Fellow	Vineeta Jain
Host Organisation	Fraunhofer Institute of Integrated Circuits, Germany
Scientific coordinator	Jakob Wicht

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During my stay at Fraunhofer for 2 years, I worked on two different projects – "SUNRISE" and "CANOPY". The first project aimed at developing techniques to detect the root causes of Quality of service degradation in wireless networks by performing automated spectrum analysis. Here, my contribution was towards developing methods to improve automated spectrum analysis by supplementing protocol analysis data to it for a better investigation of root cause analysis of QoS degradation problems. This additional information enables quick identification and rectification of disruptions by taking measures such as reallocation of resources to non-interfering channels or sounding an alarm in case of abnormal or unusual traffic. Moreover, the monitoring and troubleshooting of industrial wireless networks benefit by combining information delivered from the protocol analysis and spectrum analysis. The work was done in a step-wise manner consisting of the following steps:

1. We generated a reference dataset for carrying out experiments for sequence alignment and testing the developed algorithms.
2. We proposed a novel Dynamic Time Warping (DTW)-based approach called Variable Adaptive DTW (VADTW). This approach consists of coarse- and fine-grained synchronization levels. The coarse-grained level divides the spectral and protocol sequences into adaptive time bins, while the fine-grained level calculates variable window limits for each frame. These limits are then used to compute the warp path using DTW.
3. We performed an exhaustive analysis of the developed method on generated synthetic dataset and real-world datasets, and did a comparative analysis with existing state-of-the-art methods to show the effectiveness and robustness of the developed method. The proposed method shows better accuracy and great improvement in execution time, which is of considerable significance given that spectral and protocol sequences can contain millions of frames.
4. We published the initial results as a poster in a conference and the final results in an IEEE journal.

The second project – "CANOPY", is focused on 5G and aims at developing ML/AI algorithms to detect different performance degradations, implement predictive fault detection, self-healing actions, and active energy efficiency management. My work here deals with time series analysis of 5G energy consumption datasets to detect similar energy consumption patterns for 5G cells. This is beneficial to get a deeper understanding of the dataset and use the information for advanced analysis like forecasting. The works done by me in the project include:

1. Get a thorough understanding the concept of "clustering" by reading the existing state-of-the-art methods.
2. Implement the existing methods on the available 5G energy dataset and analyze the results and gaps of the existing methods.
3. Propose a new method for clustering time series by dividing a long time series into optimal subsequences and then applying clustering and classification to find similar subsequences that represent significant patterns present in the data. This is more towards Exploratory Data Analysis of vast datasets by applying clustering.
4. Evaluate the proposed method on the 5G real-world dataset collected in the context of the project. The dataset contains the energy management indicators that provide a

comprehensive overview of energy consumed by all cells for 22 urban sites for which the geographical locations were also available, and spans for a period of 7 months, from October 2022 to April 2023.

5. Publish the results of the work in a conference.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

1. **Vineeta Jain**, Jakob Wicht, Ulf Wetzker, and Andreas Frotzscher. *Poster: Synchronizing Spectral and Protocol Analysis for Complementary Troubleshooting of Wireless Standards*. In Proceedings of the 19th International Conference on Embedded Wireless Systems and Networks 2022 (EWSN '22, Linz Austria, October 03-05 2022), pp 194–196. → Accepted and Published
2. Jakob Wicht, Ulf Wetzker, and **Vineeta Jain**. *Spectrogram Data Set for Deep-Learning-Based RF Frame Detection*. Data 7.12 (2022): 168. → Accepted and Published
3. **Vineeta Jain**, Vladimir Fokow, Jakob Wicht and Ulf Wetzker. *A Dynamic Time Warping Based Method to Synchronize Spectral and Protocol Domains for Troubleshooting Wireless Communication.* in IEEE Access, vol. 11, pp. 64668-64678, 2023. → Accepted and Published
4. **Vineeta Jain,** Zihao Huang, Anna Richter, Ulf Wetzker, and Andreas Frotzscher. *Exploratory Data Analysis of Time Series using Subsequence Clustering.* 11th IEEE Swiss Conference on Data Science, May 30 – 31, 2024, Zurich → Submitted and Pending

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

Attended 19th International Conference on Embedded Wireless Systems and Networks 2022 (EWSN '22) held at Linz Austria from October 03-05 2022 to present the poster.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

Visited the VTT Centre at Oulu, Finland for a week from 07-11 November 2022 as a part of REP. There, I was hosted by "5G and beyond" group headed by Dr. Jyrki Huusko. They started their group in 1970s with work on 3G followed by 4G and now 5G and beyond. It was a fruitful visit as I got a chance to see their 5G testbeds and understand the working.

Jakob Wicht

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