Modeling and analysis of multicast communication in windmills

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During the past 20 years, the field of wind energy has experienced an enormous growth. The windmills being constructed are increasing in complexity, production capacity and physical size. Along with this development, windmill parks are becoming a still more common part of the landscape. The increasing complexity of the systems raises a demand for more sophisticated means of controlling the energy production. The internals of a modern windmill consist of numerous embedded systems collaborating closely to solve the task of controlling the machinery and monitoring the process. This collaboration means that the different modules need to communicate in order to exchange measurements, parameter values and commands. Since some of the data being exchanged is related to safety critical tasks in the windmill, a reliable and predictable media for communicating between the nodes in the system is needed. The variance of nature in the data being exchanged in the system is reflected in the variance of the requirements to the communication system; different demands arise when dealing with the different types of information being exchanged in the system. The combination of two basic types of requirements forms the challenge in selecting and designing proper communication protocols. Information that is used for real time controlling of the process must be delivered in a periodic manner with little minimal in the scheduling. Timing is critical while reliability is less critical. In the other case information representing commands and shared parameters should be reliably distributed to all relevant recipients. The level of reliability is defined by a set of requirements to the ordering and predictability of the protocol. In this case, timing is less critical. This makes the process of designing the communication system a very complex task, in which the designer has to pay attention to contradicting requirements of varying importance in a dynamic and complex system. In some cases the design communication systems like this is based on partly evolved models and in other cases the design is merely based on heuristics and non-theoretic evaluations of the problem.

This thesis will apply modeling techniques to the subject in order to evolve a sufficient way to analyze performance and reliability aspects related to internal inter-node communication in a modern windmill. The models will be based on two or more generic and commonly used methods for implementing multicast communication. The

result will be an evaluation of the performance of each of these approaches when applied to the specific problem domain. The models will be developed using a method by the name of *Coloured Petri Nets (CPN)*. This method makes it possible to investigate both the performance and the reliability of distributed systems. The University of Aarhus is home for a research group in the field of CPN. This group has worked on developing a generic tool for modeling and evaluating systems using the CPN method and this tool will be used for modeling the earlier mentioned models in this thesis. The work with a real life problem will form an interesting environment for using a theoretic approach to analyzing and solving complex problems like this.

Along with the model-based analysis, the thesis also contains an evaluation of the most common protocols in the field of multicast communication. This evaluation will be accompanied by a theoretic description of key aspects of reliable communication, real time predictability in multicast communication and the methods for modeling a system like the one in question. This evaluation will form a foundation for selecting a proper approach to solving the specific problem.

The work will be based on a specific case supplied by the Danish windmill manufacturer Vestas Wind Systems. The company has currently installed more than 26,000 windmills worldwide and is continuously working on developing still more advanced systems for controlling and monitoring the windmills. The company will supply detailed information about requirements and properties for a specific application of the multicast communication system described earlier. This information will be used throughout the work on the thesis in order to conduct a case study based on a real life problem.

The main aim of the work on the thesis represents a combination of the two sub-tasks described here; the result is an evaluation of the problem based on a theoretical investigation and accompanied with guidelines for designing a reliable and predictable system that corresponds to the real time and safety requirements described in the specific problem.

The problem described here is common in nature to other typical types of distributed systems. This makes part of the work done in this thesis applicable to other fields than the windmill industry.