Synergies of Radio Frequency and Free Space Optics Communication: New Hybrid Solutions for Next Generation Wireless Mesh Networks

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Abstract

In this article, we describe the limitations of radio frequency (RF) and Free Space Optics (FSO) technologies, and show that a hybrid approach that uses both communication media in a suitably coordinated manner is capable of addressing the shortcomings of each. The nature of the required coordination between RF and FSO communication technologies, and the merits derived thereof, are the subject of our research. We report on an initial hardware implementation of a prototype Hybrid RF/FSO node. The properties of the node are used to inform the development of an Integer Linear Programming (ILP) model for this coordination process in RF/FSO networks. We show that by making suitable choices of beam-widths and power levels, the proposed model can be used to design robust hybrid RF/FSO communication infrastructures that minimize power consumption, while satisfying specified joint throughput and end-to-end delay requirements.

Keywords: Hybrid RF/FSO, Wireless Optical, RF, FSO, Topology Control, QoS, Linear Programming.

1. INTRODUCTION

Over the past years, the fields of computer and telecommunication networks have experienced tremendous growth, as many new communication technologies have been developed to help address scalability challenges, arising from requirements in the face of widespread adoption. These requirements include: higher bandwidth, security and privacy guarantees, low end to end delay and responsiveness, high network connectivity and coverage, etc.

In the history of the intellectual development of ideas, there is frequent academic bias towards “pure solutions”—in this case, communication systems that use just one core communication technology. Unfortunately, no single communication technology has been found, to date, which can satisfy all these requirements. For instance, in ad-hoc networks, researchers recently started

[40] S.D. Milner, C.C. Davis, "Hybrid free space optical/RF networks for tactical operations," Military Communications Conference(MILCOM), 2004.
[41] V. Vishnevskiy, O. Semenova, "Queueing System with Alternating Service Rates for Free Space Optics-Radio Hybrid Channel.", MACOM 2010: 79-90
[42] W. K. Seah, Z. A. Eu, and H.-P. Tan, "Wireless sensor networks powered by ambient energy harvesting (WSN-HEAP) – survey and challenges," in Proc. VITAE '09, May 2009.
[43] H. Willebrand, B. S. Ghuman, "Free space optics: enabling optical connectivity in today's networks", Sams Publishing, 2002.
[44] R. Ramirez-Iniguez, S. M. Idrus, Z. Sun, "Optical wireless communications: IR for wireless connectivity", CRC Press, 2008, 143:167
[45] A. Umar, "Mobile Computing and Wireless Communications", nge solutions. inc, 2004
[46] L. Dordova, O. Wilfert, "Free space optical link range determination on the basis of meteorological visibility", Radioelektronika, April 22, 2009.
[47] I. Djordjevic, W. Ryan, B. Vasic, "Coding for Optical Channels", Springer, 2010, p. 84:121.
[48] J. Hecht, "Understanding Fiber Optics", National Instruments, Sep 6, 2006.
[49] B. Wang, G. Yan, C. Yan, "Fiber length and chromatic dispersion measurement technology using a novel optical frequency domain reflectometry", OSA-IEEE-COS, 2010.
[50] A.M. Fraine, R. Egorov, D.S. Simon, O.V. Minaeva, A.V. Sergienko, "High resolution measurement of polarization mode dispersion with quantum interferometry", Photonics Society Summer Topical Meeting Series, IEEE, 2011.
[51] I.B. Djordjevic, L.L. Minkov, X. Lei, T. Wang, "Suppression of Fiber Nonlinearities and PMD in Coded-Modulation Schemes With Coherent Detection by Using Turbo Equalization", Optical Communications and Networking, IEEE/OSA Journal, November 2009.
[52] D.L. Polla, M.B. Wolfson, "RF MEMS integration present & future trends", Radio-Frequency Integration Technology, RFIT, 2009.