Urgency of Information for Context-Aware Timely Status Updates in Networked Cyber-Physical Systems

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ABSTRACT

As 5G and Internet-of-Things (IoT) are deeply integrated into vertical industries such as autonomous driving and industrial robotics, timely status update (TSU) is crucial for remote monitoring and control. In this regard, Age of Information (AoI) has been proposed to measure the freshness of status updates. However, it is irrelevant of context and just a metric changing linearly with time. We propose a context-aware metric, named as Urgency of Information (UoI), to measure the nonlinear time-varying importance and the non-uniform context-dependence of the status information. Then we establish a theoretical framework for UoI characterization and provide UoI-optimal status updating and user scheduling schemes in both single-terminal and multi-terminal cases. Specifically, an update-index-based scheme is proposed for a single-terminal system, where the terminal always updates and transmits when its update index is larger than a threshold. For the multi-terminal case, the UoI of the proposed scheduling scheme is proven to be upper-bounded and its decentralized implementation by Carrier Sensing Multiple Access with Collision Avoidance (CSMA/CA) is provided. Simulation results show that the proposed updating and scheduling schemes notably outperform the existing ones such as round robin and AoI-optimal schemes in terms of UoI, error-bound violation and control system stability.

BIOGRAPHY

Zhisheng Niu graduated from Beijing Jiaotong University, China, in 1985, and got his M.E. and D.E. degrees from Toyohashi University of Technology, Japan, in 1989 and 1992, respectively. During 1992-1994, he worked for Fujitsu Laboratories Ltd., Japan, and in 1994 joined with Tsinghua University, Beijing, China, where he is now a professor at the Department of Electronic Engineering. During 1997-1998, he visited Hitachi Central Research Laboratory as a HIVIPS senior researcher. His major research interests include queueing theory and traffic engineering, wireless communications and mobile Internet, vehicular communications and smart networking, and green communication and networks. Dr. Niu has been serving IEEE Communications Society since 2000, first as Chair of Beijing Chapter and then as Director of Asia-Pacific Board, Director for Conference Publications, Chair of Emerging Technologies Committee, and Director for Online Contents. He has also served as editor of IEEE Wireless Communication, associate Editor-in-Chief of IEEE/CIC joint publication China Communications, and Editor-in-Chief of IEEE Trans. Green Commun. & Networks. He received the Outstanding Young Researcher Award from Natural Science Foundation of China in 2009, Best Paper Awards from IEEE Communication Society Asia-Pacific Board in 2013 and from Journal of Communications and Information Networks (JCIN) in 2019, Distinguished Technical Achievement Recognition Award from IEEE Communications Society Green Communications and Computing Technical Committee in 2018, and Harold Sobol Award for Exemplary Service to Meetings & Conferences from IEEE Communication Society in 2019. He was selected as a distinguished lecturer of IEEE Communication Society as well as IEEE Vehicular Technologies Society. He is a fellow of both IEEE and IEICE.

All are welcome!