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Revelation of Finest Communication using Adaptive Power Control for Free-Space-Optical MANET Structure Blocks

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Abstract

Free Space Optics (FSO) has become a viable administration, high-bandwidth communication wireless alternative to fiber optic cabling. The primary scalable advantages of FSO over fiber are its rapid deployment time and significant cost savings. Today's information transformation approaches have economy depends on the transmission of data, voice and multimedia across telecommunication networks through all direction protocol. The global telecommunication network has seen massive switching expansion over the last few years. First came over the tremendous growth of the long haul wide area network (WAN), followed by high frequency signals in metropolitan area networks (MANs). Despite new technologies optical networks are the most ideal medium foe high bandwidth communications. It comprehensive solution of represents one of the most promising approaches for addressing the emerging broadband access market. It unlimited offers cum many features of accessing technology, principal among them being low start up and operational low costs technique, rapid deployment and high fiber link bandwidth architecture. FSO is primarily throughput deployed where high performance, high security level, rapid deployment, and cost-savings are critical issues mainly focused

Keywords:*Fiber, Multimedia, Networks, Telecommunication, Optical*

1. Introduction

Free Space Optics (FSO) is gaining market acceptance as a functional, wireless, high-bandwidth access tool. Fiber-optic cabling is still the preferred media for long haul, high-bandwidth transport. However, because of FSO's lower cost and significantly shorter installation time, FSO is now considered a viable option to fiber for short-haul access distances of 4 km or less. As the awareness of FSO technology increases, and as the installation base of FSO links increases, FSO is overcoming the early market barriers that faced this new access [1] technology. Free Space Optics (FSO), also known as Optical Wireless or Laser-com (i.e. Laser Communications), is a re-emerging technology using modulated optical beams to establish short, medium or long reach wireless data transmission. Most of the attention on FSO communication systems it was initially boost by military purposes and first development of this technology was dedicated to the solution of issues related to defense applications.

Our current "age of technology" is the result of many brilliant inventions and discoveries, but it is our ability to transmit information, and the media we use to do it, that is perhaps most responsible for its evolution. Despite new technologies, optical network remains the most ideal medium for high bandwidth communications for true connectivity [2]. There are two distinct types of optical communications: fiber optics and optical wireless systems based on free space optics technology. Free space optical communications is a line-of-sight (LOS) technology that transmits a modulated beam of visible or infrared light through the atmosphere for broadband communications.

2. System Model

Free space optics or optical wireless is a telecommunication technology that uses light propagating in free space to transmit data between two points. It is a line of sight broadband communication technology that uses optical pulse modulated signals to wirelessly transmit data. Instead of the pulses of light being contained within a glass fiber, they are transmitted in a narrow beam through the atmosphere.

Free space optics technology is wireless networking that uses light beams instead of radio waves; it's laser-based optical networking without the fiber optic It's based on connectivity between FSO-based optical wireless units, each consisting of an optical transceiver with a transmitter and a receiver to provide full duplex (bi-directional) capability. Figure.1 each optical wireless unit uses an optical source, plus a lens or telescope that transmits light through the atmosphere to another lens receiving the information. At this point, the receiving lens or telescope connects to a high-sensitivity receiver via optical fiber. A free-space optical link consists of 2 optical transceivers accurately aligned to each other with a clear line-of-sight.

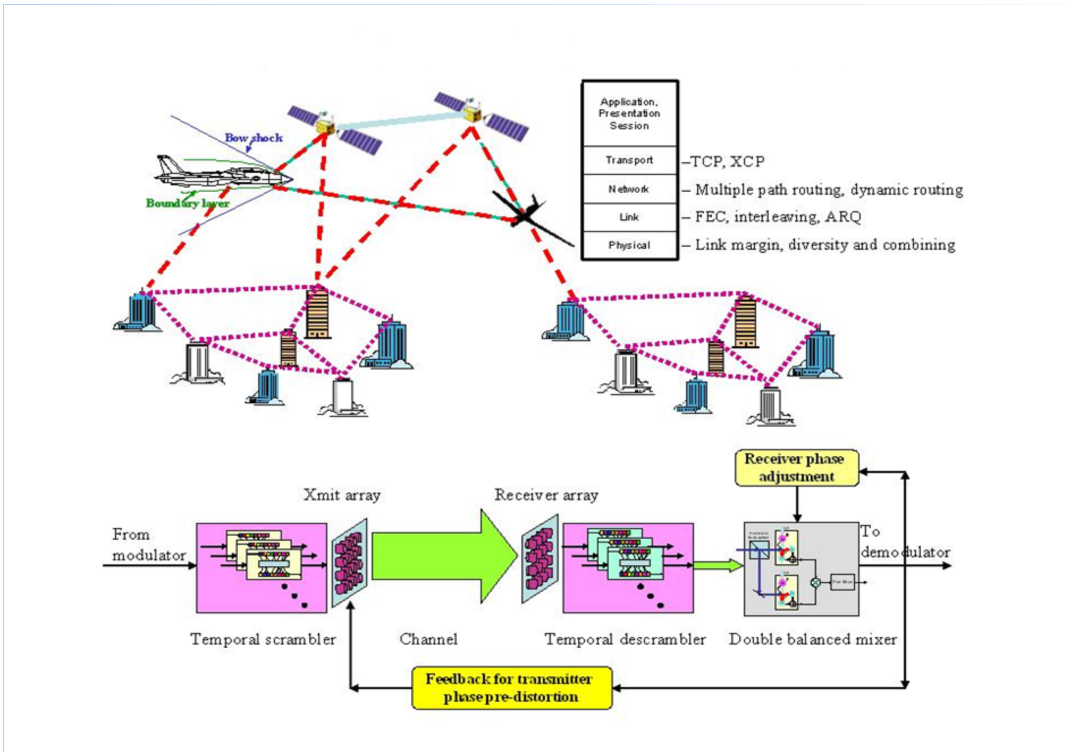

Figure 1. Free-Space-Optics Architecture

Typically, the optical transceivers are mounted on building rooftops or behind windows. These transceivers consist of a laser transmitter and a detector to provide full duplex capability. It works over distances of several hundred meters to a few kilometers.

2.1Optical propagation through fog

FSO systems run in the infrared (IR) spectrum, which is at the low end of the light spectrum. Specifically, the optical signal is in the range of 1 THz in terms of frequency. At this frequency, the signal involves a wavelength, in the range of μ (microns), with a micron being 1/1,000,000 meter. Contemporary systems now run signals in the far end of the infrared range, with wavelengths in the 780-850 nm range, and even the 1550 nm range. Laser beams at 800nm wavelength are near infrared and therefore invisible. The collimated light beam entering the eye in this wavelength region is concentrated by the factor of 100,000 times when strikes the retina. Because retina has no pain sensors, at 800nm the retina could be permanently damaged. But the laser beams at 1550nm wavelength are absorbed by the cornea and the lens and do not focus on the retina.

The better choice is to use wavelengths near 1550nm because the Eye safety regulations permit 50 times more transmitted power at 1550nm than 800nm.The higher allowable power is a significant advantage of the 1550nm wavelength, but a number of other performance related factors affects this wavelength trade. The most significant challenge facing FSO is posed by atmospheric attenuation, particularly fog.

The wavelength dependence of Mie scattering is highly sensitive to the specific nature of fog droplets. Mie scattering generally results in reduced attenuation at longer wavelengths.The transverse distribution intensity remains Gaussian at every point in the system; only the radius of the Gaussianand the radius of curvature of the wavefront change. Imagine that we somehow create a coherent light beam with a Gaussian distribution and a plane wavefront at a position x=0. The beam size and wavefront curvature will then vary with x as shown in Figure 2.

For propagation distances less than a few kilometers, variations of the log-amplitude are typically much smaller than variations of the phase. Over longer propagation distances, where turbulence becomes more severe, the variation of the log-amplitude can become comparable to that of the phase. Based on the atmosphere turbulence model adopted here and assuming weak turbulence,

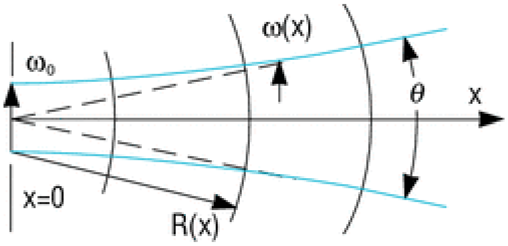

Figure 2. Wave front radius

The beam size will increase, slowly at first, then faster, eventually increasing proportionally to x. The wavefront radius of curvature, which was infinite at x = 0, will become finite and initially decrease with x. At some point it will reach a minimum value, then increase with larger x, eventually becoming proportional to x. The equations describing the Gaussian beam radius ω(x) and wavefront radius of curvature R(x) are:

$$\omega^2(x) = \omega_0^2\left[1+\left(\frac{\lambda x}{\pi\omega_0^2}\right)^2\right] \qquad (1)$$

$$R(x) = x\left[1+\left(\frac{\pi\omega_0^2}{\lambda x}\right)^2\right] \qquad (2)$$

where ω_0 is the beam radius at x = 0 and λ is the wavelength. The entire beam behavior is specified by these two parameters, and because they occur in the same combination in both equations, they are often merged into a single parameter, x_R, the Rayleigh range:

$$x_R = \frac{\pi\omega_0^2}{\lambda} \qquad (3)$$

In fact, it is at $x = x_R$ that R has its minimum value.

The downconverted heterodyne or homodyne power is maximized when the spatial field of the received signal matches that of the local oscillator. Any mismatch of the amplitudes and phases of the two fields will result in a loss in downconverted power. Phase-compensated receivers offer the potential for overcoming atmospheric limitations by adaptive[3] tracking of the beam wave-front and correction of atmospherically induced aberrations.The throughput of a transmission system can be increased by increasing the symbol rate,thus increasing the bandwidth utilized, or by increasing spectral efficiency. In many applications, bandwidth is constrained, and it is desirable to maximize spectral efficiency. Binary modulation encodes one bit per symbol, while non-binary modulation encodes more than one bit per symbol, leading to higher spectral efficiency.

In this study, we compare the spectral efficiencies and power efficiencies of several modulation formats using coherent detection in the presence of multiplicative noise (fading) from atmospheric turbulence and additive white Gaussian noise (AWGN). We assume that at the receiver, the dominant noise source is shot noise from the local oscillator laser, which can be modeled accurately as AWGN that is statistically independent of the turbulence fading.

We have numerically evaluated the performance of adaptive field conjugation array receivers in coherent laser communications through the turbulent atmosphere. We analyzed coherent fiber arrays consisting of densely packed multiple subapertures in a hexagonal arrangement, considering the effects of log-normal amplitude fluctuations and Gaussian phase fluctuations, in addition to local oscillator shot noise.

3. SPATIAL DIVERSITY RECEPTION

Spatial diversity reception, which has been well-studied for application at radio and microwave frequencies, has the potential to mitigate the degradation caused by atmospheric turbulence. Spatial diversity reception in free-space optical communication has been proposed and studied in the performance of spatial-diversity optical reception on turbulence channels, assuming that turbulence-induced fading is uncorrelated at each of the optical receivers. We consider two types of receive diversity combining. First we assume the receiver has knowledge of theinstantaneous channel state, making perfect maximal ratio combining (MRC) diversity possible. In this diversityscheme, the receiver co-phases the intermediate signals, adjusts their amplitudes separately, and sums them to obtaina composite signal with improved SNR. The rate at which phase and amplitude must be adjusted will be dictated bythe rate at which the atmospheric turbulence fluctuates, generally no higher than 1 kHz.

The MRC receiver is theoptimal combining technique in that it yields a carrier with the highest mean SNR and lowest SNR fading. Theoptimum electronic gain for each receiver should be proportional to the received signal field amplitude. Note thatwhen the electronic gains and phase delays are back-propagated into the LO, the optimum gain and phaseadjustments would result in an amplitude and phase match of this synthetic LO field to the distorted signal field.

$$
\begin{aligned}
V_{22}^{(2)}(u|z) = {} & \tfrac{1}{32}\left[k_{22}^{+(2)}(u)k_{22}^{-(0)}(u) + k_{22}^{+(0)}(u)k_{22}^{-(2)}(u)\right] + \tfrac{1}{16}k_{22}^{+(1)}(u)k_{22}^{-(1)}(u) \\
& + \sum_{a<b}\left(\frac{1-2W_a}{\sinh(2u-2z_a)}\right)\overset{s}{\otimes}\left(\frac{1-2W_b}{\sinh(2u-2z_b)}\right) + \frac{1}{8}\sum_{a=1}^{N}\frac{1-4H_a^2}{\cosh(u-z_a)^2} \\
& + \sum_{a<b}\left(\frac{e^{-u+z_a}W_a^+ + e^{u-z_a}V_a^+}{\sinh(2u-2z_a)}\right)\overset{s}{\otimes}\left(\frac{e^{u-z_b}W_b^- - e^{-u+z_b}V_b^-}{\sinh(2u-2z_b)}\right) \\
& + \sum_{a<b}\left(\frac{e^{u-z_a}W_a^- + e^{-u+z_a}V_a^-}{\sinh(2u-2z_a)}\right)\overset{s}{\otimes}\left(\frac{-e^{-u+z_b}W_b^+ + e^{u-z_b}V_b^+}{\sinh(2u-2z_b)}\right) \\
& + \frac{1}{2}\sum_{a}\sum_{b}\left(\frac{1-2W_a}{\sinh(2u-2z_a)}\right)\overset{s}{\otimes}\left(\frac{1-2W_b}{\sinh(2u+2z_b)}\right) \\
& + \frac{1}{2}k_{22}^{+(0)}(u)k_{11}^{-(0)}(u)\sum_{a}\sum_{b}\left(\frac{e^{-u+z_a}W_a^+ + e^{u-z_a}V_a^+}{\sinh(2u-2z_a)}\right) \\
& \overset{s}{\otimes}\left(\frac{e^{-u-z_b}W_b^- - e^{u+z_b}V_b^-}{\sinh(2u+2z_b)}\right) \\
& + \frac{1}{2}k_{22}^{+(0)}(u)k_{33}^{-(0)}(u)\sum_{a}\sum_{b}\left(\frac{e^{u-z_a}W_a^- + e^{-u+z_a}V_a^-}{\sinh(2u-2z_a)}\right) \\
& \overset{s}{\otimes}\left(\frac{-e^{u+z_b}W_b^+ + e^{-u-z_b}V_b^+}{\sinh(2u+2z_b)}\right) \\
& + (a \leftrightarrow b,\ z_a \leftrightarrow -z_b),
\end{aligned}
$$

In order for this assumption to hold true, the spacing between receivers should exceed the fading correlation length in the plane of the receivers. It may be difficult to satisfy this assumption in practice, for various reasons. Available space may not permit sufficient receiver spacing. In power-limited links, which often employ well-collimated beams, the receiver spacing required for uncorrelated fading may exceed the beam diameter.

Free Space Optics (FSO) is widely regarded as the next-generation high-speed wireless communication technology. FSO has demonstrated its capability to deliver data faster than any other state-of-the-art wireless communication technology. Today, terrestrial FSO links are able to reach 150 kilometers; multiplexed data rates of 2.5Gbps have been achieved; Acquisition, Pointing, and Tracking (APT) systems have been successfully deployed between communication satellites; and carrier-class availability are being offered by FSO vendors. However, FSO has not seen widespread use in the military.

This is attributed to the fact that military platforms are largely mobile, while the progress in the commercial arena has largely been confined to links between fixed sites.This thesis analyzes the features of FSO technology while being mindful of how these apply to the military. These features include the bandwidth, spectrum use, bit errorrates, communications security, free-space loss, and power consumption. The limitationsand challenges presented by atmospheric effects, directional precision, line-of-sightobstructions, and laser safety are also studied. A final section will look at the acquisition,pointing, and tracking mechanisms that are necessary for deploying FSO on mobileplatforms.

4. Performance Analysis

4.1. Leveraging FSO Technology

Lasers operate in the infrared, visible and ultraviolet regions of theelectromagnetic spectrum, from one millimeter down to 100 nanometers in wavelength.Typically, lasers are described by their wavelength as contrasted with radar systems thatare characterized by frequency, because the laser’s frequency is 10,000 to 1,000,000times higher than typical microwave radars. Both microns (mm or 10-6 meters) ornanometers (nm or 10-9meters) will be used in this study to characterize lasers. Incontrast, radar systems usually have wavelengths on the order of millimeters tocentimeters. This chapter explores the inherent benefits of using lasers forcommunication.

4.2. Bandwidth

Military operations demand secure, relevant, and timely information. For thisreason, information superiority on the battlefield is one of the first objectives. Largevolumes of Intelligence, Surveillance, and Reconnaissance (ISR) imagery and video areincreasingly being sent from sensors to shooters. Faster data links are needed for faster
response timelines. Also, new missions may be enabled, like the sending of video insteadof still imagery, or the sending of higher quality imagery and video. With faster links, allof this can be achieved while still meeting the required response times. FSO systemsoperate at significantly higher frequencies than the other RF systems of today. Therefore,they have the potential of reducing the timeline for delivering information. This sectionlooks at the implications of operating in the EMR bands used for FSO.

4.3. Higher Frequencies

A signal of higher frequency can potentially send data at a higher rate. If thedistortion and attenuation effects of the atmosphere are non-existent, then the data ratetheoretically possible from an electro-magnetic radiation (EMR) wave is directlyproportional to its frequency (called the carrier). Of course, suitable modulation schemes 8need developing to take advantage of this carrier frequency. It gives an indicativerange of frequencies for the different EMR bands. The radio and microwave bands are widely used today for wirelesscommunication. Above the frequency of 3

Terahertz (3.0 ´ 1012 Hz) starts the infraredband. Visible light takes up a small range of frequencies above infrared (2.0´ 1014 to 4.3´1014 Hz) while ultraviolet radiation has the highest frequencies of the opticalwavelengths (7.5 ´ 1014 to 6.0 ´ 1016 Hz).Many of the FSO systems available today operate in the near infrared band, whichhas a frequency range on the order of magnitude of 1014 Hz.

Comparing this withmicrowave frequencies (magnitude of 109 to 1012 Hz), FSO systems in the near infraredband can potentially provide a 100 to 100,000 times higher data rate than the microwave 9radios we have today. Of course, this depends on the type of modulation used (i.e. howthe carrier is changed or varied so that it becomes an information-bearing signal).LightPointe's [6] FlightApex is one of the highest bandwidthcommercially available FSO products today. It uses lasers at a frequency of almost 200Terahertz (2 ´ 1014 Hz) to achieve full-duplex speeds of 2.5 Gbps for distances of up to1km.LightPointe's FlightApex Linkhead.

The Lawrence Livermore National Laboratory has demonstrated an FSO link ofthe same data (2.5 Gbps) over a distance of 28 km. With the help of wavelength divisionmultiplexing (WDM), the LLNL had previously managed to scale the capacity of an FSOlink to 20 Gbps between buildings.

5. Effect of Atmospheric Turbulence

In this section we study the influence of atmospheric turbulence on the acquisition process and show howto modify the optimization procedure to take account of turbulence. Turbulence leads to random fluctuationsof the refractive index, which can cause spreading of the beam beyond that caused by diffraction,wander of the beam centroid, change of angle of arrival, and fluctuations in the irradiance of the receivedbeam. In principle, all of these can affect the acquisition process. In short-range links that use mill radianbeam widths, when atmospheric turbulence is not strong, beam spreading, beam wander, and change of angle ofarrival are not significant.

For example, assuming moderate turbulence with refractive-index structureparameter C_{n2} _ 10_{15}, 1.55-_m wavelength, and 3-km link distance, we can apply the Rytov approximationin analyzing beam propagation.We find that in the presence of turbulence the long-term beam radius is enlarged by only 10_4 _i.e., by a factor 1 _ 10_4_ and that the standard deviation of the beamangular displacement is 0.01 mrad, which is negligible compared with the beam divergence of 1 mrad. Thechange of angle of arrival is even smaller, and its standard deviation is several orders of magnitude smallerthan the receiver's bearing resolution. The effect of turbulence-induced irradiance fluctuationson the detection process warrants further attention. We first consider the reception of the IVcode, as this determines the beam divergence.

Now we can determine the minimum allowable value of _SNR_ based on the required bit-error probability P_b. We find that the minimum allowable _SNR_, stillreferred to as SNR$_2$, must be increased by approximately 10 dB to achieve the required value of P_b.Once we determine SNR$_2$, the rest of the optimization procedure will be exactly as described previously, andThe divergence in the *x* direction has been reduced to increase the received light intensity, allowing the requiredvalue of $P_b$to be achieved in the presence of turbulence.

As a result of this change, the scan timefor the double-looped scan is increased from 18 to approximately 57 ms.We now consider reception of the all-1 code. The value of P_{FA} is unaffected by turbulence, but turbulencedoes affect computation of P_{MD}. We can estimate the correlation length of turbulence intensity fluctuations to be d_0 __*d* _68 mm. The component of the relative velocity between the air mass and the beam path that lies perpendicularto the beam path, denoted by $v_{\_}$, can range from several tens to several hundreds of metersper second. We can estimate the correlation time of Figure 3 turbulence intensity fluctuations$_{16}$ as _$_0$ d_0_$v_{\wedge}$.We conclude that _$_0$ lies between approximately 100 and 1 ms.

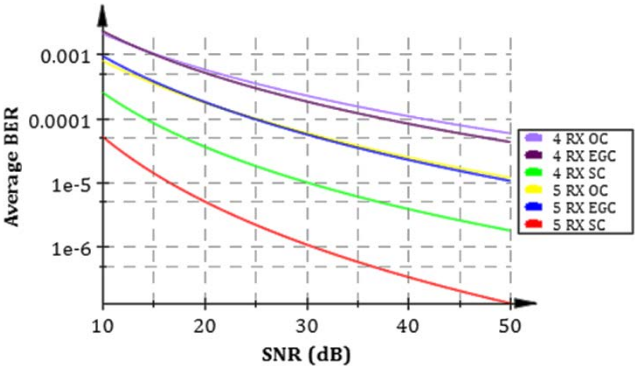

Figure 3. Bit rate analysis

During reception of the all-1 code, thebeam flashes over the recipient for a duration of approximately 1 _s, which is much shorter than _$_0$.Finally, summing the times required for the standard raster scan and the double-looped scan, we find the total acquisition time in the presence of turbulence to be approximately 164 ms, a 70% increase from the 96 ms in the absence of turbulence. In the above, we have considered only the case of moderate turbulence and weak fluctuations.

In the case of strong turbulence, the log-normal distribution must be modified, e.g., to the gamma–gamma distribution. Other than replacement of the distribution, the analysis remains identical to that given above. Aside from simply decreasing the beam divergence to increase the received intensity, other techniquescan be used to combat turbulence, including adaptive optics, diversity reception, and various detectiontechniques.16 If any of these approaches is taken, the only portion of the optimization procedure that mustbe modified is calculation of the minimum average SNR required to achieve the required probabilities ofFA and MD. Once the SNR requirement is determined, the rest of the optimization procedure remains as described above.

6. Result Analysis with Discussion

Rethinking Metrics of Good ness, Traditional metrics suchas bisection bandwidth and diameter largely reflect a static.We also tried other baseline loads. FSO outperforms other solutions under all scenarios, but the relative gain decreases at higher load as there is less scope for improvement. Perspective of the topology For the types of flexible networks we envision, we need to rethink these metrics; e.g., we need a notion of dynamic bisection bandwidth based on the best achievable bandwidth by some realizable topologyfor a given network partition.

Optimal Topologies, Given new dynamic performance indices,we need to reason about the pre-configured alignmentof SMs that optimizes these metrics. While the random andextended hypercube designs work well, we do not know ifthese are provably (near-) optimal. Furthermore, choosingan optimal run-time topology is effectively an online optimizationproblem—given a pre-configured topology, currentconfiguration and traffic patterns, what is the best way to reconfigurethe network? What makes this challenging is thateven the offline version of this problem is intractable.

FSOs for Modularized Data centers,while our currentwork focuses on the inter-rack fabric, FSOs might also beuseful for containerized architectures. This context introducesnew challenges and opportunities. Specifically, aceiling mirror is not feasible in outdoor scenarios and weneed other mechanisms for line-of-sight. At the same time, the coarser aggregation maypermit higher switching latencies and thus be amenable toslower (mechanical) steering mechanisms that can providefull re-configurability.

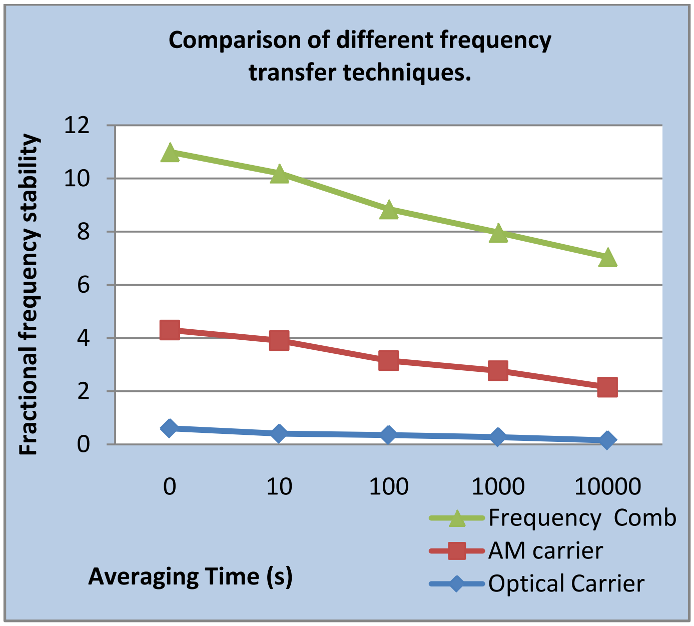

Figure: Comparison of different frequency transfer techniques.

Multipath and Traffic Engineering, We could further improvethe performance using multi-path TCP or bettertraffic engineering. We posit that multi-path TCP hasnatural synergies with re-configurability as it can alleviatetransient congestion and connectivity issues.Other Benefits, In addition to the quantitative benefits weexplored, FSO-based flexible architectures also offer otherqualitative advantages. First, by acting as an enabler for newtopologies, it naturally inherits the properties they provide;e.g., random graphs offer incremental expandability.Second, selectively disabling links may also decrease energycosts. Furthermore, by eliminating the wired infrastructure,FSOs can potentially reduce cooling costs by avoidingproblems due to airflow obstruction.

7. Conclusions

The future will require higher and higher bandwidth solutions to meet the needs of corporations and individuals. Cost effective alternatives need to be found to augment the legacy WAN technologies in providing secure, redundant links between corporate resources, the Internet and the telephone company carriers. Free-Space Optics can meet these needs and will be used in an ever-increasing way to provide these solutions in the future. FSO systems offer a viable solution toward building optical connectivity in a cost-effective, quick, and reliable manner in certain situations With its cost effective and high bandwidth qualities.

Optical wireless operating in the near infrared wavelength range is an alternative transport technology to interconnect high capacity networking segments. Optical wireless communication systems are among the most secure networking transmission technologies It is extremely difficult to intercept the optical wireless light beam carrying networking data because the information is not spread out in space but rather kept in a very narrow cone of light.

Spatial diversity reception can also help to mitigate turbulence-induced fading. When the spacing between receivers is not much greater than the fading correlation length, diversity gain is reduced by correlation, but ML detection can be used to overcome some of this loss. We have shown that in the dual-receiver case, ML diversity reception outperforms the conventional EGC method.

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