Challenges and novel research opportunities for Free Space Optical Networks: Need for measurements and modeling to overcome shortcomings in the atmospheric channel model

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With tremendous advances in the FSO technology over the last decade excellent progress has been made to showcase the potential of modern FSO links in many areas. However, the Achilles heel of the FSO approach is still reliability – especially under low visibility conditions.
Based on our research, the solution to overcome this roadblock lies in better understanding of the atmospheric channel which allows for utilization of more resilient spectral regions and / or modulation approaches. The modeling used even today for predicting losses in an atmospheric channel rely typically on very few spectral data points (in the visible and NIR regime) fitted by empirical formulas. Those are then extrapolated to predict losses in other spectral region – without or with only limited experimental verification.
Our measurements in indoor atmospheric simulation as well as in an outdoor links have shown that these models typical overestimate losses. For example the Kruse-Mie model estimates losses based on visibility and while the NIR link was following well the losses predictions in a 500m outdoor test link - the losses for a MIR link diverged already for 6km visibility and the model overestimated the MIR drastically for visibility below 1km. Additionally the beam wander predicted with scintillation effect (based based on Rytov Variance) has been overestimated for longer wavelengths, while in reality MIR systems in areas with strong turbulence are more favorable to use. Most recently we have examined the combined losses due to scattering on small particles (like aerosols) in turbulent media and have found much higher losses for the commonly used NIR wavelengths compared to MIR links (under same conditions the NIR link reached up to 40dB losses while the MIR link had less than 8dB losses).

All of this three shortcomings clearly showcase that longer wavelength (MIR) have much better propagation condition – especially in low visibility conditions – yet outdated models deliver wrong predictions, disqualifying longer wavelength links already in the modeling stage. Improvement or replacement of these models is hence a key ingredient towards better reliability success of FSO links (and increase their reliability) – and hence a consolidated effort is needed in generating the needed data pool (through parallel link quality measurement for widely spaced wavelengths) - which then can lead to updated models. It should be pointed out that extending the spectral range into the THz spectral regions may be worthwhile – the cosmic background radiation is located in the THz spectral region – and its signature travels nearly undisturbed through the whole universe.