TIMICO
Middleware and Communication Protocols for Dependable Systems
Real-time Ethernet

Practicalities

About: This note covers a module. A module consists of two consecutive lecture days.
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Subject

This module is about Ethernet and how it complies with dead-line guarantees in real-time systems. We cover some of the existing methods that facilitate real-time Ethernet, and how Ethernet can be applied as a field-bus technology; hereby, Ethernet enable vertical integration of anything from sensors and actuators to back and front office software applications.

Agenda

Day 1

- L1: Single segment Ethernet

- L2: Multi segment Ethernet

- L3: Real-time Ethernet

- E1: Exercises

Day 2

- E2: Exercises

- AP: Presentation of reading number 6

Readings

1. Decotignie, J.-D., "The Many Faces of Industrial Ethernet", IEEE Industrial Electronics Magazine, vol. 3, issue 1, pp. 8–19, 2009

2. Decotignie, J.-D., "Ethernet-Based Real-Time and Industrial Communications", Proceedings of the IEEE, vol. 93, no. 6, 2005, pp. 1102–1117

3. Zwerina, K., "Standards-Based Real Time Ethernet Now Off-The-Shelf", Industrial Ethernet Book, issue 29, November 2006, pp. 1–4

4. C. Rojas and P. Morell, "Guidelines for Industrial Ethernet Infrastructure Implementation: A Control Engineer's Guide", IEEE, (IAS/PCA 52nd) Cement Industry Technical Conference, 2010, pp. 1–18

5. B. Galloway and G.P. Hancke, "Introduction to Industrial Control Networks", IEEE, Communications, Surveys, and Tutorials, Vol. 15., No. 2, 2013, pp. 860–880

6. G. Carvajal, C.W. Wu and S. Fischmeister, "Evaluation of Communication Architectures for Switched Real-Time Ethernet", IEEE Transactions on Computers, Vol. 63, No. 1, 2014, pp. 218–229

Exercises

Single segment Ethernet

1. Discuss the cause of non-determinism in single segment Ethernet

2. Discuss the functioning of CSMA/CD and in particular the Back-Off Algorithm (BOA)

3. Discuss medium monopolization – and the likelihood thereof – by BOA

4. State the expected back-off time in BOA as a function of collisions, i.e. $E(c)$

5. What is the maximum back-off time when the truncation occurs after $c = 10$ collisions?

6. Sketch a NFA that models non-determinism in single segment Ethernet

Switched Ethernet

1. Discuss the benefits of micro-segmentation

2. What kind of network device offer micro-segmentation capabilities?

3. Discuss the role of CSMA/CD in fully switched (full duplex) Ethernet

4. Why are latency and packet delay variations of concern in switched Ethernet?

5. How may latency and packet delay variations influence dead-line guarantees of a real-time system based on Ethernet?

6. How does overflow and overflow prevention in switches impact predictability of worst-case transmission time bounds?

7. Discuss the purpose of the Spanning Tree algorithm

Real time Ethernet

1. Discuss the motivation for having Ethernet as a field-bus technology

2. Discuss the relevance of leaving bandwidth for normal asynchronous traffic in real-time Ethernet deployments

3. Discuss the Ethernet Frame structure and how it supports real-time Ethernet methods

4. Discuss the real-time facilitating techniques applied in ProfinetIRT, EtherCAT, Ethernet Powerlink, Sercos III, and EtherNet/IP

5. How is overhead/payload ratio reduced in EtherCat?

6. Why is the Precision Time Protocol important to Ethernet/IP?

7. Discuss the Leaky Bucket algorithm and how it is relevant to real-time Ethernet?

Note on exercises

I will mark with a star those exercises I consider to be most important; if none are marked, they are all equally important. The exercises are to help you fully understand the contents of the course, and master the theories, methods, and techniques presented in the lectures. Also, doing the exercises helps you gain a self confidence that most often shines positively through in an exam situation. When you have done all exercises it is good idea to think critically about the course material covered. Spend a few moments to think about the following:

- Summarize the main topics of this module and reconsider what you learned

- How did you succeed in your learning, and can you improve your learning process?

- How can the teaching-learning process be improved?

Of course, I will be happy to discuss the exercises and the course contents with you; however, before coming to me, it is very important that you engage in a discussion with your fellow students. Most often, the challenges you encounter are also challenges for others. Discussing with your fellow students is a good and social way of learning.