CPS-IoT Week 2022 − Tutorial

Localization-of-Things for Cyber-Physical Systems

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Motivation and objectives: The availability of real-time high-accuracy location awareness is essential for current and future wireless applications, particularly for the Internet-of-Things, cyber-physical systems, and 5G/B5G ecosystem. Reliable localization and navigation of people, objects, and vehicles – Localization-of-Things – is a critical component for a diverse set of applications including connected communities, smart environments, vehicle autonomy, asset tracking, medical services, military systems, and crowd sensing. The coming years will see the emergence of network localization and navigation in challenging environments with sub-meter accuracy and minimal infrastructure requirements. Network localization and navigation give rise to a new paradigm for context-aware wireless communications, enabling a variety of new applications that rely on position information of mobile nodes. As the ability to localize devices in wireless networks becomes increasingly important, it is necessary for researchers in communications to be aware of both the fundamentals and the state of the art in location-aware networks. This tutorial is aimed at students and practitioners to provide this knowledge in a rigorous, yet concise form.

Scope: Attendees of this tutorial will learn about location-aware networks in two ways. On the one hand, they will get a high-level overview of fundamental performance bounds, ranging techniques, positioning algorithms, and network experimentation. On the other hand, the tutorial will serve as an introduction to the state of the art in location inference for active and passive localization employing wideband wireless technologies. Results based on measurements collected via network experimentation employing wideband and ultra-wideband radios are used to illustrate the concepts.

Abstract: The availability of real-time high-accuracy location awareness is essential for current and future wireless applications, particularly those involving Internet-of-Things, cyber-physical systems, and beyond 5G ecosystem. Reliable localization and navigation of people, objects, and vehicles – Localization-of-Things – is a critical component for a diverse set of applications including connected communities, smart environments, vehicle autonomy, asset tracking, medical services, military systems, and crowd sensing. The coming years will see the emergence of network localization and navigation in

challenging environments with sub-meter accuracy and minimal infrastructure requirements.

We will discuss the limitations of traditional positioning, and move on to the key enablers for high-accuracy location awareness: *wideband transmission* and *cooperative processing*. Topics covered will include: fundamental bounds, cooperative algorithms for 5G and B5G standardized scenarios, and network experimentation. Fundamental bounds serve as performance benchmarks, and as a tool for network design. Cooperative algorithms are a way to achieve dramatic performance improvements compared to traditional non-cooperative positioning. To harness these benefits, system designers must consider realistic operational settings; thus, we present the performance of cooperative localization based on measurement campaigns.

Outline: The presentation outline is as follows.

1. Goals
2. Localization
    a. Problem Formulation
    b. Requirements
3. Localization Basics
    a. Measurement Phase
    b. Localization Phase
    c. Performance Evaluation
4. Localization Systems
    a. Examples
    b. Limitations
5. High-accuracy Localization
    a. Theoretical Foundation
    b. Cooperative Algorithms
    c. Network Experimentation
    d. Performance Evaluation
6. Localization of Untagged Objects
    a. Problem Formulation
    b. Performance Evaluation
7. Research Directions
8. Summary and Conclusions

Duration: Half-day

Instructor biographies: The instructors have multiple years of experience in providing high-quality tutorials to audiences from academia, industry, and the government.

Moe Win is a Professor at the Massachusetts Institute of Technology (MIT). Prior to joining MIT, he was at AT&T Research Laboratories for five years and at the Jet Propulsion Laboratory for seven years. His research encompasses fundamental theories, algorithm design, and network experimentation for a broad range of real-world problems. His current research topics include network localization and navigation, network interference exploitation, and quantum information science. Professor Win has served the IEEE Communications Society as an elected Member-at-Large on the Board of Governors, as elected Chair of the Radio Communications Committee, and as an IEEE Distinguished Lecturer. Over the last two decades, he held various Editorial posts for IEEE journals and organized numerous international conferences. He has served on the SIAM Diversity Advisory Committee. He was honored with two IEEE Technical Field Awards: the IEEE Kiyo Tomiyasu Award and the IEEE Eric E. Sumner Award. Other recognitions include the IEEE Communications Society Edwin H. Armstrong Achievement Award, the Cristoforo Colombo International Prize for Communications, the Copernicus Fellowship and the *Laurea Honoris Causa* from the University of Ferrara, and the U.S. Presidential Early Career Award for Scientists and Engineers. Professor Win is elected Fellow of the AAAS, the EURASIP, the IEEE, and the IET. He is an ISI Highly Cited Researcher.

Andrea Conti is a Professor at the University of Ferrara and Research Affiliate at the MIT Wireless Information and Network Sciences Laboratory. His research interests involve theory and experimentation of wireless systems and networks including network localization and distributed sensing. He received the HTE Puskás Tivadar Medal, the IEEE Communications Society's Stephen O. Rice Prize in the field of Communications Theory, and the IEEE Communications Society's Fred W. Ellersick Prize. Dr. Conti has served as editor for IEEE journals, as well as chaired international conferences. He has been elected Chair of the IEEE Communications Society's Radio Communications Technical Committee. He is a co-founder and elected Secretary of the IEEE Quantum Communications & Information Technology Emerging Technical Subcommittee. Professor Conti is an elected Fellow of the IEEE and of the IET. He has been selected as an IEEE Distinguished Lecturer.

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