Nithin Manyamvollu A1879720

Title: Hybrid Optical/Radio Frequency Communication Channel Model

Introduction: Free Space Optical (FSO) and Radio Frequency (RF) communication systems play roles in today's communication networks with their strengths and drawbacks. FSO systems allow for data transfer with bandwidth capabilities. However, they face challenges from attenuation caused by atmospheric factors such as fog, rain, and turbulence. In contrast, Radio Frequency (RF) systems offer communication in harsh weather conditions but come with limited bandwidth capacity (ITU-R P.1817-1 2012). This study is focused on creating models that predict signal loss (attenuation) in Free Space Optics (FSO) and Radio Frequency (RF) systems using the Random Forest algorithm. The goal is to understand how environmental factors affect the performance of these systems under weather conditions and improve the planning and implementation of communication technologies in adverse weather situations.

Methods: The plan involves utilizing Random Forest algorithms to estimate attenuation for both Free Space Optics (FSO) and Radio Frequency (RF) communication setups by leveraging data in real-time scenarios. Random Forest stands out as a decision tree learning technique recognized for its capacity to handle non-linear connections among input factors.

- **FSO Model**: The FSO Model considers elements like visibility conditions and fog thickness along with aerosol levels and humidity correlated with temperature and wind speed in its calculations with the focus on measuring signal attenuation (expressed in dB, per kilometer).
- **RF Model**: In modeling using Random Forest, important factors to consider are the strength of rainfall, amount of cloud cover, present temperature conditions and wind speed levels. These factors primarily affect attenuation in signal transmission. The main variable under observation is the degree of signal attenuation (expressed in dB per kilometer).

We will test both models using weather and signal strength data and evaluate their performance using Root Mean Square Error (RMSE) which helps assess the average prediction error and R squared (R^2) which indicates how closely the predictions match the real data values mathematically defined as follows:

$$RMSE = \sqrt{\frac{1}{N}\sum_{n=1}^{N}(y_n - \hat{y}_n)^2}$$

N is the number of observations,
y_n represents the actual observed attenuation values,
$\hat{y}_n$ denotes the predicted values.

$$R^2 = 1 - \frac{\sum_{n=1}^{N}(y_n - \hat{y}_n)^2}{\sum_{n=1}^{N}(y_n - \bar{y})^2}$$

y_n represents the observed attenuation values,
$\hat{y}_n$ denotes the predicted values,
$\bar{y}$ is the mean of the observed values.

Source: Lecture notes

Data and Insights: The data set given for this study contains factors like visibility levels and rain intensity alongside temperature, humidity and wind speed. These elements will be utilized to educate the Random Forest models in forecasting attenuation in Free Space Optics (FSO) and Radio Frequency (RF) communication systems. The project's main points are outlined in the presentation slides that are provided. FSO works best in clear weather, while RF makes sure that communication is constant in situations where it is raining or foggy (Shakir 2018). Previous research findings indicate that in Free Space Optical (FSO) systems the Attenuation of signal quality is mainly caused by aerosols and fog as rain. On the hand, in Radio Frequency (RF) systems rain attenuation has been identified as the influencing factor (Majumdar & Ricklin 2008).

Evaluation: The evaluation of the models will involve looking at RMSE and R^2 as previously discussed to gain an understanding of the prediction accuracy and the model's ability to perform on data sets without prior exposure to them. Comparing these metrics with established models like those suggested by ITUR P618 and ITUR P1817 will help confirm the Random Forest models predictive capabilities. A low RMSE value paired with a R^2 value signifies a model that fits well and can effectively forecast signal attenuation amidst changing weather conditions.

Timeline (12 Weeks)

- **Weeks 1-2**: **Completed** – Project understanding, proposal writing, dataset provided.
- **Weeks 3-5**: Develop the FSO model using Random Forest and train it on the dataset.
- **Weeks 6-7**: Develop the RF model, train it on relevant data and refine parameters.
- **Weeks 8-9**: Test and evaluate both models using RMSE and R^2 metrics.
- **Weeks 10-11**: Compare model performance with ITU-R models and refine as necessary.
- **Week 12**: Prepare and submit the final report

Conclusion: The predictive models developed in this study will provide a comprehensive solution for estimating signal attenuation in FSO and RF communication systems under different weather conditions. The upcoming models will be the foundation for studies on combined communication systems that switch between FSO and RF depending on environmental conditions in real time. With enhancements in forecasting signal weakening accurately this investigation adds to creating resilient communication networks that can function efficiently even under difficult weather circumstances.

References: W. M. R. Shakir, "Performance Evaluation of a Selection Combining Scheme for the Hybrid FSO/RF System," in *IEEE Photonics Journal*, vol. 10, no. 1, pp. 1-10, Feb. 2018, Art no. 7901110, doi: 10.1109/JPHOT.2017.2771411. Available: https://ieeexplore.ieee.org/document/8100959

ITU-R P.1817-1, 2012, *Propagation Data Required for the Design of Terrestrial Free-Space Optical Links*, ITU. Available: https://www.itu.int/rec/R-REC-P.1817/en.

ITU-R P.618-8, 2003, *Propagation Data and Prediction Methods Required for the Design of Earth-Space Telecommunication Systems*, ITU. Available: https://www.itu.int/rec/R-REC-P.618/en.

Majumdar, AK & Ricklin, JC 2008, *Free-Space Laser Communications: Principles and Advances*, Springer, New York.