Scientific Report

First name / Family name	Senka Hadzic
Nationality	Bosnian
Name of the *Host Organisation*	Fraunhofer FOKUS
First Name / family name of the *Scientific Coordinator*	Mathias Kretschmer
Period of the fellowship	01/05/2014 to 30/04/2015

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During my ERCIM fellowship, the main task was to optimize the channel allocation scheme in WiBACK[1], a wireless backhaul technology developed at Fraunhofer FOKUS making use of heterogeneous multi-radio nodes. Wireless backhaul deployments provide a solution for broadband access especially in rural areas, where the lack of sufficient profitability prevents operators to invest in infrastructure. In multi-radio networks, smart channel assignments are desirable for several reasons. Apart from minimizing interference from external networks, another goal is to improve the capacity when some links are heavily used. Channel bonding mechanisms in the IEEE 802.11 n/ac standards allow for higher throughput, but also increase the likelihood of co-channel interference. At the initial stage, frequency allocation in the WiBACK system was based on local optimization, and channel reallocation only taking place after a link is down. Therefore the goal of this ERCIM tenure was to propose a method to centrally assign frequencies within a WiBACK specific topology.

Several optimization goals had to be achieved: the aim was to minimize the interference and maximize the guard interval between neighbouring interfaces, while at the same time guaranteeing high throughput. In certain frequency bands (e.g., U-NII band), regulatory restrictions require a maximum allowed transmission power, hence it is of interest to use particular frequencies for long distance links (~10 km). The combination of maximum allowed Tx power and the highest modulation and coding scheme (MCS) index allows to achieve high throughput over long distance links. In collaboration with other team members, an algorithm working on the principles of graph edge colouring was proposed. Performance evaluation was done using simulations in Python. Random graphs of different sizes were created using the NetworkX library in Python. The algorithm was tested using 20 MHz and 40 MHz channel width.

Besides the channel allocation problem, considerable research was also done in order to bring WiBACK into the context of emerging topics such as 5G and software defined networking (SDN). In that sense, together with other team members, a novel representation of the entire architecture has been proposed. WiBACK already builds upon SDN-like concepts to provide a specialized backhauling solution. The design principles align with fundamental principles of SDN, in terms of centralized management, separated control and data plane, and technology independent messaging. After an extensive survey on SDN in wireless networks, key challenges have been identified and a framework for software defined wireless networks (SDWN) has been proposed. Although the principal directions of future 5G wireless communication systems are small cells and network densification in urban areas, one cannot neglect the rural areas. In order to deliver a cost-effective and energy efficient solution in such scenarios, long-range 802.11 links operating in unlicensed spectrum can be used for wireless backhaul and broadband coverage extension. Certain aspects of WiBACK can provide a basis to be adopted in future backhaul networks since efficiency, flexibility and reliability are its main characteristics.

In summary, besides carrying out the initially proposed research plan on channel assignment optimization, I had the opportunity to expand my knowledge on emerging topics in today's wireless networks, namely 5G and SDN.

[1] www.wiback.org

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

- S. Hadzic, P. Batroff, C. Niephaus, O. Aliu and M. Kretschmer: „On the flexibility of future wireless backhaul networks“, submitted to IEEE Wireless Communications Magazine, April 2015. (pending)

- O. Aliu, S. Hadzic, C. Niephaus and M. Kretschmer: “A guide towards software defined wireless networks”, submitted to IEEE Transactions on Network and Service Management, March 2015. (pending)

- C. Niephaus, O. Aliu, M. Kretschmer, S. Hadzic and G. Ghinea: “WiBACK: A SDN-enabled wireless backhaul architecture for future 5G networks”, submitted to IET Networks, January 2015. (pending)

- C. Niephaus, G. Ghinea, O. Aliu, S. Hadzic and M. Kretschmer: “SDN in the Wireless Context - Towards Full Programmability of Wireless Network Elements”, in IEEE Conference on Network Softwarization (NetSoft), April 15-17, 2015, London, UK. (accepted)

- C. Niephaus, O. Aliu, M. Kretschmer, S. Hadzic and G. Ghinea: “WiBACK: A Back-haul network architecture for 5G networks”, in IET International Conference on Frontiers of Communications, Networks and Applications (ICFCNA), November 3-5, 2014, Kuala Lumpur, Malaysia. (accepted)

- M. Rademacher, S. Hadzic, P. Batroff, O. Aliu and M. Kretschmer: “Towards centralized spectrum allocation optimization for multi-channel wireless backhauls”, in AFRICOMM 2014, Kampala, Uganda, November 24-25, 2014. (accepted)

- C. Niephaus, M. Kretschmer, G. Ghinea, S.Hadzic and E.Schuetz: “Exploiting the benefits of converged satellite and terrestrial access networks”, in AFRICOMM 2014, Kampala, Uganda, November 24-25, 2014. (accepted)

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

- Future Networks Conference, University of Braunschweig, September 25-26, 2014, Braunschweig, Germany.

- FOKUS Day, Fraunhofer Institute for Open Communication Systems, October 9, 2014, Berlin, Germany.

- AFRICOMM 2014 – 6th International Conference on e-Infrastructure and e-Services for Developing Countries, Makerere University, November 24-25, 2014, Kampala, Uganda.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

Swedish Institute of Computer Science (SICS), September 15-19, 2014.

- Visited the Decisions, Networks and Analytics (DNA) Laboratory, hosted by Prof. Bengt Ahlgren.
- Presentation related to research activities at Fraunhofer FOKUS.
- Discussions with researchers on common topics such as software defined networking (SDN) and 5G.

University of Cyprus (UCY), March 23-27, 2015.

- Visited the Networks Research Laboratory (NetRL), hosted by Prof. Andreas Pitsillides.
- Colloquium on spectrum allocation for multi-channel wireless backhauls.
- Discussions with UCY researchers on graph-theoretical models for channel assignment in wireless networks.