3 Timeliness in Ethernet Based Network Control Systems

This chapter provides a state of the art analysis for one of the three main contributions of this work that is an efficient and simple scheduling approach. Section 3.1 gives an overview about relevant industrial network topologies. Since in this work only Ethernet based communication technologies are considered in section 3.2 the Ethernet standard is briefly described and in 3.3 its real-time capabilities are discussed. All Ethernet based communication technologies, which are considered in this work and also the way how they achieve real-time performance is described in section 3.4.

3.1 Network Topology

In order to connect network devices that are distributed in a plant, a network structure is needed that would span them together. The arrangement of connected components is called network topology and it can have different shapes. The shape is mostly dependent on the physical location of the components to be connected. The most common topology in the industrial environment is a line or so called daisy chain, which follows the arrangement of the production line [101], as shown in figure 3.1. Notice that the following shortcuts has been used to describe the illustrated components in figures 3.1 - 3.4: IO device (IOD), Production Module (PM). The size of the line depends on the dimension of the production line and the network components to be connected.

The PROFINET IRT engineering guideline [81] is a document created by a group of

![Figure 3.1: Line topology in production systems](image_url)
industrial communication experts from different companies that helps to better understand, configure and build the time triggered communication protocol PROFINET IRT. It contains real and typical examples of networks in industrial plants containing topologies, such as comb, tree, ring or mix of all these topologies. A brief description about each of them is given below.

According to [81], another common arrangement in plant networks is the simple tree topology, also called comb (a line with single branches), see figure 3.2. It demands network devices (at least in the backbone part) that contain more than two ports. Such topology already offers some freedom of flexibility. Additional components can be connected at the end of each branch.

![Figure 3.2: Simple tree (comb) topology in production systems](image)

Further modularisation of the production line may increase the number of branches in the network topology, thus creating e.g. a complex tree topology, see figure 3.3. It is a flexible arrangement that includes many devices equipped with more than two ports allowing to create additional branches. In modular production systems, it is common to have multiple PLCs that may be distributed among the topology, see PM B.a and the Control Cabinet with multiple PLCs in the given example. Since there are many devices that have more than two ports, it is easier to attach a new network component, which provides high flexibility.

Ring topology is used for applications that require high level of reliability. This topology may consist of single ring or multiple rings coupled together. Such topology is shown in figure 3.4, here four rings has been coupled together.

The most complex topology that is used in current industrial systems is the one that is a mixture of the above mentioned topology types, as shown in figure 3.5. Such arrangement may contain also several rings that are connected with the remaining network structure. Another important aspect that distinguishes TTEB networks from other environments, such as home and office, is decreased number of ports in the network devices, e.g. device that supports PROFINET IRT have typically 2 or 4 ports. EtherCAT devices have typically 2, 3 or 4 ports. Switches offered for TTEthernet can have up to 24 ports.

Summarising, the network topology used in industrial automation is tightly related with the physical arrangement of the plant. Going in the direction of modularised manufacturing systems with high reliability requirements, the topology can get more com-