NSF Engineering Research Center for
Reconfigurable Manufacturing Systems
University of Michigan

Factory-Wide Time Synchronization for Diagnostics, Control and Safety

MOTIVATION AND CHALLENGE

Synchronizing multiple clocks on a control network is imperative to the functioning of many networked applications in manufacturing such as motion control and coordinated diagnostics. The next generation of distributed/modular control will be tasked with harder, faster and more critical applications. Methods chosen to synchronize and maintain the stability of the clocks that run these controllers have to be capable of meeting these stringent specifications. The goal of this project is to *deliver analysis, methods and best practices for utilizing timing, time stamping and networked time synchronization* protocols such as IEEE 1588 in manufacturing control systems. The time synchronization solutions, best practices and, eventually, standards that will be developed with the help of this project will help industries move towards these levels of precision and indeed move to new paradigms for design and implementation of control systems.

Several time synchronizing protocols exist that support Ethernet networks. NTP, which has a synchronization accuracy on the order of 10 milliseconds, is used to synchronize internet servers and Local Data Networks. Hardware-based time synchronization solutions such as IEEE 1588 can provide synchronization capabilities for Ethernet systems in the order of 10s of microseconds.

BENEFITS

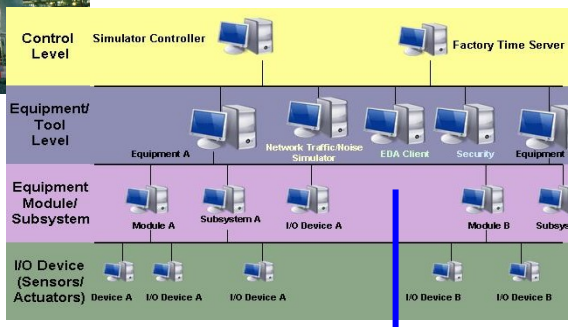
- ✓ Provide guidance for selecting and utilizing time synchronization capabilities in manufacturing.
- ✓ Quantify the capabilities of IEEE 1588 hardware time synchronization, especially as they relate to operation of control, diagnostics and safety systems
- ✓ Provide a simulation tool that analyzes performance of factory-wide Equipment Data Acquisition (EDA) systems
- ✓ Provide parameterization of time synchronization performance in both wired and wireless systems
- ✓ Provide technical input into development of industry time synchronization standards

OVERVIEW OF THE WORK

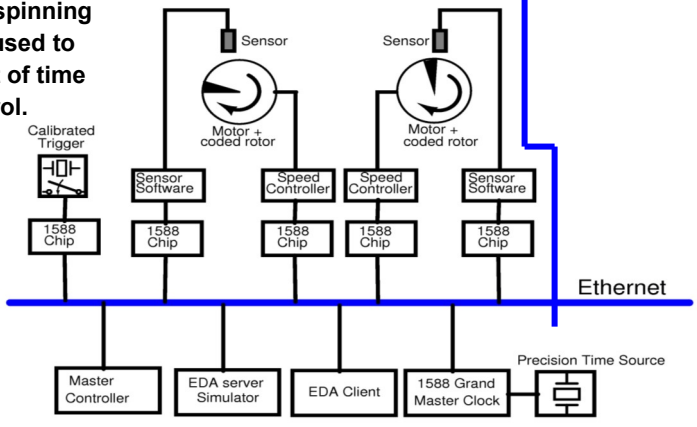
Two parallel interests are being explored:

1. Studying the accuracy achievable with the software time sync methods available. This includes studying the effect of application code and limitations imposed by the programming environment on the time synchronization accuracy.
2. Utilize a test bed equipped with hardware time synchronization and time stamping capabilities to develop and characterize best methods for providing time synchronization services. The idea is to translate the improvement in time quality to overall control system performance and possibly looking at designing controllers specifically to exploit accurate time assessment. This testbed can be operated in a system-in-the-loop mode along with our configurable factory wide diagnostics simulator, allowing the characterization of performance in real world network conditions.

A distributed control application such as in the plant pictured here requires precise time synchronization over all network layers. The traffic across these layers is simulated by the EDA simulator illustrated below.



The testbed currently being developed will allow us to study low level time stamping accuracy and control under real network conditions. The figure below shows a schematic of the testbed, a pair of spinning coded rotors are used to assess the impact of time accuracy on control.



GOALS

The goals for this project are an assessment of the *end to end delay* problem to evaluate the benefit of network time synchronization and time stamping, technology transfer of a life-like factory network simulator of an equipment data acquisition system capable of reproducing data traffic in any factory, and development of *best methods for utilizing time synchronization mechanisms such as IEEE 1588 and NTP.*

PRELIMINARY RESULTS

- Network delay contributions have been quantified and show that *delays associated with device speed and its variability dominate in network communication*:

	UDP	VPN	OPC	DeviceNet
Delay Average (ms)	0.33	1.21	1.48	0.3-1.2
Delay Variation (3σ) (ms)	0.09	0.49	2.43	0.005-0.2
Network Contribution (ms)	0.035	0.035	0.035	0.188
% of Delay Due to Network	11%	3%	2%	63%

Network delay contributions

- Initial tests with time stamping data packets at the application layer indicate that application processing time is a dominant cause of variation.
- The drift and steady state offset in a slave clock is degraded when synchronizing over a wireless link.

CURRENT STATUS

- *A simulator has been developed which successfully creates scenarios typical of equipment data acquisition systems including the capability for traffic and noise generation and XML messaging seen on the factory floor.* The simulator allows for a practical perspective to study the accuracy achievable and potential network factors contributing to accuracy degradation of factory-wide time synchronization
- A study on the time-stamping performance over a wired Ethernet network has been conducted evaluating various time-stamping methods and locations.
- Performance of the time synchronization service over wireless media is a current focus area.
- *A test-bed to analyze low level (hardware) time synchronization, time stamping and IEEE 1588 is in the design phase.*

FUTURE MILESTONES

- Complete study of time synchronization performance over wireless media.
- Implement the new scalable design for the factory-wide diagnostics traffic simulator.
- Design and develop a IEEE 1588 hardware time synchronization test-bed
- Evaluate different mechanisms for accurate time stamping in sensor/actuator systems
- Develop best practices for factory-wide time synchronization (allowing for hardware

DELIVERABLES

- Comprehensive report that characterizes time precision over wireless networks.
- A test-bed used for characterizing the application of low level time stamping on a networked control system
- Configurable factory-wide diagnostics system simulation tools that provide for performance analysis of systems and assessment of need for / impact of addition of time synchronization capability.
- Time synchronization in manufacturing best practices document.

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