TIMICO Middleware and Communication Protocols for Dependable Systems
Module 6: Time Triggered Ethernet – TT-Ethernet

Practicalities

About: This note covers a module. A module consists of two consecutive lecture days.
Lecturer: Finn Overgaard Hansen, office E-305. foh@ase.au.dk
Revision: November 28, 2014, updated December 2, 2014.

Subject

The theme for this module will be an introduction to the fairly new Time Triggered Ethernet protocol called TT-Ethernet. TT-Ethernet combines the traditional switched Ethernet with time triggered functionality for obtaining dependable real-time communication on top of the Ethernet protocol.

Introductory background readings

- Wikipedia: http://en.wikipedia.org/wiki/TTEthernet

Agenda

Day 1

- **Lecture 6.1: Introduction to Time Triggered Ethernet**
- **Lecture 6.2: TT-Ethernet protocol and Safety Critical TT-Ethernet**
- **Exercise 4: Time Triggered Ethernet (TT-Ethernet)**

Day 2

- **Lecture 6.3: Summary**
- **Student Article Presentation:** ***Application of a CAN BUS transport for DDS middleware.***

Details

Day 1

- **Lecture 6.1: Introduction to Time Triggered Ethernet**
  This lecture introduces the basic ideas behind TT-Ethernet and the basic architecture and functionality of a TT-Ethernet based system including the functionality of the TT-Ethernet switch. Readings 1 and 2 with reading 5 as an optional reading..
- **Lecture 6.2: TT-Ethernet protocol and Safety Critical TT-Ethernet**
  This lecture presents some protocol details and continues with a presentation of how a safety critical TT-Ethernet system is build. Readings 3 and 4.
- **Exercise 4: Time Triggered Ethernet (TT-Ethernet)**

Day 2

- **Lecture 6.3: Summary**

- **Student Article Presentation: *Application of a CAN BUS transport for DDS middleware***
  The article integrates the lessons about DDS with the CAN bus lesson, as it describe how DDS middleware can be implemented on to of a CAN Bus.

Readings

1. Hermann Kopetz; Astrit Ademaj; Petr Grillinger; Klaus Steinhammer. *"The Time-Triggered Ethernet (TTE) Design"*. 8th IEEE International Symposium on Object-oriented Real-time distributed Computing (Seattle, Washington: TU Wien), May 2005: page 22–33.
   - This paper introduces the Time-Triggered Ethernet protocol.
2. K. Steinhammer et al. ”*A Time-Triggered Ethernet (TTE) Switch”.* DATE '06 Proceedings: Design, Automation and Test in Europe, 2006, page 1-6.
   - This paper introduces the design of a TTE switch.
3. A. Ademaj et. al. *“Fault-Tolerant Time-Triggered Ethernet Configuration with Star Topology”.* Arcs’06 19th International Conference on Architecture of Computing System. 2006, page 95-105.
   - This paper describes the architecture for a safety critical and fault-tolerant Time-Triggered Ethernet system.
4. A. Ademaj, H. Kopetz, “Time-Triggered Ethernet and IEEE1588 Clock Synchronization”. 2007 International symposium on Precision Clock Synchronization, Vienna 2007, page 41-43.
   - This paper describes how IEEE1588 can be combined with TT-Ethernet.
5. Hermann Kopetz: “*The rationale for Time-Triggered Ethernet”,* Real-Time Systems Symposium, 2008.
   - This is more a background paper, which describes the rationale behind time triggered systems in general and more specific the rationale for inventing TT-Ethernet.
6. T. Steinbach, F. Korf, T. C. Schmidt. *"Comparing time-triggered Ethernet with FlexRay: An evaluation of competing approaches to real-time for in-vehicle networks"*. 8th IEEE International Workshop on Factory Communication Systems (WFCS), May, 2010: page 199–202.
7. Rojdi Rekik, Salem Hasnaoui, “*Application of a CAN BUS transport for DDS middleware”.* Proceedings ICADIWT '09. Second International Conference on the Applications of Digital Information and Web Technologies. 2009: page 766-771.
   - SAP Article: Shows how DDS can be implemented on top of a CAN Bus.

Slides

- **Time Triggered Ethernet – TT-Ethernet**

Exercise 4: Time Triggered Ethernet (TT-Ethernet)

Goal: Obtain experience with calculations of a Time-triggered system using Time Triggered Ethernet.

Assignments:

1. What are the maximum number of user bytes in an event triggered TT-Ethernet layer 2 frame?
2. Calculate layer 2 protocol overhead in an event triggered TT-Ethernet message, when sending 1 byte of user information – using a standard header.
    i. (Layer 2 Protocol overhead= number of protocol overhead data / total frame length in %)
3. Calculate layer 2 protocol overhead in an event triggered Ethernet message, when sending the maximum allowed number of user bytes (found in question 1.) - using a standard header.
4. What are the maximum number of user bytes in a time triggered TT-Ethernet frame? (use the largest TT-Ethernet header in the calculation).
5. One of the TT-Ethernet nodes measures a 16 bit value from a sensor using an A/D converter. What is the frame length for sending this value as a TT-Ethernet frame ?
6. If you want to optimize the utilization of the network for shorter TT user messages, how many user bytes should you then collect and send in the same frame?
7. How many minimum frames can you transmit on Layer 1 on a 100 Mbit/s TT-Ethernet ?
8. How many maximum frames can you transmit on Layer 1 on a 100 Mbit/s TT-Ethernet?
9. What is the maximum possible theoretical sampling frequency for a node allocated to send a 16 bit sensor value as a TT-message, assuming that the time for reading the sensor can be neglected and the node uses the whole TT-Ethernet bandwidth?
10. Assuming that 10% of the TT-Ethernet bandwidth is reserved to TT messages and the rest is used for normal Ethernet event messages. The system have 10 TT-nodes , each sampling a sensor and sending a 4 bytes user message in a reserved timeslot for each node.
    How many TT-frames can be send pr. Sec on the network?
    What is the maximum sampling frequency for one of the nodes?

Evaluation:

Will be evaluated and discussed on the class.