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Quality of Service Implementation for Free Space Optics Communications

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Contents

Introduction 1
Background 1
Description and Operation 1
Summary 3
References 3

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Quality of Service Implementation for Free Space Optics Communications

Introduction

Free Space Optics (FSO) enables networking between nodes without direct physical connection through transmission of light signals propagating in free space. Despite its benign connotation, the free space medium (air, space, etc.) imparts a number of distortions, including static and dynamic attenuation to the optical signal. As a consequence, FSO systems must possess adequate link budget margin to operate during periods of increased attenuation to prevent partial or even complete degradation of the network. Concomitantly, some software applications have QoS requirements for proper operation. Other applications contain heartbeat or ping messages which require exchange and receipt at regular intervals. FSO systems with QoS capabilities would enable these applications to function with improved performance on FSO links. The memorandum introduces a process for improving the resiliency of critical networking packets, marked by a Quality of Service (QoS) metric, over an FSO link.

Background

For an FSO system, the link margin M_{link} is given by [1]

$$M_{link}[dB] = P_{RX,dBm} - S_r - A$$

Above $P_{RX,dBm}$ is the signal power received, S_r is the receiver sensitivity and A are losses associated with the medium.

For optical receivers limited by shot noise the sensitivity S_r is inversely proportional to the bandwidth BW [2]

$$S_r \propto \frac{1}{BW}$$

For a given system, link geometry and propagation medium, higher bandwidths require greater link margins to achieve the same performance. Conversely, lower bandwidths effectively increase the link margin, given equivalent link parameters. The QoS implementation presented here utilizes lower bandwidths for network packets with high QoS values which yields a greater link margin and increased resiliency against variations in the free space medium.

Description and Operation

The figure below shows a block diagram of an exemplar FSO Link with elements specific to the QoS implementation shown in red. The table below defines the components shown in the block diagram.

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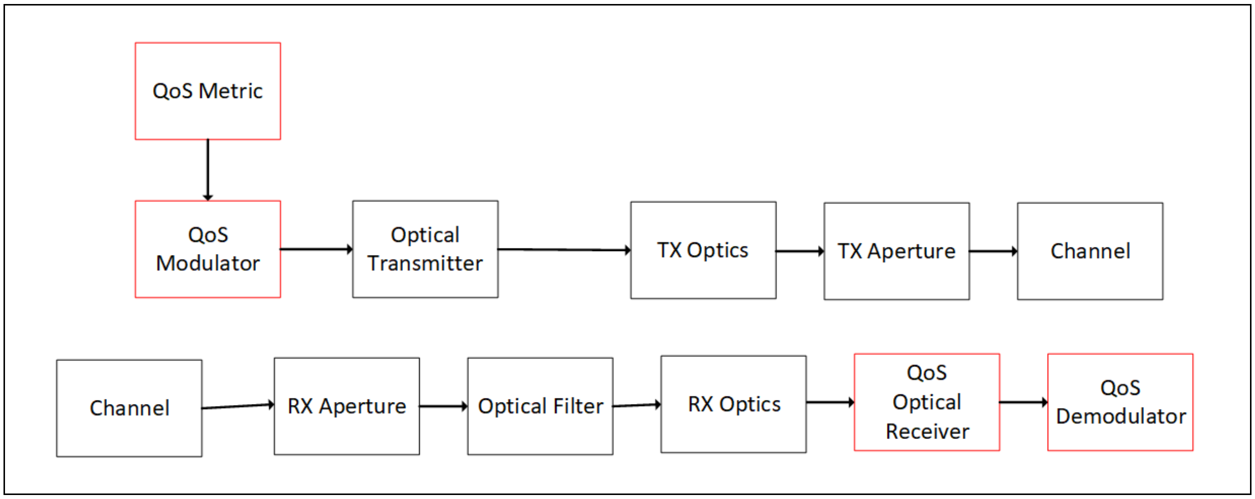

Figure 1 –QoS FSO System Block Diagram

Component	Description
QoS Metric	Numerical value representing QoS of an individual packet converted to a digital word
QoS Modulator	Develops the modulated representation of the data source. The bandwidth of the modulated representation is set by the QoS metric
Optical Transmitter	Amplifies optical source (commonly an EDFA)
TX Optics	Steers optical beam (commonly a FSM)
TX Aperture	Couples transmitter to channel (lenses for OTA applications)
Channel	Media between TX and RX subsystems (atmosphere for OTA applications)
RX Aperture	Couples channel to receiver (lenses for OTA applications)
Optical Filter	Spectral limiting filter
RX Optics	Steers optical beam (commonly a FSM)
QoS Optical Receiver	Develops intermediate frequency (IF), or baseband digital signal from optical signal accounting for variations in bandwidth due to QoS metric
QoS Demodulator	Recovers data source from the signal accounting for variations in bandwidth due to QoS metric

Table 1 – QoS FSO Component Descriptions

The concept of operation is now presented. The application generating the data source assigns a QoS value to each data packet. The QoS value may reside internally to the packet structure, e.g. an additional digital word, or externally, e.g. socket or port number. The FSO system converts this value to a QoS metric based on the capability of the system to synthesize transmit signals of varying bandwidths. The QoS modulator synthesizes a waveform with bandwidth selected by the QoS metric. This implementation may take the form of time-division multiplexing either at the intra- or inter-packet level; there are fixed time intervals arranged between the transmit and receive FSO systems for specific waveform bandwidths. The transmit and receive process continues in a typical fashion until the signal reaches the QoS optical receiver followed by the QoS demodulator. Here the bandwidth set by the QoS metric is accounted for in either the analog or digital domain using standard engineering practices. Recovery of the original data source follows standard implementations.

Summary

This memorandum introduced a process for implementing QoS in an FSO network. FSO systems with QoS capabilities enable these applications to function with improved performance on FSO links.

References

[1] O. W. H. Henniger, "An introduction to free-space optical communications," *Radioengineering,* vol. 19, no. 2, pp. 203-212, 2010.

[2] M. &. J. G. &. P. S. &. S. S. Leong, "Receiver Sensitivity in Optical and Microwave, Heterodyne and Homodyne Systems," *Journal of Optical Communications,* vol. 35, 2014.