Title: What is HyFi? An Introduction to Hybrid LiFi and WiFi Networks

Duration: half day (3 hours)

Presenters:

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Short bio:
Xiping Wu received the Ph.D. degree from the University of Edinburgh in 2015. He is currently an Assistant Professor in the School of Electrical and Electronic Engineering at University College Dublin (UCD). Prior to joining UCD, he was a Research Fellow at University of Oxford. His main research interests are in the areas of 6G mobile communications, optical wireless communications (OWC) and the Internet of Things (IoT). A particular focus is on developing hybrid networks that integrate OWC and radio frequency (RF), empowered by software-defined networking (SDN) and artificial intelligence (AI). He has authored or co-authored over 50 journal and conference articles in these areas, attracting more than 1000 citations with a google scholar h-index of 19. He is a Senior Member of IEEE and a regular reviewer for multiple prestigious journals and conferences. He was a technical program committee member for IEEE GLOBECOM 2020 and IEEE VTC Fall 2018. He also served as a session chair for IEEE conferences including IEEE WCNC 2017, IEEE PIMRC 2015, IEEE ICC 2014, etc.

Description:

To tackle the rapidly growing number of mobile devices and their expanding demands for Internet services, network convergence is envisaged to integrate different technology domains in the 6G era. For indoor wireless communications, one promising approach is to coordinate light fidelity (LiFi) and wireless fidelity (WiFi), namely hybrid LiFi and WiFi networks (HyFi). This emerging hybrid network, which combines the high-speed data transmission of LiFi and the ubiquitous coverage of WiFi, would redefine the network architecture and potentially enhance network capacity as well as flexibility. This tutorial will present a comprehensive introduction to HyFi, starting with the system framework in terms of network architectures, cell deployments, multiple access and modulation schemes, illumination requirements and backhaul. Afterwards, key performance metrics and recent achievements are summarized to demonstrate the superiority of HyFi against stand-alone networks. Further, the unique challenges facing HyFi are elaborated on four key research topics: user behavior modeling, interference management, handover, and load balancing. Finally, the potential of HyFi in the application areas is presented, exemplified by indoor positioning and physical layer security.

Expected audience:

Background of audience: wireless communications

Expected number of attendees: 30

List of publications in the past 5 years:

[1] **X. Wu***, M. D. Soltani, L. Zhou, M. Safari and H. Haas, "Hybrid LiFi and WiFi Networks: A Survey," *IEEE Commun. Surveys Tuts.*, vol. 23, no. 2, pp. 1398-1420, 2nd Quart., 2021
[2] **X. Wu***, D. C. O'Brien, X. Deng and J. M. G. Linnartz, "Smart Handover for Hybrid LiFi and WiFi Networks," *IEEE Transactions on Wireless Communications, vol. 19, no. 12. pp. 8211-8219, Dec. 2020.*
[3] **X. Wu*** and D. C. O'Brien, "Parallel Transmission LiFi," *IEEE Transactions on Wireless Communications, vol. 19, no. 10, pp. 6288-6276, Oct. 2020.*
[4] **X. Wu*** and H. Haas, "Load Balancing for Hybrid LiFi and WiFi Networks: To Tackle User Mobility and Light-Path Blockage," *IEEE Transactions on Communications*, vol. 68, no. 3, pp. 1675-1683, Mar. 2020.
[5] **X. Wu*** and H. Haas, "Mobility-aware load balancing for hybrid LiFi and WiFi networks," *IEEE/OSA Journal of Optical Communications and Networking*, vol. 11, no. 12, pp. 588-597, Dec. 2019.
[6] **X. Wu*** and H. Haas, "Handover Skipping for LiFi," *IEEE Access*, vol. 7, pp. 38369-38378, 2019.
[7] **X. Wu***, H. Haas and P. M. Grant, "Cooperative Spatial Modulation for Cellular Networks," *IEEE Transactions on Communications*, vol. 66, no. 8, pp. 3683-3693, Aug. 2018.
[8] **X. Wu***, M. Safari and H. Haas, "Access Point Selection for Hybrid Li-Fi and Wi-Fi Networks," *IEEE Transactions on Communications*, vol. 65, no. 12, pp. 5375-5385, Dec. 2017.
[9] C. Chen, D. A. Basnayaka, A. A. Purwita, **X. Wu** and H. Haas, "Wireless Infrared-based LiFi Uplink Transmission with Link Blockage and Random Device Orientation," *IEEE Transactions on Communications, 2020.*
[10] Z. Zeng, M. D. Soltani, Y. Wang, **X. Wu** and H. Haas, "Realistic Indoor Hybrid WiFi and OFDMA-Based LiFi Networks," *IEEE Transactions on Communications*, vol. 68, no. 5, pp. 2978-2991, May 2020.
[11] Z. Chen, D. A. Basnayaka, **X. Wu** and H. Haas, "Interference Mitigation for Indoor Optical Attocell Networks Using an Angle Diversity Receiver," *Journal of Lightwave Technology*, vol. 36, no. 18, pp. 3866-3881, Sep. 2018.
[12] M. D. Soltani, **X. Wu**, M. Safari and H. Haas, "Bidirectional User Throughput Maximization Based on Feedback Reduction in LiFi Networks," *IEEE Transactions on Communications*, vol. 66, no. 7, pp. 3172-3186, Jul. 2018.
[13] C. Chen, D. A. Basnayaka, **X. Wu** and H. Haas, "Efficient Analytical Calculation of Non-Line-of-Sight Channel Impulse Response in Visible Light Communications," *Journal of Lightwave Technology*, vol. 36, no. 9, pp. 1666-1682, May 2018.
[14] Y. Wang, **X. Wu** and H. Haas, "Load Balancing Game with Shadowing Effect for Indoor Hybrid LiFi/RF Networks," *IEEE Transactions on Wireless Communications*, vol. 16, no. 4, pp. 2366-2378, Apr. 2017.
[15] Y. Wang, D. A. Basnayaka, **X. Wu** and H. Haas, "Optimization of Load Balancing in Hybrid LiFi/RF Networks," *IEEE Transactions on Communications*, vol. 65, no. 4, pp. 1708-1720, Apr. 2017.
[16] L. Yin, W. O. Popoola, **X. Wu** and H. Haas, "Performance Evaluation of Non-Orthogonal Multiple Access in Visible Light Communication," *IEEE Transactions on Communications*, vol. 64, no. 12, pp. 5162-5175, Dec. 2016.
[17] **X. Wu*** and D. C. O'Brien, "A novel machine learning-based handover scheme for hybrid LiFi and WiFi networks," in *2020 IEEE Global Communications Conf. Workshop (GCwks), Taipei, 2020.*
[18] **X. Wu*** and D. C. O'Brien, "A Novel Handover Scheme for Hybrid LiFi and WiFi Networks," in *2020 IEEE International Conference on Communications (ICC)*, Dublin, 2020, pp. 1-6.
[19] **X. Wu*** and H. Haas, "RSS-Based Handover Skipping for Ultra-Dense Attocell Networks," in *2019 IEEE 89th Vehicular Technology Conference (VTC2019-Spring)*, Kuala Lumpur, 2019, pp. 1-5.
[20] **X. Wu***, C. Chen and H. Haas, "Mobility Management for Hybrid LiFi and WiFi Networks in the Presence of Light-Path Blockage," in *2018 IEEE 88th Vehicular Technology Conference (VTC-Fall)*, Chicago, IL, 2018, pp. 1-5.

[21] **X. Wu*** and H. Haas, "Access point assignment in hybrid LiFi and WiFi networks in consideration of LiFi channel blockage," in *2017 IEEE 18th International Workshop on Signal Processing Advances in Wireless Communications (SPAWC)*, Sapporo, 2017, pp. 1-5.
[22] **X. Wu***, M. Safari and H. Haas, "Joint Optimisation of Load Balancing and Handover for Hybrid LiFi and WiFi Networks," in *2017 IEEE Wireless Communications and Networking Conference (WCNC)*, San Francisco, CA, 2017, pp. 1-5.
[23] **X. Wu***, D. Basnayaka, M. Safari and H. Haas, "Two-stage access point selection for hybrid VLC and RF networks," in *2016 IEEE 27th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, Valencia, 2016, pp. 1-6.
[24] **X. Wu***, M. Safari and H. Haas, "Bidirectional Allocation Game in Visible Light Communications," in *2016 IEEE 83rd Vehicular Technology Conference (VTC Spring)*, Nanjing, 2016, pp. 1-5.
[25] Y. Tan, **X. Wu** and H. Haas, "Performance Comparison Between Coherent and DCO-OFDM LiFi Systems," *in 2019 IEEE International Conference on Communications (ICC)*, Shanghai, 2019, pp. 1-6.
[26] Z. Zeng, M. D. Soltani, **X. Wu** and H. Haas, "Access Point Selection Scheme for LiFi Cellular Networks using Angle Diversity Receivers," in *2019 IEEE Wireless Communications and Networking Conference (WCNC)*, Marrakesh, 2019, pp. 1-6.
[27] C. Chen, M. D. Soltani, M. Safari, A. A. Purwita, **X. Wu** and H. Haas, "An Omnidirectional User Equipment Configuration to Support Mobility in LiFi Networks," in *2019 IEEE International Conference on Communications Workshops (ICC Workshops)*, Shanghai, 2019, pp. 1-6.
[28] T. H. Loh, David Cheadle, **X. Wu**, Harald Haas, Juan Liu, Pan He and Yong Bi, "Link Performance Evaluation of 5G mm-wave and LiFi Systems for the Transmission of Holographic 3D Display Data," in *2019 13th European Conference on Antennas and Propagation (EuCAP)*, Krakow, 2019, pp. 1-4.
[29] V. Jungnickel, M. Hinrichs, K.L. Bober, C. Kottke, A.A. Corici, M. Emmelmann, J. Rufo, P-B. Bök, D. Behnke, M. Riege, **X. Wu**, R. Singh, D.C. O'Brien, S. Collins, F. Faulkner, M.M. Vazquez, M.C. Bech, F. Geilhardt, R-P. Braun, X. Deng, E. Tangdiongga, A.M.J. Koonen, "Enhance Lighting for the Internet of Things," in *2019 Global LIFI Congress (GLC)*, Paris, 2019, pp. 1-6.
[30] Y. Wang, **X. Wu** and H. Haas, "Resource Allocation in LiFi OFDMA Systems," in *2017 IEEE Global Communications Conference*, Singapore, 2017, pp. 1-6.
[31] M. D. Soltani, **X. Wu**, M. Safari and H. Haas, "Access point selection in Li-Fi cellular networks with arbitrary receiver orientation," in *2016 IEEE 27th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, Valencia, 2016, pp. 1-6.
[32] Y. Wang, **X. Wu** and H. Haas, "Fuzzy logic based dynamic handover scheme for indoor Li-Fi and RF hybrid network," in *2016 IEEE International Conference on Communications (ICC)*, Kuala Lumpur, 2016, pp. 1-6.
[33] Y. Wang, **X. Wu** and H. Haas, "Analysis of area data rate with shadowing effects in Li-Fi and RF hybrid network," in *2016 IEEE International Conference on Communications (ICC)*, Kuala Lumpur, 2016, pp. 1-5.

Relevance:

Next-generation communication systems are expected to provide full coverage, high spectral and energy efficiency, low latency, and massive connectivity. One of the key approaches is integrating wireless technologies of different spectra, including radio frequency (RF), millimetre Wave (mmWave), Terahertz (THz), and visible light communications (VLC). Among them the network convergence of RF and VLC is of great importance, as VLC has potential for reducing energy consumption by providing illumination and communication at the same time, while RF could provide ubiquitous connectivity. The prevalent applications of RF and VLC for indoor wireless communications are WiFi and LiFi. This emphasizes the research on hybrid LiFi and WiFi networks (HyFi) as a key direction towards the 6G mobile communications, which

are expected to be rolled out in 2030. This tutorial would shed light on this emerging type of hybrid wireless network to researchers and engineers from a broad area of wireless communications.

Previous editions: NA

Presentation material: Under preparation