A Decade Later - Challenges: Device-free Passive Localization for Wireless Environments

Moustafa Youssef
Wireless Research Center
E-JUST, Egypt
Email: moustafa.youssef@ejust.edu.eg

***Abstract*—The proliferation of RF networks coupled with the diverse and growing set of mobile devices, opened the doors for a new class of context awareness through contact-free ambient sensing. Since our initial challenges paper in 2007, the field of device-free passive sensing has witnessed an exponential growth; covering areas such as intrusion detection, mobile healthcare, whole-home gesture recognition, traffic estimation, border protection, among others.**

In this talk, we give a holistic overview of the area of contact-free ambient sensing based on RF technology, highlighting how it evolved over a decade from binary-detection in controlled environments to commercial systems for border protection and smart homes. We also give insights about the current trends and possible future research challenges.

I. Introduction

Many ambient and human context sensing systems have been proposed over the years including infrared-based [1], inertial sensors-based [2], computer vision-based [3], among many other systems. However, all these systems usually depend on instrumenting the environment with special hardware, attach devices to the humans, have a limited range, and/or do not work in all scenarios (e.g. in smoke conditions). In addition many of these systems require the device being tracked to actively participate in the sensing process by running part of the sensing algorithm.

Radio frequency (RF) technologies, on the other hand; such as WiFi; bluetooth, FM, and cellular networks, are quickly replacing their wired counterparts and becoming ubiquitous communication technologies. Building on this, we introduced the concept of device-free passive localization [4], in which the context of an entity can be sensed, without carrying any devices nor participating actively in the sensing process, by monitoring and analyzing the changes in the signal of the already installed RF infrastructure. In our initial challenges paper, we envisioned a system that can perform detection of human presence, tracking, and identification of different activities and subject classes; showing a proof of concept detection and tracking system using standard WiFi hardware. Such RF-based ambient sensing allowed context awareness as a value-added service as well as ubiquitous deployment.

The device-free passive sensing concept has been well-received by the research community, leading to a proliferation of device-free passive ambient sensing systems in novel domains over the last decade including radio tomographic imaging techniques [5], [6], multi-persons tracking systems [7]–[13], finer-grained channel state information (CSI)-based sensing [14]–[16], whole-home activity and gesture recognition [17]–[20], robust detection [21]–[24], cyber-physical systems security [25], [26], traffic congestion and speed estimation [27], [28], reducing deployment overhead [29]–[31], understanding the underlying system [32]–[36], human counting [9], [37], minimal hardware tracking [14], [15], mobile devices control [38]–[40], human subject differentiation [41], vital signs monitoring [42]–[44], emotion detection [45], elderly monitoring [10], [46], to name a few. Moreover, there has been a growing number of startup companies that provide commercial-grade device-free passive ambient sensing systems for different application domains.

Looking ahead, in this talk, we identify current research challenges and future possibilities for extending this exciting field of research.

Speaker's Biography

Moustafa Youssef is an Associate Professor at Egypt-Japan University of Science and Technology (E-JUST) and Founder & Director of the Wireless Research Center of Excellence, Egypt. His research interests include mobile wireless networks, mobile computing, location determination technologies, pervasive computing, and network security. He is an associate editor for the ACM TSAS, a previous area editor of the ACM MC2R and served on the organizing and technical committees of numerous prestigious conferences. Prof. Youssef is the recipient of the 2003 University of Maryland Invention of the Year award, the 2010 TWAS-AAS-Microsoft Award for Young Scientists, the 2012 Egyptian State Award, the 2013 and 2014 COMESA Innovation Awards, the 2013 ACM SIGSpatial GIS Conference Best Paper Award, among many others. He is also an ACM Distinguished Scientist and an ACM Distinguished Speaker.

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