Li *et al. EURASIP Journal on Wireless Communications and Networking* (2016) 2016:11
DOI 10.1186/s13638-015-0514-z

EURASIP Journal on Wireless Communications and Networking
a SpringerOpen Journal

RESEARCH Open Access

AVATARS: a software-defined radio based teleoperating cyber-physical system for disaster environment exploration

Lian Li*, Cailian Chen, Yiyin Wang, Yong Cao and Xinping Guan

Abstract

In this paper, we develop a software-defined radio (SDR)-based teleoperating cyber-physical system (CPS) for disaster environment exploration, named AVATARS, which includes a telerobot and a teleoperator. The telerobot of AVATARS can be sent into some dangerous or inaccessible disaster environments for search and rescue tasks. Assisted by the environment information collected by the telerobot, the teleoperator can have a better understanding of the detected disaster environment, and the telerobot can be teleoperated more precisely to accomplish tasks effectively. Wireless communications play a vital role for AVATARS to guarantee its flexibility and scalability. To support reliable wireless transmission and real-time wireless teleoperation, we design an efficient and reliable wireless link to enhance the effective throughput of AVATARS. In the link, wireless communication efficiency is improved by using the packets pipelining and accumulative acknowledgement strategy based on the traditional stop-and-wait ARQ protocol. Sequentially, cognitive radio techniques are explored, and an adaptive channel switching mechanism is proposed to mitigate channel interferences in the crowded ISM band. Furthermore, three different kinds of control information are integrated into a single acknowledgement (ACK) packet to reduce communication overhead. The wireless link is implemented on SDR platforms, and extensive experiments under different conditions are carried out to evaluate its performance. The effective throughput of AVATARS can be enhanced more than four times compared with the traditional stop-and-wait ARQ protocol. We also present a video demo to show the powerful and interesting performance of AVATARS.

Keywords: Teleoperation, CPS, Cognitive radio, Effective throughput, SDR

1 Introduction

Teleoperating cyber-physical system (CPS) is a coordinated robotic system with autonomous motion control, local computations, and wireless communications [1]. This kind of system usually includes one or many telerobots and a teleoperator. The telerobot is a device that has autonomous work ability and can also be controlled remotely by a teleoperator through human operation. The teleoperating CPS is able to meet sudden and temporary requirements for exploration and rescue tasks in accidents and disasters [2, 3]. For example, three species of telerobots were used at the World Trade Center (WTC) 9/11 disaster to actively explore the rubble of the building and inspect the building foundations [4]. However, there is a gap between the wealth of distributed information captured by multiple robots and the understanding of the unknown physical situation of the disaster environment. Wireless communications within robots and between robots and teleoperator are essential to bridge this gap by locally carrying out computation/configuration and transmitting the required and partially processed data. Thus, being able to quickly, reliably, and cost effectively transmit the fused data of vision, infrared, sonar sensors, and other sensors is fundamental for disaster environment exploration.

In this paper, we develop a software-defined radio (SDR)-based teleoperating CPS, called AVATARS, for disaster environment exploration. Here, the name of AVATARS borrows from video games to represent the mobile agent (the robot) as an eyeball. We focus on

*Correspondence: li_li_an@sjtu.edu.cn
Department of Automation, Shanghai Jiao Tong University, 200240 Shanghai, China