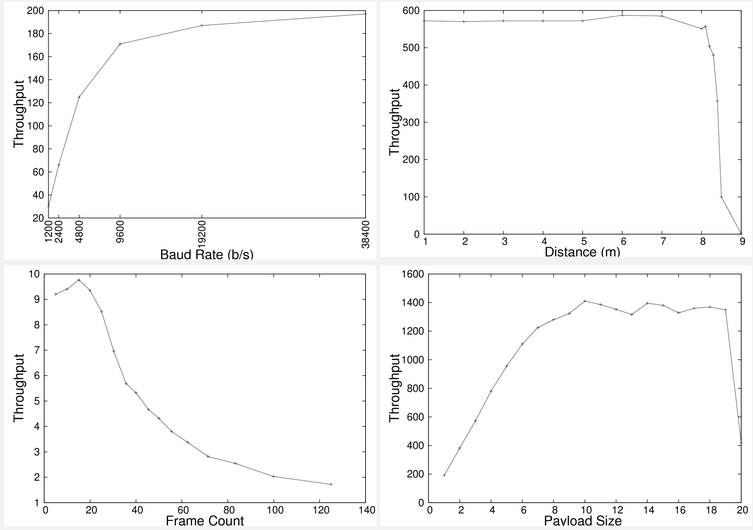

Figure 4: Graphs showing experiment results for various setups

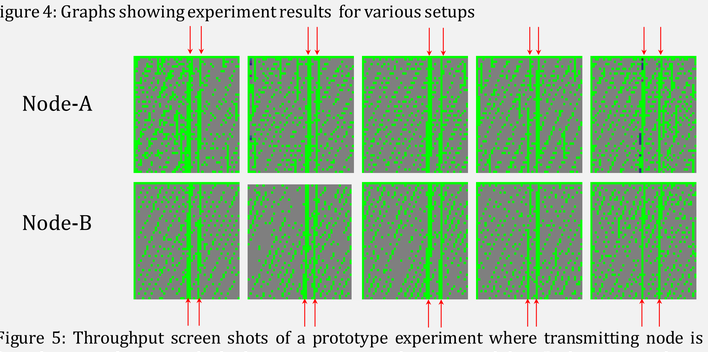

Figure 5: Throughput screen shots of a prototype experiment where transmitting node is mobile. Straight green lines in which the transmitting node gains mobility. Red arrows indicate loss of alignment (and data) due to mobility. Once the mobile node returns to its place, data phase is restored and transmission continues. (Green spots show data loss)

Conclusions

- We demonstrated a prototype of multi-transceiver spherical FSO node which can successfully hand-off multiple data flows between FSO transceivers.
- FSO communication systems can be embroidered with such auto-alignment mechanisms and cross layer buffering schemes in order to overcome the inherent challenges of FSO directionality.

References

[1] V. W. S. Chan, "Optical space communications: a key building block for wide area space networks," *Proceedings of IEEE Lasers and Electro-Optics Society*, pp. 41-42, 1999.

[2] J. Derenick, C. Thorne, and J. Spletzer, "On the deployment of a hybrid fso/rf mobile ad-hoc network," *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems, 2005.*

[3] M. Bilgi and M. Yuksel, "Multi-element free-space-optical spherical structures with intermittent connectivity patterns," *Proceedings of IEEE INFOCOM Student Workshop*, 2008.