Fellow	<RUPENDER / **SINGH**>
Host Organisation	< VTT Technical Research Centre of Finland >
Scientific coordinator	< Jyrki / **Huusko** >

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During my tenure, I worked on a project "Sustainable Network Security Tech for 6G (SUNSET-6G)" at VTT Technical Research Center of Finland. The details are given below:

I contributed to Task 2.1 within WP2, addressing the definition of sustainability goals in 6G security. Our efforts primarily involved comprehending the essence of sustainability. To achieve this, a comprehensive literature review was conducted, enabling us to establish a project-specific definition. In the context of our project, sustainability is intrinsically linked to the optimization of resource utilization, including spectrum allocation and hardware, to curtail energy consumption. Simultaneously, we examined the prevailing Key Performance Indicators (KPIs) associated with 6G. Drawing insights from various reports on 5G KPIs, we incorporated select pre-established indicators while also introducing novel ones. Notably, KPIs like Anomaly Detection Precision, Security Conformance, and Tenant Data Privacy were identified as critical for nurturing secure and sustainable 6G networks. Despite their significance, scant documentation was available for these newly proposed KPIs, further compounded by the absence of standardized references in the realm of 6G.

Second, I worked on another interesting problem in which RF and VLC technologies were combined together to support communication between a BS and a UE present on the HST, where it was assumed that the BS-relay links were subject to DSR fading while the onboard passengers were served with VLC links. The impact of the speed of HST was considered in terms of imperfect CSI at the relay, where the correlation between estimated channel gain and precise channel gain was characterized with the help of Jake's model. Particularly, a performance framework was presented to investigate the effects of the Doppler shift on HST communication. The statistical characteristics, including PDF and CDF, for the proposed system were derived. Subsequently, we proceeded to derive the key performance metrics, including the outage and average BER, along with the corresponding closed-form expressions for the secrecy metric, i.e., Secrecy Outage Probability (SOP), accompanied by their respective asymptotic expressions. This study highlights the advantages of using the proposed mixed RF-VLC system for dealing with future challenges in HST communication, including spectrum scarcity and eavesdropping attacks.

The third interesting issue on which I worked was to identify the role of physical layer security (PLS) in Satellite communication. In this direction, we provided a thorough examination of the current state-of-the-art in the field of PLS in satellite communication. We have also presented an overview of various satellite network architectures. This research provides future research directions by highlighting several open research issues.

Finally, I proposed a hybrid THz-FSO system in which two eavesdroppers were present on both the THz and FSO links. I assumed that the THz and FSO links followed α-μ and M distributed fading models, respectively, while taking into account pointing errors. I developed a framework to analyze the security performance of the system by calculating the SOP. I investigated how various parameters affecting the THz and FSO links impact the security of the system. The results indicate that the FSO link is more susceptible to eavesdropping attacks compared to the THz link. Additionally, the findings suggest that the conditions of the FSO channel have a minimal impact on the system's security when THz eavesdropping is considered. In contrast, the security of the system is significantly influenced by the THz channel conditions.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

1. **Rupender Singh**, Ijaz Ahmad, Jyrki Huusko, “Mixed RF-VLC Relaying Systems for High-Speed Rail Communication”, ***IEEE Photonics Journal***, 2023. DOI:10.1109/JPHOT.2023.3303362.

2. Ijaz Ahmad, Andrea Gentili, **Rupender Singh**, Juhani Ahonen, Jani Suomalainen, Seppo Horsmanheimo, HeikkiKeranen, Erkki Harjula, ”Edge Computing for Critical Environments: Vision and Existing Solutions”, ***ITU Journal on Future and Evolving Technologies (ITU J FET)***, 2023. (accepted).

3. **Rupender Singh**, Ijaz Ahmad, Jyrki Huusko, “The Role of Physical Layer Security in Satellite-Based Networks”, ***2023 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6GSummit)***, Gothenburg, Sweden,2023, pp. 36-41.

4. **Rupender Singh**, Ijaz Ahmad, Jyrki Huusko, "On Secrecy Performance of Mixed THz-FSO Relaying System", ***IEEE Conference on Standards for Communications and Networking (IEEE CSCN 2023)***, (under review).

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

1. **Rupender Singh**, Ijaz Ahmad, Jyrki Huusko, “The Role of Physical Layer Security in Satellite-Based Networks”, ***2023 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6GSummit)***, Gothenburg, Sweden,2023, pp. 36-41.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

I have not visited any other ERCIM institute.