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Research article

Effects of wireless packet loss in industrial process control systems

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ABSTRACT

Timely and reliable sensing and actuation control are essential in networked control. This depends on not only the precision/quality of the sensors and actuators used but also on how well the communications links between the field instruments and the controller have been designed. Wireless networking offers simple deployment, reconfigurability, scalability, and reduced operational expenditure, and is easier to upgrade than wired solutions. However, the adoption of wireless networking has been slow in industrial process control due to the stochastic and less than 100% reliable nature of wireless communications and lack of a model to evaluate the effects of such communications imperfections on the overall control performance. In this paper, we study how control performance is affected by wireless link quality, which in turn is adversely affected by severe propagation loss in harsh industrial environments, co-channel interference, and unintended interference from other devices. We select the Tennessee Eastman Challenge Model (TE) for our study. A decentralized process control system, first proposed by N. Ricker, is adopted that employs 41 sensors and 12 actuators to manage the production process in the TE plant. We consider the scenario where wireless links are used to periodically transmit essential sensor measurement data, such as pressure, temperature and chemical composition to the controller as well as control commands to manipulate the actuators according to predetermined setpoints. We consider two models for packet loss in the wireless links, namely, an independent and identically distributed (IID) packet loss model and the two-state Gilbert-Elliot (GE) channel model. While the former is a random loss model, the latter can model bursty losses. With each channel model, the performance of the simulated decentralized controller using wireless links is compared with the one using wired links providing instant and 100% reliable communications. The sensitivity of the controller to the burstiness of packet loss is also characterized in different process stages. The performance results indicate that wireless links with redundant bandwidth reservation can meet the requirements of the TE process model under normal operational conditions. When disturbances are introduced in the TE plant model, wireless packet loss during transitions between process stages need further protection in severely impaired links. Techniques such as retransmission scheduling, multipath routing and enhanced physical layer design are discussed and the latest industrial wireless protocols are compared.

1. Introduction

Industrial process control is a control problem where various sensing and automation technologies are used to supervise the production activities in a plant. In the past few decades, the use of process control has been growing rapidly in conjunction with various plant management systems, such as inventory management, product quality check, plant safety monitoring and environmental control, for optimizing the entire plant operation [1]. In industrial process control, control strategies are generally built around organizing sensing and actuation to serve comprehensive and complicated control tasks. The control data in process control mainly consists of process variables (PVs) and manipulated variables (MVs), the former being the data acquired from field sensors and the latter the commands that need to be applied to actuation devices. In order to achieve the control objectives, the control data needs to be reliably communicated over secure communications links.

Wired communications has been traditionally adopted for use in control systems, because it provides direct, reliable connections between field instruments and control units by wires/cables, multiplexers and fieldbus protocols. However, wired communications has its own limitations. For example, wired connections do not scale well or support network reconfiguration as the process control evolves, larger networks need to be supported, or more data is generated. As an alternative solution, field instruments equipped with wireless adaptors can communicate with each

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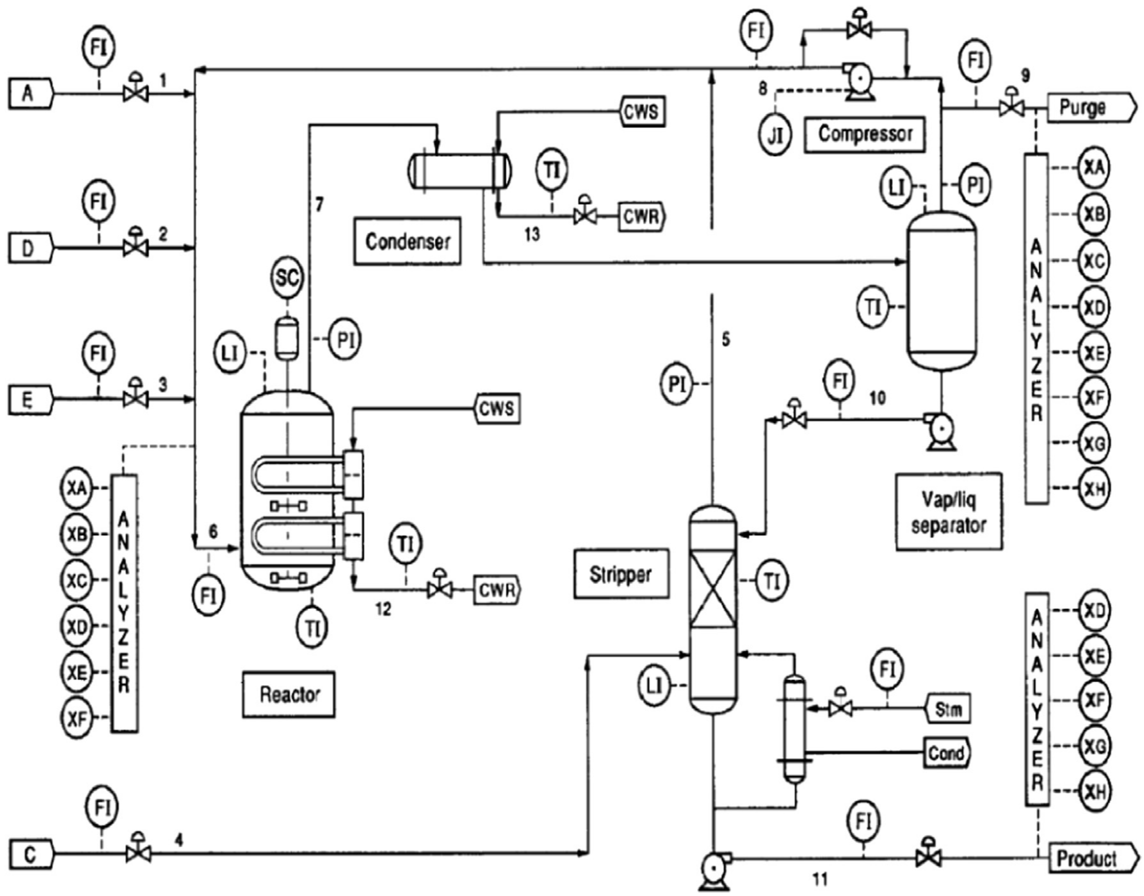

Fig. 1. Tennessee Eastman process control problem [9].

III. Communications Channel Model

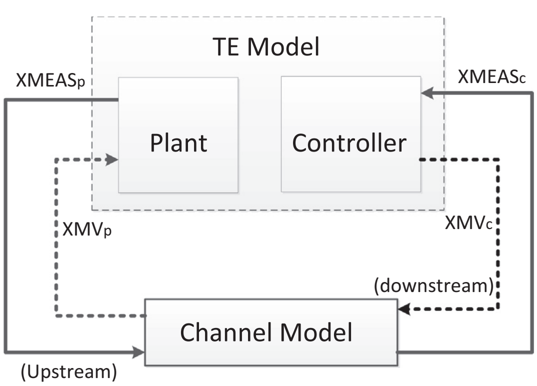

Fig. 2. Integrated TE model with communications channel model.

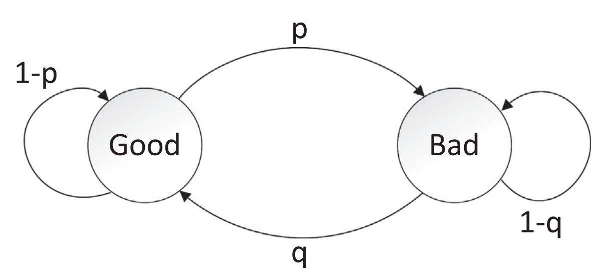

Fig. 3. The two-state GE channel model.

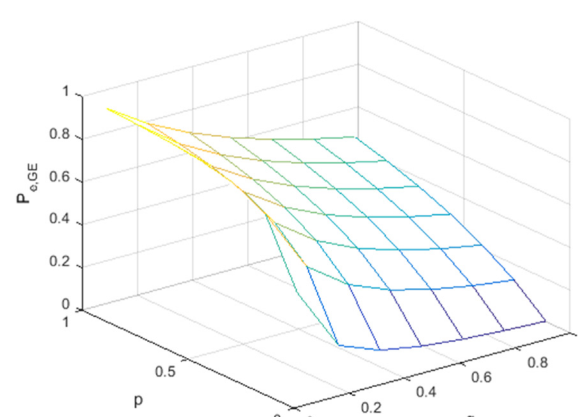

Fig. 4. Average PER under different p and q values in GE model ($P_{e,G}$=**0**, $P_{e,B}$=**1**).

other and the process controller over the air [2]. Wireless networking offers simple deployment, reconfigurability, scalability, and reduced operational expenditure, and is easier to upgrade than wired solutions. Moreover, it supports flexible communication bandwidth allocation to meet the needs of the control system. Therefore, wireless communications is becoming popular in plants for either reducing the deployment cost to reach the remote nodes in a sparse network or increasing the access capability in a limited space in comparison with cable connectors [3]. Accordingly, a number of wireless industrial communication protocols have been standardized, such as ISA100.11a [4] and WirelessHART [5].