Building Multi-Vendor T&E Systems in iNET

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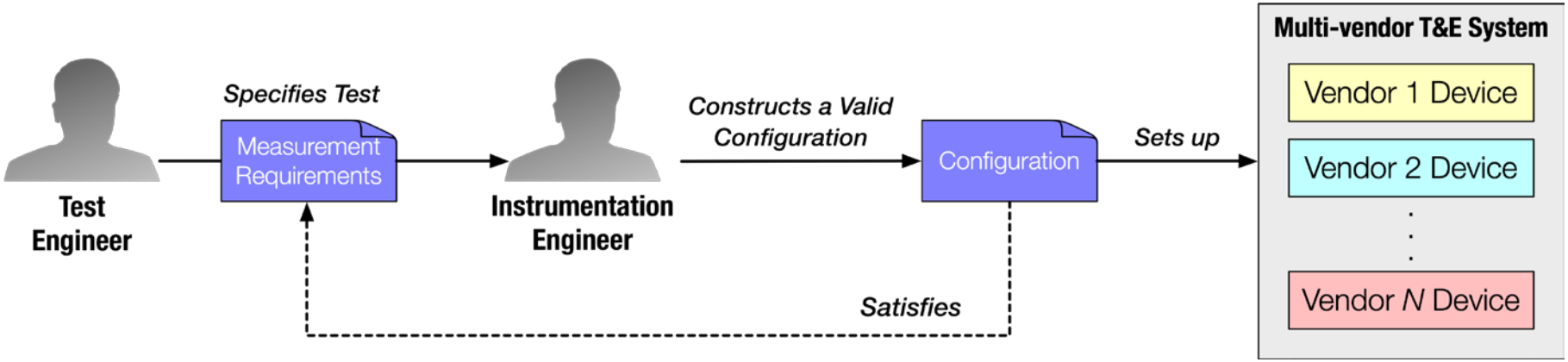
MAY 15, 2019

Context: Multi-Vendor Systems



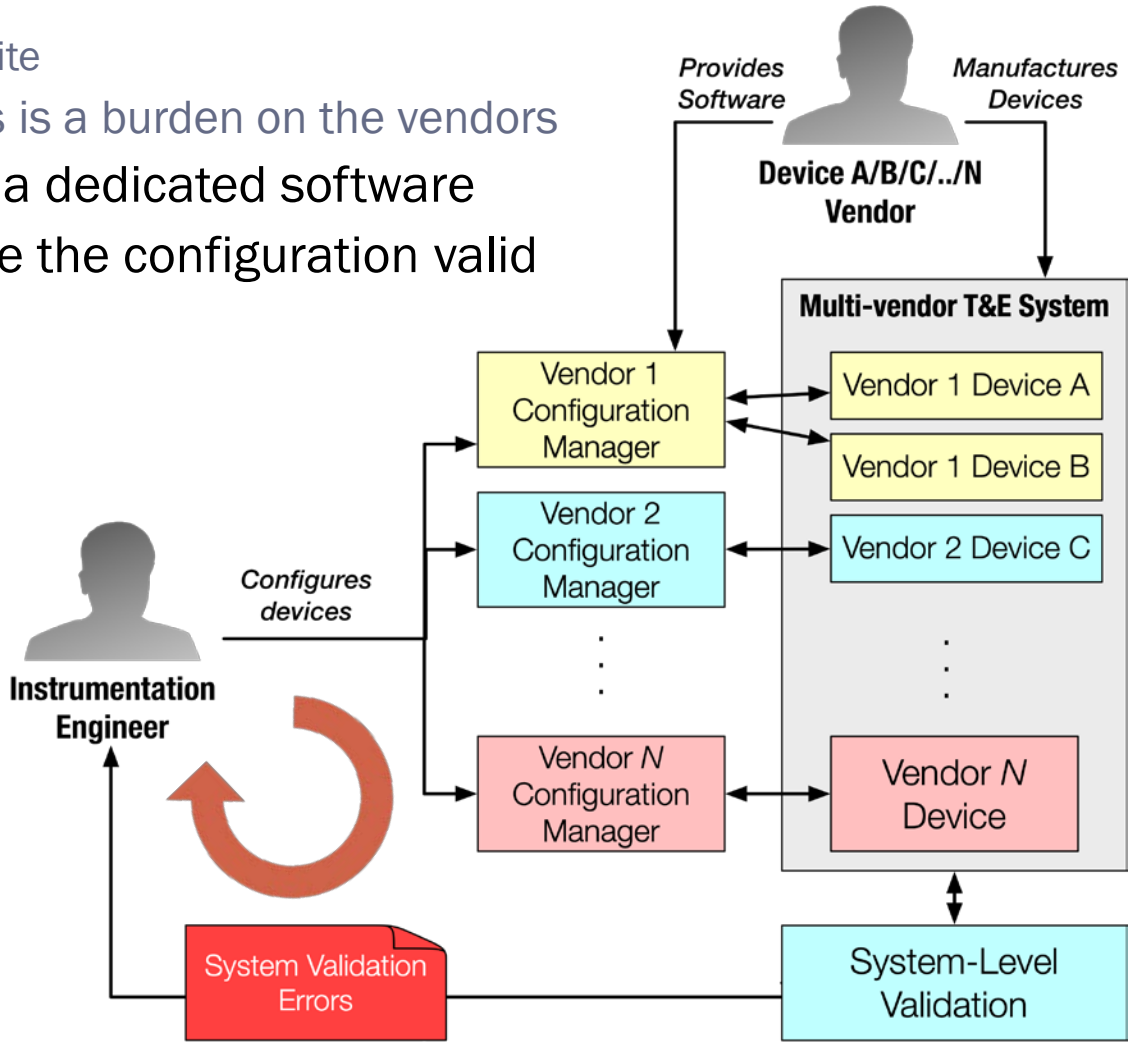
- Benefits:
  - Engineers can choose the best device for the task, regardless of the vendor
  - Vendors can compete in terms of performance and cost

The “hidden” constraints

- A single vendor alone cannot anticipate:
  - Dependencies on the settings from devices from other vendors, for instance:
    - Timing constraints imposed by one device can affect the timing of another one
  - Systemic constraints that are specific to a particular customer, for instance:
    - Limitations on the total bandwidth, weight, or power usage
    - Globally unique properties, e.g. Role ID
    - Values that can be reused only within a specific scope, e.g. RF MAC cannot be reused across different Radio Access Networks
- Access to device constraints is needed to effectively build multi—vendor systems
- However, today, device constraints are “hidden”, hard-coded in the vendor configuration software (e.g. in Java)

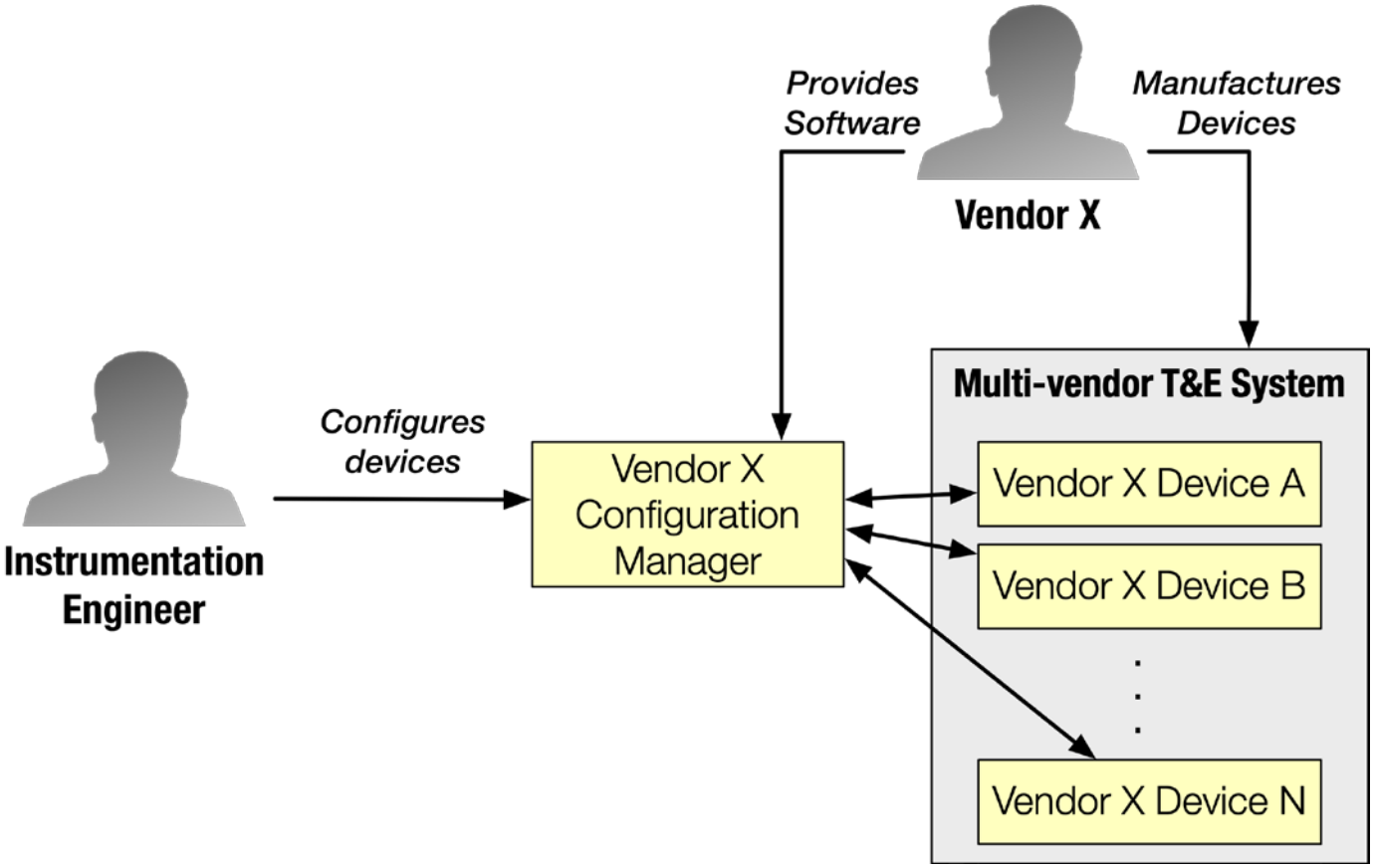
Multi-Vendor Systems Today

- Vendor-specific configuration software
  - "Hides" the constraints
  - Requires training for each software suite
  - Keeping up with standard updates is a burden on the vendors
- System-level validation requires a dedicated software
- Many iterations required to make the configuration valid
  - Last minute changes are hindered



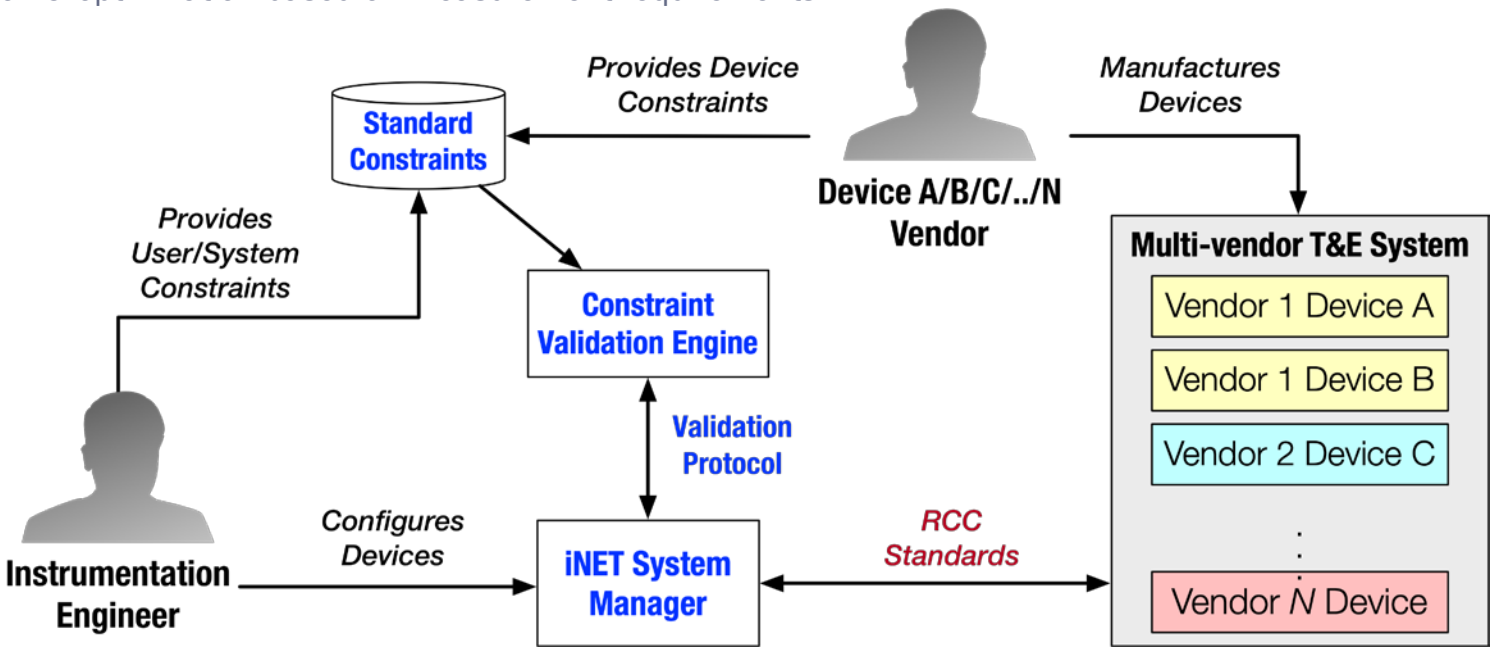
Common Reality

- Multi-vendor systems are expensive, impractical
- In practice, they are often avoided via vendor lock-in
  - Capability, performance, and cost of T&E devices may need to be compromised

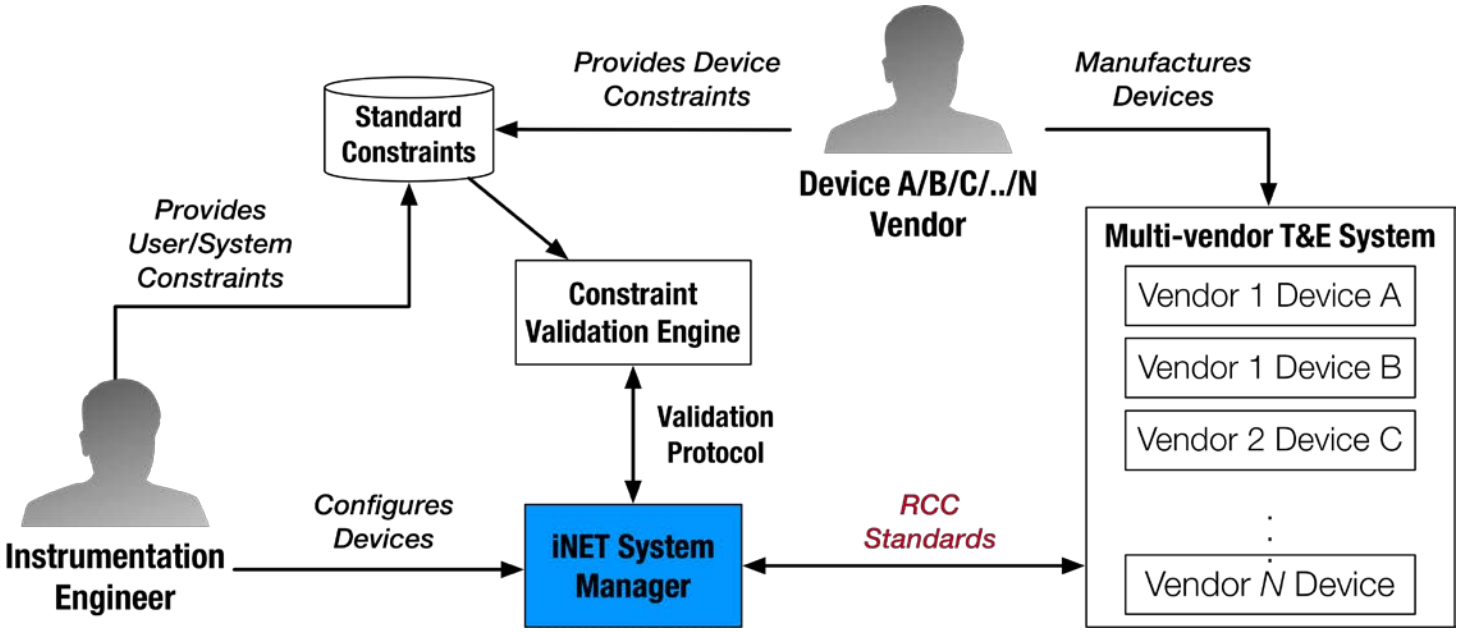


Multi-Vendor Systems: Tomorrow

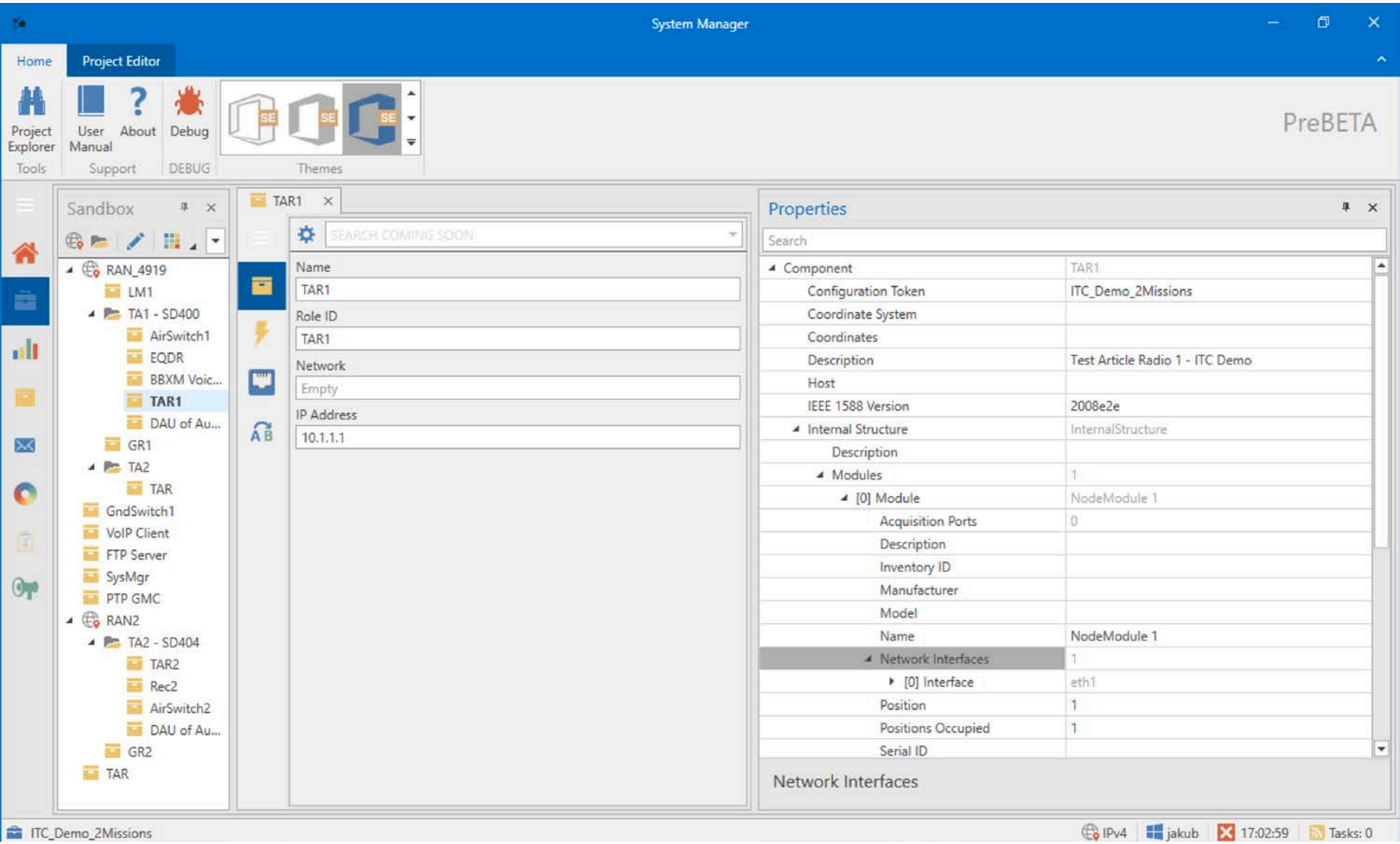
- Standard constraint language
- Standard validation protocol
- Vendor-neutral, third-party configuration software and constraint engines
- Single validation process for device and system constraints
- Users only need to use one software suite
- Vendors no longer need to maintain configuration software
- Multi-vendor systems become practical
  - New market opportunities
- New use cases possible:
  - Deconfliction
  - Automatic configuration & optimization based on measurement requirements



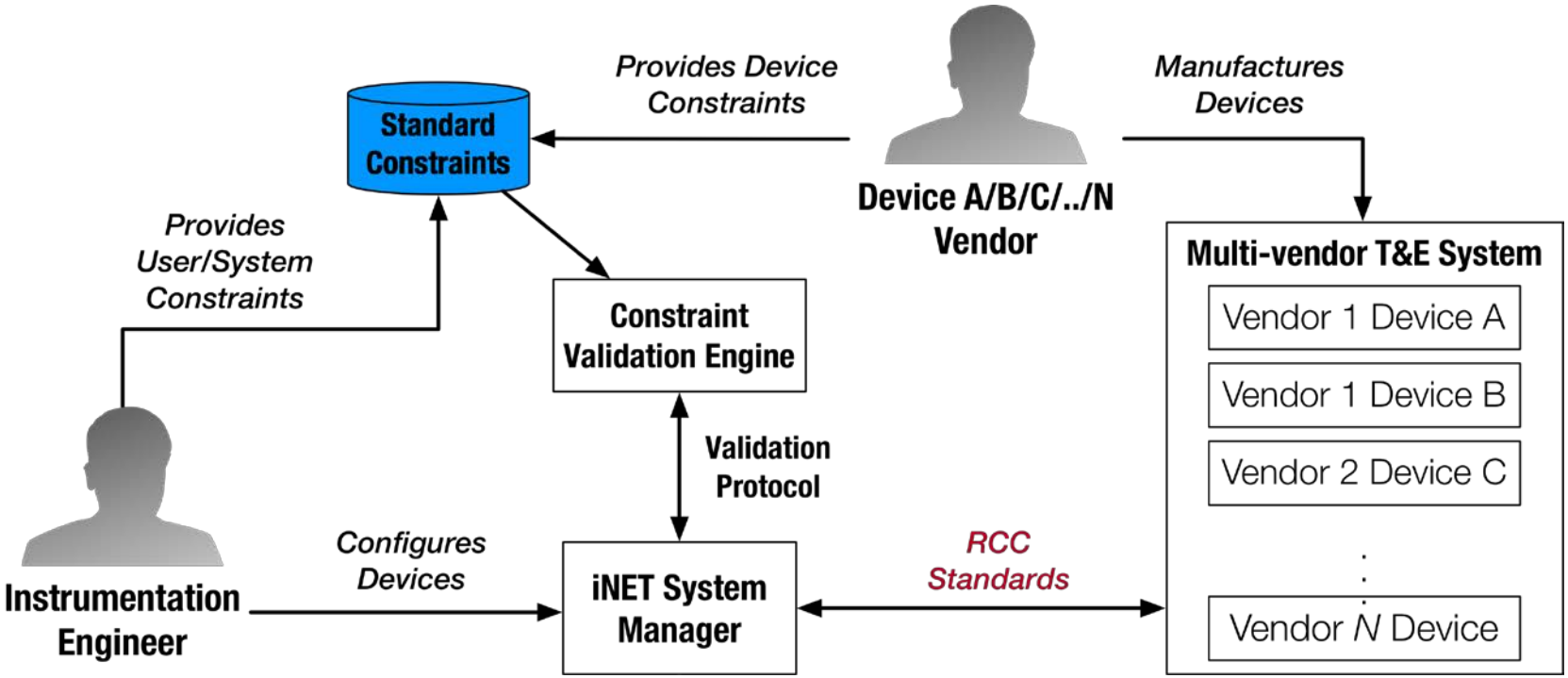
iNET System Manager



iNET System Manager

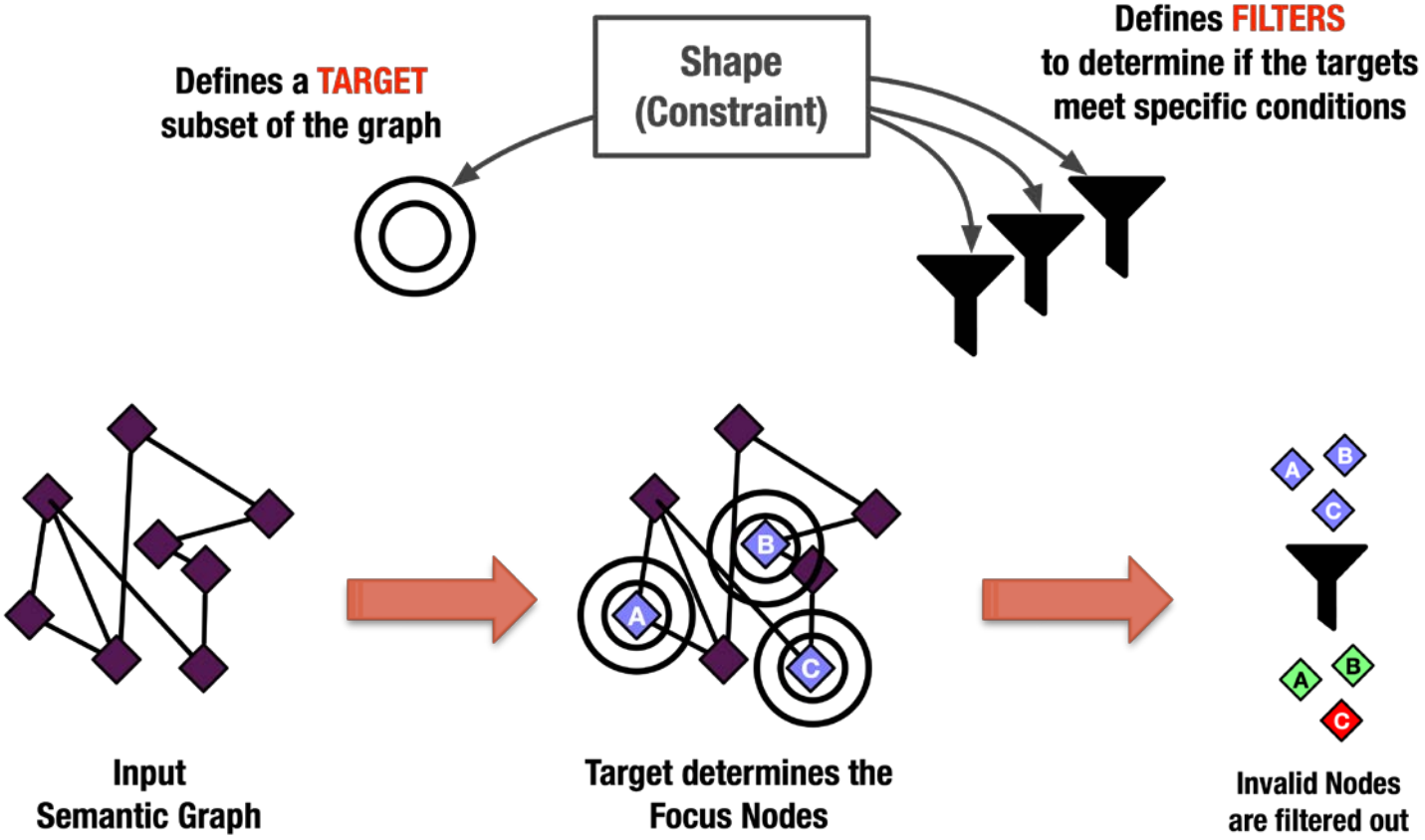


TACL:
A Proposal for a T&E Constraints Language



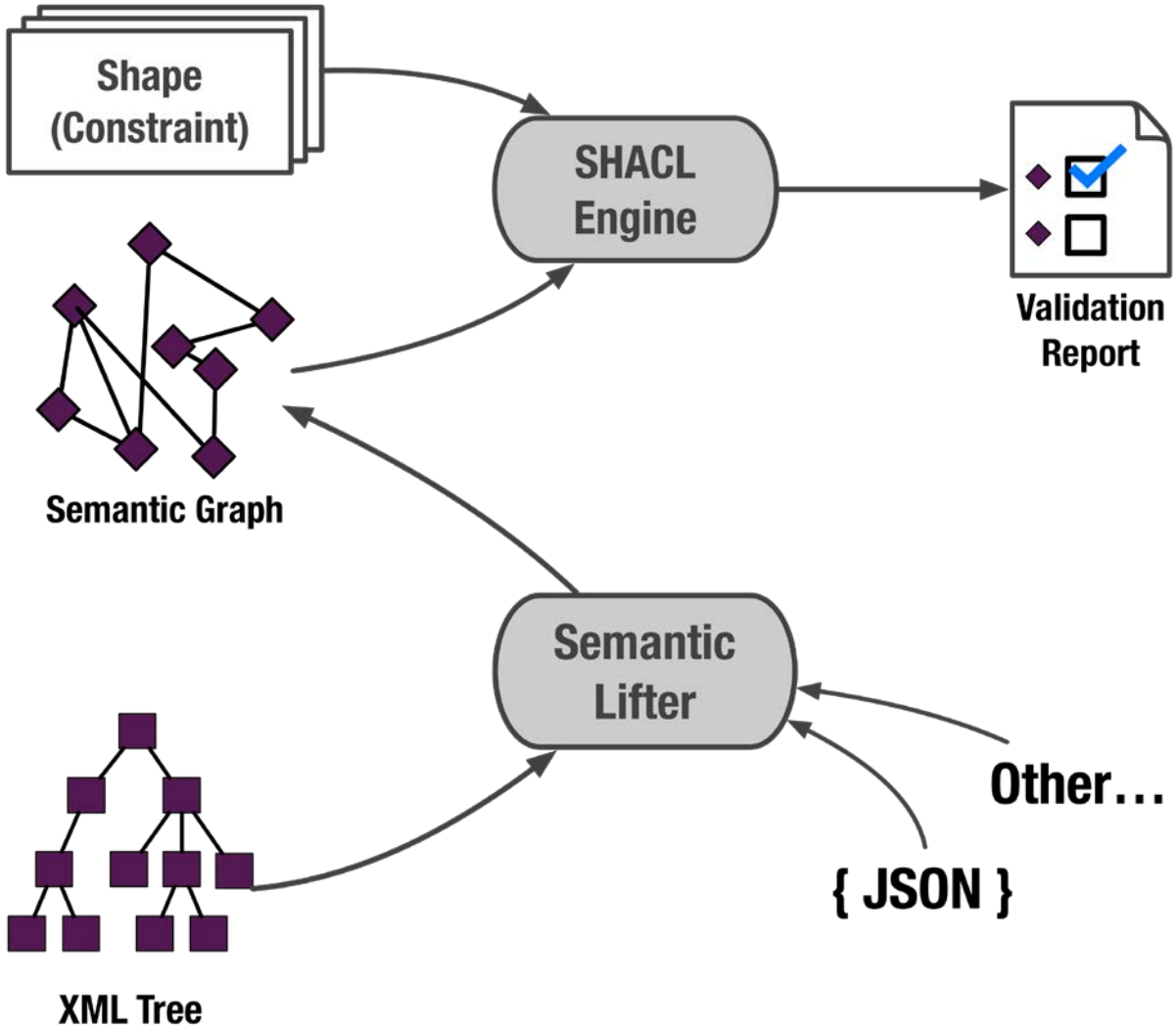
W3C SHACL – Shapes Constraint Language

- A language for validating semantic graphs against a set of conditions, called **Shapes**



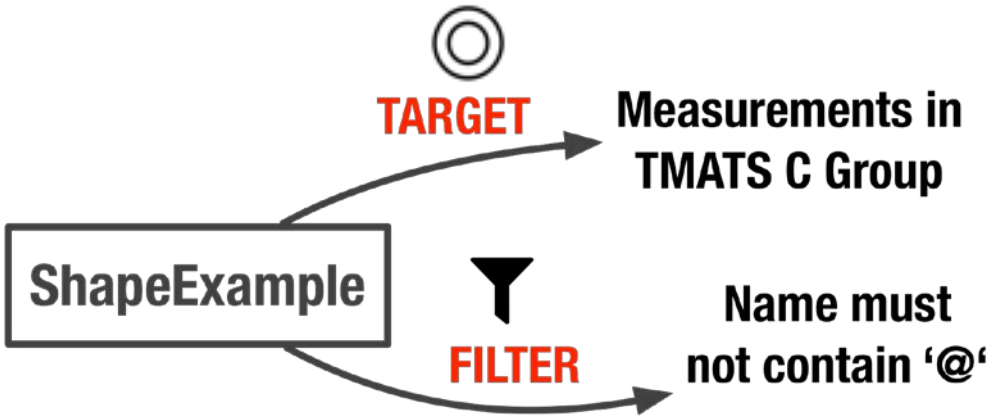
- TARGETS and FILTERS can use FUNCTIONS in their definitions

Processing Shapes with a SHACL Engine



Shape Example

Names of the Measurements in the TMATS C Group must not contain the symbol '@'



ShapeExample (SHACL)

TARGET

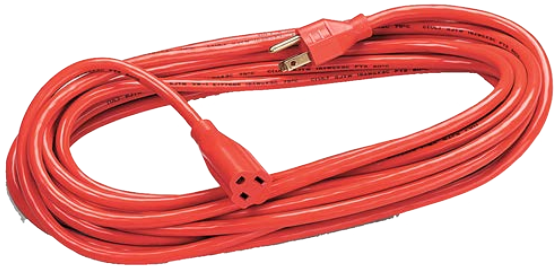
FILTER

```
sh:targetClass C:Measurement

sh:property [
  sh:path Common:hasName
  sh:pattern "^[^@]*$"
]
```

TACL – T&E Extension of SHACL

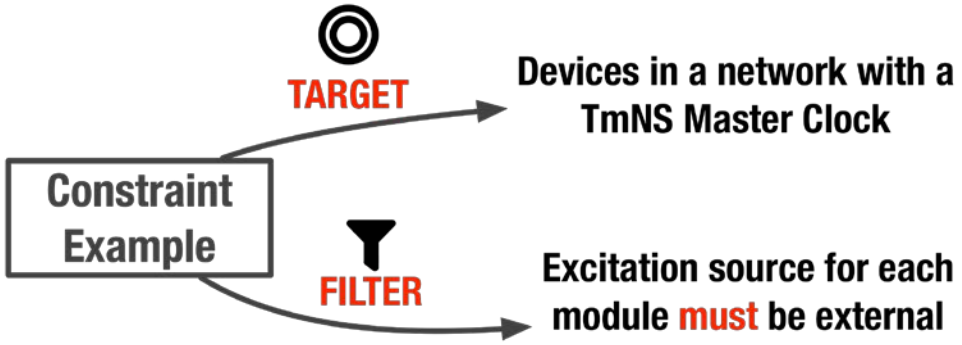
- Proposal –standardize **TACL**:
  - MDL/TMATS Ontology (semantic graph)
  - Common T&E Extensions for SHACL:
    - Targets
    - Filters
    - Functions



- ITC'18 Best Standards Paper Award
  - *"Introducing TACL – A Proposal for a New Standard T&E Constraint Language"*

TACL Example

For all devices in a network with a TmNS Master Clock, the excitation source for each module must be external.



TARGET

FILTER

Constraint Example (TACL)

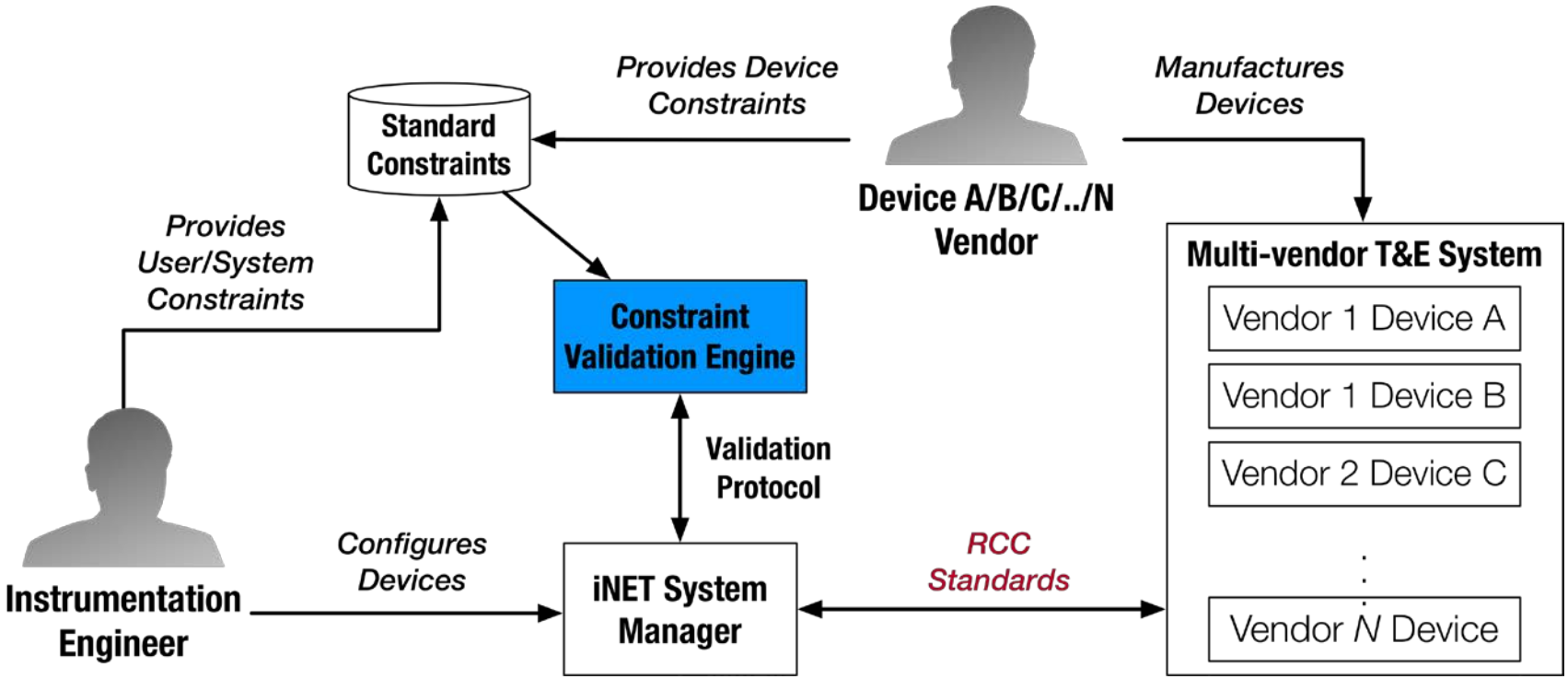
```
sh:target [
   a tacl:DeviceOnNetworkWith;
   tacl:appKind mdl:TmNSMasterClock ]

tacl:allModulesWithExcitationSource "External" .
```

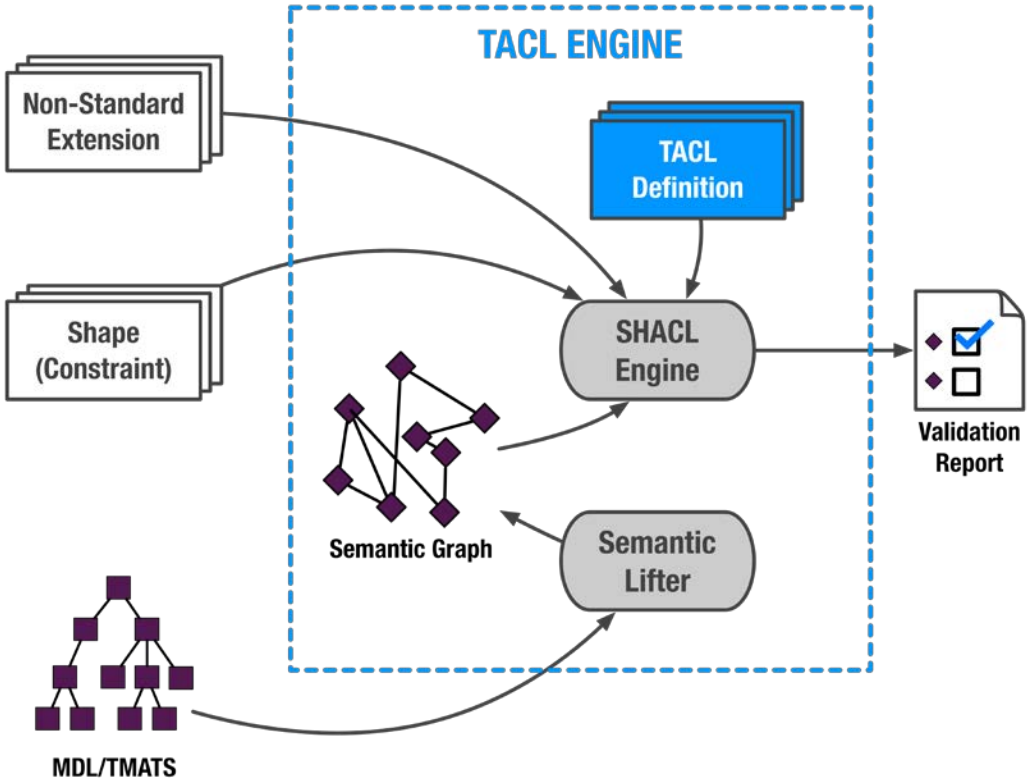
TACL – Benefits

- TACL hides the nitty—gritty details under the covers
- It introduces a layer of separation from the data model
- Constraints written with TACL are succinct and resilient to schema changes
- It can be processed with SHACL engines available today
- As an extension of a W3C standard, TACL benefits from:
  - W3C Endorsement
    - Long-lasting support
    - Guarantee of quality
  - Access to a growing user group
    - Discussion groups
    - Forums
    - Active development efforts
  - Access to open-source tools
    - Validators
    - GUI's

Constraint Validation Engine

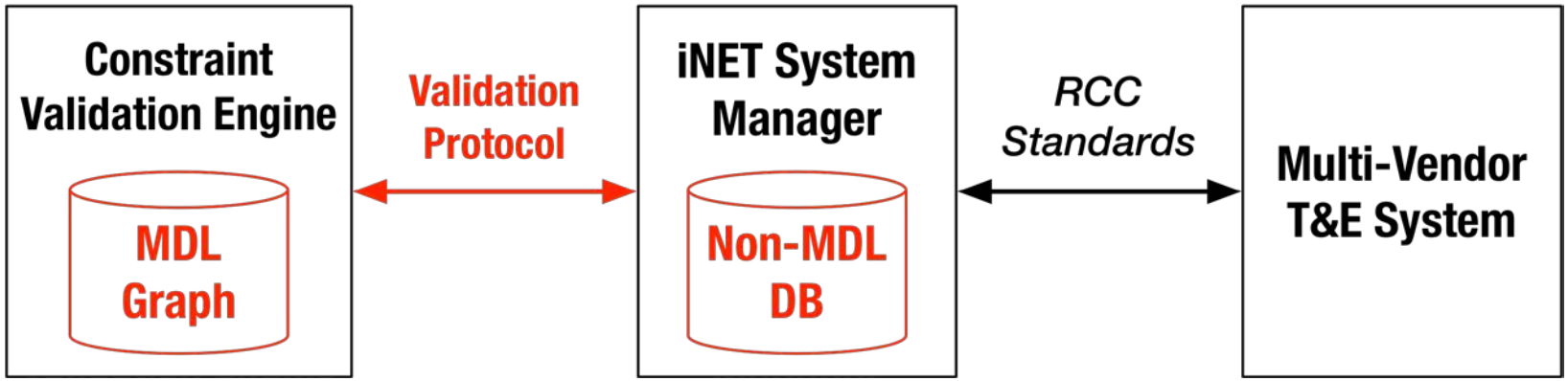


- xVISor is a reference implementation of a TACL Engine
  - Supports TACL validation of MDL 1.0 and TMATS/XML 106-17
  - Developed in Java



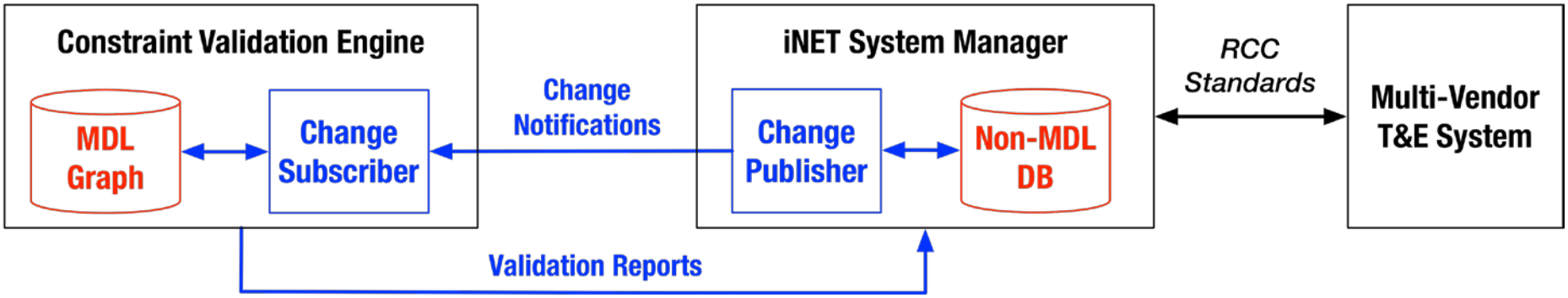
Architectural Challenge

- Premise:
  - The users expect almost-instant feedback if any constraint is violated
  - Constraints are developed against MDL graph (ontology)
  - System Manager uses proprietary data model
- Challenge:
  - How to avoid the “Validate now” button?



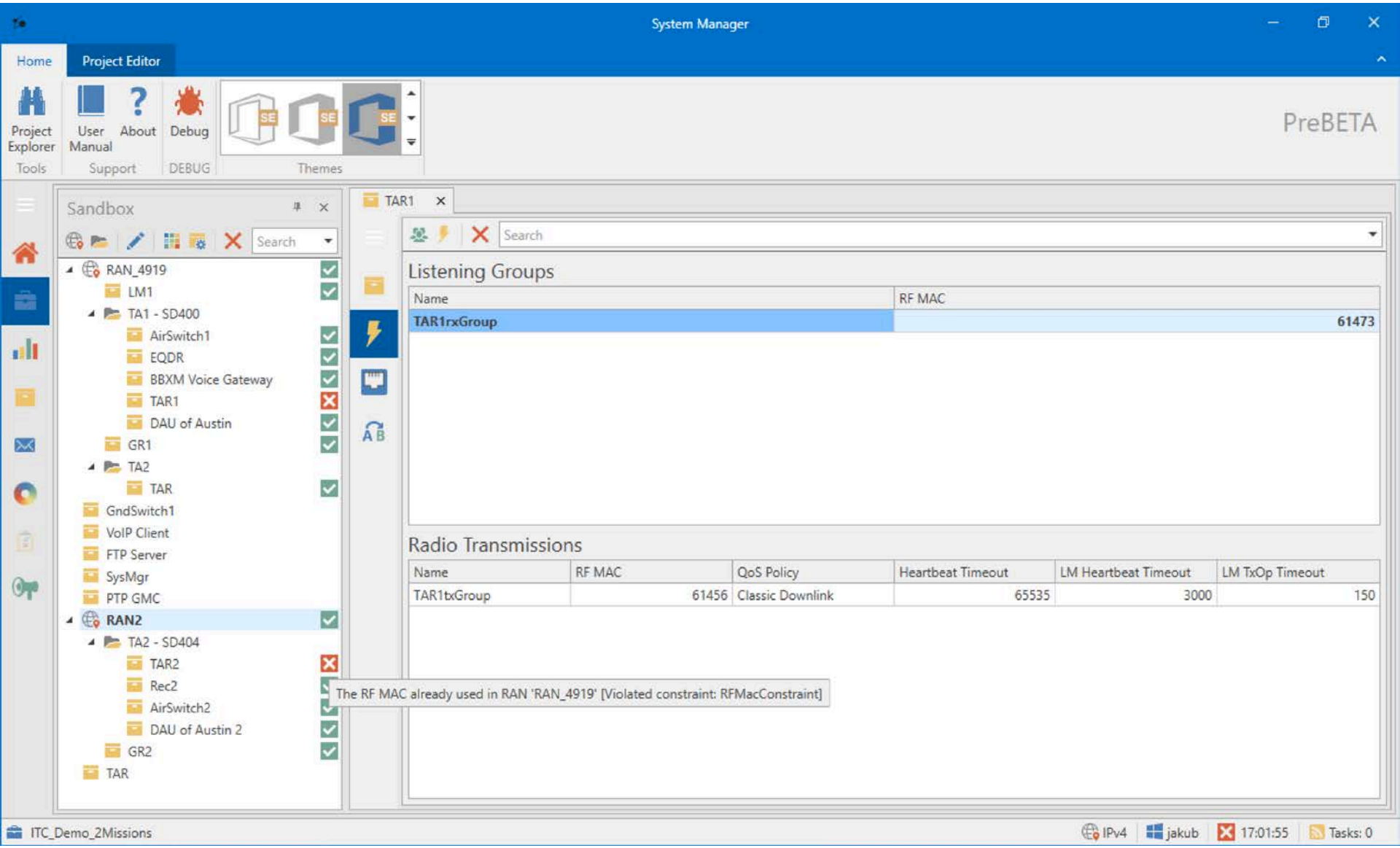
Integration with iNET System Manager

- Solution:
  - System Manager pushes configuration state changes via notifications
  - Validation Engine performs the same changes to its internal data model and executes the validation



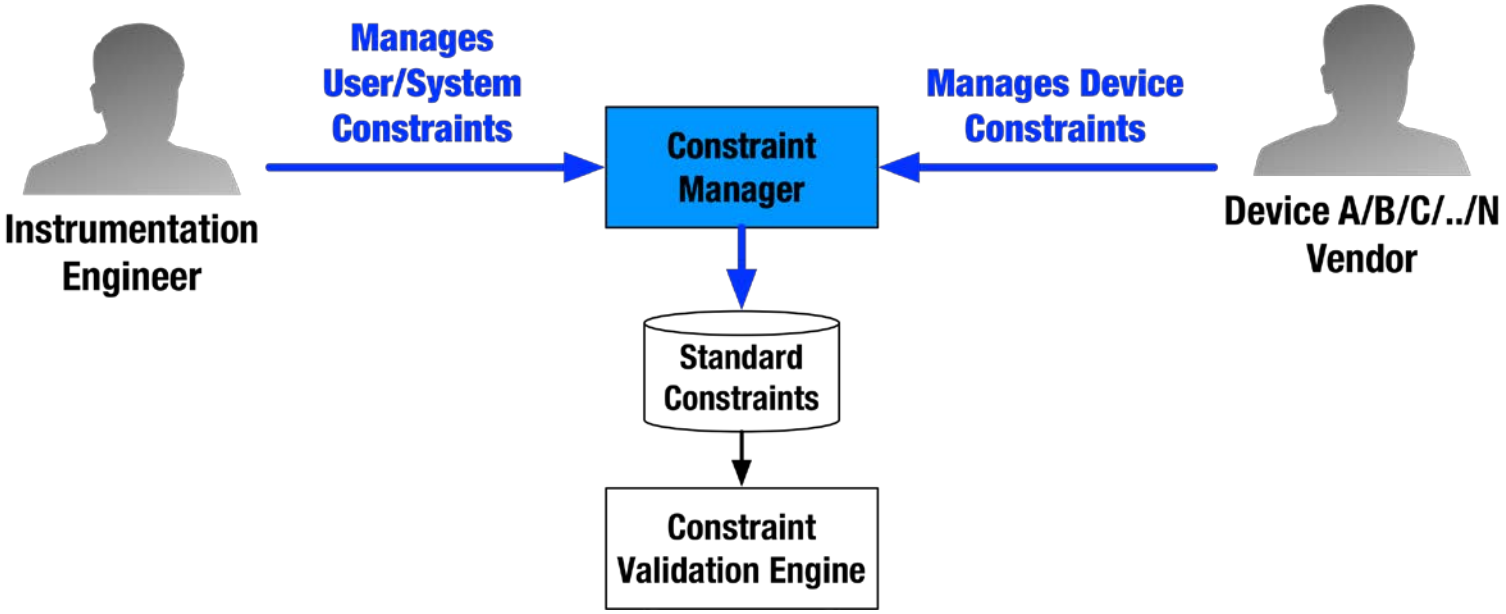
This protocol needs to be standardized!

ITC'18 Demo: iNET System Manager and xVISor

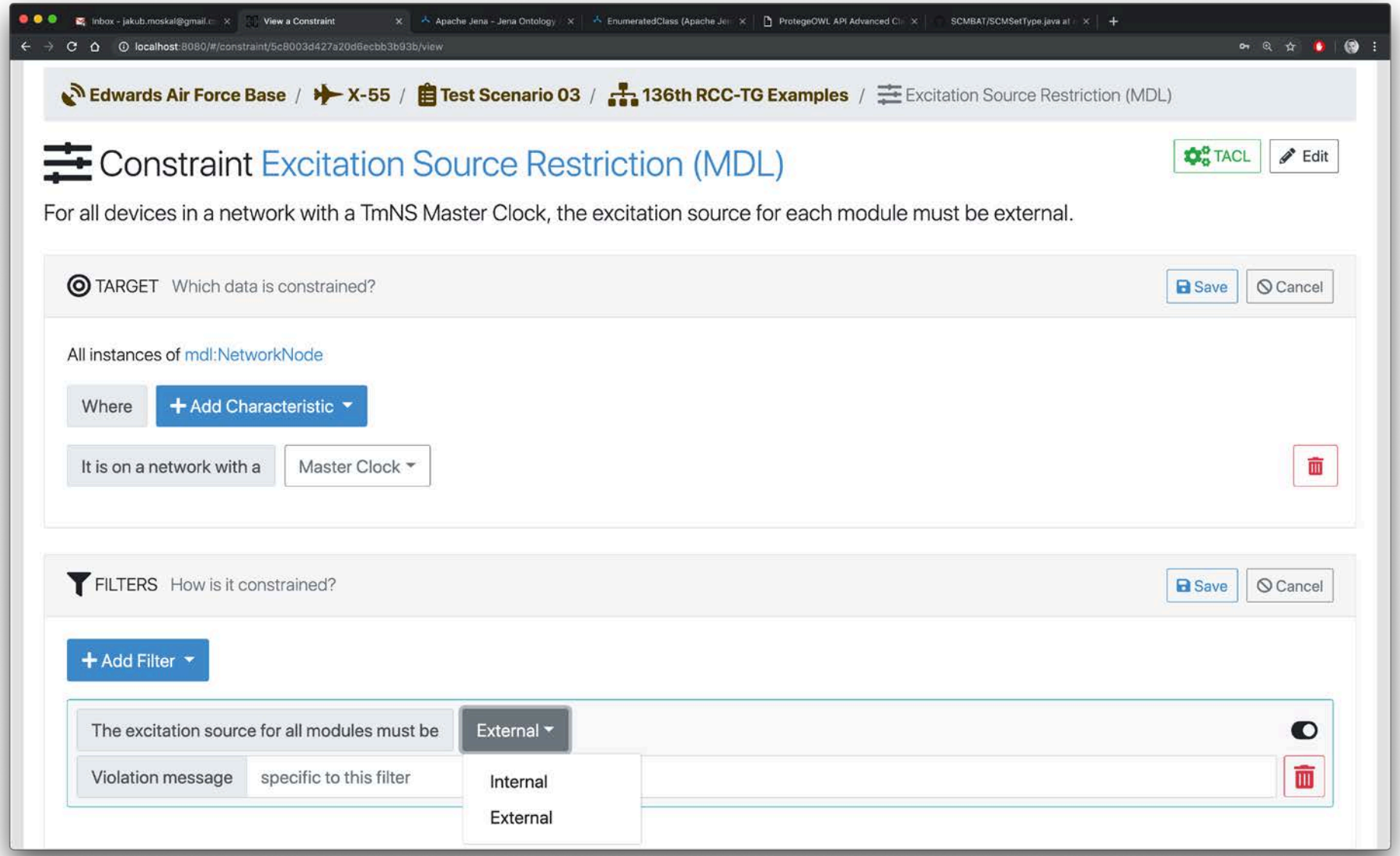


Tool Support: Constraint Manager

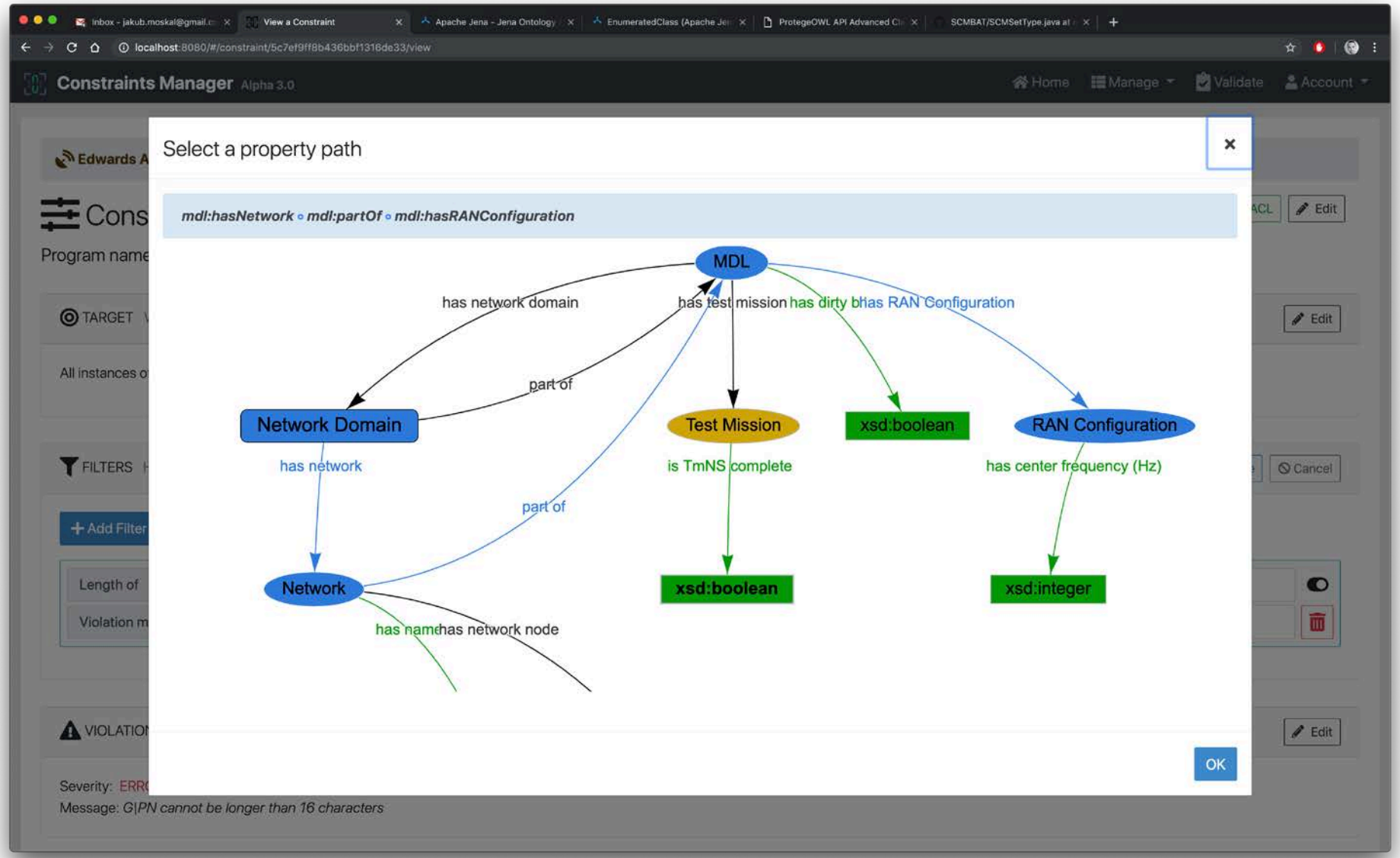
- Rationale:
  - In our opinion, TACL should be the standard constraint language
  - Even though TACL expressions are rather succinct and readable, even for complex constraints, they still require a form of coding
  - We developed a Constraint Manager – proof of concept tool that allows creating TACL constraints using widgets, and *without* coding



Constraints Manager (1/2)



Constraint Manager (2/2)



Standards Create New Opportunities

- To be standardized:
  - TACL, the constraint language
  - Constraint Validation Protocol

- Once standardized (or in the process of), new opportunities open up:
  - Automatic deconfliction: conflict between constraints is detected, a tool suggests how to mitigate it without causing a ripple effect with other constraints
    - E.g. if you lower the gain to X, the configuration will be valid
  - Generation of a configuration based on:
    - Measurement Requirements
    - Device inventory
    - Database of past and present configurations

Thank You!

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Backup Slides

About VIStology

- Past and present R&D DoD contracts



- Professional collaborations
  - BAE, BBN, JHU APL, Lockheed Martin, Northeastern University, Raytheon, Referentia Systems, Southwest Research Institute, Vulcan, W3C, Wireless Innovation Forum

- Areas of expertise
  - Information Integration and Fusion,
  - Situation Awareness,
  - Formal Reasoning Systems,
  - Artificial Intelligence,
  - Cognitive Radio,
  - Cognitive EW,
  - System Engineering,
  - Ontology Engineering

- Products and Services
  - **BaseVISor** – highly efficient inference engine
  - **ConsVISor** – consistency checker for ontologies
  - **DeVISor** – future-proof matchmaking middleware
  - **HADRian** – next generation COP system for HA/DR

SBIR Program

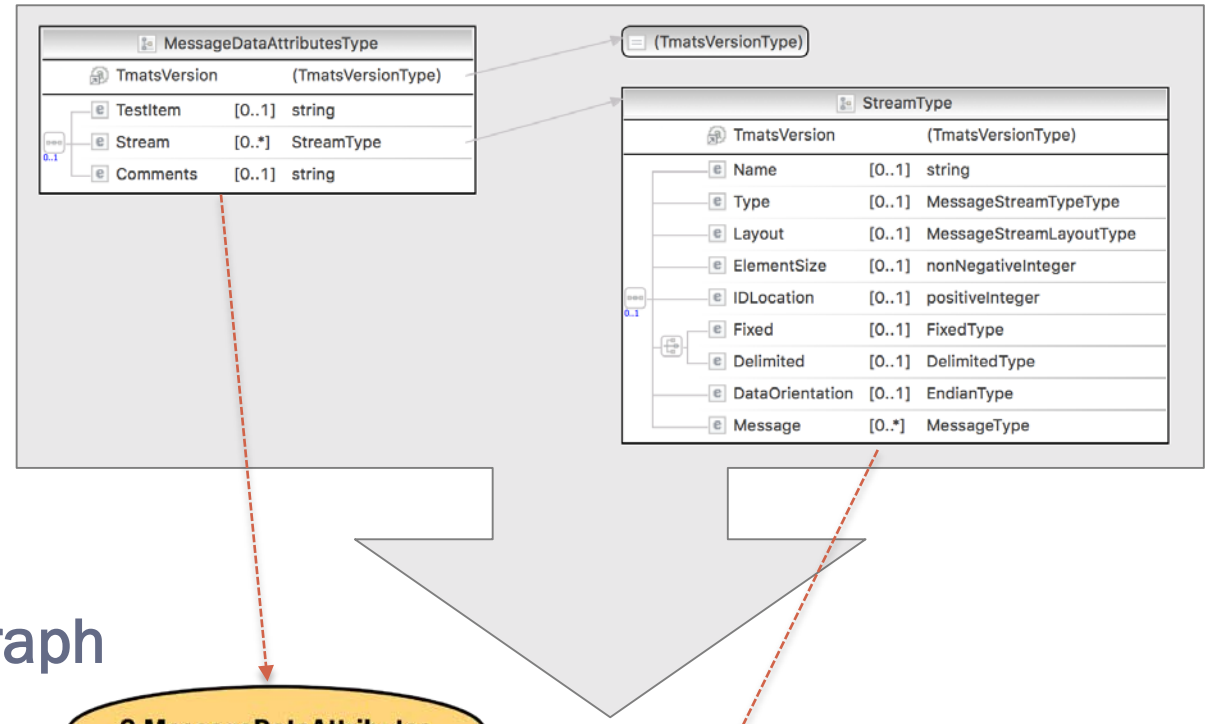
- VIStology (lead) and SwRI (sub) are funded via a Phase II SBIR (AF141-227)
  - Full description can be found here (look for "AF141-227"): http://www.acq.osd.mil/osbp/sbir/solicitations/sbir20141/af141.htm
- Objective:
  - *Develop methods for capturing semantic rules of Test & Evaluation metadata and automate validation of related XML instances.*
- Phase II objectives:
  - *Refine and expand the rule structures and the mechanisms for capturing the rules developed in Phase I.*
  - *Work towards standardizing these structures and the non-software based mechanisms (as a non-proprietary standard).*
  - *Develop software to automate the validation process and, to the extent possible, the deconfliction and optimization processes.*
- Period of performance:
  - Phase I: 07/2014 – 02/2015
  - Phase II: 09/2016 – 12/2018, no-cost extension until 12/2019

SHACL Core

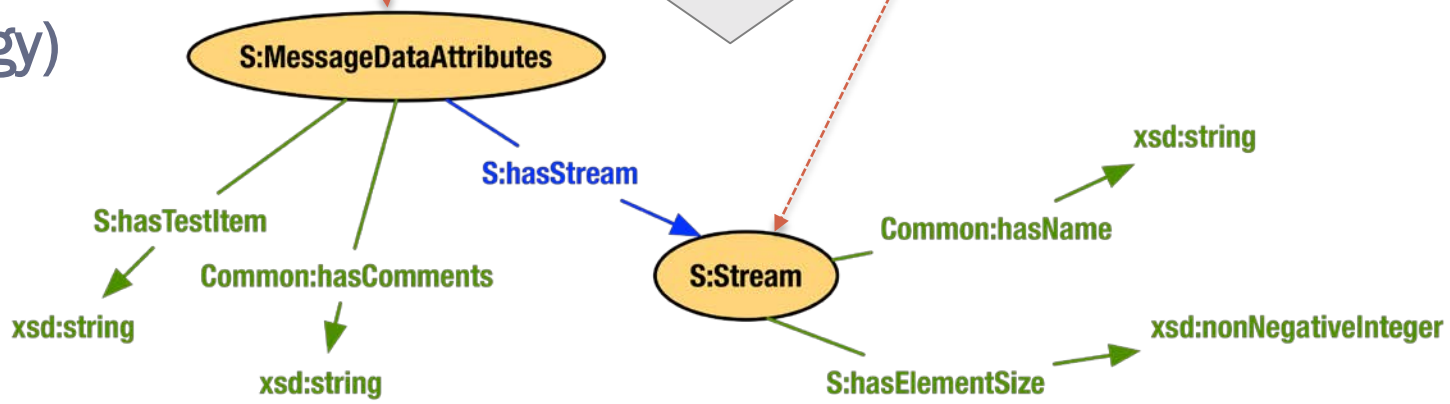
- Sufficient for simple constraints (similar to XSD)
- Supported by every SHACL-compliant engine
- Examples:
  - Checking cardinality, e.g. measurements must have a name
  - Checking value range, e.g. modules cannot occupy more than 2 slots
  - String length, regex, e.g. network node names cannot use the '@' character
  - Comparison of values of different properties, e.g. TmNSApp's last validation date/time must be greater than its last configuration date/time

From T&E XML to a Semantic Graph

XML/XSD



Semantic Graph (Ontology)



Extending SHACL

- Arguably most powerful feature of SHACL is its extensibility
- SHACL Core can be extended to a specific domain by defining custom:
  - Targets
  - Filters
  - Functions
- Why extend?
  - Encapsulate complex constraints in simple expressions
  - Operate using familiar domain terms, not generic language expressions
  - Increase reusability → improve efficiency and maintenance of the constraints
  - Build more resilience from XML schema changes

Any SHACL constraints are validated with a standard W3C SHACL engine.
They do not require changes in the engine.

TACL Targets

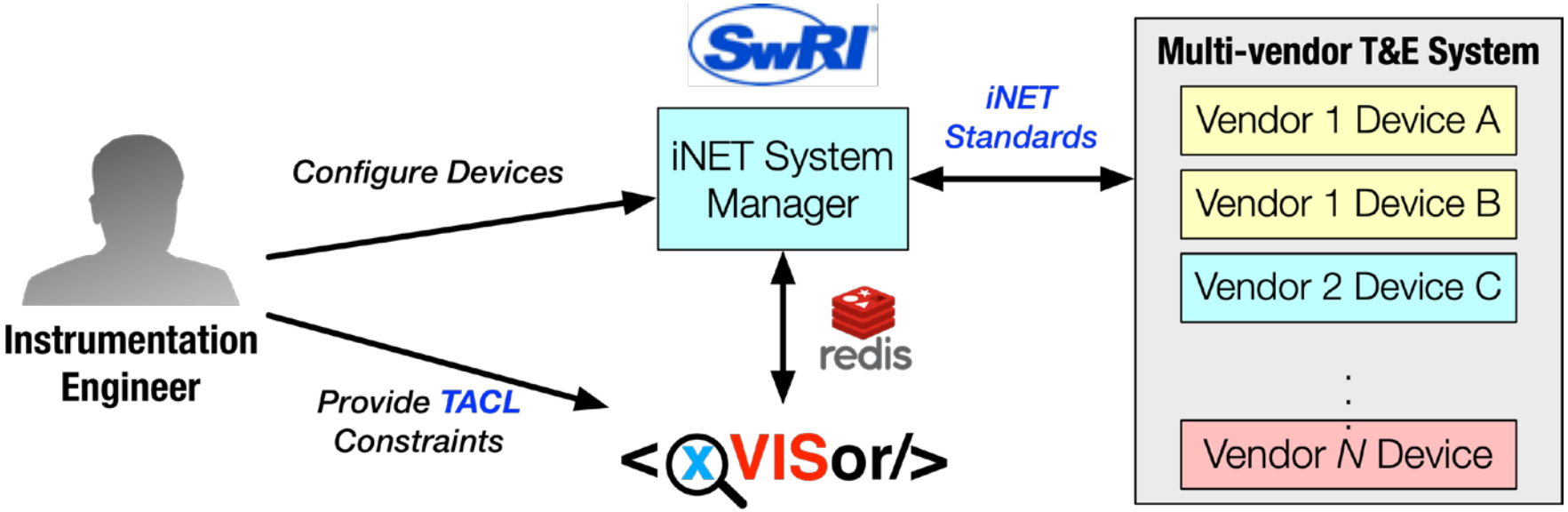
- SHACL Core primarily supports two kinds of targets:
  - Single node, e.g. a concrete Device Module
  - A class of nodes, e.g. all TmNSApps
- TACL targets are more specific:
  - Devices produced by vendor X
  - NetworkNodes with a TmNSRadio whose power level is greater than X dBm
  - TmNSApps on NetworkNodes that have a module with a network interface whose DHCP is disabled

TACL Filters

- SHACL Core contains filters that are entirely domain-independent (~ XSD):
  - Property X must have a value that is >= Y
  - The length of property X must be less than Y
- TACL filters are more specific:
  - The total weight of all sub-elements may not exceed X
  - A coefficient order cannot be higher than X
  - A value of a given property must be unique in the entire configuration

ITC'18 Demo: iNET System Manager and xVISor

- Redis-based integration with partial change notifications
- Very minimal effort to expose the changes to xVISor
- Good performance (according to the audience)
- TACL constraints can be changed at runtime
- Validation can be disabled (useful when building from scratch)



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14. ABSTRACT
Despite their numerous benefits, T&E XML-based languages like MDL and TMATS do not address all of the challenges related to building multi-vendor T&E systems in a truly vendor-agnostic workflow. In particular, they cannot harness the complexity of constraints that may pertain to vendors' hardware or to express system-level constraints that span across entire networks of devices and differ across different users.

We developed a concept of TACL -- a language for formulating constraints on configurations represented in MDL and TMATS. TACL is a backwards-compatible extension of the W3C Shape Constraints Language (SHACL). SHACL treats constraints as first-class citizens and facilitates building high-level domain-specific expressions resulting in constraints that closely resemble the user's intent and are not boggled with low-level data structures. A reference implementation of a TACL engine (xVISor) has been developed and integrated with the iNET System Manager. The resulting system is capable of fully configuring cross-vendor systems without relying on any vendor-provided software.

15. SUBJECT TERMS
TACL(T&E extension to SHACL), SHACL(Shapes Constraint Language), MDL(Metadata Definition Language), XML(Extensible Markup Language), Ontology, RDF(Resource Description Framework), OWL(Web Ontology Language), Semantics, Constraints

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