Tutorial T-9: Communication Architectures and Networking for Electric Vehicles in the Smart Grid

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Tutorial Overview

Worldwide electric vehicle sales are expected to be over 3.5 million annually by 2020 according to a Forbes forecast. A significant portion of those vehicles will be Plug-in Electric Vehicles (PEVs) that are plugged-in to the grid through a standard home outlet or to a charging station using a SAE J1772 connector. The volume of electric vehicle charging load is expected to be correlated with peak electricity usage which will dramatically impact the stability of the already stressed power grid. A large number of recent studies have addressed the uncontrolled charging problem and came up with novel architectures, models and networks that allow controlling the heavy PEV loads. Meanwhile, electric vehicle batteries can be considered as Distributed Energy Resources (DERs) once several batteries are controlled as one by an aggregator. This is usually referred to as vehicle-to-grid (V2G) while charging is known as grid-to-vehicle (G2V). V2G applications are expected to be predominant in microgrids which are small scale power grids with the ability to connect and disconnect to the power grid and those that may span a residential home, a building or a neighborhood.

In this tutorial we will first provide a comprehensive background on electric vehicles, batteries, electric vehicle supply equipment types, charging properties, in addition to fundamentals of operation of the generation, transmission and distribution in the smart grid. Then, we will lead the audience to the challenges of electric vehicle charging with in-depth presentation on its impacts on supply, ramping, renewable energy integration, regulation and distribution equipment (transformers, feeders, protection switches, etc.). Along with challenges, we will introduce the opportunities when charging occurs overnight and reduces start-up and ramping costs in the next morning and discuss the options of using electric vehicle batteries as a resource in the smart grid. Next, we will present the communication technologies and networks that are used for connecting electric vehicles to the smart grid communication networks. We will discuss both vehicle to charging station communications as well as charging station to smart grid communications and present wireless, powerline, Ethernet and optical-wireless solutions. The state-of-the-art research in architectures and analytical models for G2V and V2G applications will be introduced in detail in the following part of the tutorial. Aggregator architectures, queuing models, network calculus, optimization-based studies, algorithms and many other solutions from academia and industry will be introduced. As a natural extension of VANETs, Connected Electric Vehicles (CEVs) and adoption of VANET technologies in CEVs will be discussed thoroughly. Worldwide testbeds designed for evaluating advanced electric vehicle applications in microgrids and the smart grid will be introduced. Before closing, we will present open issues and future directions which will give valuable hints for the audience who are willing to pursue cutting-edge research in the electric vehicle and smart grid domains.

Presenter Biographies

Dr. Hussein T. Mouftah is a Distinguished University Professor and Senior Canada Research Chair in

Wireless Sensor Networks at the School of Electrical Engineering and Computer Science of the University of Ottawa, Canada. He has been with the ECE Dept. at Queen's University (1979-2002), where he was prior to his departure a Full Professor and the Department Associate Head. He has six years of industrial experience mainly at Bell Northern Research of Ottawa (then known as Nortel Networks). He served as Editor-in-Chief of the IEEE Communications Magazine (1995-97) and IEEE ComSoc Director of Magazines (1998-99), Chair of the Awards Committee (2002-03), Director of Education (2006-07), and Member of the Board of Governors (1997-99 and 2006-07). He has been a Distinguished Speaker of the IEEE Communications Society (2000-2008). He is the author or coauthor of 9 books, 60 book chapters and more than 1300 technical papers, 12 patents and 140 industrial reports. He is the joint holder of 19 Best Paper and/or Outstanding Paper Awards. He has received numerous prestigious awards, such as the 2007 Royal Society of Canada Thomas W. Eadie Medal, the 2007-2008 University of Ottawa Award for Excellence in Research, the 2008 ORION Leadership Award of Merit, the 2006 IEEE Canada McNaughton Gold Medal, the 2006 EIC Julian Smith Medal, the 2004 IEEE ComSoc Edwin Howard Armstrong Achievement Award, the 2004 George S. Glinski Award for Excellence in Research of the U of O Faculty of Engineering, the 1989 Engineering Medal for Research and Development of the Association of Professional Engineers of Ontario (PEO), and the Ontario Distinguished Researcher Award of the Ontario Innovation Trust. Dr. Mouftah is a Fellow of the IEEE (1990), the Canadian Academy of Engineering (2003), the Engineering Institute of Canada (2005) and the Royal Society of Canada RSC Academy of Science (2008).

Dr. Melike Erol Kantarci is an assistant professor at the Department of Electrical and Computer Engineering at Clarkson University, Potsdam, NY. Previously, she was the coordinator of the Smart Grid Communications Lab and a postdoctoral fellow at the School of Electrical Engineering and Computer Science, University of Ottawa, Canada. She received the Ph.D. and M.Sc. degrees in Computer Engineering in 2009 and 2004, respectively. During her Ph.D. studies, she was a Fulbright visiting researcher at the Computer Science Department of the University of California Los Angeles (UCLA). She received the B.Sc. degree from the Department of Control and Computer Engineering at the Istanbul Technical University, in 2001. She has received a Fulbright PhD Research Scholarship (2006) and the Siemens Excellence Award (2004), and she has won two Outstanding/Best Paper Awards. She has delivered invited talks at various venues including Communications Research Center (CRC) of Canada, National Research Council (NRC) of Canada, IEEE Ottawa Chapter and Turkish Naval Research Center. She is an occasional reviewer of transactions and journals, and a TPC member for various conferences. Her main research interests are smart grid, cyber-physical systems, electrification of transportation, wireless sensor networks, underwater sensor networks, mobility modeling, localization and internet traffic analysis. She has over 1000 citations and her h-index is 19 according to Google Scholar. She is an editor of International Journal of Distributed Sensor Networks published by Hindawi. She is an IEEE member and the past vice chair for Women in Engineering (WIE) at the IEEE Ottawa Section.