



University of New Hampshire
**InterOperability
Laboratory**

Testing The Limits: TSN and SPE Updates

Presented by Bob Noseworthy and
Griffin Leclerc
February 9, 2021



UNH-IOL at a Glance

The UNH-IOL as founded in 1988. Main UNH campus is located in Durham, New Hampshire, USA

The UNH-IOL is a non-profit neutral, third-party laboratory dedicated to testing data networking technologies through industry collaboration.

The UNH-IOL has been involved with TSN since the days of Residential Ethernet ('05) and in Ethernet Physical layer test since 1988.

- Principal developer of Avnu Automotive Certification Test Plans & Tools
- Principal developer of OPEN Alliance Physical layer, PCS, Phy Control and Sleep/Wake Test Plans



Agenda

Overview of 802.1 Time Sensitive Networking and 802.3 Single Pair Ethernet activities {20 Min}

- Digital Factory Updates
- APL & 1588 Updates

Timing Security Updates {10 Mins}

- 1588/PTP Security TLV
- NTP NTS Update

Q/A and Open Discussion {30 Mins}

- Put questions in Zoom Q&A Box
- Those asking a question will be given permission to speak

Today's Speakers

Bob Noseworthy



Principal Engineer,
TSN, SPE, 1588 Technologies

Involved with:
APL Group Certification,
Avnu Alliance's Certification,
IEEE PTP Certification,
Open Alliance Certification,
End-user TSN Profile development &
IEEE 802.1 TSN Working Group

Griffin Leclerc



Graduate Researcher
UNH-IOL &
Department of Computer
Science

Actively involved in TSN and
IEEE 1588 compliance
validation and leading NTS
performance study

SPE Summary Updates

10BASE-T1L and APL (Advanced Physical Layer)

APL Certification testing online and expanding to the APL Group membership and organization labs

10BASE-T1L PMA, PCS, PHY-Control and Auto-Negotiation In development

- PMA fully available and PCS partially available

Tooling available:
PCB Test Fixtures

- Bias Tees for Spur/ Trunk Source/Load
- Line taps + more

<https://license.unh.edu/products/iol/APL>

Test Software expected this month

Service offering migrating to a 10BASE-T1 Service group

- APL Testing available as Pay-per-test
- Silicon conformance testing moving out of “Low-speed SPE” group

SPE Summary Updates (2)

100BASE-T1 to MultiGig, OPEN Alliance and Ethernet Alliance + Plugfests!

Contributing to Open Alliance Errata and ISO process for 100BASE-T1 test plans.

Continuing to develop MultiGig PMA test capability launch and work with industry leaders for MultiGig PCS/PhyC compliance testing

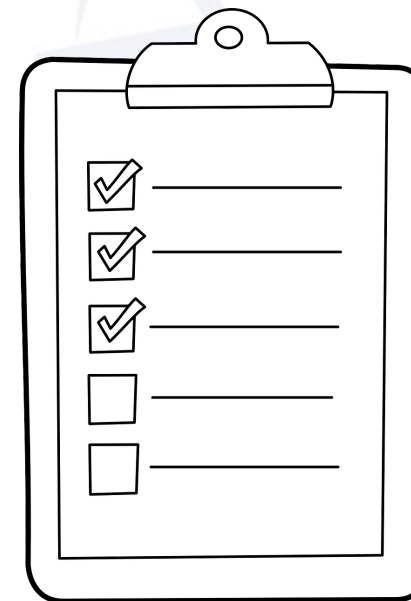
Participating in discussions with the Ethernet Alliance SPE group on potential activities for further EA driven validation

Anticipating Summer 2022 plugfests for SPE interests *(potential for 10BASE-T1L through MultiGig SPE – possibly include 1000BASE-T1 Type B and 40Meter reach)*
UNH-IOL Hosting EA High Speed Networking Plugfest April 25-29 & IBTA May 2-6

TSN Updates - Beyond AVB

Validation of TSN Standards

- .1Qbu/.3br: UNH-IOL Pre-emption conformance testing, including negative test cases, available since 2017
- .1Qbv: Time aware scheduling (TAS) testing performed for some IP & silicon providers
- .1Qci: Ingress Policing (Per-Stream Filtering and Policing) in development
- IEEE 802.1AS-2020, IEEE 1588-2019, and related profiles: C37.238-2017, IEC/IEEE 61850-9-3{2016}, ITU-T G.8275.1 & G.8275.2 available or in dev.
- Test plans currently available or expected in '22



TSN Updates - TSN Profiles

TSN Standards → TSN Profiles

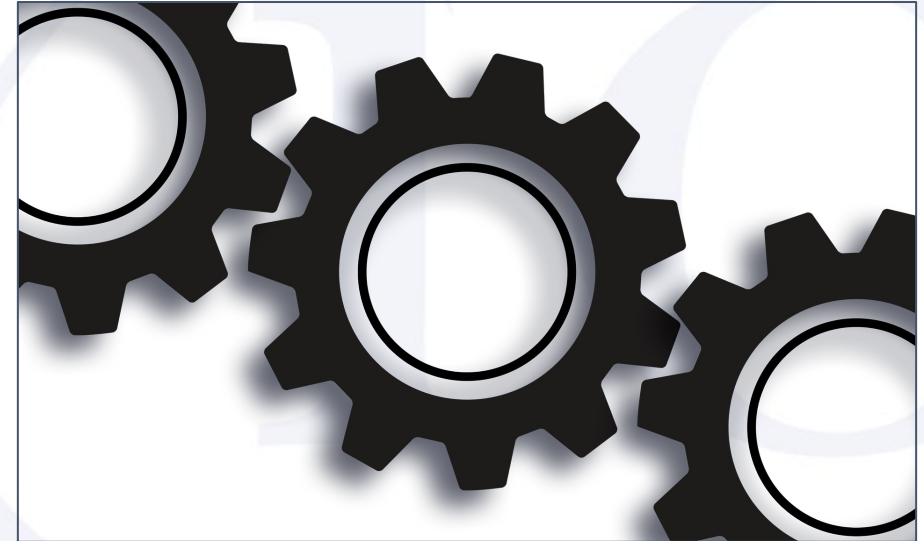
- AVB was ~5 IEEE standards, TSN has >42 & climbing
- Most standards have multiple options, some orthogonal
- TSN Profiles must exist to define interoperable solutions for a given use case
 - Example: IEEE 802.1BA (AVB Profile)
- Several profiles are in-flight, none complete:
 - IEEE 802.1DG (Automotive)
 - IEC/IEEE 60802, (Industrial Automation)
 - IEEE 802.1DF, (Telecom Service Provider)
 - IEEE 802.1DP (Aerospace)
- Currently authored 2 profiles for large end-user needs (not yet publicly available, expected to be in 2022)



Industry Updates

Industrial Automation / Process control

- Supporting needs of the APL Group
 - PNO, FieldComm Group, ODVA, OPC Foundation
 - In discussions with several member organizations and member companies to offer further services
- Tracking APL further specification definitions
- Tracking IEEE 802.3 100BASE-T1L
- Developing full Silicon Validation for 10BASE-T1L
- Tracking IEC/IEEE 60802 and related CA discussion
- Supporting Research interests in Industry 4.0 / Digital Factory



NSF I/UCRC CDFI

NSF - U.S. National Science Foundation

I/UCRC - Industry / University Collaborative Research Center

CDFI - Center for Digital Factory Innovations

CENTER FOR DIGITAL FACTORY INNOVATIONS (CDFI)

To drive innovative research with our industrial partners that enables the future digital factory by allowing the synchronization of processes—cyber, physical and human—and creating a manufacturing system endowed with efficiency, resilience, and intelligence.

Nicholas Kirsch



University of
New Hampshire

Noel Greis



Christopher Saldana



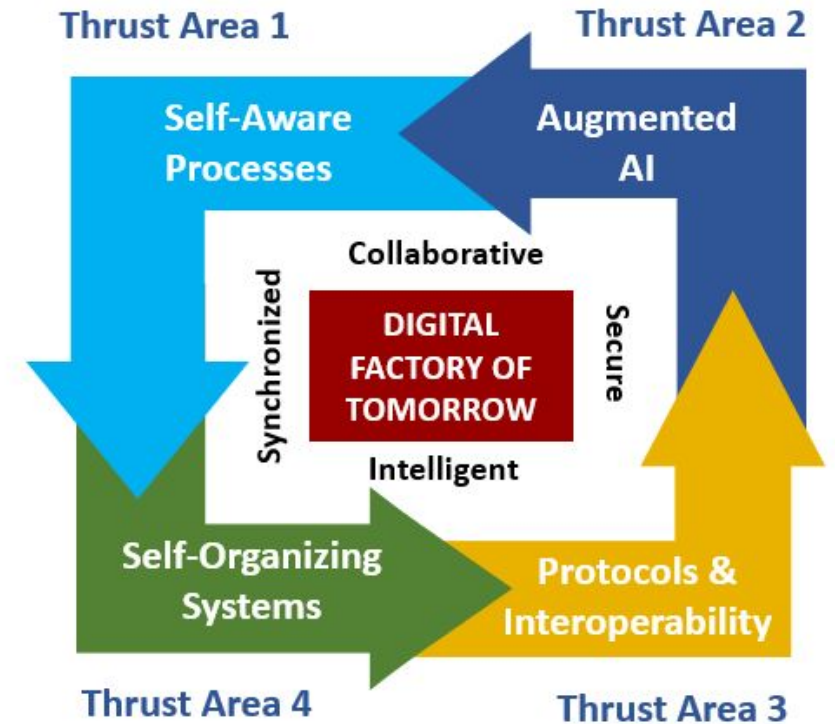
Center Overview

Vision: We envision interconnected, self-aware factories and processes that manufacture products through automation and the marriage of intelligent human-machine interactions.

Objective: To catalyze Internet-of-Things for Manufacturing (IoTfM) advancement and adoption for the purposes of improved product performance, enhanced productivity, work force development, and economic growth.

Importance: To benefit US industry by generating new knowledge/methods to accelerate innovation, reduce waste, increase productivity, bring transparency to the value chain, and provide unique training opportunities for the critical, future workforce.

Technical insights: AI/ML integration, future workforce, future factory computing, self-optimizing systems.



Areas of CDFI Industry-Motivated Research

Self-Aware Processes

Dynamic and self-aware manufacturing processes which contribute integrated sensors and accompanying adaptive, cloud-based optimization and control systems for processes, such as machining, forming, and robotics.

Self-organization and control of production systems which feature autonomy and reconfigurability within a distributed environment to allow local intelligence to the edge, enabled by machine learning and 5G networking for real-time control of the factory environment.

Self-Organizing Systems

Synchronized
Collaborative
**DIGITAL
FACTORY OF
TOMORROW**
Secure
Intelligent

Augmented AI

AI-Enabled Human-in-the-Loop in the Digital Factory which assures human-machine cooperation in a cyber-physical system environment through artificial intelligence (AI) algorithms and machine learning for applications such as discrete processes and cobots.

Deterministic protocols, interoperability, and cybersecurity which focuses on communication platforms from time sensitive networks to wireless connectivity to the secure transfer of data for a given manufacturing process or entire factory environment.

Protocols & Interoperability

Where Are We In The Process?



Center Leadership & Universities

CDFI University Sites



University of New Hampshire

Advanced manufacturing processes with next generation communication systems focused on time-sensitive networking, interoperability and cybersecurity.

- John Olson Advanced Manufacturing Center
- InterOperability Laboratory
- Connectivity Research Center



North Carolina State University

Digital technologies that transform data collected across the digital factory into actionable intelligence and self-managing capabilities.

- Digital Solutions Laboratory
- NCSU High Performance Computing Center
- ReasonSmart Data Analytics Platform



Georgia Tech

Advanced manufacturing and computing with a focus on additive/hybrid manufacturing, digital/smart manufacturing and manufacturing robotics.

- Advanced Manufacturing Pilot Facility
- CODA Computing Complex
- Factory Information Systems Laboratory

CDFI Leadership

Dr. Nicholas Kirsch (Center Director, UNH Site Director)

- Associate Professor, Electrical & Computer Engineering
- Expertise: wireless communication networks, MIMO communications systems, cognitive radio, transparent antennas, and spectrum sensing

Dr. Noel P. Greis (NCSU Site Director)

- Research Professor, Operations and Supply Chain Management
- Expertise: Industry 4.0, machine learning, and intelligent technologies for digital manufacturing

Dr. Christopher Saldana (GT Site Director)

- Ring Family Professor and Associate Professor, Mechanical Engineering
- Expertise in digital manufacturing and hybrid manufacturing process development

Industry Updates

IEEE Conformity Assessment Advancing toward approved Test Specification

- Continuing to support
 - Launch of IEEE 1588 Power Profile Certification
 - OCs, BCs, and TCs
 - Validation of IEEE 1588-2008 & IEC/IEEE 61850-9-3 & optionally IEEE C37.238-2017
 - PTP Violet for in-house pre-testing
- **Test Suite Specification in review prior to ballot**
- NIST and UNH-IOL collaboration and correlation effort
- Join the program and pass testing to become certified and listed in the IEEE Registry

IEEE SA
STANDARDS
ASSOCIATION



IEEE
1588
Certified



Industry Updates

- Officially Members (finally!) as of late Jan'22
- Exploring potential to further assist with:
 - o Leveraging existing UNH-IOL draft ITU-T 8275.1 and 8275.2 test plans
 - o Leveraging existing UNH-IOL expertise with IPv6, service provider networks, plugfest and test bed hosting



Timing Security

- **Time Sensitive Networks** depend on secure & reliable **time**
- In 2018: UNH-IOL & CS Department supported Dragos Maftei's thesis:
 - IMPLEMENTING PROPOSED IEEE 1588 INTEGRATED SECURITY MECHANISM
 - <https://www.cs.unh.edu/cnrg/publications/dmaftei-thesis-18.pdf>
 - Open source update to PTPd available to implement Security TLV
- GAP: The IEEE 1588-2019 Security TLV does not define key exchange mechanisms



NTP Network Time Security (NTS)

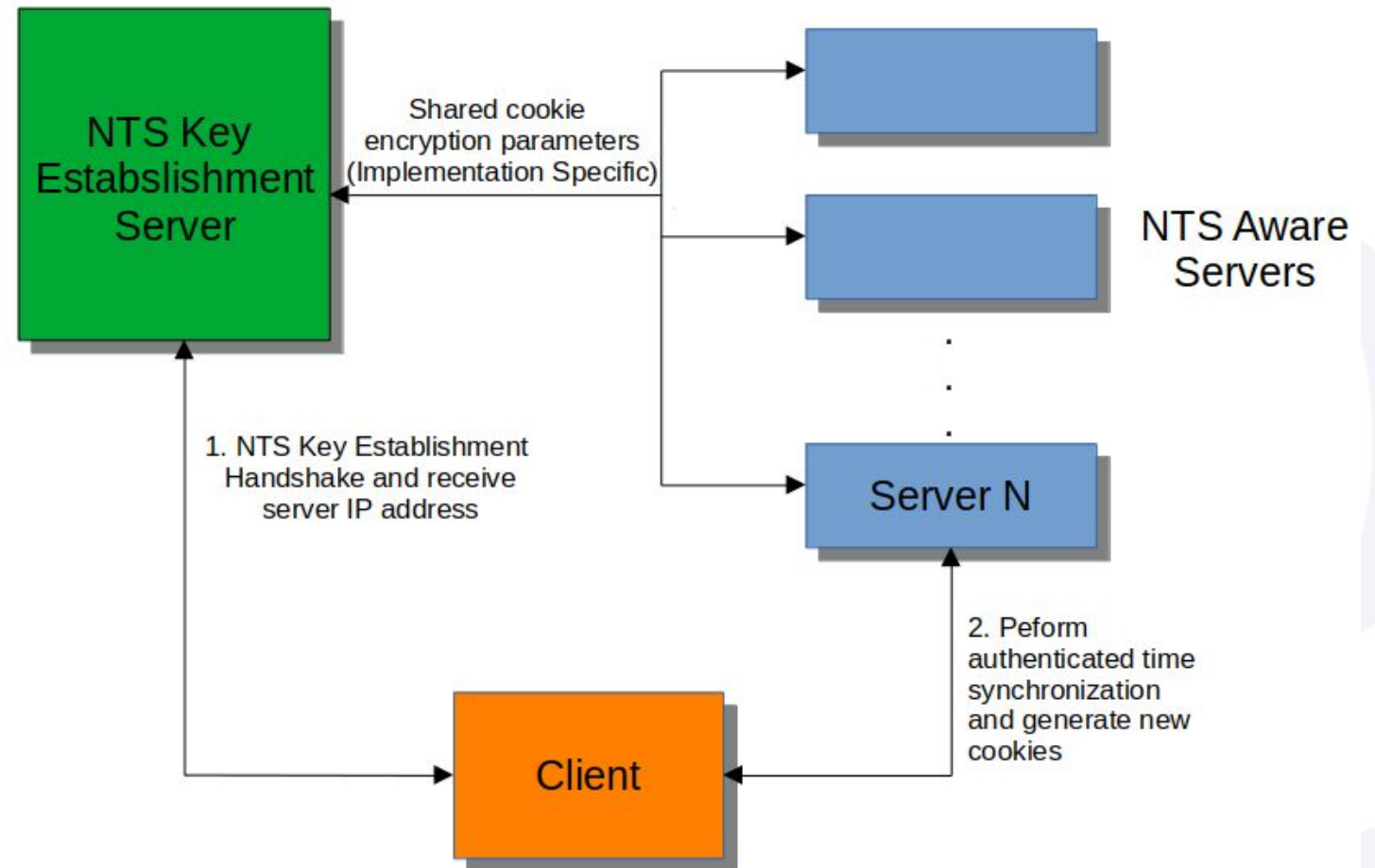
- With support from the Internet Society, UNH-IOL is supporting graduate researchers pursuing compliance, interoperability and performance study of NTP's NTS
- NTS is of interest to NTP and 1588 worlds alike
 - Likely path to be taken by future 1588 Security update
- Note, UNH supports the International IEEE Symposium on Precision Clock Synchronization (ISPCS), including its plugfest activities.

Network Time Security

RFC 8915

<https://datatracker.ietf.org/doc/html/rfc8915>

Ensures time originates from a trusted source



An adaptation of Figure 1 from RFC8915

The InterOperability Effort

Protocol Conformance Testing

Ensures NTS implementations conform to the RFC

Interoperability Testing

Ensures NTS implementations provide well formed timing information

Performance and Scalability Study

Quantify resource impact introduced by using NTS over NTP

Experiment Design

Augment Cloudflare's open source NTS implementation with Cargo Bench

Isolate NTS operation from NTP for a baseline comparison

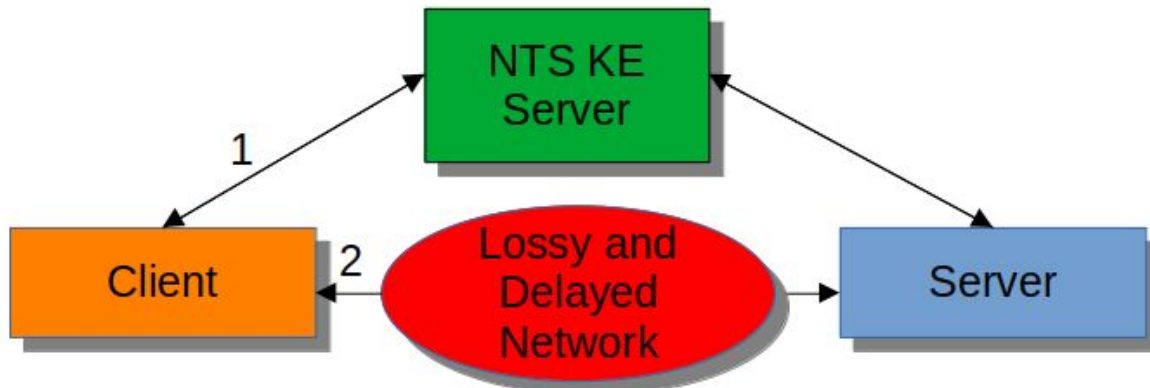
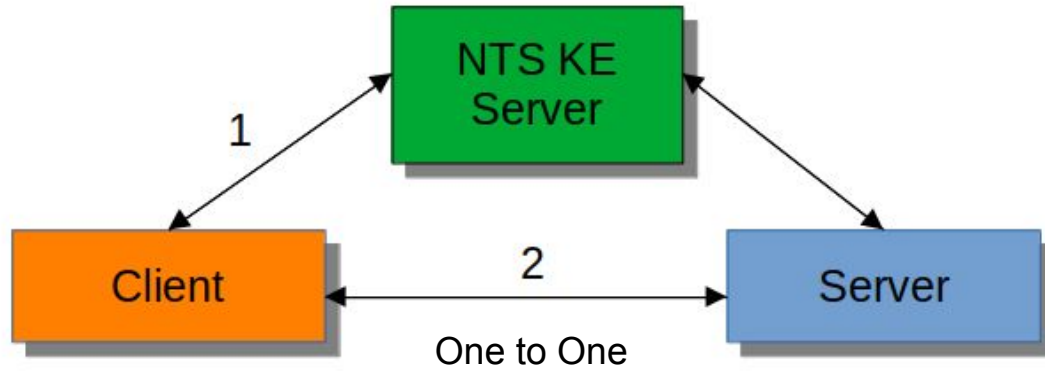
Deploy the Clients and Servers to gather measurements using a variety of topologies

Performance and Scalability

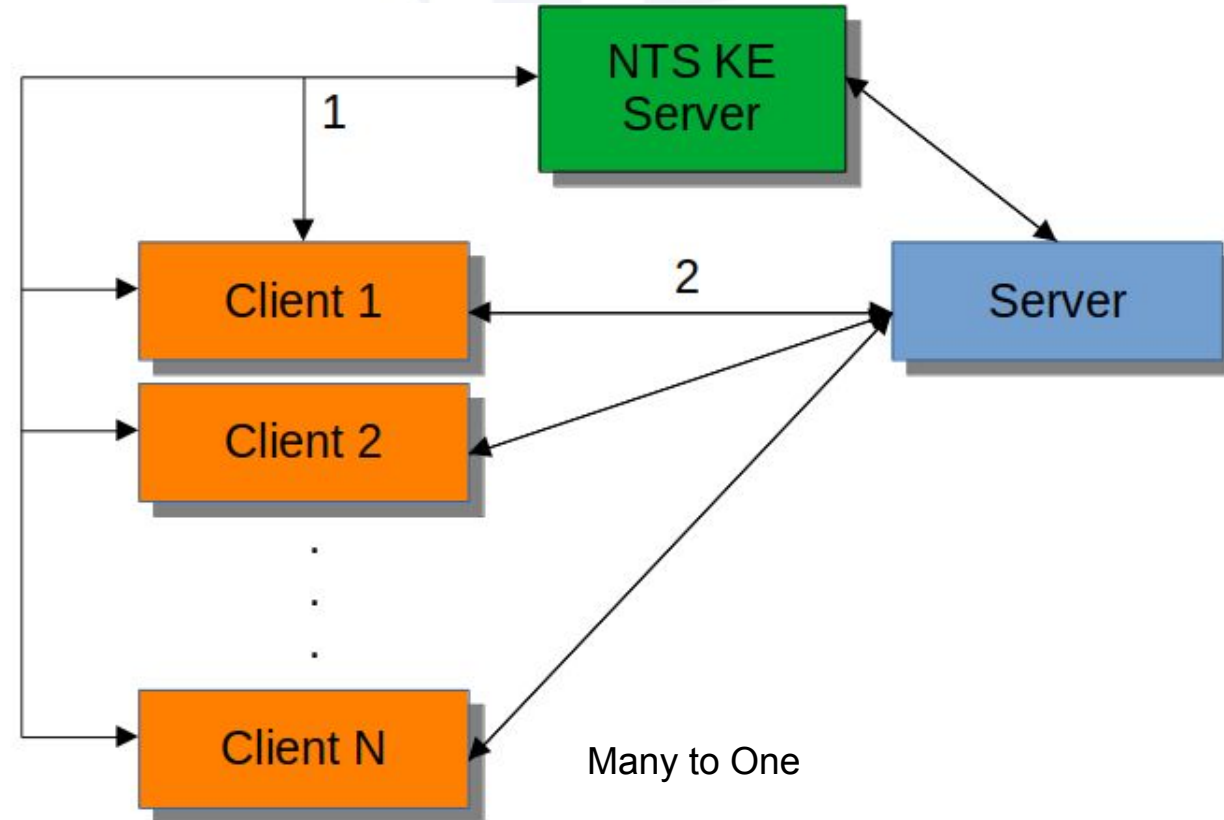
Quantify any additional resource requirements introduced by NTS

- Additional CPU cycles consumed
- System memory usage
- Timing protocol performance

Experiment Topologies



Emulated Network Interference



Future Needs / Q&A

Several areas are open to further development, **with sufficient interest:**

With sufficient interest:

- 10BASE-T1S (OPEN Alliance TC14) support
- 100/1000BASE-T1 Interoperability testing (per OPEN definition)
 - Extending our TC1/TC12 service offering
- Full coverage of OPEN TC8 ECU & TC11 Silicon validation
 - Could be provided via Violet[®] and supported hardware solutions
 - Potential partnership with T&M equipment provider
- Accelerate & expand Timing Security / Quality of Time testing
- Accelerate & expand custom FPGA TSN NIC development
- Accelerate coverage of TSN Profiles In I.A., Telecom, Automotive, etc.

Questions and Requests ?
Contact us on how to 'kickstart' such efforts.

We want to hear from you!



Q&A

Input from the discussion in Dec'22:

Interest expressed / updates given on:

- 1000BASE-T1 Type B and 40Meter reach, as benefits the Agricultural industry (aef-online.org)
- Multiple inquiries around plugfest activities and organization, MultiGig SPE, TSN, Management, Security all potential topics of focus/event.
- Research efforts for Digital Factories, through efforts UNH, Georgia Tech, and NCSU are pursuing to form an NSF I/UCRC (Industry/University Cooperative Research Center), with a planning meeting at Georgia Tech in ~~March 22-23~~ {postponed to June-Sept'22 due to Covid concerns - contact us for details as they settle} with a research scope including AI, ML, self-organizing systems, Wireless & TSN technology- contact us for more information!

Thanks for your Questions!
Contact us (see next slide) for options on how to 'kickstart' such efforts.

We want to hear from you!



Contact Information

Single Pair Ethernet and Time Sensitive Networking Testing Services

Bob Noseworthy

Principal Engineer
ren@iol.unh.edu

Jason Sisk

Technical Manager
jsisk@iol.unh.edu

Mike Goding

Sales Support
MikeG@iol.unh.edu

Michelle Whisnant

Operations Manager
mwhisnant@iol.unh.edu

