A Comparison of FSO and RF Communication in Wireless Sensor Networks

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Abstract

Free space optics (FSO) and radio frequency (RF) have been widely used in wireless communication. In this work, we compare the technologies to provide system designers useful metrics.

1. Introduction

Traditional wireless sensor networks are bound by the provable limits in per-node throughput for radio frequency (RF) based communications. Nowadays, there have been increased interests in the development of sensor nodes that can communicate via free space optics (FSO) [1-4]. FSO refers to the transmission of modulated visible or infrared (IR) beams through the atmosphere to obtain broadband communications. In this work, we provide a comparison work of FSO and RF communication. This comparison can provide useful information for system designers.

2. Comparison of FSO and RF Communication

At lower data rates, RF is excellent at providing coverage due to the scattering and the diffraction of the radio waves, and the sensitivity of the receivers that can be constructed. Channels are robust to being blocked by obstacles. However, higher data rates require higher frequencies. At these frequencies, the radio signal propagation becomes line of sight, and problems become similar to that of using light. Components operating at these frequencies are expensive, and the advantages of radio (coverage, and receiver sensitivity) become less clear.

As an alternative to the radio frequency (RF) technology, free-space optical (FSO) communication emerged as a promising candidate providing broadband, flexible, secure and low-cost communication links between stationary platforms. Applications using FSO have proved its merits [5],[9-12]. The comparison is provided in Table I.

Table I A Comparison of FSO and RF Communication

Parameters	Radio-Frequency	Optical Communication
Spectrum	2 to 6 GHz	0.8 to 1.5 THz range (IR band)
Capacity	11, 54Mbps, 100Mbps,	Up to 10 Gbps, 160Gbps (lab)
Bandwidth	10 – 12 Mbps	200THz (700-1500nm)
Range	20m - 4km	20m – 1.2km
Output Power	5.15-5.25 MHz 50mW; 5.25-5.35 MHz 250mW; 5.725-5.825 MHz 1W.	650nm 5-500mW; 880nm 2.5-500mW; 1310nm 45-500mW; 1550nm 50-500mW
Power Consumption [6],[7],	2.31E-02 (J/Mb)	2.00E-03 (J/Mb)
Power Loss [8]	2.4 GHz 100dB/km; 915 MHz 92dB/km; 5.7 GHz 108dB/km.	Clear 5-15dB/Km; Rain 20-50dB/Km; Snow 50-150dB/Km; Fog 50-300 dB/Km
Security	Low	High

Perhaps the greatest advantage of FSO technology is its high throughput. The need for such a channel is evident when considering bandwidth hungry applications. Terabit per second throughputs have been demonstrated under laboratory conditions. In contrast, widespread RF technologies (e.g. 802.11x) are limited to link throughputs on the order of 10s of Mbps across distances of 10s of meters. Besides, the deployment of an FSO link avoids the stringent restrictions on the usage of the limited bandwidth in RF networks. It also avoids interference with existing RF communications infrastructure and is cheaply deployed since no government licensing of scarce spectrum is required.

The main limitation of FSO is the requirement that a direct line-of-sight path exists between a sender and a receiver (e.g. flying objects such as birds may block the transmission). Another main problem of FSO is that the availability of services is weather sensitive (e.g. heavy rain, fog, snow or strong wind).

There are also some other constraints: eye safety limitation (IEC60825-1,Amendment 2), SNR varies significantly with the distance and ambient noise, accurate alignment of transmitter-receiver necessary, etc. However, researchers have been working to enhance its performance in various ways, e.g. with multibeam architectures, larger power margins, backup systems, etc.

3. Conclusion

Free Space Optics is being increasingly considered as an attractive option for the rapid provisioning of multi-gigabit per second links. In our work, we provide a comparison between FSO and RF technologies. The main contribution is to provide useful metrics for system designers. The metrics can be adopted as a method for quantitatively defining system performance.

Reference

[1] J. M. Kahn, R. H. Katz, and K. S. J. Pister, "Next century challenges: Mobile networking for "smart dust"", in Proc. ACM/IEEE International Conference on Mobile Computing and Networking, Seattle, Washington, August 15-19, 1999, pp. 271–278.

[2] B. A. Warneke, M. D. Scott, B. S. Leibowitz, L. Zhou, C. L. Bellew, J. A. Chediak, J. M. Kahn, B. E. Boser, and K. S. J. Pister, "An autonomous 16mm3 solar-powered node for distributed wireless sensor networks," in Proc. IEEE Sensors, Orlando, Florida, January 2002, pp. 1510–1515.

[3] W. Mao and J. M. Kahn, "Free-space heterochronous imaging reception of multiple optical signals," IEEE Transactions on Communications, vol. 52, no. 2, pp. 269–279, February 2004.

[4] J. Llorca, A. Desai, U. Vishkin, C. Davis, and S. Milner, "Reconfigurable optical wireless sensor networks," in Proc. SPIE vol. 5237, Optics in Atmospheric Propagation and Adaptive Systems VI, J. D. Gonglewski and K. Stein, Eds., Barcelona, Spain, February 2004, pp. 136–146.

[5] "A Fiber-optic Powered Wireless Sensor Module Made on Elastomeric substrate for Wearable Sensors", the 26th Annual International Conference of the IEEE EMBS,2004

[6] D-Link Corporation, "DLINK 802.11(g) PCMIA card," www.dlink.com, 2005

[7] FreeScale Corporation, "XS110 UWB datasheet," www.freescale.com, 2005

[8] Cambridge Silicon Radio, "CSR Bluecore2 datasheet," www.csr.com, 2005

[9] "Optical wireless communication in distributed sensor networks", The International Society for Optical Engineering

[10] Dominic O'Brien, "optical wireless communications challenges and prospects", University of Oxford.

[11] "Urban Optical Wireless Communication Networks" IEEE Communication Magazine, February 2003

[12] Brian J. d'Auriol and Tanushree Ghosh, "A Systems Model for Computation, Communication, Command and Control (C4) in a Spacecraft or Satellite Cluster", Proceedings of The International Conference on Parallel and Distributed Computing, Applications and Technologies (PDCAT) 2006, December 4-7, 2006, Taipei, Taiwan, pp. 285-290, IEEE Computer Societ