Building Multi-Vendor T&E Systems in iNET

JAKUB MOSKAL

MIECZYSLAW "MITCH" KOKAR

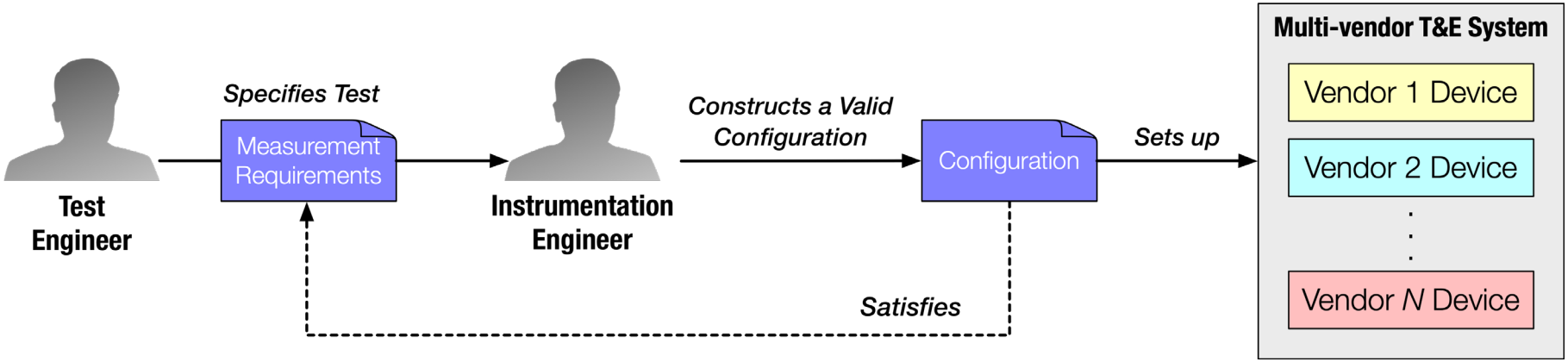
BEN ABBOTT

AUSTIN WHITTINGTON

JON MORGAN

MAY 15, 2019

Context: Multi-Vendor Systems



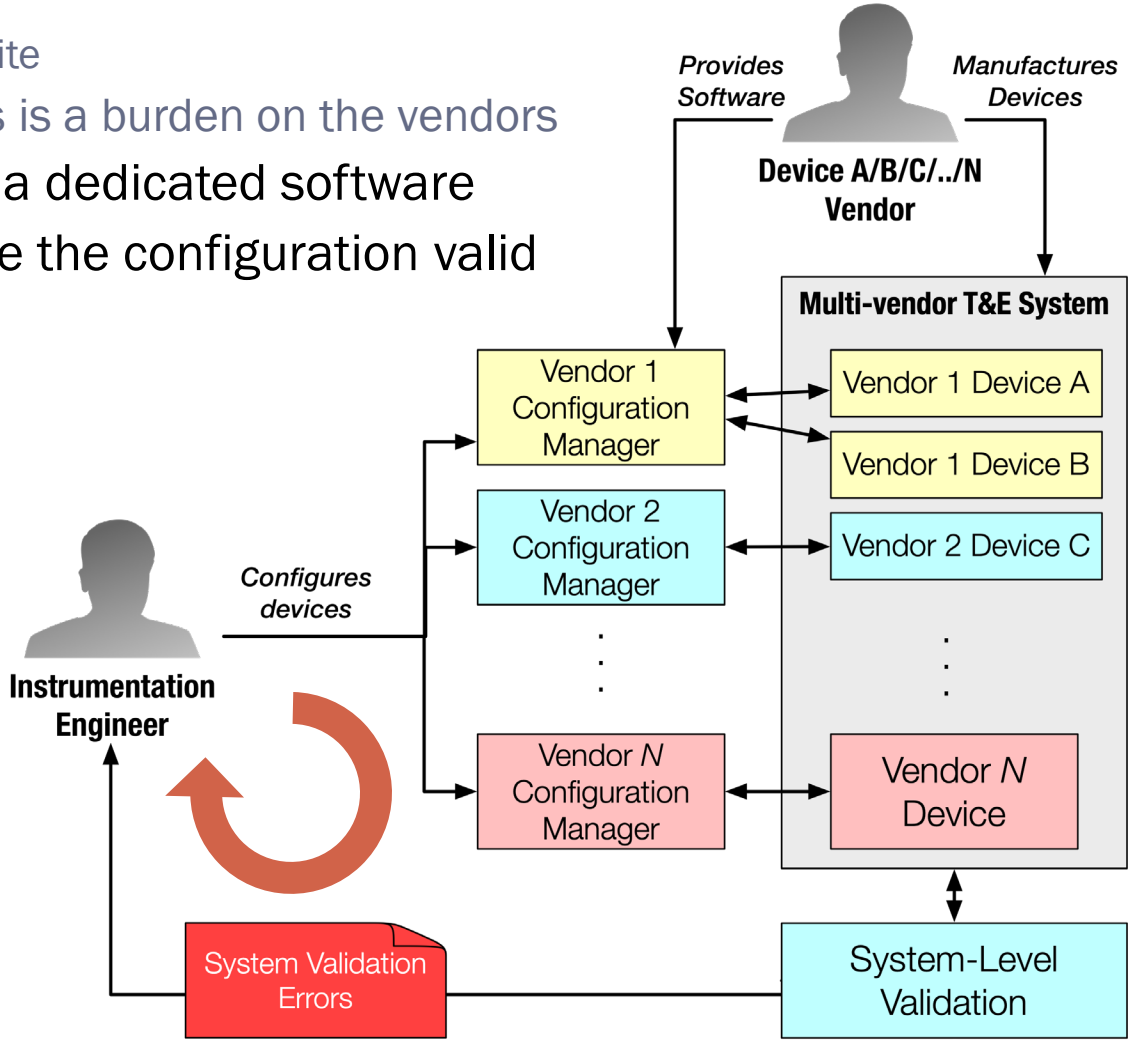
- Benefits:
  - Engineers can choose the best device for the task, regardless of the vendor
  - Vendors can compete in terms of performance and cost

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)

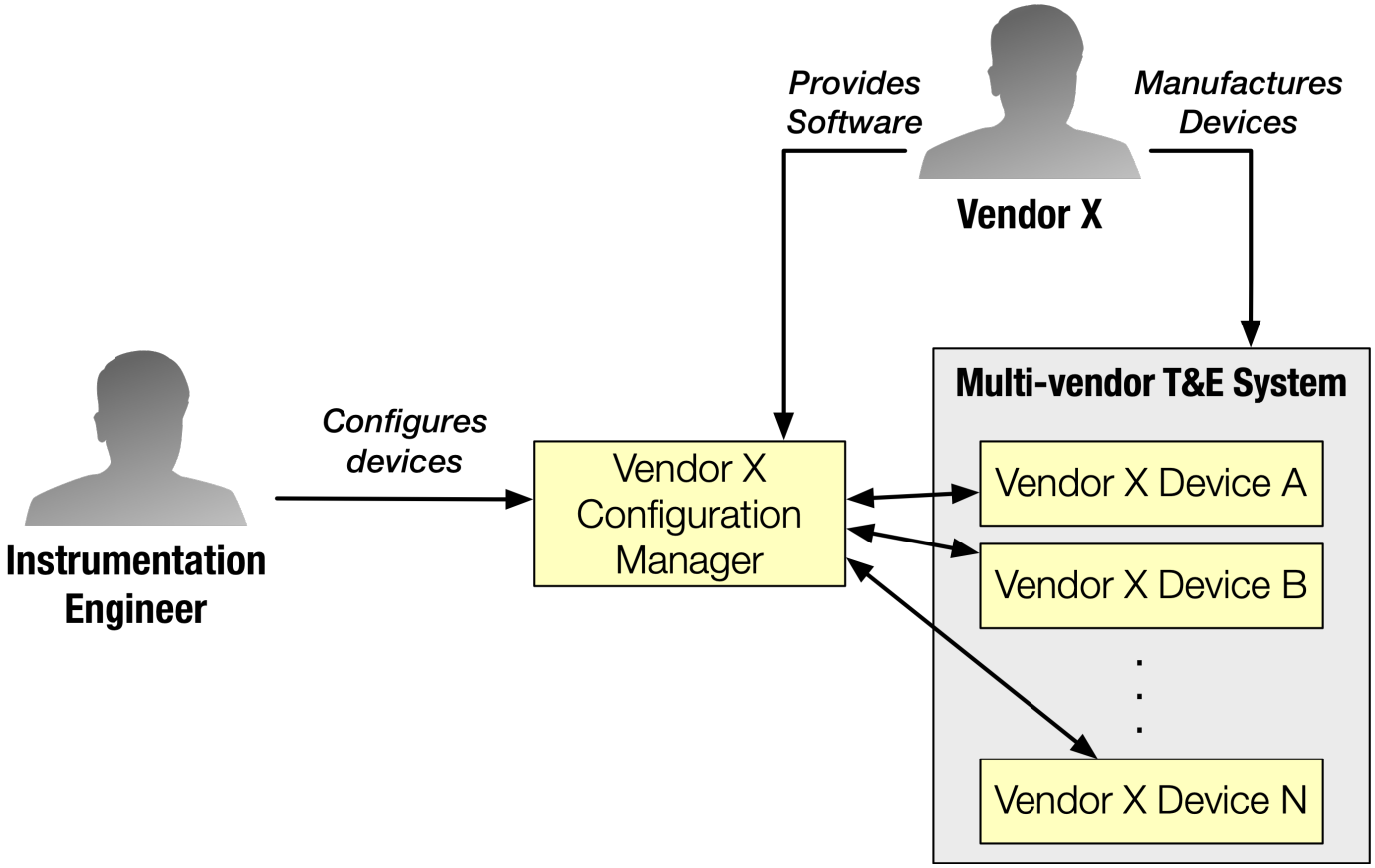
Multi-Vendor Systems Today

- 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



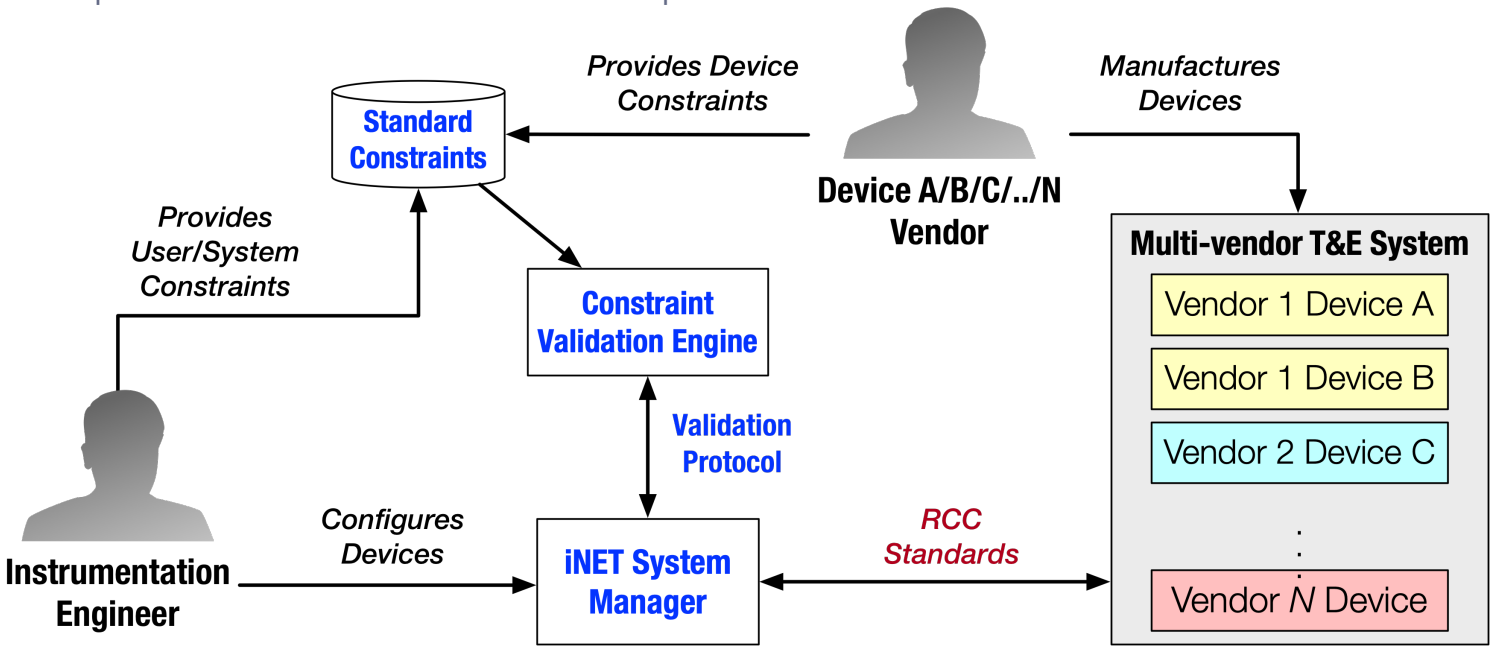
Common Reality

- 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

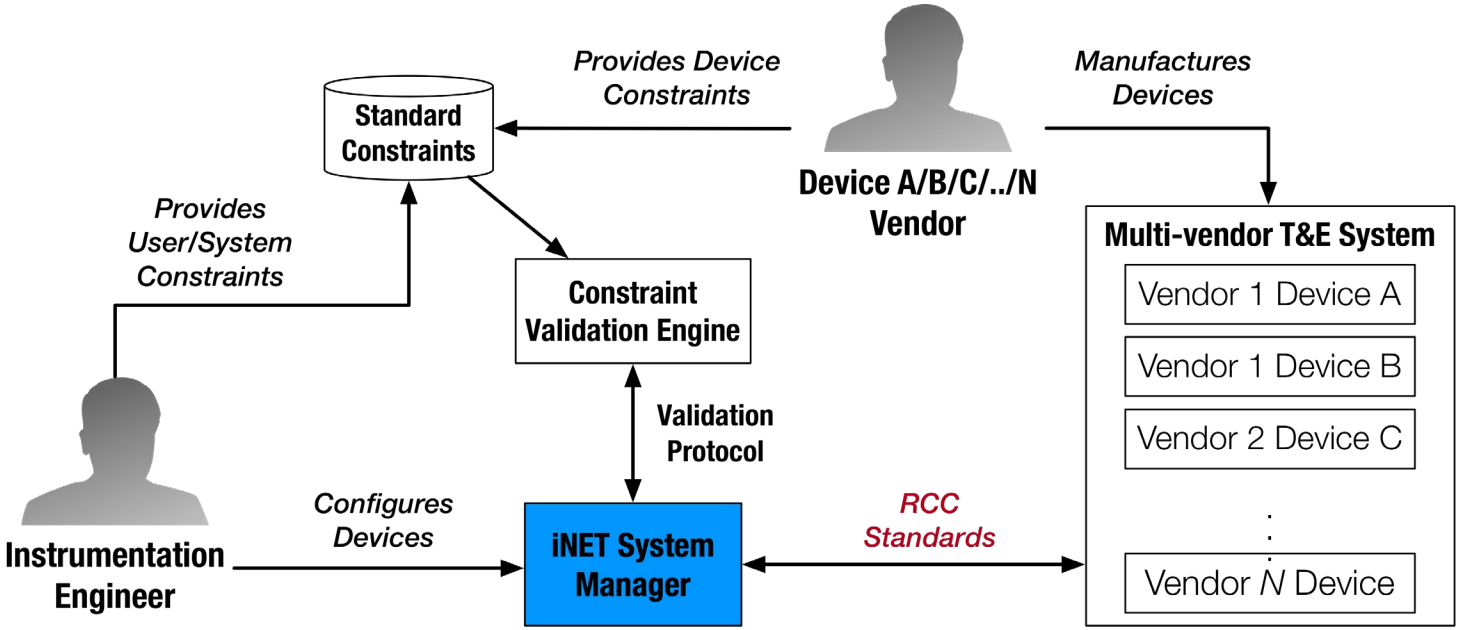


Multi-Vendor Systems: Tomorrow

- 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

System Manager

Home | Project Editor

Project Explorer | User Manual | About | Debug

Tools | Support | DEBUG | Themes

PreBETA

Sandbox

- RAN_4919
  - LM1
  - TA1 - SD400
    - AirSwitch1
    - EQDR
    - BBXM Voic...
    - TAR1
    - DAU of Au...
  - GR1
  - TA2
    - TAR
- GndSwitch1
- VoIP Client
- FTP Server
- SysMgr
- PTP GMC
- RAN2
  - TA2 - SD404
    - TAR2
    - Rec2
    - AirSwitch2
    - DAU of Au...
  - GR2
- TAR

TAR1

SEARCH COMING SOON

Name: TAR1

Role ID: TAR1

Network: Empty

IP Address: 10.1.1.1

Properties

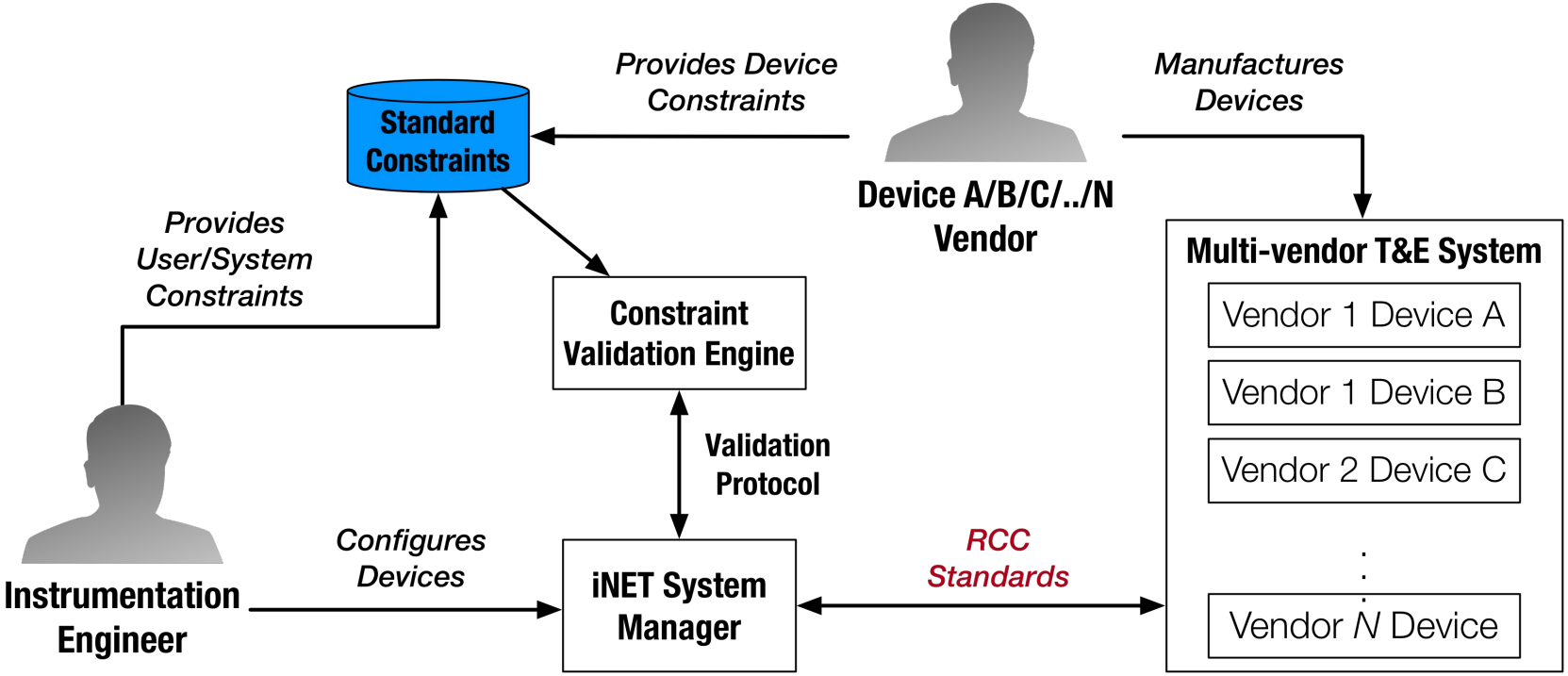
Search

Component	TAR1
Configuration Token	ITC_Demo_2Missions
Coordinate System	
Coordinates	
Description	Test Article Radio 1 - ITC Demo
Host	
IEEE 1588 Version	2008e2e
Internal Structure	InternalStructure
Description	
Modules	1
[0] Module	NodeModule 1
Acquisition Ports	0
Description	
Inventory ID	
Manufacturer	
Model	
Name	NodeModule 1
Network Interfaces	1
[0] Interface	eth1
Position	1
Positions Occupied	1
Serial ID	

Network Interfaces

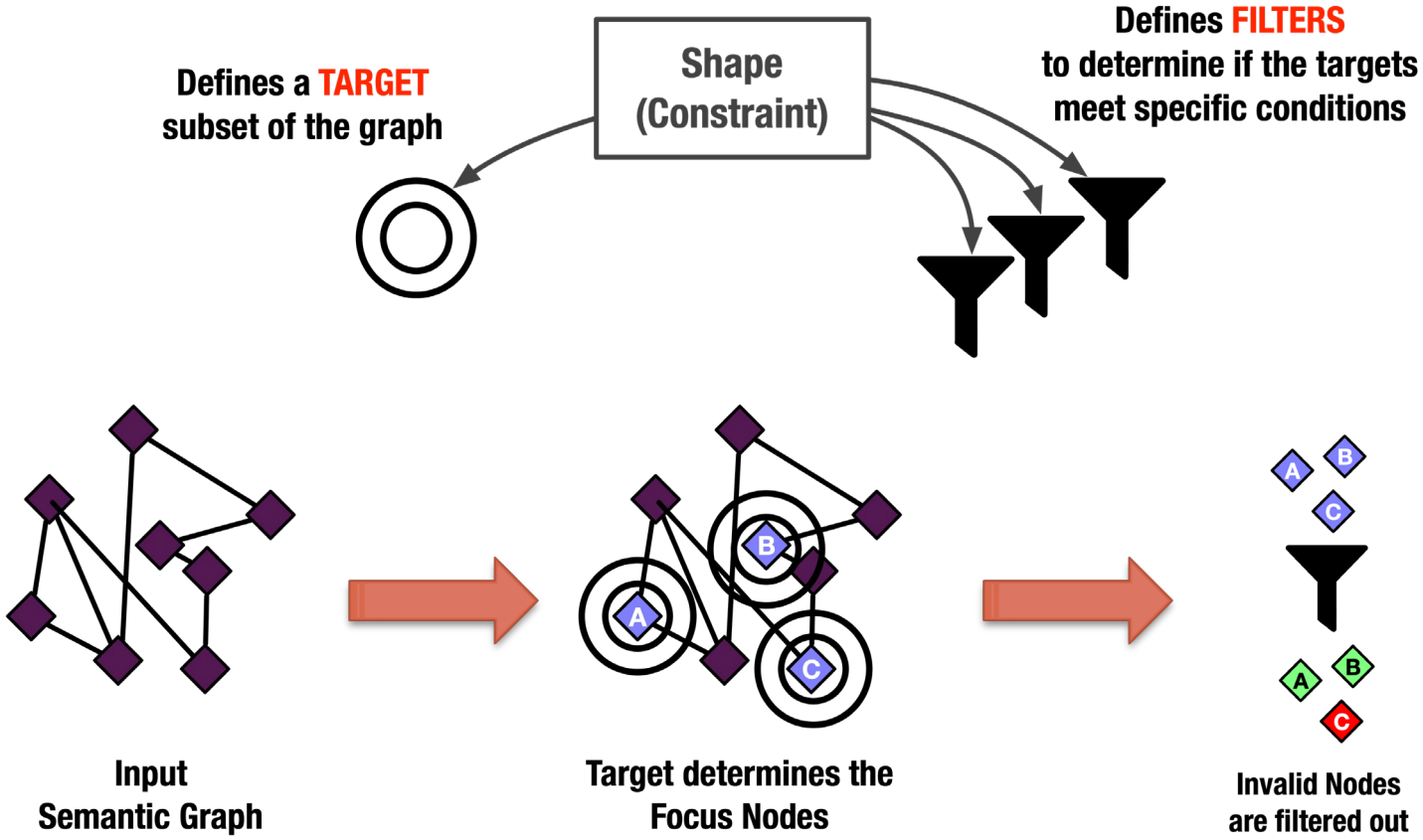
ITC_Demo_2Missions | IPv4 | jakub | 17:02:59 | Tasks: 0

TACL:
A Proposal for a T&E Constraints Language



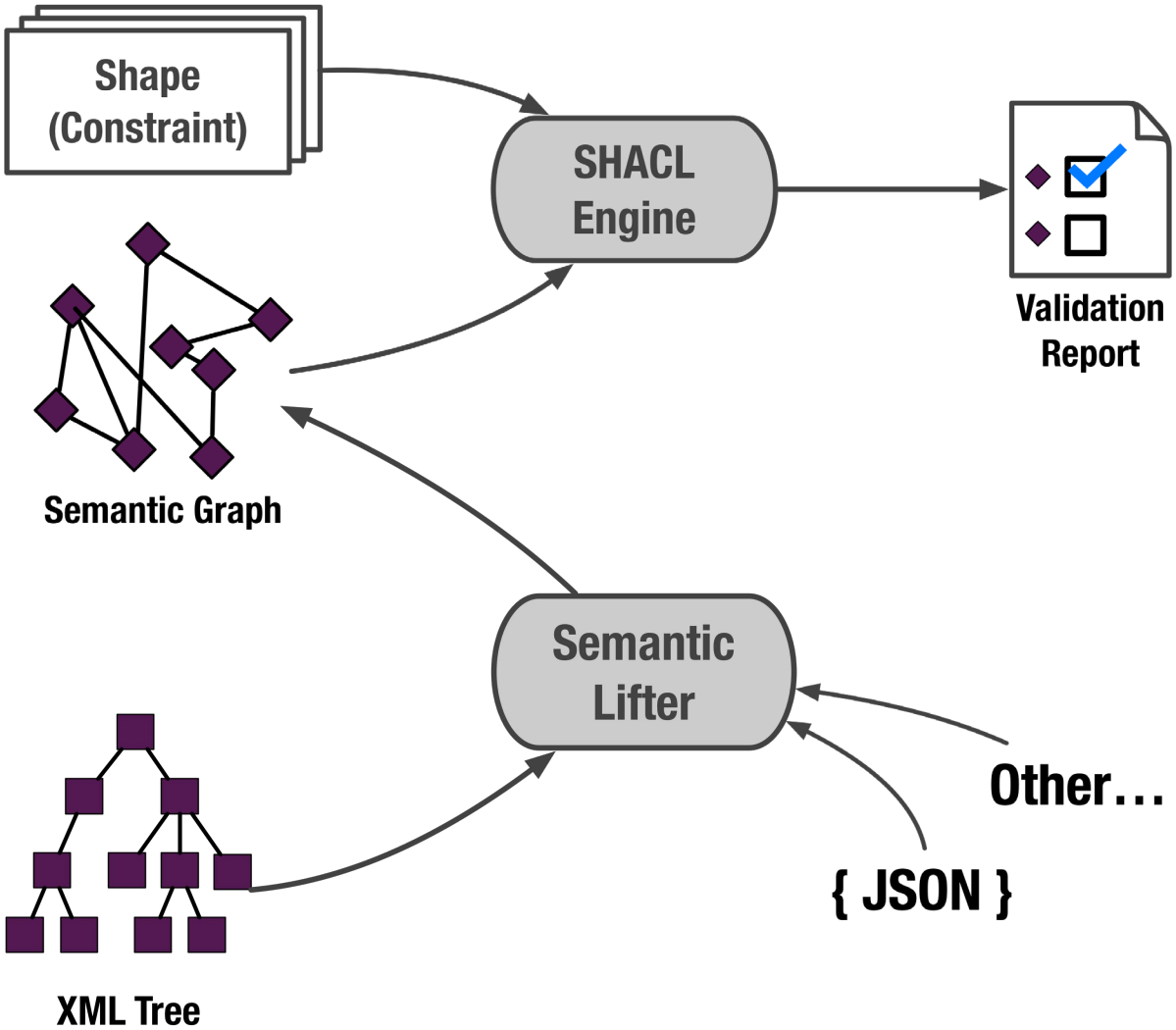
W3C SHACL – Shapes Constraint Language

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



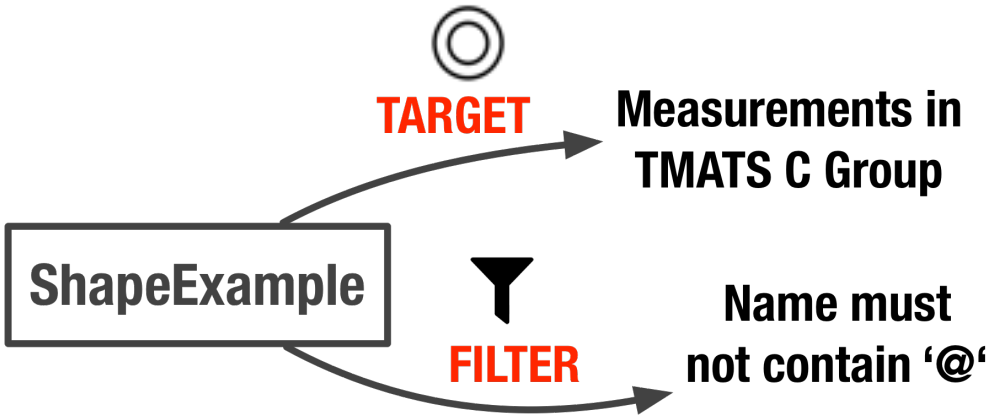
- TARGETS and FILTERS can use FUNCTIONS in their definitions

Processing Shapes with a SHACL Engine



Shape Example

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



TARGET

FILTER

ShapeExample (SHACL)

```
sh:targetClass C:Measurement

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

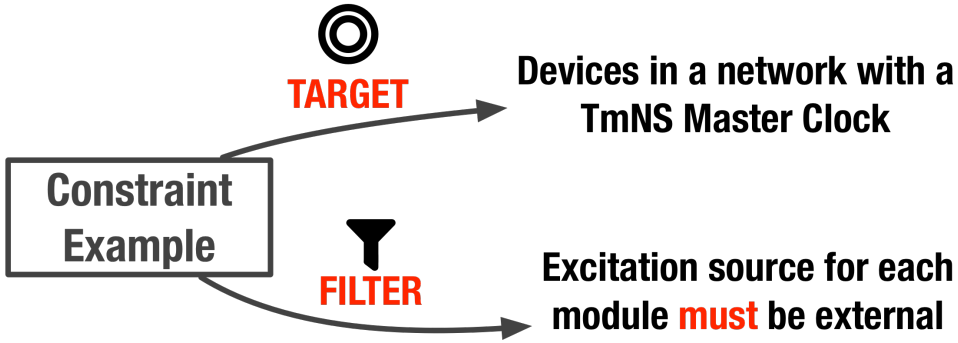
TACL – T&E Extension of SHACL

- 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.



Constraint Example (TACL)

TARGET

FILTER

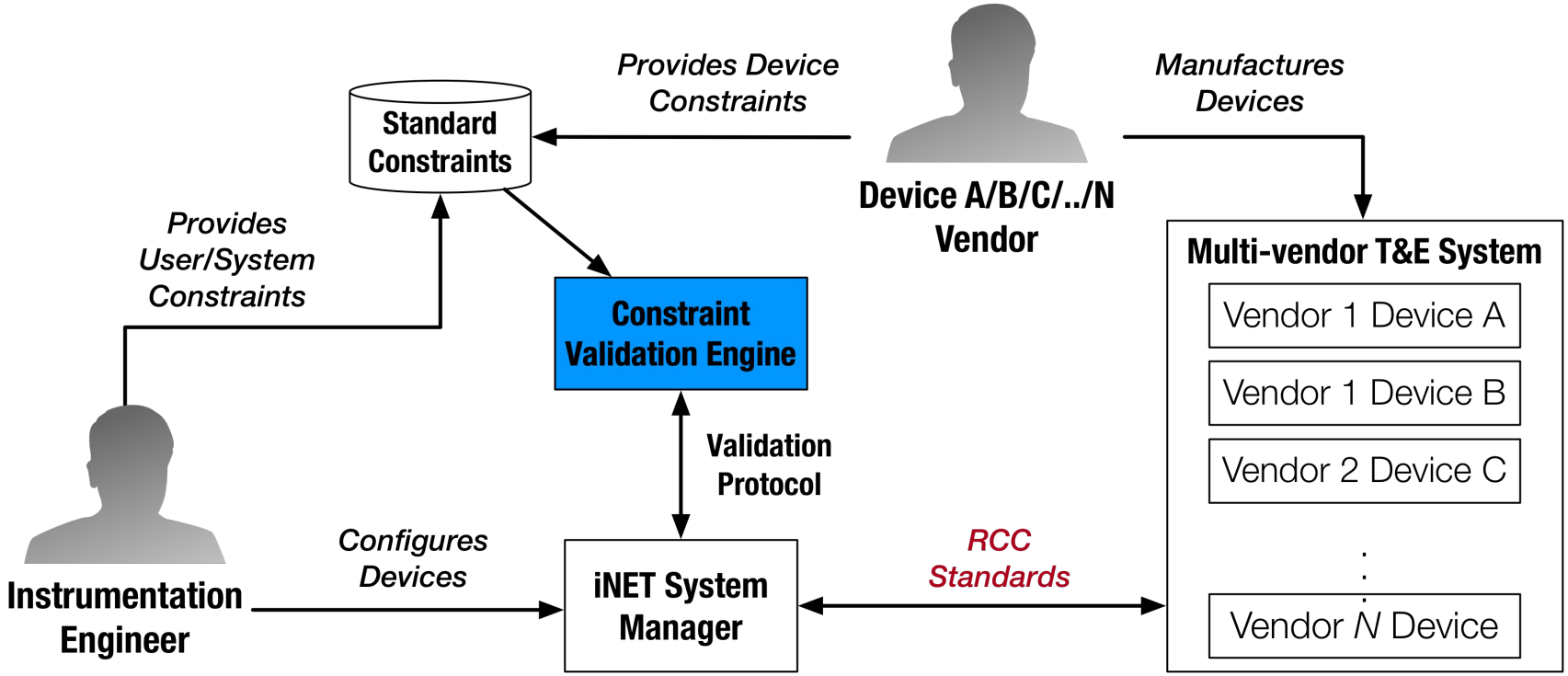
```
sh:target [
   a tacl:DeviceOnNetworkWith;
   tacl:appKind mdl:TmNSMasterClock ]

tacl:allModulesWithExcitationSource "External" .
```

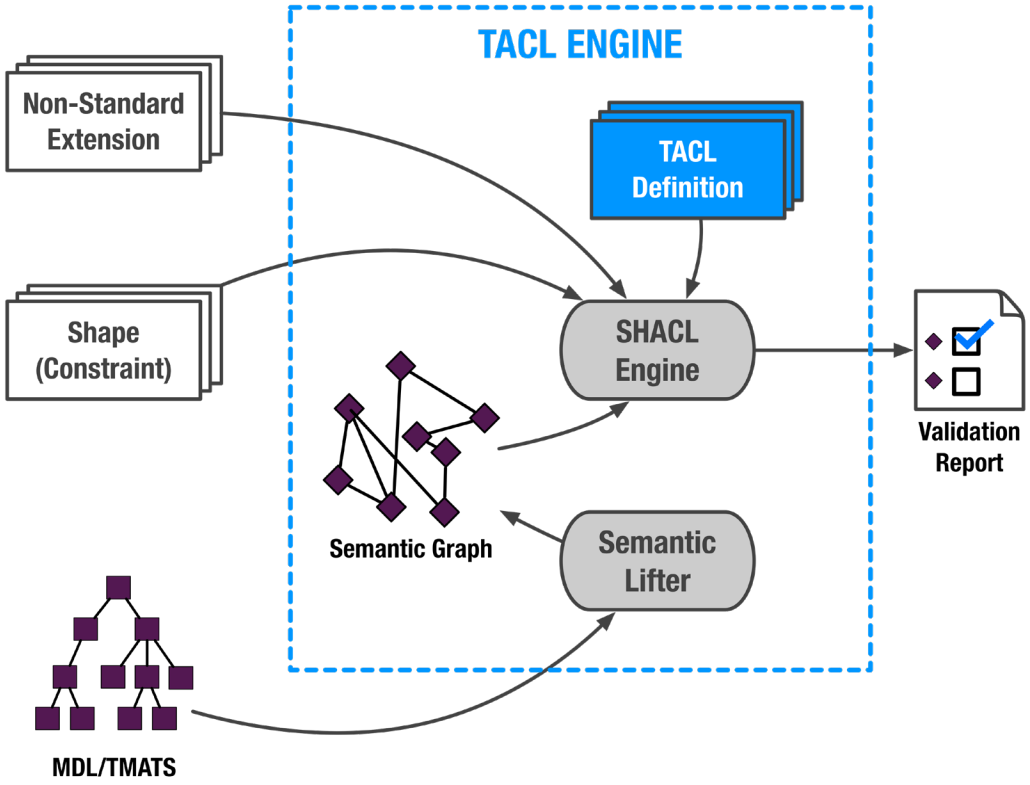
TACL – Benefits

- 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

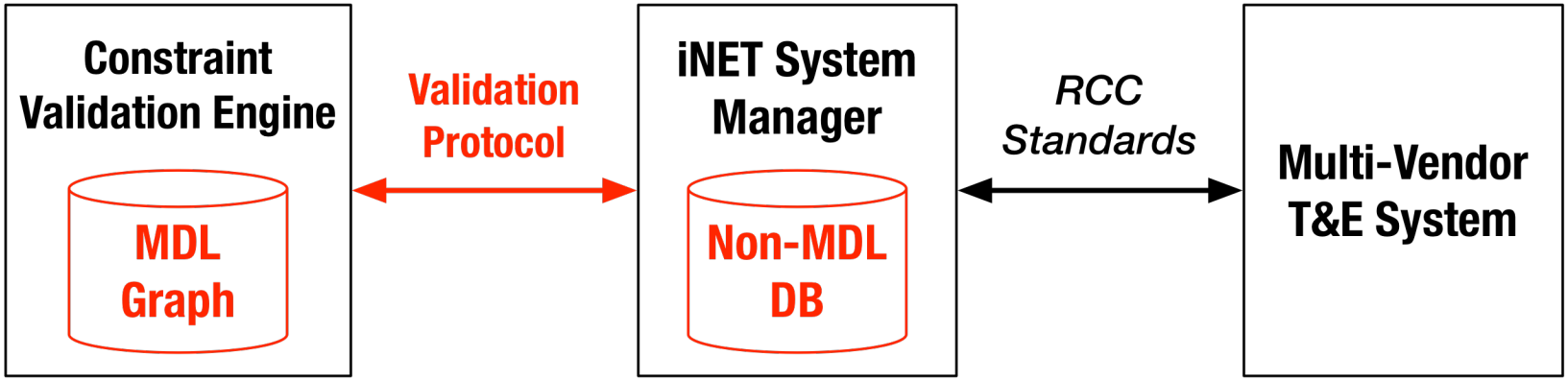


- xVISor is a reference implementation of a TACL Engine
  - Supports TACL validation of MDL 1.0 and TMATS/XML 106-17
  - Developed in Java



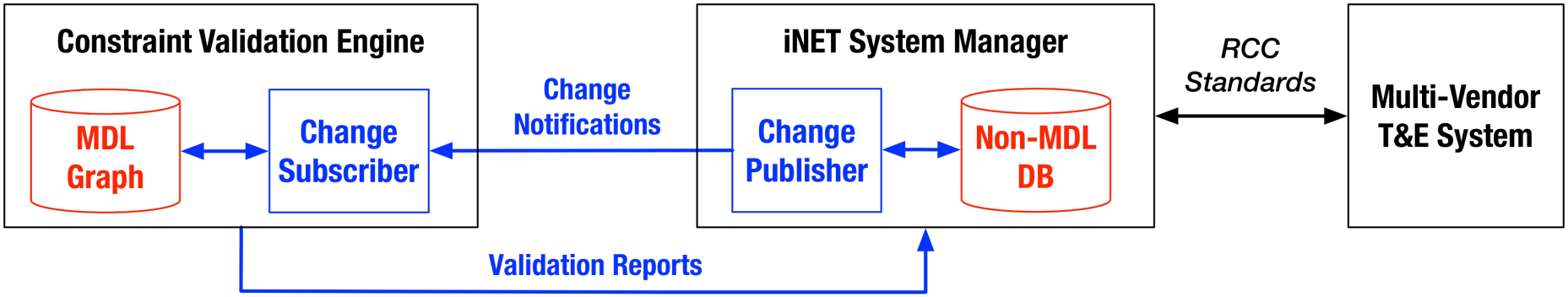
Architectural Challenge

- 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

System Manager

Home | Project Editor

Project Explorer | User Manual | About | Debug

Tools | Support | DEBUG | Themes

PreBETA

Sandbox

- RAN_4919
  - LM1
  - TA1 - SD400
    - AirSwitch1
    - EQDR
    - BBXM Voice Gateway
    - TAR1
    - DAU of Austin
  - GR1
  - TA2
    - TAR
- GndSwitch1
- VoIP Client
- FTP Server
- SysMgr
- PTP GMC
- **RAN2**
  - TA2 - SD404
    - TAR2
    - Rec2
    - AirSwitch2
    - DAU of Austin 2
  - GR2
- TAR

TAR1

Listening Groups

Name	RF MAC
TAR1rxGroup	**61473**

Radio Transmissions

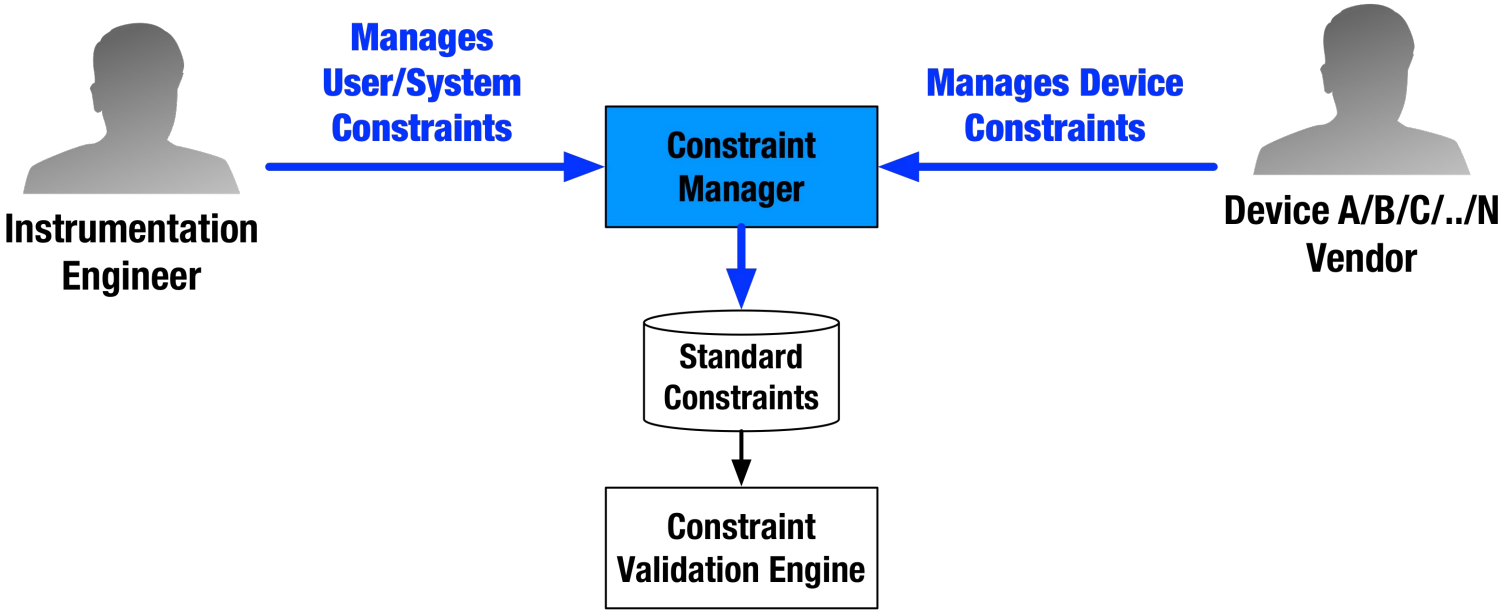
Name	RF MAC	QoS Policy	Heartbeat Timeout	LM Heartbeat Timeout	LM TxOp Timeout
TAR1txGroup	61456	Classic Downlink	65535	3000	150

The RF MAC already used in RAN 'RAN_4919' [Violated constraint: RFMacConstraint]

ITC_Demo_2Missions | IPv4 | jakub | 17:01:55 | Tasks: 0

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)

Edwards Air Force Base / X-55 / Test Scenario 03 / 136th RCC-TG Examples / Excitation Source Restriction (MDL)

Constraint Excitation Source Restriction (MDL)

TACL Edit

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

TARGET Which data is constrained? Save Cancel

All instances of mdl:NetworkNode

Where + Add Characteristic

It is on a network with a Master Clock

FILTERS How is it constrained? Save Cancel

+ Add Filter

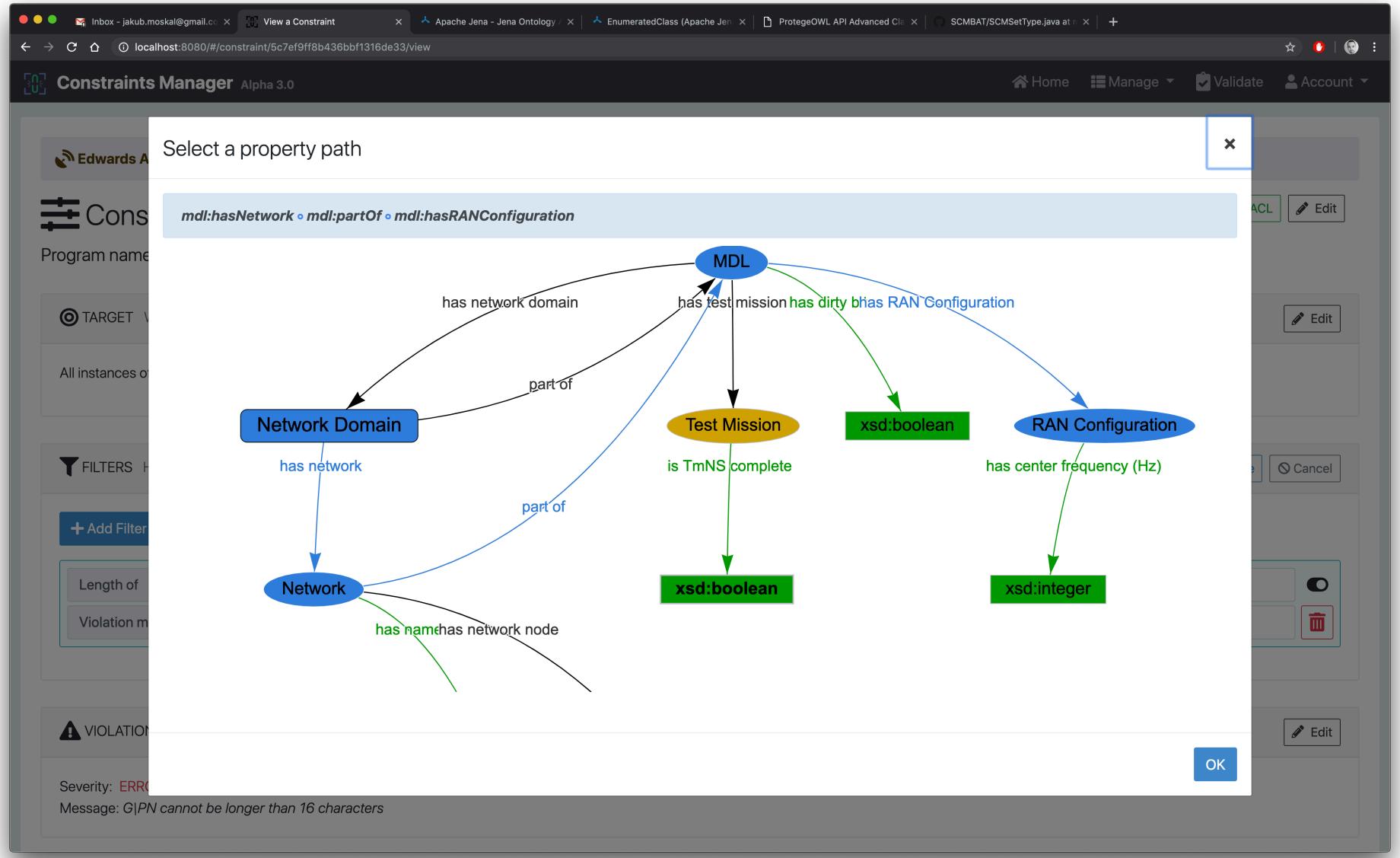
The excitation source for all modules must be External

Violation message specific to this filter

Internal

External

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!

VIStology, Inc.

http://www.vistology.com

+1 (508) 788-5088

Southwest Research Institute

http://www.swri.org

+1 (210) 684-5111

JT4, LLC

Edwards AFB

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

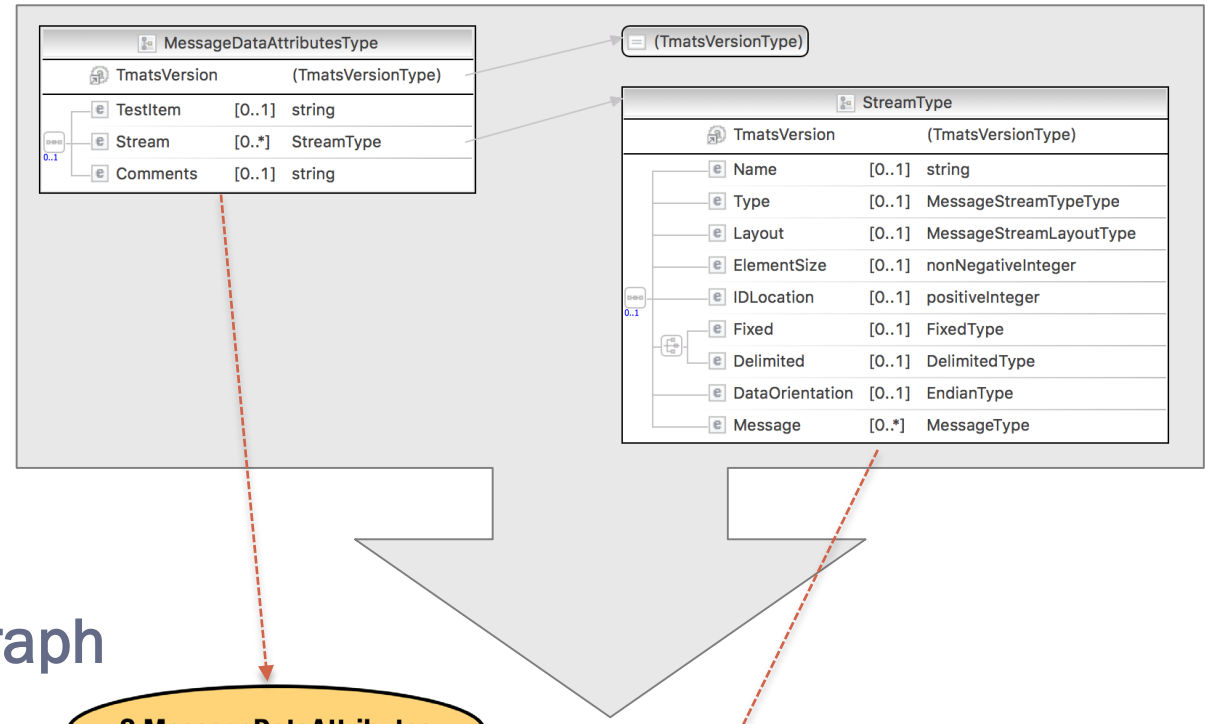
- VIStology (lead) and SwRI (sub) are funded via a Phase II SBIR (AF141-227)
  - Full description can be found here (look for "AF141-227"): http://www.acq.osd.mil/osbp/sbir/solicitations/sbir20141/af141.htm
- Objective:
  - *Develop methods for capturing semantic rules of Test & Evaluation metadata and 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

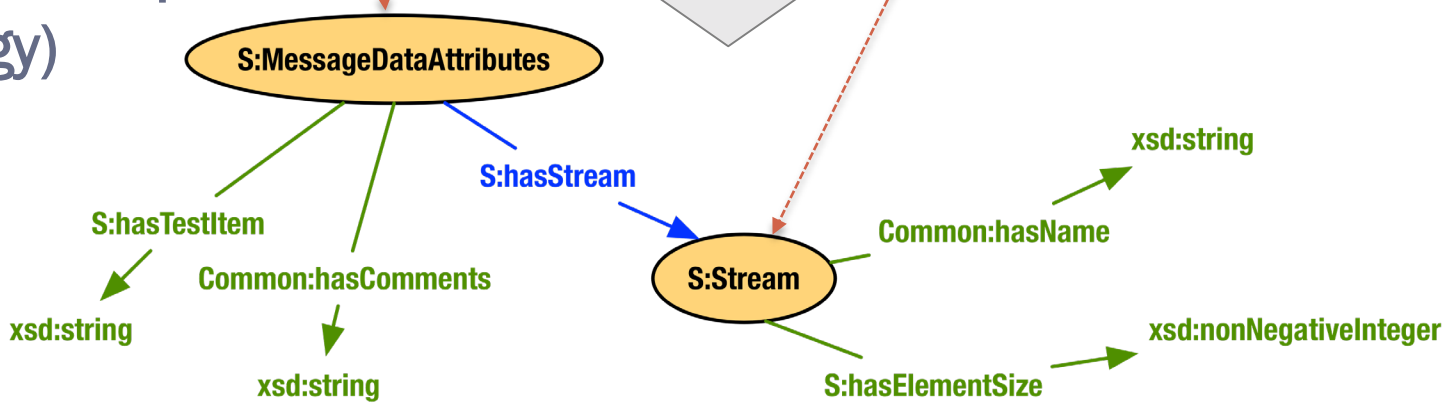
- Sufficient for simple constraints (similar to XSD)
- Supported by every SHACL-compliant engine
- Examples:
  - Checking cardinality, e.g. measurements must have a name
  - Checking value range, e.g. modules cannot occupy more than 2 slots
  - String length, regex, e.g. network node names cannot use 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)