Comparison of wireless optical communication availability data and traffic data

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***Abstract*— Optical Wireless link provides high bandwidth solution to the last mile access bottleneck. However, an appreciable availability of the link is always a concern. Free Space Optics (FSO) links are highly weather dependent and fog is the major attenuating factor reducing the link availability. However the traffic requirement of a LAN may not require 99.999% availability of FSO at all instants. A hybrid network with intelligent switch over can fulfil the availability and bandwidth requirement. In this paper statistical data of fog and FSO availability in Graz (Austria) has been compared to the traffic data of Technical University Graz (Austria).**

***Keywords*— FSO, Fog, Availability, Traffic data, Simulation**

I. Introduction

The rising need for high bandwidth transmission capability link along with security and ease in installation has led to the interest in free space optical communication technology. It provides highest data rates due to their high carrier frequency in the range of 300 THz. FSO is license free, secure, easily deployable and offers low bit error rate link. These characteristics motivate to use FSO as a solution to last mile access bottleneck. Wireless optical communication can find applications for delay free web browsing and data library access, electronic commerce, streaming audio and video, video on demand, video teleconferencing, real time medical imaging transfer, enterprise networking, work-sharing capabilities and high speed interplanetary internet links [1].

In any communication system, transmission is influenced by the propagation channel. The propagation channel for FSO is atmosphere. Among various atmospheric attenuation effects on FSO link, fog is the most important factor [2]. Research studies have shown that attenuation has peak values of 130 dB/km in continental fog conditions in Graz (Austria) and 480 dB/km in maritime fog conditions in La Turbie (France) [3]. This makes the carrier class availability 99.999% questionable. However, traffic data requirements may help in assessing the so called 99.999% availability need for a link. In addition to that, the required bandwidth is also to be considered. In order to overcome the reduced FSO availability, it can be combined with backup links, such as wireless LAN (WLAN) links compliant to IEEE 802.11a/b/g standard. 802.11a/b/g/n networks operating at carrier frequencies below 10 GHz can be used as back-up link for providing comparable data rates. The fog attenuation for frequencies below 10 GHz is negligible [4] and increased humidity causes less than 5 dB/km [5].

In this paper we would like to analyse the possibility of interconnecting the three main campuses of the Technical University Graz (TUG) with FSO/WLAN switch-over links. Akbulut et al [6] developed such an experimental hybrid FSO/RF communication system between the two of five campuses of Ankra University located at different locations in the city.

For this purpose we collected the traffic data between the three campuses and the main router of the university, connecting the whole network to the internet. In addition to that measured availability data [5, 7] is used to analyse the correspondence between the traffic bandwidth requirements and FSO link availability.

The remainder of this paper has been organized as follows: Section II describes measured availability of optical wireless links for Graz. Section III presents the traffic statistics of TUG, whereas in section IV a detailed analysis is done to compare the traffic statistics of TUG and availability of FSO links. Concluding remarks finalize this paper in section V.

II. The FSO Availability Data

The availability of system *A(t)* is the probability that the system works correctly at time *t*. If the cumulative period of an existing link is T_{UP} and cumulative period of the total time of measurement is $T_{UP} + T_{DOWN}$, the availability is given by [2]

$$A = \frac{T_{UP}}{T_{UP} + T_{DOWN}} .100\ \% . \qquad (1)$$

The availability of optical wireless link and mmW link for a distance of 2.7 km in Graz were measured over 15 months

(2001-2002), and for more than 4 years for a FSO system over the same link distance (2000 – 2004). Bit error rate tester from Wandel and Goltermann ANT-20 was used to send the test data. The FSO equipment was a commercial GoC MultiLink system with 155 Mbps bit rate (STM-1) with multiple beam technology for transmitter and receiver optics. The properties of the FSO systems used for the experiment are given in table 1.

TABLE 1

PROPERTIES OF FSO SYSTEM USED

System	FSO
T_X wavelength/ frequency	850 nm
T_X technology	VCSEL
T_X power	2 mW (+ 3 dBm)
T_X aperture diameter	4 x 25 mm convex lense
Beam divergence	2.5 mrad
R_X technology	Si-APD
R_X acceptance angle	2 mrad
R_X aperture	4 x 80 mm convex lense
R_X sensitivity	- 41 dBm
Spec. Margin	7 dB/km
Spec. Distance	2 km

One FSO unit was mounted on the roof platform of the department building in Inffeldgasse (Graz) and the opposite FSO unit was mounted on the roof platform of Observatory Lustbuehel (Graz). The link distance was approximately 2.7 km. Test configuration was a loop test. Test data provided by a bit error rate tester at a rate of 155 Mbps was transmitted from Inffeldgasse to Lustbuehel where it was received and immediately transmitted back to Inffeldgasse. The bit error rate tester located at Inffeldgasse compared the transmitted and the received signal and together with date and time recorded signal quality parameters and link availability. The bit error tester made records at a resolution of 0.1 s of link availability. Average availability over one year was found to be 93.65 % [5]. As shown in Figure 1, high availability in excess of 99.9 % was achieved over the 2.7 km link path even with only 7 dB/km specific link margin during the summer months, but very poor availability was found in autumn and winter, as low as 80 %. An impression of seasonal and diurnal dependency of system availability is given by Figures 2, 3 and 4, showing an evaluation of the measured data. Haze and fog were nearly the exclusive reason for broken links in autumn and winter.

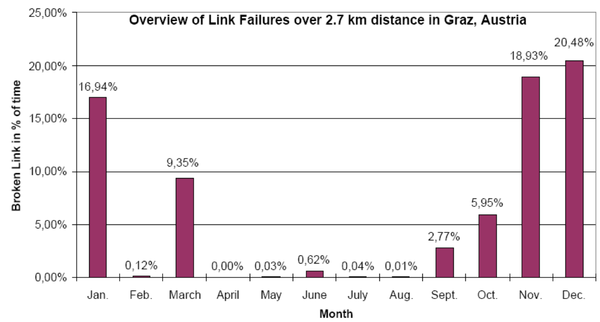

Fig. 1: Measured average unavailability [2]

The average results are given for different times of all the months.

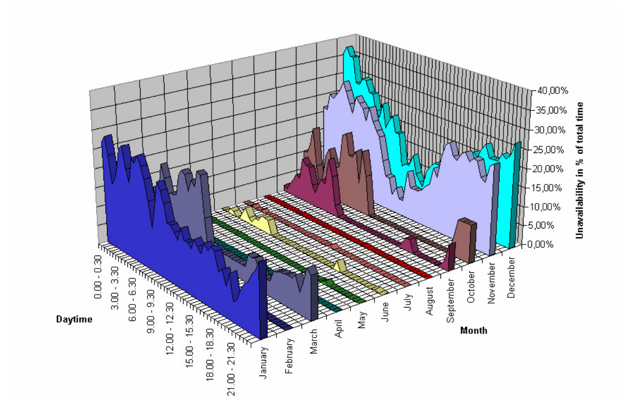

Fig. 2: Average values of half hour periods every month [2]

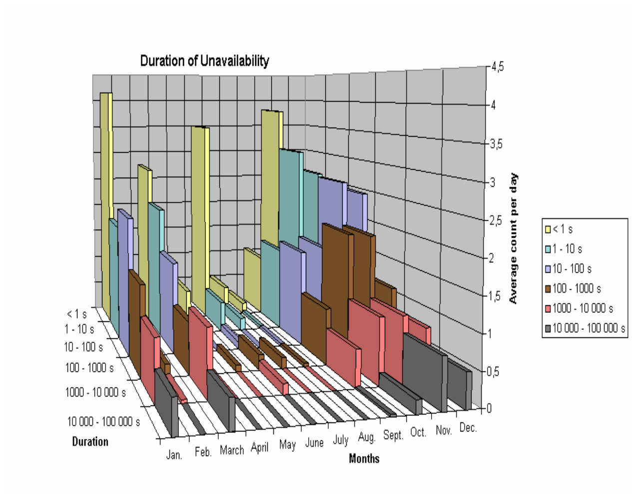

Fig. 3: Durations of periods of unavailability in a year [2]

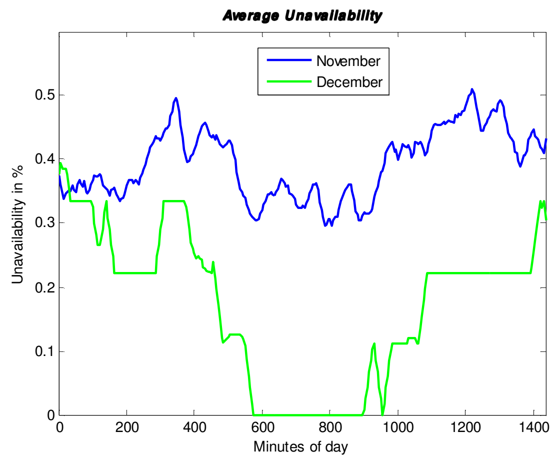

Fig. 4: Average FSO unavailability during November and December 2000 [7]

As it can be seen, availability is high especially during daytime. Haze and fog, as they are mentioned to be the major reasons for a link failure, occur mostly during dusk, dawn and the night, at least for the continental climate of Graz. This explains the availability curve of the FSO link. As mentioned above, the WLAN link is not affected by fog and haze, therefore it is considered to be available all the time.

III. Traffic Data of Technical University of Graz

The following traffic data were recoded using the Multi-Router-Traffic-Grapher (MRTG) on December 3rd 2008 [8]. In all figures, green is incoming and blue is outgoing traffic. Figure 5 shows the overall internet traffic data for the TUG for the last 48 hours. As it can be seen, there had been peaks of traffic load from 10am to 4pm and occasional very low load during night and early morning. There was medium traffic load from 8am to 10am and from 4pm to 6pm, respectively. This coincides with the office and lecture hours at the TUG.

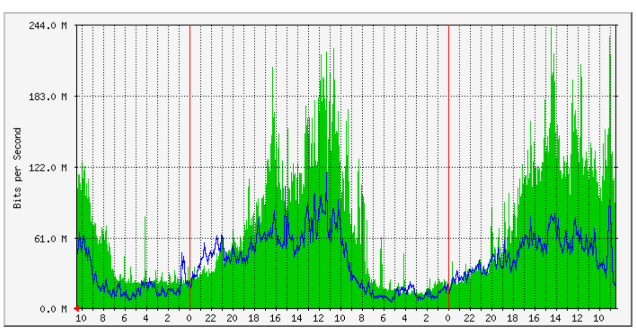

Fig. 5: Overall traffic data recorded for 48 hours (5 min averaged)

Figures 6 and 7 show that these considerations hold not only for one particular day, but for all days on average. On weekends and during holidays traffic is usually lower, but the form of the traffic curve does not change. This way we can perform the following simulations on the basis of traffic data for one day. There are parts in figure 7 in which traffic load is close to zero. During this time, however, the supervising system did not record any data, although there was traffic.

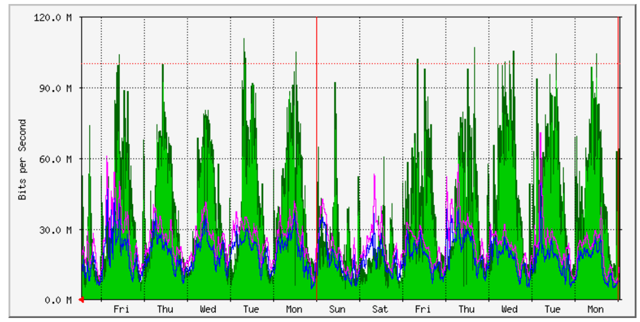

Fig. 6: Overall traffic data recorded for 13 days (30 min averaged)

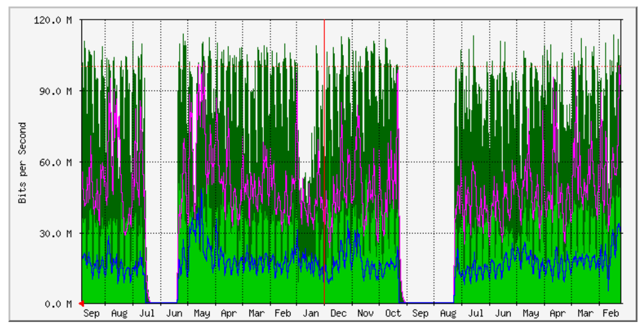

Fig. 7: Overall traffic data recorded for 19 months (1 day averaged)

The campus of the TUG is divided into three main sites, known as “Alte Technik”, “Neue Technik” and “Inffeldgründe”, the latter being the biggest one, containing the most offices and computer rooms accessible for students. Therefore, as it can be verified by looking at figure 9, the average traffic for this site is the highest.

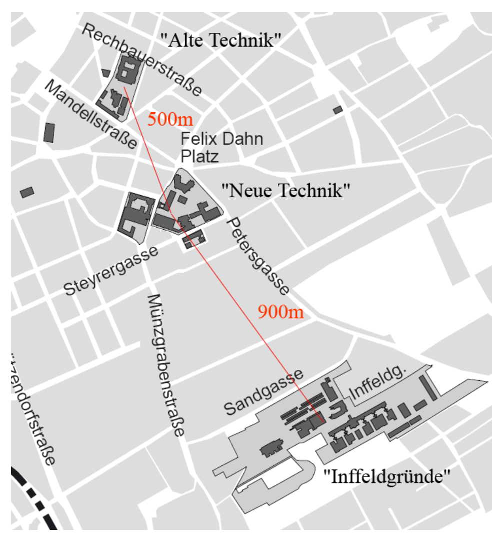

Fig. 8: Map of the campuses of the Technical University Graz [9]

In addition to that, also the traffic between the main internet gateway and the three campuses was recorded. This way, we could easily evaluate the possibility of an FSO/WLAN system for interconnecting these areas. Figures 9, 10 and 11 show the traffic for these campuses for 48 hours, again averaged over 5 minutes.

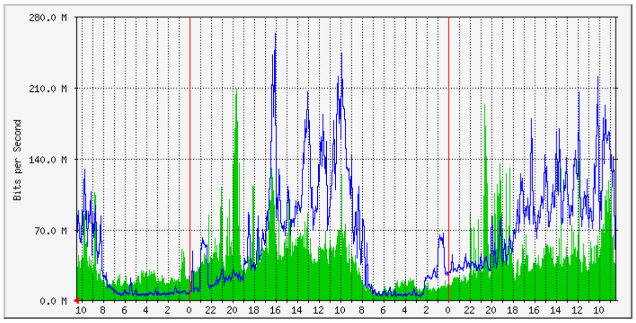

Fig. 9: Traffic data recorded for Campus “Inffeldgründe”

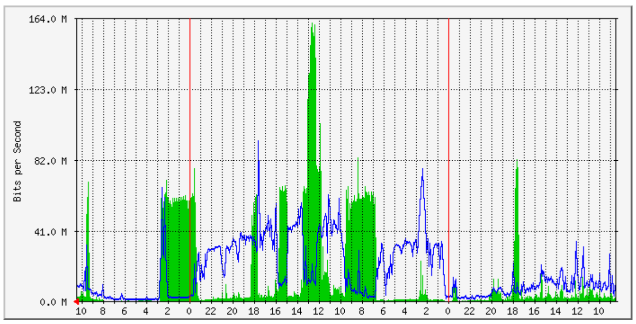

Fig. 10: Traffic data recorded for Campus “Neue Technik”

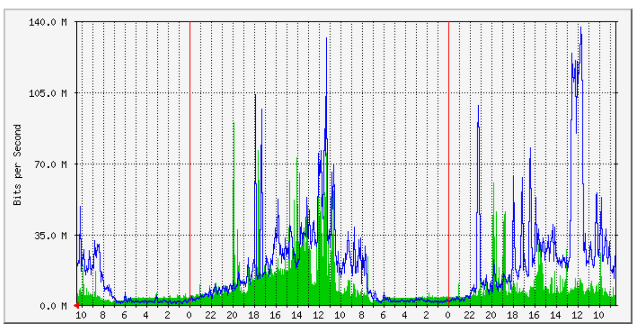

Fig. 11: Traffic data recorded for Campus “Alte Technik”

IV. Simulation and Results

For the simulations we used the data recorded with the above mentioned FSO system, mainly for the months of November and December [7]. The data, however, were recorded in some kind of a worst-case scenario: The link distance of 2.7 km in fact exceeds the specification of the FSO system available at the TUG. Therefore, if shorter distances are chosen, the effects of fog and haze can be limited and, consequently, availability is increased. As it can be seen in figure 8, the distances between the different sites of the campus are lower than 1 km, increasing the error margin for the used FSO system.

As a set of parameters for the simulation we chose a full duplex bandwidth of 155 Mbps for FSO and 15 Mbps for WLAN, respectively. The time for switching over, during which link loss occurs, was estimated to be 3 s. This set of parameters resulted in curves for the average achieved bandwidth as shown in figures 12 and 13.

These values for the average achievable bandwidth were now compared with the bandwidth requirements for the links between the main router and the different sites of the campus. These curves were obtained by averaging the data of nine workdays in the month of December, 2008. As it can be seen from comparison with figures 9, 10 and 11 the diurnal changes in traffic are also reflected in the average. Both incoming and outgoing traffic was taken into account.

The resulting curves were compared to the achieved bandwidths in figures 12 and 13 as well. It is obvious, especially from figure 13, that intervals with high data rates coincide with intervals of high availability. Therefore we can make the assumption that an FSO/WLAN hybrid system is a satisfactory way of providing internet access to the discussed sites of the campus.

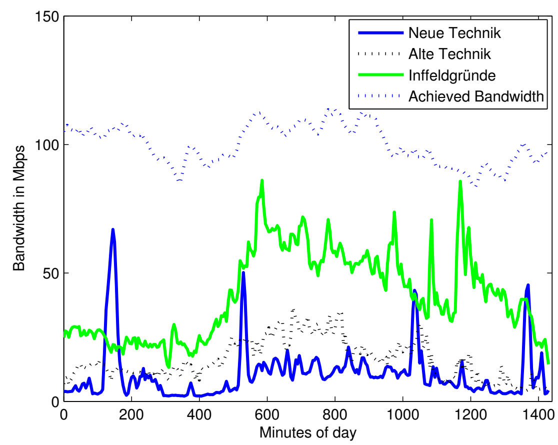

Fig. 12: Average required and achieved bandwidth for November

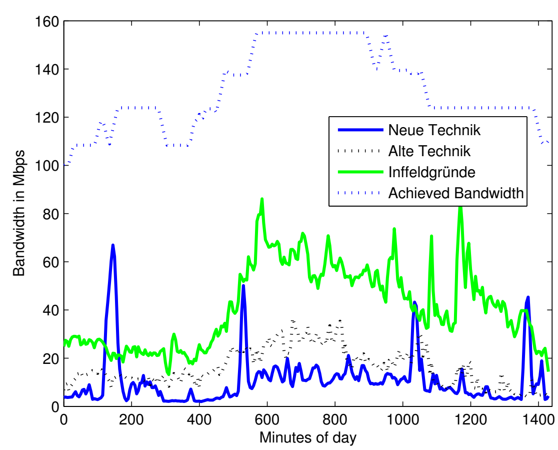

Fig. 13: Average required and achieved bandwidth for December

Still, obtaining the required bandwidth on average may not be enough in many applications. It is not acceptable to maintain an average bandwidth of 100 Mbps, since for FSO this may mean that the link is unavailable for more than a third of the time. During this time the bandwidth is strongly limited by the capacities of the WLAN link, which is assumed to be 15 Mbps. Considerations have to be made if this lower bandwidth is sufficient to successfully interconnect the different campuses of the TUG.

As it can be seen in the figures 10 and 11, the maximum bandwidth throughout one day most of the time exceed 15 Mbps, thus even the sites “Neue Technik” and “Alte Technik” could not be supplied via WLAN without losing too much performance. This loss of performance during peaks in the traffic curve is not negligible.

Figure 9 on the other hand shows that the necessary bandwidth for campus “Inffeldgründe” exceeds the assumed 15 Mbps even on an all-day-average. WLAN back-up therefore has to be considered as a futile attempt to maintain availability to all users connected to the according network. Moreover, peak bandwidths even exceed the FSO specifications of 155 Mbps. However, there may be solutions to that problem. For one, multiple FSO and WLAN links could be used simultaneously, employing a load sharing mechanism as it is introduced in [10]. Furthermore, the WLAN link(s) could be multi-channel or multiple-input-multiple-output (MIMO) links as they are suggested in the IEEE 802.11n draft [11]. Future studies will show if this technology originally developed for short-distance links can be applied for long-range directional links as well, similar to preceding 802.11a/b/g technologies.

Furthermore, proper timing of automatic bandwidth consuming tasks, such as automatic updates and similar, could also enhance the performance of an FSO/WLAN hybrid system. This way, single peaks could be spread over a longer interval of time, which in turn reduced the maximum required bandwidth.

V. Conclusions

The benefits of FSO motivate to use it as last mile access. However, the deterioration of weather attenuation cannot be neglected and has to be coped with back-up links of acceptable data rates. The behaviour of switch-over for such a hybrid network has been analysed for traffic data as well as availability data. It was shown that peaks in the bandwidth requirement coincide with peaks of achievable bandwidths.

Therefore, an FSO/WLAN switch-over system can be seen as a successful way to provide internet access to office buildings and lecture halls, since bandwidth is limited in times of little usage mainly. Availability, however, is ensured almost throughout the whole time, and is only limited by the time required for detecting an FSO failure and reacting on it.

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