Free Space Optics – Monitoring Setup for Experimental Link

FSO sensors monitoring system

Ján Tóth
Department of Electronics and Multimedia Communications, Faculty of Electrical Engineering and Informatics
Technical University of Košice
Košice, Slovakia
jan.toth@tuke.sk

Ľuboš Ovseník, Ján Turán
Department of Electronics and Multimedia Communications, Faculty of Electrical Engineering and Informatics
Technical University of Košice
Košice, Slovakia
lubos.ovsenik@tuke.sk; jan.turan@tuke.sk

***Abstract*—This paper deals with advanced Free Space Optics communication technology. Two FSO nodes are needed in order to make a connection. Laser diodes are used as light sources. Simple OOK modulation is involved in this technology. FSO system offers multiple advantages indeed. However, a direct visibility is required in order to set up a communication link. This fact yields perhaps the most significant weakness of this technology. Obviously, there is no a chance to fight the weather phenomena like fog, heavy rain, dust and many other particles which are naturally present in the atmosphere. That's why there is a key task to find a suitable solution to keep FSO link working with high reliability and availability. It turns out that it's necessary to have knowledge about weather situation when FSO link operates (liquid water content - LWC, geographical location, particle size distribution, average particle diameter, temperature, humidity, wind conditions, pressure and many other variable weather parameters. It's obvious that having most of mentioned parameter's values stored in database (implicitly in charts) would be really beneficial. This paper presents some of mentioned indicators continuously gathered from several sensors located close to one of FSO nodes.**

Keywords—availability; reliability; FSO; application; sensors; weather

I. Introduction

Free Space Optics is an advanced communication technology which is based on a very simple operational principle. It's based on On/Off keying modulation combined with suitable light sources (mainly by laser diodes with an accurate spectral width. The high security system is just one of the numerous advantages offered by FSO links. It's almost impossible to leak the information from the FSO communication channel. The amount of detected/received optical signal is one of the most important parameter at the same time. It has been already mentioned that a direct visibility between two FSO heads is strongly required. FSO link's operational wavelengths are situated within tree *optical windows* (850, 1330 and 1550 nm). These wavelengths are very close to an average particles size distributed in the atmosphere. Optical signal gets attenuated significantly when interacting with these particles. There are basically two interactions involved in attenuation process. It's absorption of the power (in form of heat) and a scattering phenomenon. Both of them results in the same conclusion – signal loss. It's obvious that fog and rain play an important role for a FSO transmission. That's why it's meaningful to monitor weather conditions and behavior around the FSO systems, especially fog and rain formation.

We have been dealing with *fog sensor* for several years at our laboratory. This device can measure so called *LWC* parameter [g/m^3]. This *LWC parameter* can be recalculated to visibility [m]. We dealt with statistical data collecting from this device in previous years. This information is very useful from the statistical point of view. It's possible to evaluate an overall FSO link availability and reliability during particular years based on both *LWC* and Visibility parameters.

FSO links are generally backed up with Radio Frequency (RF) links. Those are less sensitive when fog appears. On the other hand, rain causes a significant attenuation for RF systems. In order to estimate an accurate way to switch between FSO link and RF in time, it would have been useful to design a complex software and hardware system. This design would automatically monitor FSO performance, switch to RF if needed and send alert messages if desired. Software part of this solution is based on open source (Nagios) monitoring project. The overall system consists of database, python check scripts executed in pre – scheduled time intervals, a web frontend (securely accessible from internet), a low cost computer and the actual sensors. The existing design collects raw *LWC*, temperature, humidity, pressure, altitude data. All these parameters are perpetually collected and stored in a database and can be displayed in scalable charts. In fact, the FSO link can be reliably switched back and forth to RF link based on this data. As it has been already mentioned the fog and implicitly visibility are the most important. These parameters are still measured by the actual fog sensor. The final and the most important task would be a setting of a *LWC* or Visibility threshold. The threshold number comes out of the Steady Model [1] software developed at out laboratory. This software provides a Max. Visibility value - recalculated back to *LWC* value. Max. Visibility parameter is specifically calculated from the actual FSO specification (for example FlightStrata 155E) [2-10]. It turns out that *LWC* parameter measured by optical Fog Sensor is being a key parameter.

II. Weather Monitoring Automation

A. Fog and Visibility measurement

Many papers, real measurements and theory have agreed that fog – as one of the atmospheric effects – lowers the receiving optical signal at both FSO nodes. Optical signal gets mostly scattered at fog particles in the air. There is no way how to suppress this fog appearance. However, it's essential to know when the fog will most likely be formed. That's why it's reasonable to find the way to measure particle concentration in atmosphere. More importantly it's quite tricky to use a proper method to process gathered data in order to make FSO link working with high availability and reliability. Fog sensor is measuring so called *LWC* parameter in [g/m^3] (Fig. 1).

Fig. 1. Free Space Optics head (model Light Point – Flight Strata 155) on the left. Fog sensor with ability of measuring different atmospohere paramteres (temperature, humidity, preassure, altitude, lwc). This setup is located within a campus of Technical University of Kosice (Vysokoskolska 4).

Much different software has been proposed since we started using a fog sensor [3]. For fog sensor data is stored in a standalone database. However, the latest software approach is following a real time access to one united database system. The latest design is already in a testing phase.

B. Calculations

Our experimental device (a fog sensor) collects three parameters. The key one is so called *LWC* [g/m^3]. All values provides by this device (connected through the RS232 port) comes to software in a raw form (voltage levels).

#lwc	temp	humi	timestamp
93	5378	2434	2015-11-18 10:17:32
93	5375	2437	2015-11-18 10:17:17
93	5375	2437	2015-11-18 10:17:02
95	5372	2437	2015-11-18 10:16:46
93	5369	2439	2015-11-18 10:16:31
93	5366	2438	2015-11-18 10:16:16
94	5363	2432	2015-11-18 10:16:01

Fig. 2. A snapshot of paramaters (lwc, temperature and humidity) from Fog sensor (online interactive check: http://fiber.web.tuke.sk/mon/index.php).

This values X_i (*lwc* column from Fig. 2) has to be converted through the following formula (1)

$$F = (X_i \frac{5}{1024} - 0.87)\frac{0.5}{2.9}, \quad (1)$$

where *-0.87* is an offset *OFSET*. This value needs to be tuned a few times a year. This is considered as a disadvantage of this system. However, it is important to empathize that this sensor is only an experimental device. Presented concept can coexist with any other device capable of a *LWC* measuring. *LWC* seems to be an accurate switching indicator for FSO/RF systems. The product of equation (1) is further multiplied by a special [3] constant C = 0.7384 g/m^3. It's important to note that *F* parameter from equation (1) has no unit. Finally, when calculating the actual visibility, it's possible to use the following formula

$$V = 0.024(LWC)^{-0.65}\ [\mathrm{m}]. \quad (2)$$

III. Software Impementation

In past, there was a problem that particular sensors standalone. There was a need to collect data from several computers. It has been reduced now.

Low cost computer is capable of carrying several software components such as database, web server etc.

As it can be seen in Fig. 2 below, we are currently testing a new device. This is made of a mentioned computer with a couple of sensors.

Sensors provide information about particular atmosphere parameters which are processed on a computer side. We have paid a quite a lot of attention to build a stable and reliable software solution. Luckily, this has been achieved. The following Fig. 3 presents a data flow from particular sensors to the end uses through a graphical interface accessible from web browser.

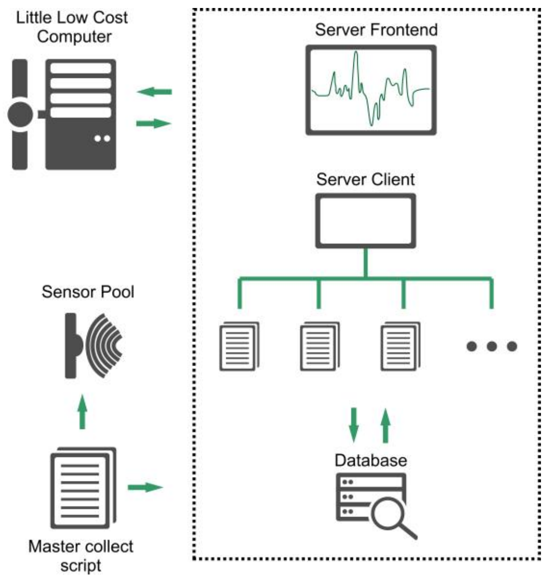
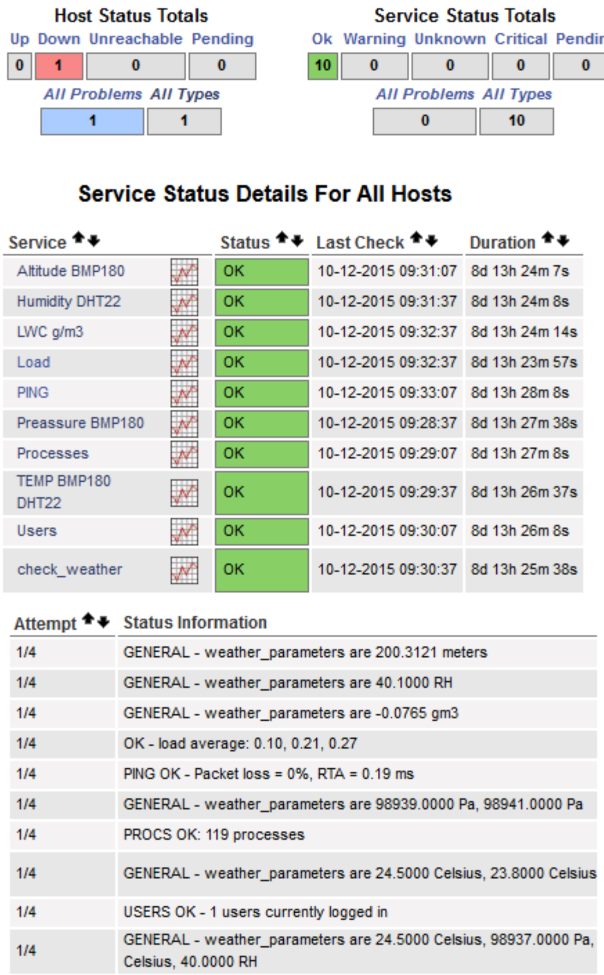


Fig. 3. Schematic data flow between sensors and a processing unit (a comuter).

Each sensor in the setup has a different communication port and protocol. There is a main python script collecting all necessary data from sensors and saves them in a database. In the following step there is a web server running an open source monitoring tool (Nagios) [12]. This server regularly contacts a database, picks up pre – defined data and displays them in charts.

IV. Experiments and Results

Fig. 3 shows an entire data flow from the actual sensors through the database, a server client to a frontend. A web server frontend (deployed on a web server) is shown in Fig. 4.



Host Status Totals

Up	Down	Unreachable	Pending
0	1	0	0

All Problems	All Types
1	1

Service Status Totals

Ok	Warning	Unknown	Critical	Pending
10	0	0	0	0

All Problems	All Types
0	10

Service Status Details For All Hosts

Service	Status	Last Check	Duration	Attempt	Status Information
Altitude BMP180	OK	10-12-2015 09:31:07	8d 13h 24m 7s	1/4	GENERAL - weather_parameters are 200.3121 meters
Humidity DHT22	OK	10-12-2015 09:31:37	8d 13h 24m 8s	1/4	GENERAL - weather_parameters are 40.1000 RH
LWC g/m3	OK	10-12-2015 09:32:37	8d 13h 24m 14s	1/4	GENERAL - weather_parameters are -0.0765 gm3
Load	OK	10-12-2015 09:32:37	8d 13h 23m 57s	1/4	OK - load average: 0.10, 0.21, 0.27
PING	OK	10-12-2015 09:33:07	8d 13h 28m 8s	1/4	PING OK - Packet loss = 0%, RTA = 0.19 ms
Preassure BMP180	OK	10-12-2015 09:28:37	8d 13h 27m 38s	1/4	GENERAL - weather_parameters are 98939.0000 Pa, 98941.0000 Pa
Processes	OK	10-12-2015 09:29:07	8d 13h 27m 8s	1/4	PROCS OK: 119 processes
TEMP BMP180 DHT22	OK	10-12-2015 09:29:37	8d 13h 26m 37s	1/4	GENERAL - weather_parameters are 24.5000 Celsius, 23.8000 Celsius
Users	OK	10-12-2015 09:30:07	8d 13h 26m 8s	1/4	USERS OK - 1 users currently logged in
check_weather	OK	10-12-2015 09:30:37	8d 13h 25m 38s	1/4	GENERAL - weather_parameters are 24.5000 Celsius, 98937.0000 Pa, Celsius, 40.0000 RH

Fig. 4. A server web page (frontend). This element displays control checks with a respect to the pre – defined thresholds. Eventually, this displays information about: altitude, humidity, temperature,preassure and most importnantly lwc [g/m^3].

Each measured atmospheric parameter has a chart icon next to its label. A green label color indicates that concerned parameters are above a pre – defined threshold. When one of the parameters drops under a certain level a label tends to get red. This principle has a practical meaning especially for *LWC* parameter. Parameters such as temperature, humidity have only informational character so far.There are several means to notify that something is wrong with FSO link thanks to this setup. Periodically executed checks (scripts) are capable of the following actions:

- automatically initiate a process of switch to a backup link,
- send an email or SMS.

Each measured parameter has automatically charts generated (four time windows - per day, per week, per month and per year). These charts (see Fig. 5) will come up when pressing a chart icon as it can be seen in Fig. 4.

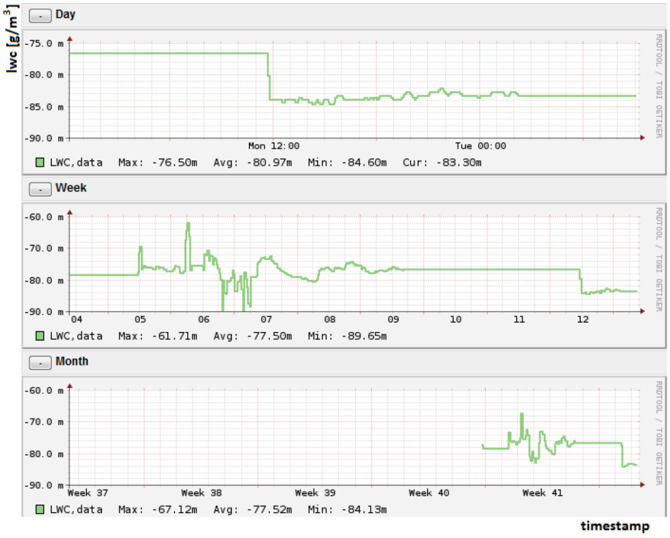


Fig. 5. Graphical representation of each considered atmospheric parameter in time (daily, weekly and monthly).

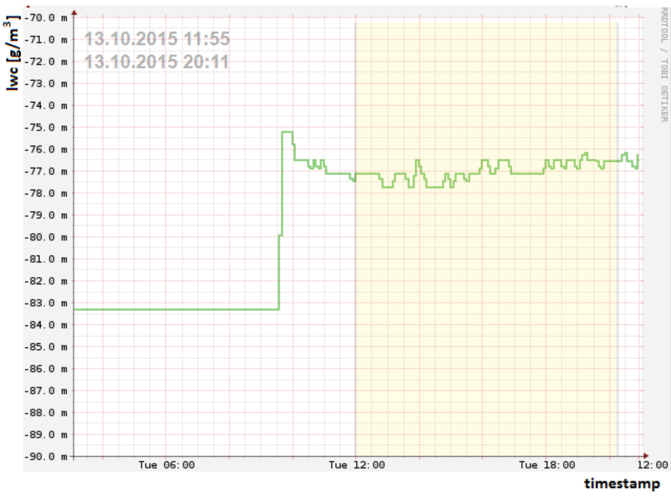


Fig. 6. Graphical representation of each considered atmospheric parameter in time (daily, weekly and monthly).

Weekly *LWC* record is shown in Fig. 6. *LWC* parameter fluctuates quite rapidly when atmosphere conditions changing as it can be seen from this figure.

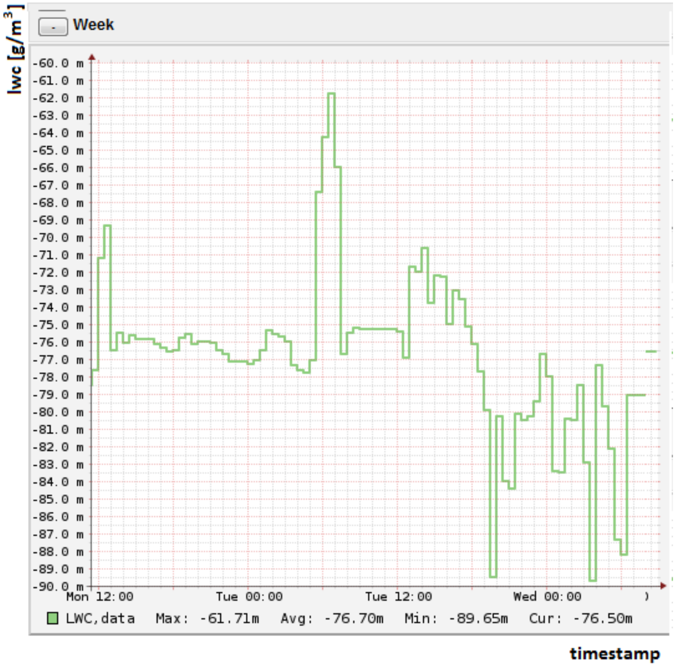


Fig. 7. Liquid Water Content (*LWC*) [g/m^3] a week representation 2015.

CONCLUSIONS

FSO links provide reliable communication usually over a distance of a few kilometers. This advanced wireless communication is indeed an accurate complementary part of nowadays complex networks. FSO technology is quite sensitive to the weather (mainly fog). FSO systems have to be backed up in order to satisfy high availability communication expectations. This paper proposed measuring of fog density in form of *LWC* parameter. It's important to consider the rain attenuation when FSO link is switched to RF back up link. Hoverer, this is not the aim of this paper. Proposed approach is easily extendable in many other atmospheric phenomenon which is not the only advantage. Future work is aimed to process with received optical power [dBm] parameter combined with *LWC*. The main goal of this paper is to propose the universal and extendable monitoring system for FSO links.

ACKNOWLEDGMENT

This work was supported by Cultural and Educational Grant Agency (KEGA) of the Ministry of Education, Science, Research and Sport of the Slovak Republic under the project no. „006TUKE-4/2014 - The Use of TUKE PON Experimental Model in Teaching. This work is also the result of the contract no. "APVV-0025-12 - Mitigation of Stochastic Effects in High-Bitrate All Optical Networks" supported by the Slovak Research and Development Agency.

REFERENCES

[1] M. Tatarko, L. Ovsenik, J. Turan, "Processing of Measured Data with a Focus on Visibility," In: Electrical Engineering and Informatics 5 : Proceedings of the Faculty of Electrical Engineering and Informatics of the Technical University of Košice. - Košice : TU, 2014 S. 920-925. - ISBN 978-80-553-1704-5

[2] Lighpointe, FlightStrata 155E- User Manual. Online: http://www.bauschnetworking.be/file/1061, (Accessed: 7 April 2015).

[3] M. Tatarko, L. Ovsenik, J. Turan, "Software package for analyze FSO links," In: Infocommunications Journal. No. 1, p. 1-9. - ISSN 2061-2079, 2013.

[4] D. M. Forin, G. Incerti, G. M. Tosi Beleffi, B. Geiger, E. Leitgeb, F. Nadeem, "Free Space Optical Technologies," in Trends in Telecommunications Technologies, March 2010.

[5] Z. Ghassemlooy, W. Popoola, S. Rajbhandari, "Optical Wireless Communications System and Channel Modelling with MATLAB®", 2013.

[6] I. Kim, E. Korevar, "Availability of Free Space Optics (FSO) and Hybrid FSO/RF Systems," in Proc. SPIE, vol. 4530, 2001, pp. 84-95.

[7] L. Csurgai-Horváth and J. Bitó, "Fog Attenuation on V Band Terrestrial Radio and a Low Cost Measurement Setup," in Future Network & Mobile Summit, Florence, Italy, Paper #47, June 2010.

[8] F. Nadeem, V. Kvicera, A. M. Saleem, E. Leitgeb, et al. "Weather Effects on Hybrid FSO/RF Communication Link," in IEEE Journal on Selected Areas in Communications, vol. 27, no. 9, December 2009, pp. 1687-1697.

[9] Z. Kolka, O. Wilfert, V. Biolkova, "Reliability of Digital FSO links in Europe," in Int. J. Electronics, Communications, and Computer Engineering, vol. 1, no. 4, pp. 236–239, 2007.

[10] S. Sheikh Muhammad, M. Saleem Awan, A. Rehman, "PDF Estimation and Liquid Water Content Based Attenuation Modeling for Fog in Terrestrial FSO Links. Radioengineering," in Vol. 19, No. 2, June 2010.

[11] M. Reymann, J. Piasecki, F. Hosein and col., "Meteorological Techniques," July 1998.

[12] Nagios. Open Source project. Online: https://www.nagios.org/projects/

BIOGRAPHY

Ján Tóth was born in Trebisov, Slovakia, on Jan. 16, 1988. He received his M.S degree from "Infoelectronics" University of Košice in 2012 at Department of Electronics and Multimedia Telecommunications, Faculty of Electrical Engineering and Informatics. He has started his PhD. studies at Technical university of Košice on September 2012. His main field of study is a reseach of full optical fiber networks and degradation factors

Ľuboš Ovseník (doc., Ing., PhD.) received Ing. (MSc.) degree in radioelectronics from the University of Technology, Košice, in 1990. He received PhD. degree in electronics from University of Technology, Košice, Slovakia, in 2002. Since February 1997, he has been at the University of Technology, Košice as Associate Professor for electronics and information technology. His general research interests include optoelectronic, digital signal processing, photonics, fiber optic communications and fiber optic sensors

Ján TURÁN (Dr.h.c., prof., RNDr., Ing., DrSc.) received Ing. (MSc.) degree in physical engineering with honours from the Czech Technical University, Prague, Czech Republic, in 1974, and RNDr. (MSc.) degree in experimental physics with honours from Charles University, Prague, Czech Republic, in 1980. He received a CSc. (PhD.) and DrSc. degrees in radioelectronics from University of Technology, Košice, Slovakia, in 1983, and 1992, respectively. Since March 1979, he has been at the University of Technology, Košice as Professor for electronics and information technology. His research interests include digital signal processing and fiber optics, communication and sensing