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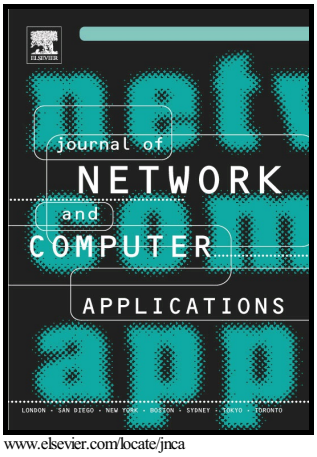

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Ubiquitous Sensor Network Simulation and Emulation Environments: A Survey

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Abstract

Recent human effort has been directed at expanding pervasive smart environments. For this, ubiquitous computing technology is introduced to provide all users with any service, anytime, anywhere, with any device, and under any network. However, high cost, long time consumption, extensive effort, and in some cases irrevocability are the main challenges and difficulties for developing ubiquitous systems. Therefore, one solution is to initially simulate, analyze, and validate practices prior to deploying sensing and computational devices in the real world. Simulation, as a performance evaluation technique, has attracted attentions due to its speed, cost-effectiveness, repeatability, scalability, flexibility, and ease of implementation. Moreover, emulation, as a hybrid method, not only offers most simulation advantages, but also benefits from tight control of implementation, as well as a certain degree of realistic results. Both simulators and emulators are significant tools for enhancing the understanding of ubiquitous sensor networks (USNs) through testing and analyzing several scenarios prior to actual sensor placements. In this regard, this paper surveys 130 simulation and emulation environments and frameworks, which were originally designed and adapted for USN. Of these 130, the 22 that have been widely used, regularly updated, and well supported by their developers are compared based on multifarious criteria. Finally, several studies that had favorably compared the performance of simulators and/or emulators are examined. We believe the present research findings will be helpful for students and researchers to pick an appropriate simulator/emulator, and for software developers and those who are keen on producing their own environment.

Keywords: Ubiquitous Sensor Network; USN; Simulator; Simulation; Emulator; Emulation; Survey

Introduction

Information technology (IT) has been penetrating into our lives to become highly associated and interwoven with our daily activities. Computers, as user interfaces, enable individuals to connect to the cyber space and facilitate persons-to-persons and persons-to-machines interactions. Due to the rapid advancement and development in IT, cyber space has begun to resemble the real (physical) space more and more (Figure 1a), because cyber space is becoming a part of our real space (e.g., augmented reality applications). The confluence of cyber space and real space has generated a new space that has been termed *ubiquitous space* (Figure 1b). In such a smart space, which is a new generation of IT, computers are fragmented and deployed into the environment and computation is made available everywhere and anywhere through *ubiquitous computing* [1]. The word *ubiquitous* is defined as "*existing or being everywhere at the same time*" [2]. The term *ubiquitous computing* (or *ubicomp* in short) was firstly introduced by Mark Weiser [3, 4], who believed that in the near future humans will not interact with a single computer at a time. Instead, they will encounter invisible networked computers that are embedded in objects and are deployed in the environment. In other words, ubicomp is seen as a technology by which sensors interact and control the environments in an invisible manner without humans intervention [5]. All the elements are connected smartly. Computing fades into the background, rather than dominating the foreground. Ultimately, this *calm* technology will make any service accessible for all users, anytime, anywhere, with any device, and under any network. Ubicomp technology is becoming pervasive across diverse fields ranging from the military to tourism and medicine to sport.