Sensor Networking with IEEE 1451 Compatibility Testing

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Abstract

Design and implementation of a testbed for testing and verifying IEEE 1451-compatible sensor systems with network performance monitoring is of significant importance. The performance parameters measurement as well as decision support systems implementation will enhance the understanding of sensor systems with plug-and-play capabilities. The paper will present the design aspects for such a testbed environment under development at University of Houston in collaboration with NASA Stennis Space Center – ToSS (Testbed of Smart Sensors).

Introduction

There is an ongoing progress in the sensors and networking technologies in order to realize a network of sensors working harmoniously similar to the chips on a motherboard of a PC. In this respect, the sensors will not be able to reach the level of integration unless they have embedded networking capabilities [1]. These capabilities have been implemented in a proprietary manner in various systems by the sensor networking companies. However, there is a strong push in the industry to harmonize the standards that enable networking and data acquisition of sensors. The need comes from reaching the ultimate goal for networked smart sensors: web access that can enable a distributed decision system.

The distributed system would be possible by following the path of the networked PCs towards creating the internet: plug-and-play capabilities of PCs paved the way towards making the internet what it has become today. Similarly, sensors with plug-and-play capabilities will enable an autonomous system to be up and running virtually for every kind of sensing application. Transducer Electronic Data Sheets (TEDS) will play an equivalent role to the drivers for PC equipment in realizing this mission.

Communication protocols that integrate the TEDS information into the protocol flow control will deliver the critical differentiated services to the network in order to guarantee an upper bound on the network latency. The control networks will emerge as more dedicated networks with strict latency bounds. Request-response and publish-subscribe types of networking paradigms will exist concurrently in a sensor networking environment [2]. Information fusion that takes into account of a random network delay with an upper bound is critical in sensor networking. Although it is desired to guarantee a deterministic delay, testbeds will enable the analysis of this delay in detail towards preparation for the worst case scenario [3]. In addition to the efforts to create time-synchronized (not only by network events) through IEEE 1588 [4], there are

experimental evaluations of potential sensor networks for their synchronization capabilities [5]. This paper is on the design of a testbed system to test and verify IEEE 1451 compatible sensor systems with networking performance monitoring.

Design Considerations

There has been a relatively long history in distributed monitoring and decision support system in control and systems research community [6, 7], and in wired or wireless networking in communication research community. However, the control research community usually is not concerned about network and communication parameters such as details in channel initialization, routing, reconfiguration, and power and topology constraints. Also, the control and decision support systems should be aware of errors caused by networking such as channel errors, delays, and packet losses. Recent research starts to make simple assumption such as error-free communication channels with capacity constraint [8], and research about the robustness of the decision support system to the loss of communication links [9]. The testbed presented here aims to bridge the gap between the two research communities. When designing and implementing such a testbed for plug-and-play intelligent sensors, we make use of a computer networking testbed as a stand-alone networking backbone with various architectural capabilities. The testbed networking backbone architecture is presented in figure 1.

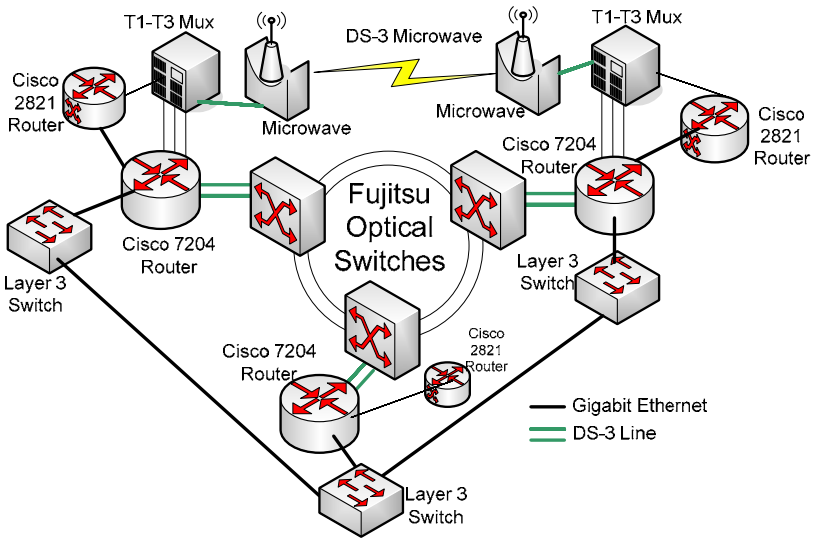

Figure. 1. Networking infrastructure backbone for the sensor testbed.

Networking nodes will be loaded with conformance tester and actual network capable application processor (NCAP) functionality to experiment with the 1451 standard-based sensor networking. Eventually, the testbed will emerge as an autonomous network of sensors with automated TEDS management and a central intelligence unit with integrated system health management (ISHM) functions.

Main Tasks

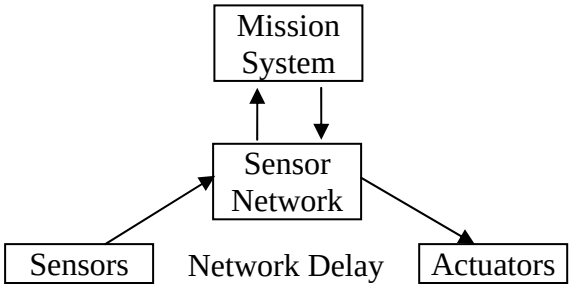

Figure 2. Control network response loop.

As presented in [10], a control loop takes into account of the network delay as shown in figure 2. The control networking performance analysis will include the protocol and standards parameters such as TEDS information delivery and updates, reconfiguration and calibration needs of smart sensors, and response timing in the network. The on-the-fly calibration and reconfiguration requirements will become as important as the data transfer with minimal and bounded latency. In this paper, we will present:

(i) Implementation metrics and requirements for monitoring and evaluation of capabilities in a Systems of Systems (SoS): The performance of the network will be monitored using the real-time control parameters. The testbed will provide networking performance monitoring and evaluation capability based on following indices: network latency, throughput, synchronization, and deterministic and random behaviors.

(ii) Assessment of the flexibility and integrability of different sensor systems. The standards of sensor interfacing will be tested and verified for SoS deployment over this testbed. Assessment methods and test scenarios will be developed in order to have a uniform performance evaluation and specification validation of standardized issues in sensor networks.

Conclusion and Future Work

Networked sensor systems with standard plug-and-play capabilities are attracting a lot of attention in the research and industry community. Specifically, IEEE 1451 standard is perceived to introduce smart sensors with plug-and-play capabilities. There is a need to develop a testbed to evaluate different architectures and protocols in IEEE-1451 enabled sensors. This testbed will play a big role in meeting this need and help quantize different performance metrics. Future work will include implementation, data collection and analysis of heterogeneous technologies in the testbed and methods to evaluate the performance of smart sensor systems. Figure 3 (a) shows a sample test procedure and (b) shows conceptual setup for testbed.

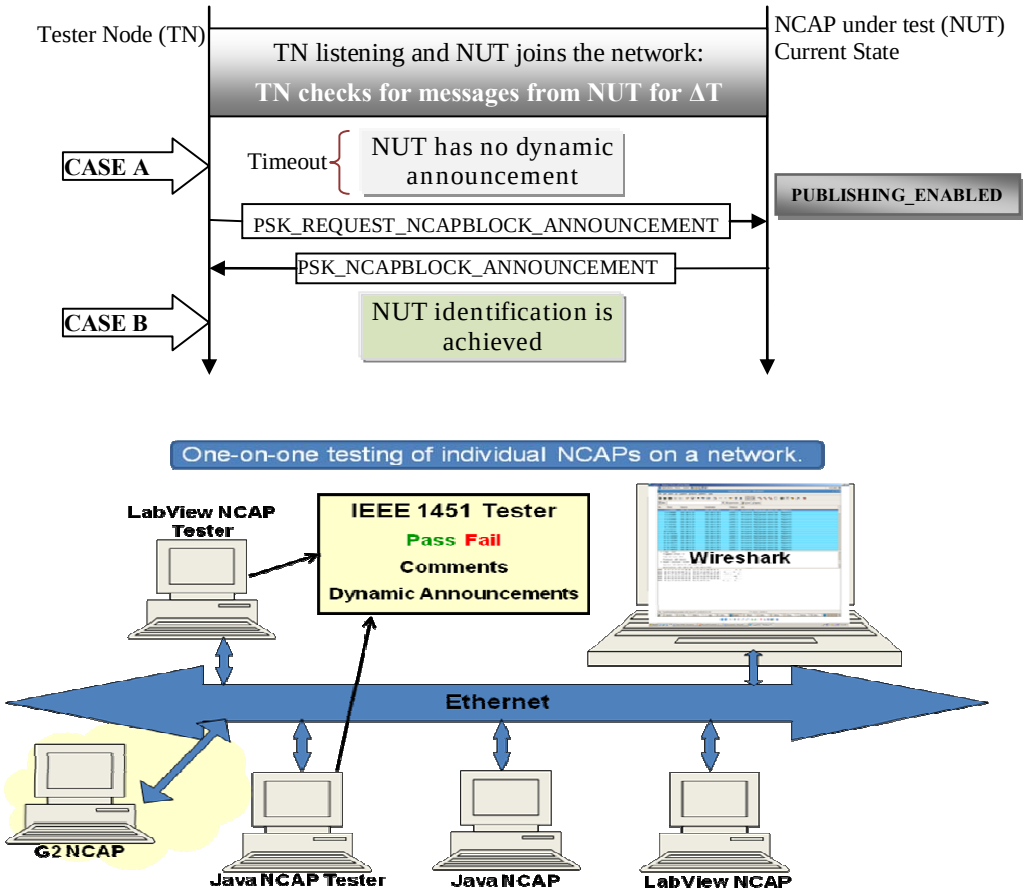

Figure 3. (a) Test procedure for the tester. (b) 1451 compatibility testing network.

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