

Building Multi-Vendor T&E Systems in iNET



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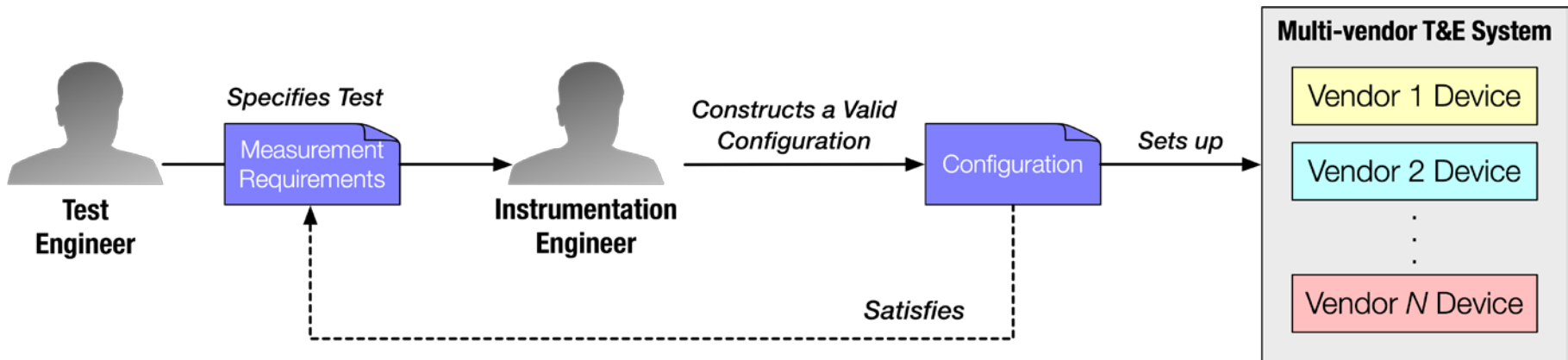
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MAY 15, 2019

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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

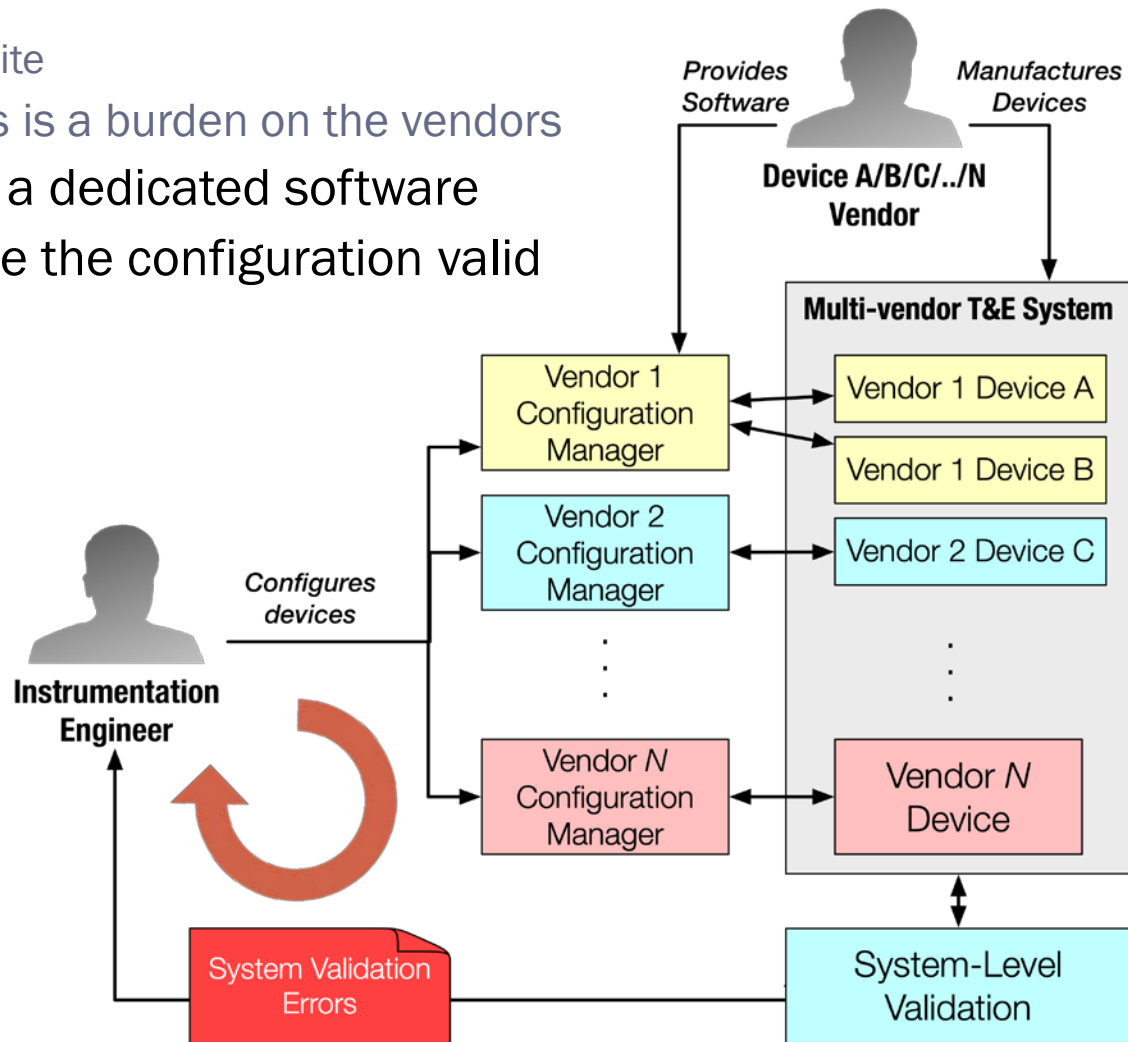


- A single vendor alone cannot anticipate:
 - Dependencies on the settings from devices from other vendors, for instance:
 - ✦ Timing constraints imposed by one device can affect the timing of another one
 - Systemic constraints that are specific to a particular customer, for instance:
 - ✦ Limitations 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



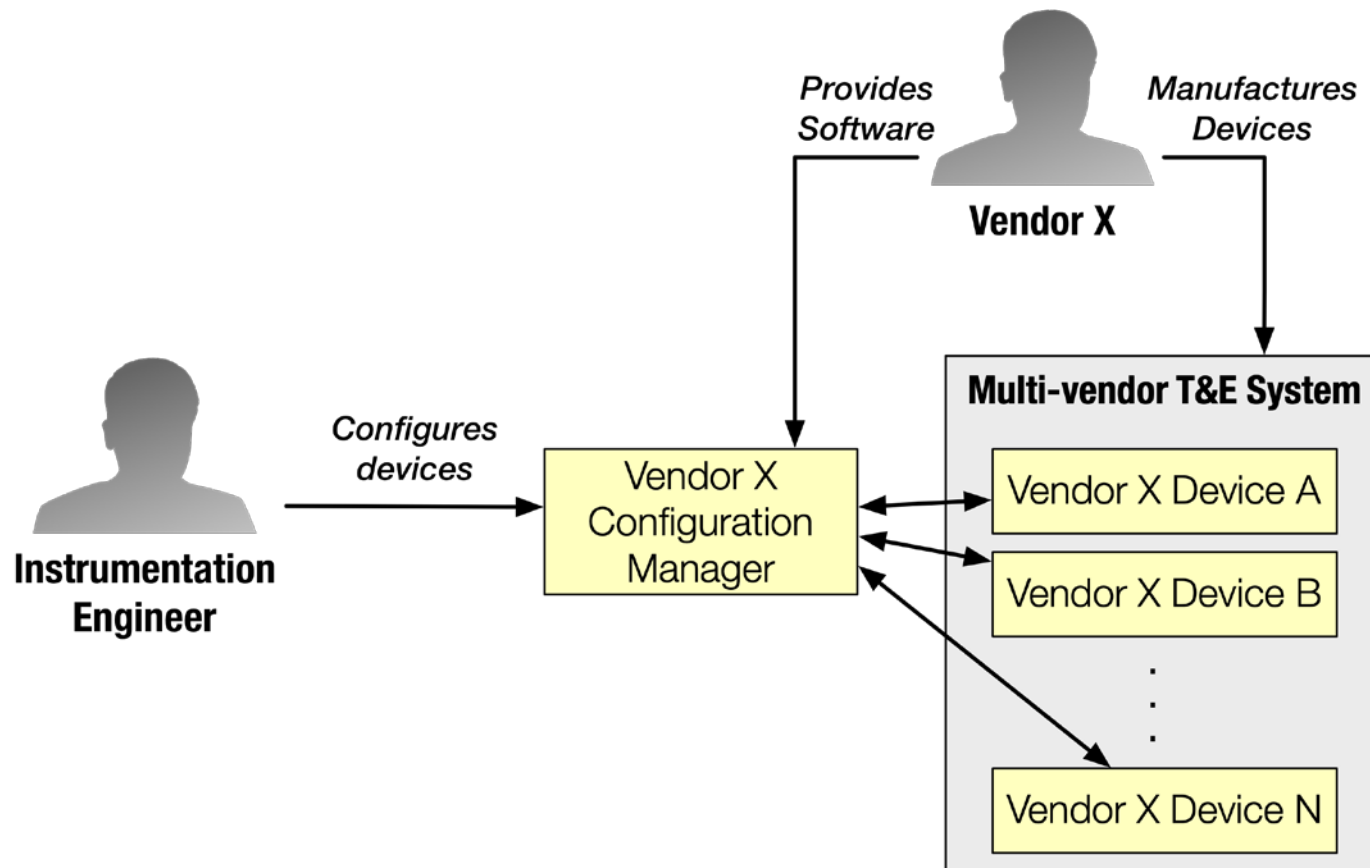
- Vendor-specific configuration software
 - “Hides” the constraints
 - Requires training for each software suite
 - Keeping up with standard updates is a burden on the vendors
- System-level validation requires a dedicated software
- Many iterations required to make the configuration valid
 - Last minute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



Common Reality



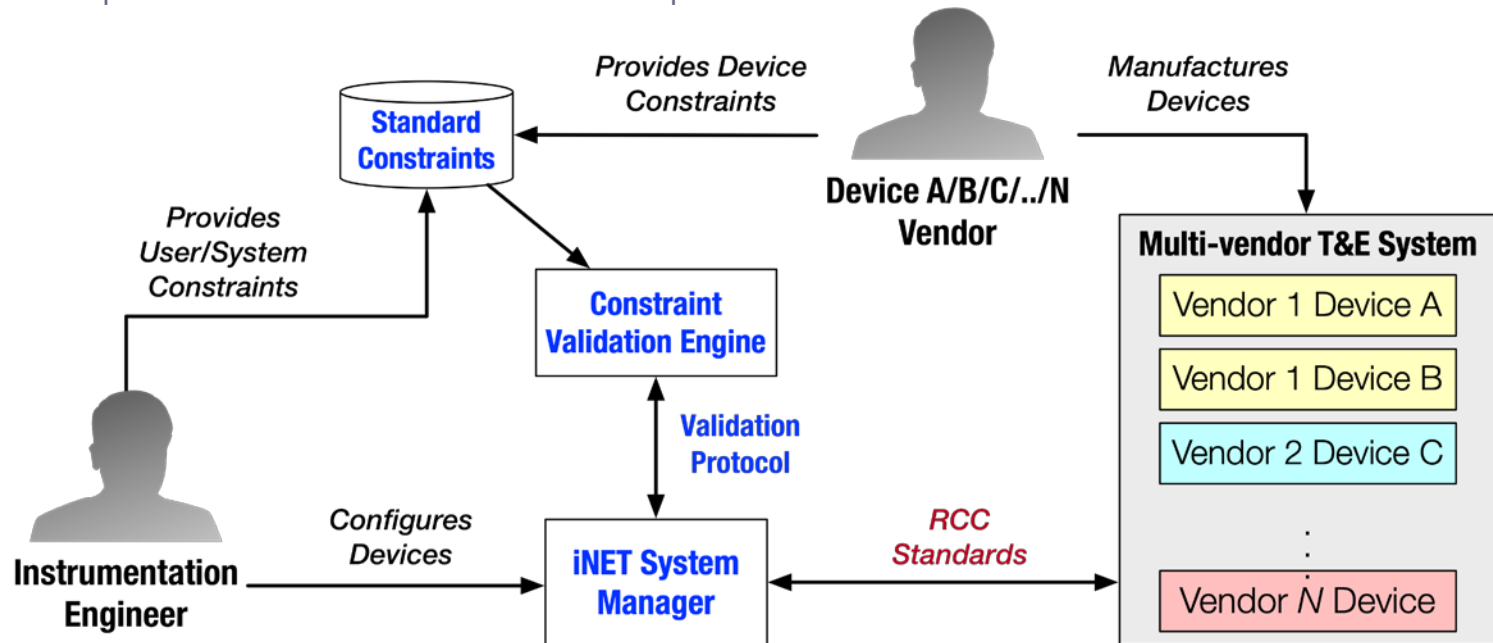
- Multi-vendor systems are expensive, impractical
- In practice, they are often avoided via vendor lock-in
 - Capability, performance, and cost of T&E devices may need to be compromised



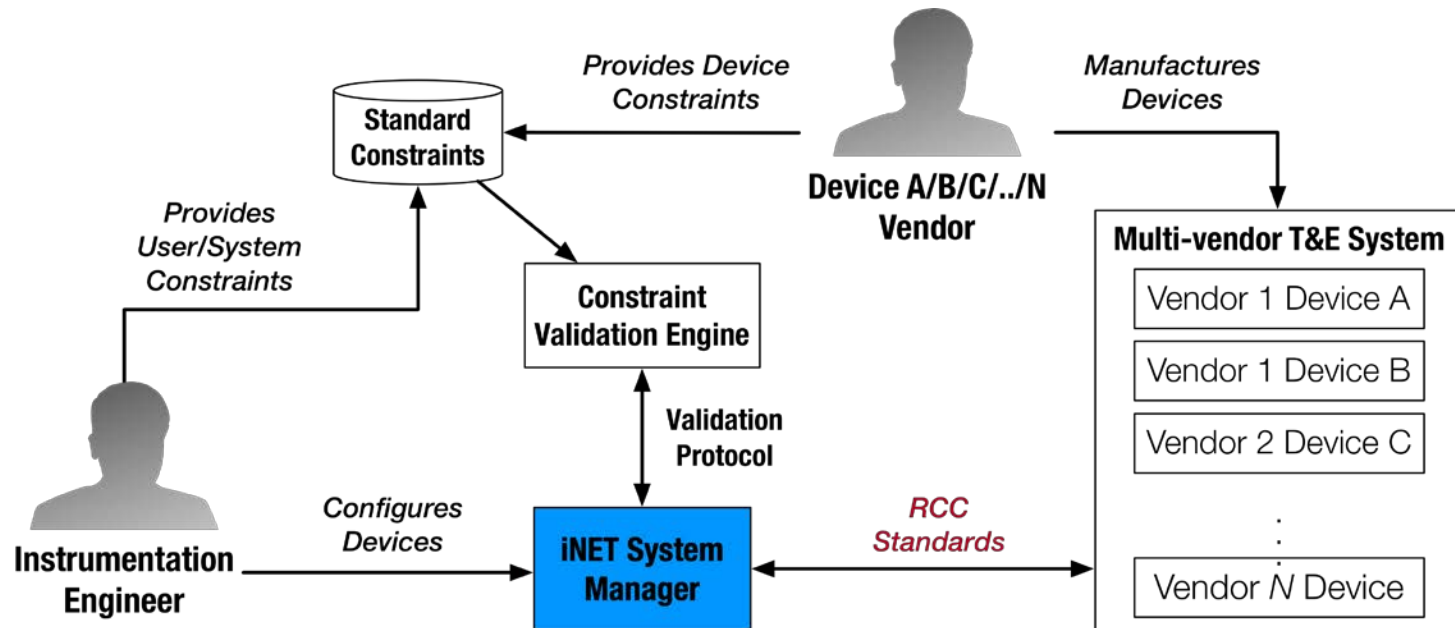
Multi-Vendor Systems: Tomorrow



- 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 Tools User Manual About Support Debug DEBUB 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

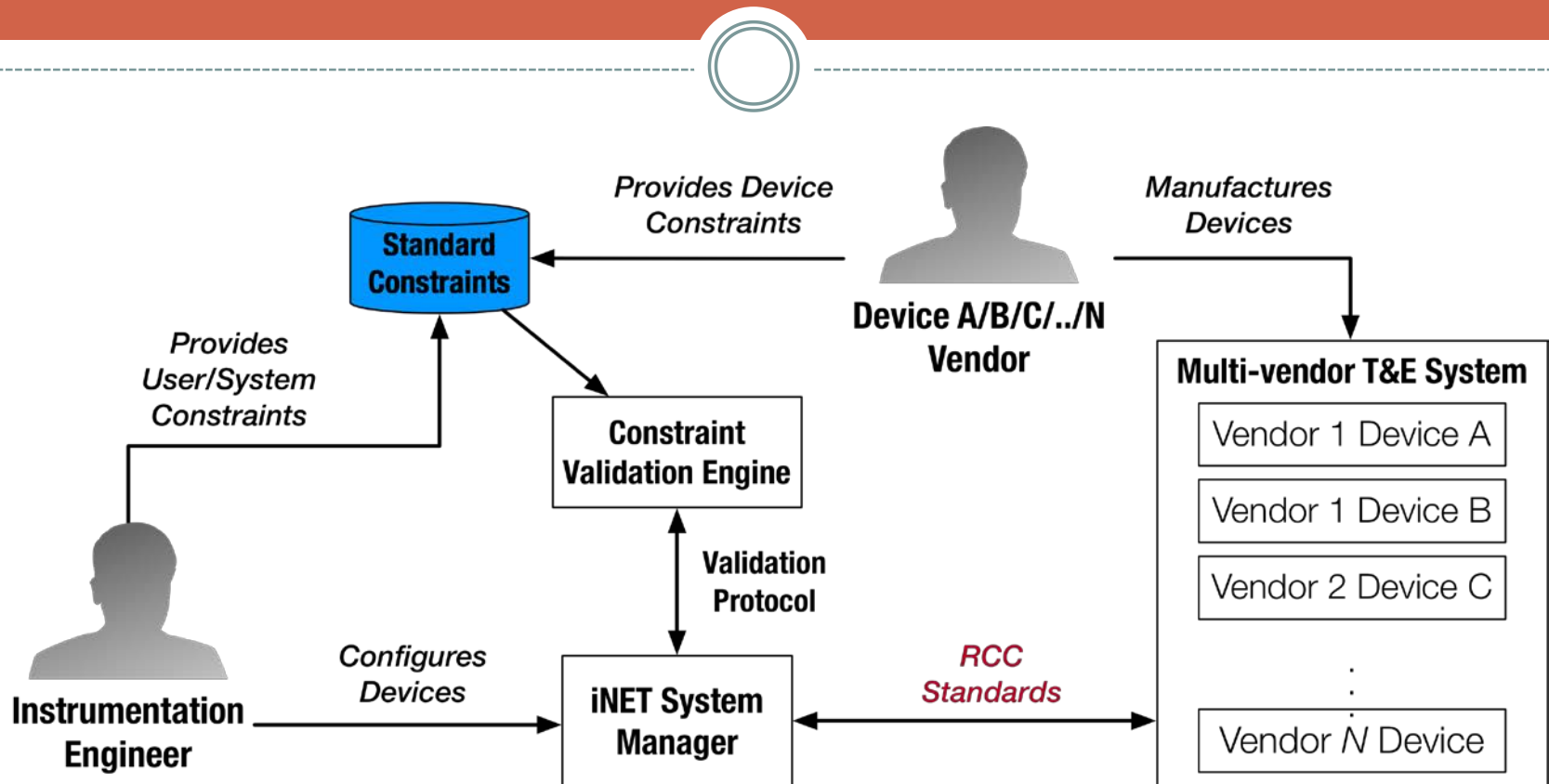
Search

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	

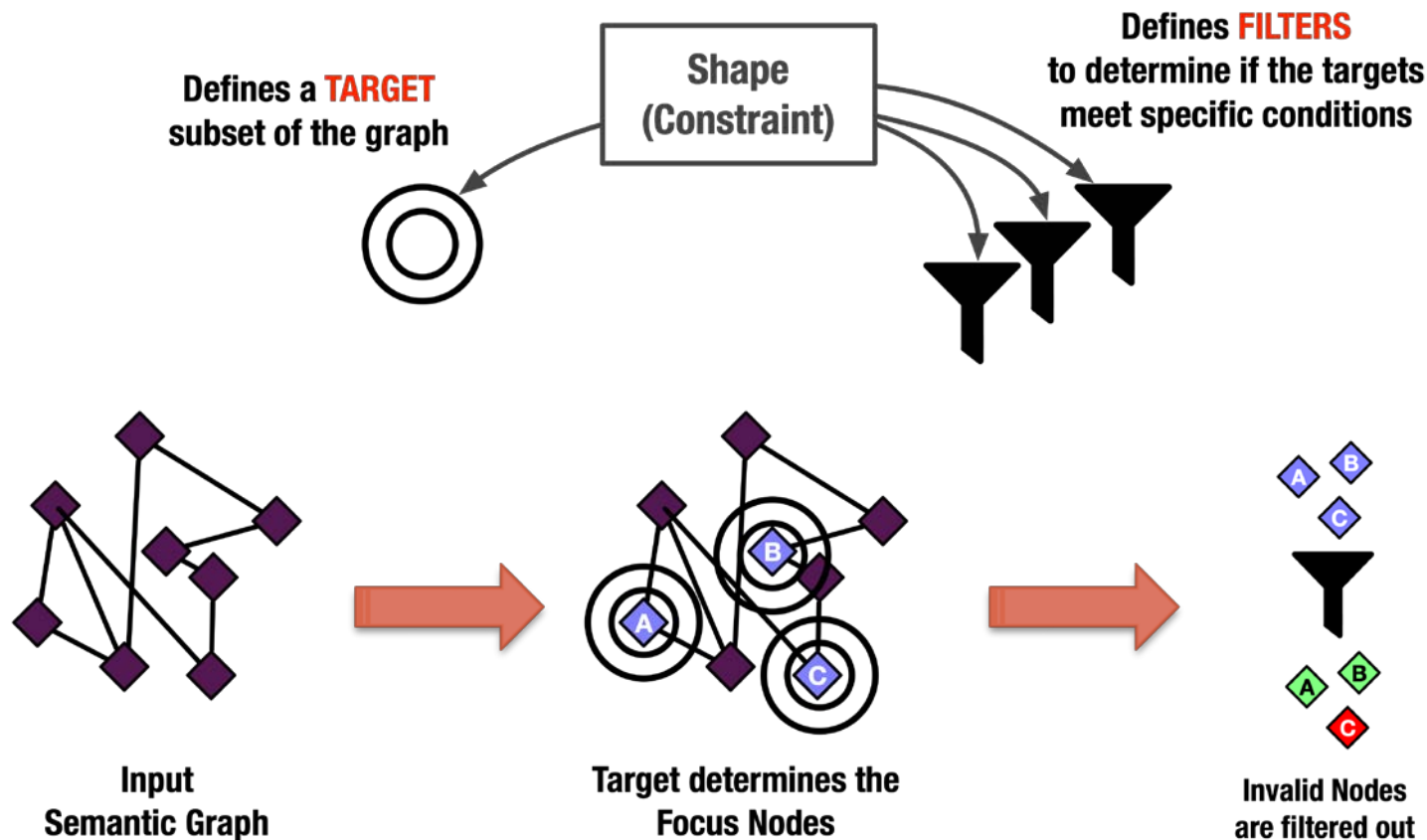
Network Interfaces

ITC_Demo_2Missions IPv4 jakub 17:02:59 Tasks: 0

TACL: A Proposal for a T&E Constraints Language

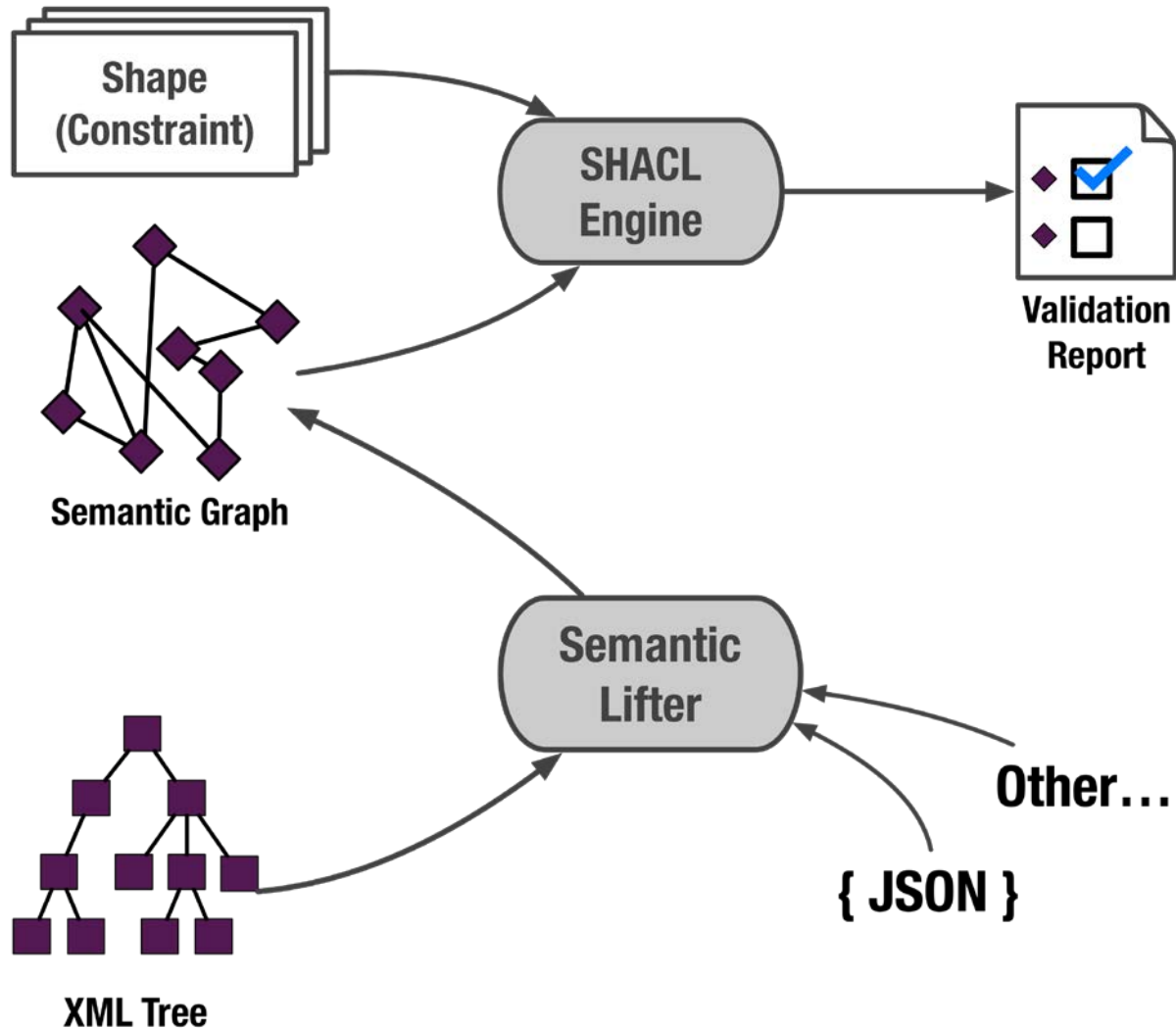


- A language for validating semantic graphs against a set of conditions, called **Shapes**



- TARGETS and FILTERS can use **FUNCTIONS** in their definitions

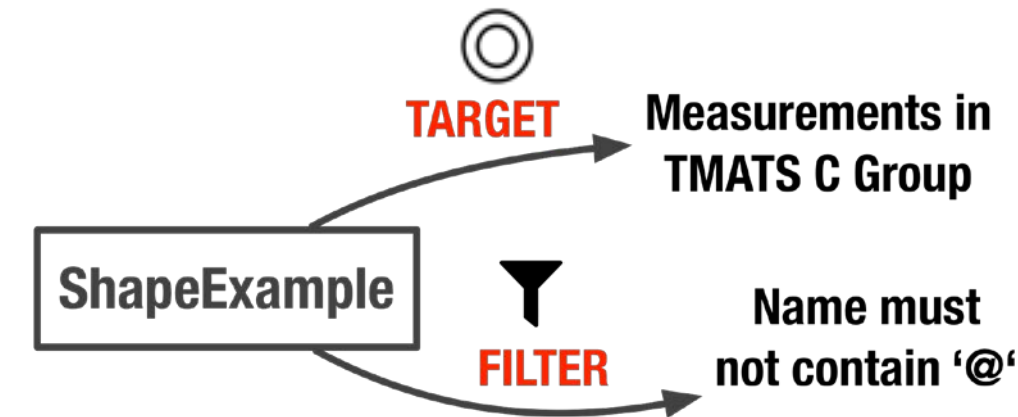
Processing Shapes with a SHACL Engine



Shape Example



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



ShapeExample (SHACL)

```
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

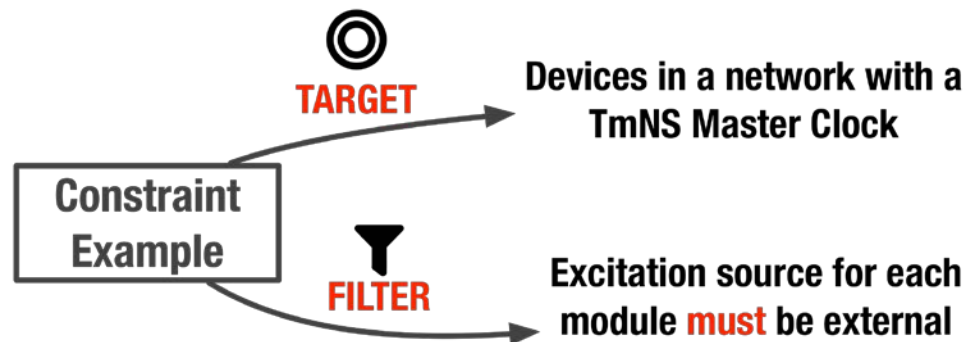
- ITC'18 Best Standards Paper Award
 - *“Introducing TACL – A Proposal for a New Standard T&E Constraint Language”*



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)

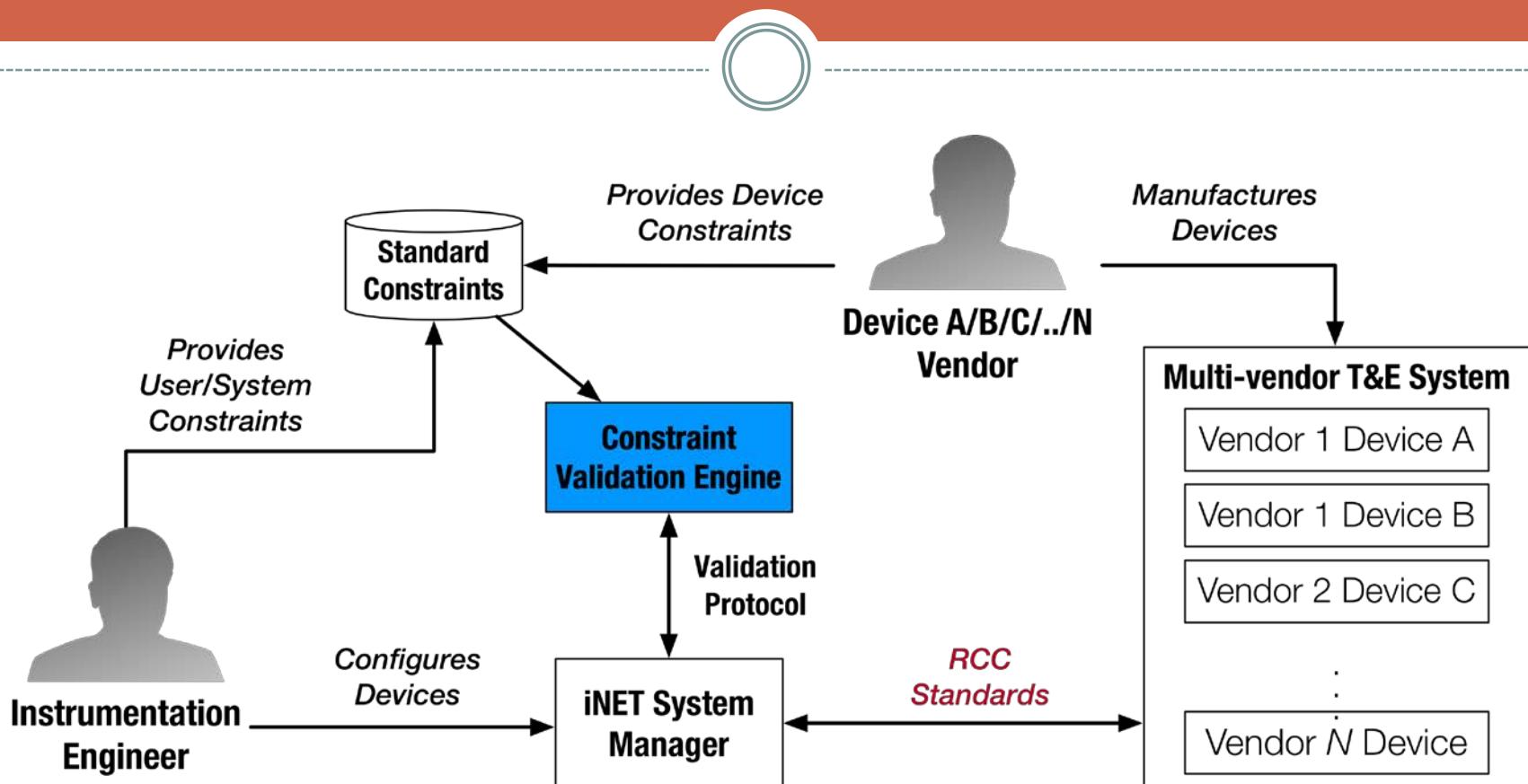
```
sh:target [  
  a tacl:DeviceOnNetworkWith;  
  tacl:appKind mdl:TmNSMasterClock ]  
  
tacl:allModulesWithExcitationSource "External" .
```

TACL – Benefits

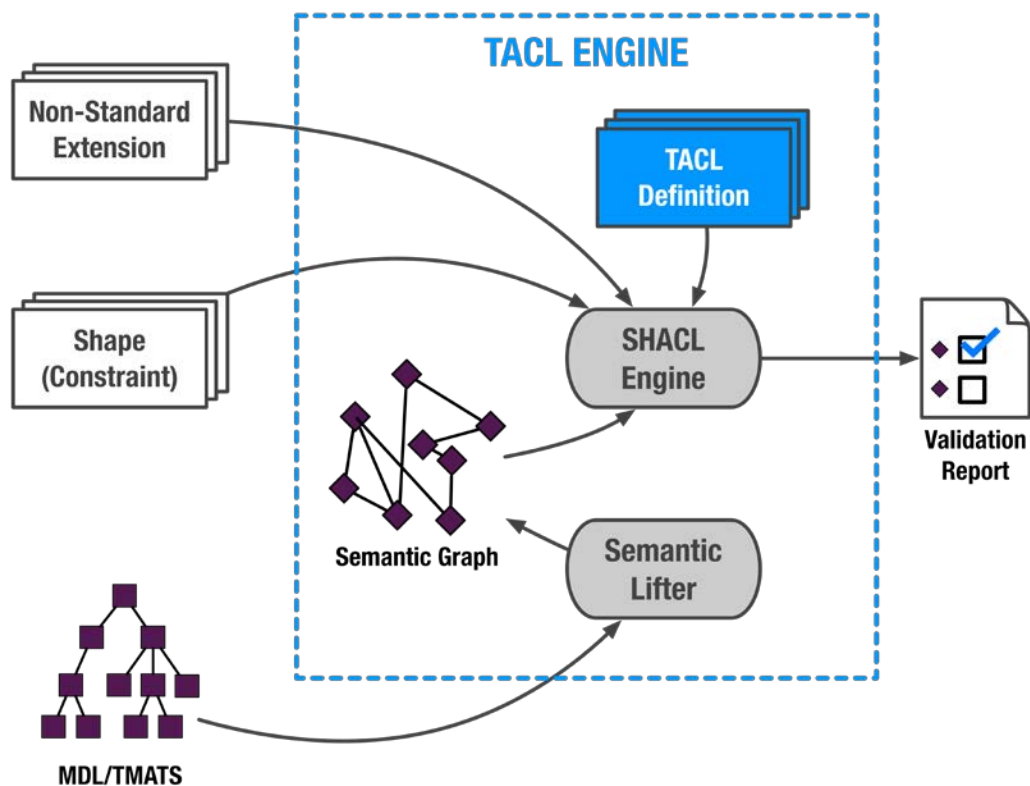


- TACL hides the nitty–gritty details under the covers
- It introduces a layer of separation from the data model
- Constraints written with TACL are succinct and resilient to schema changes
- It can be processed with SHACL engines available today
- As an extension of a W3C standard, TACL benefits from:
 - 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

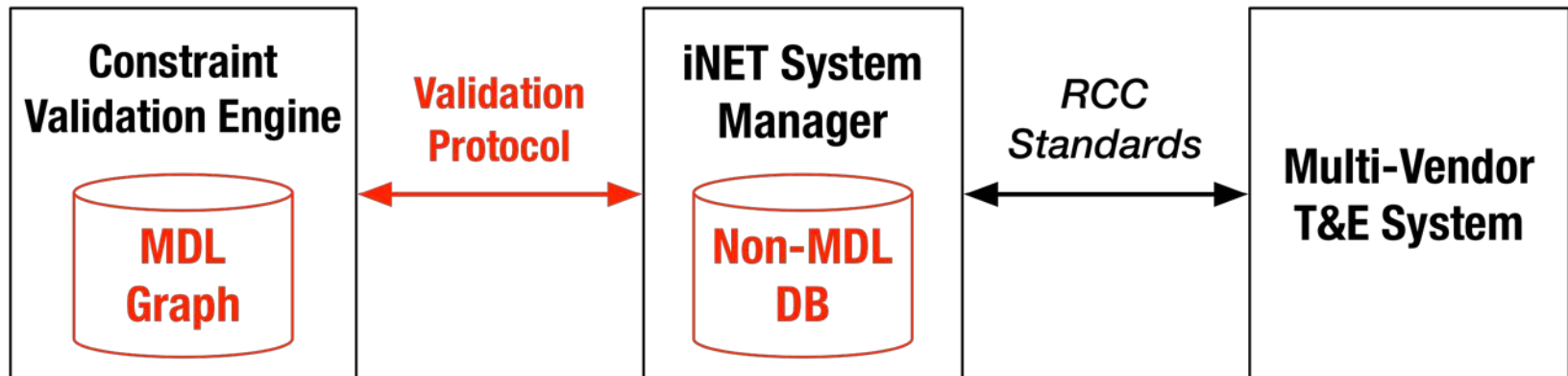


- Premise:

- 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?

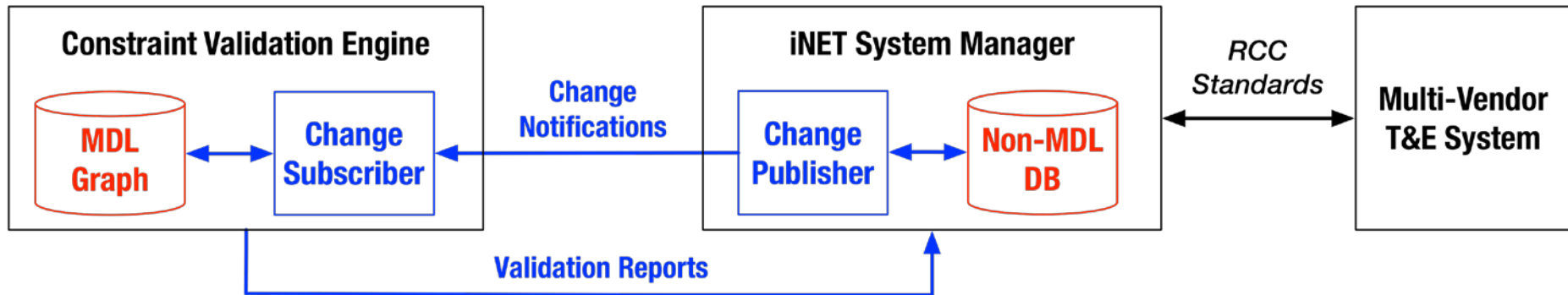


Integration with iNET System Manager



- **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!



System Manager

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 - 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]

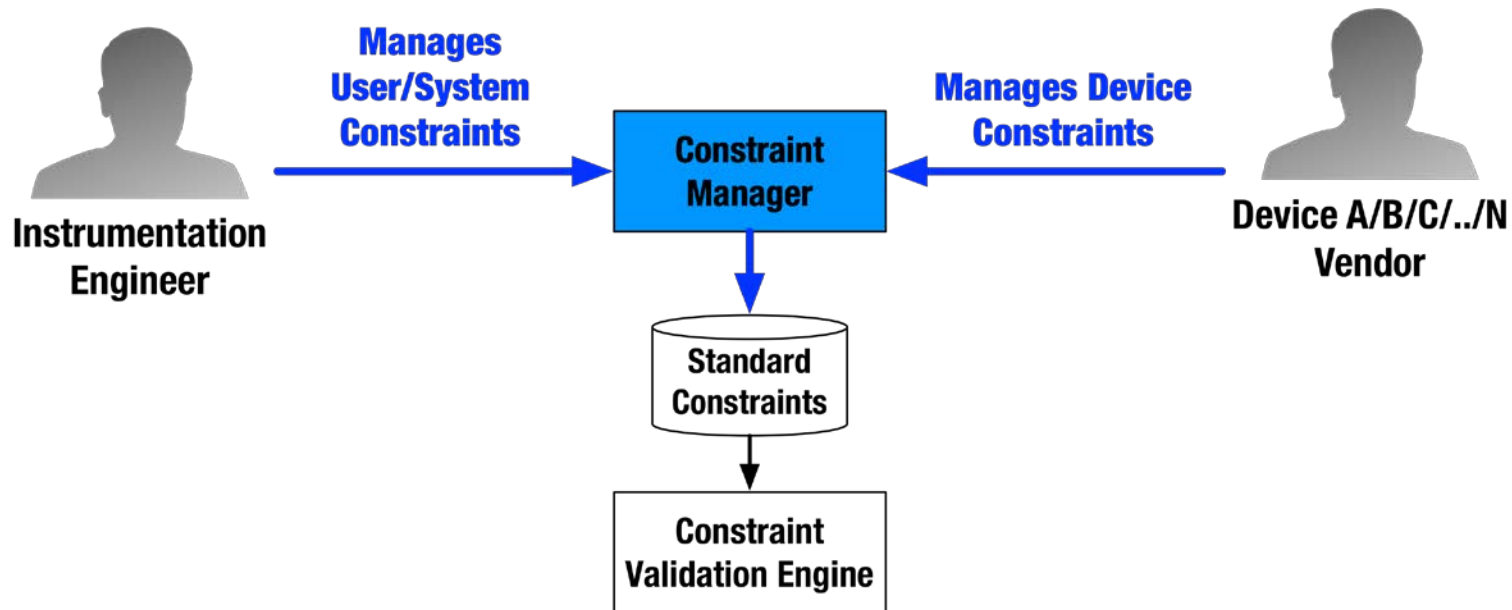
ITC_Demo_2Missions IPv4 jakub 17:01:55 Tasks: 0

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)

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 Trash

FILTERS How is it constrained? Save Cancel

+ Add Filter

The excitation source for all modules must be External Toggle

Violation message specific to this filter Trash

- Internal
- External

Constraint Manager (2/2)



Constraints Manager Alpha 3.0

Select a property path

`mdl:hasNetwork ◦ mdl:partOf ◦ mdl:hasRANConfiguration`

```
graph TD; MDL((MDL)) -- "has network domain" --> ND[Network Domain]; MDL -- "part of" --> Net((Network)); MDL -- "has test mission" --> TM((Test Mission)); MDL -- "has dirty bit" --> XB1[xsd:boolean]; ND -- "has network" --> Net; TM -- "is TmNS complete" --> XB2[xsd:boolean]; Net -- "has name" --> XS1[xsd:string]; Net -- "has network node" --> XI1[xsd:integer]; Net -- "part of" --> MDL; Net -- "part of" --> RC((RAN Configuration)); RC -- "has center frequency (Hz)" --> XI2[xsd:integer];
```

OK

Severity: ERROR
Message: G|PN cannot be longer than 16 characters



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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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



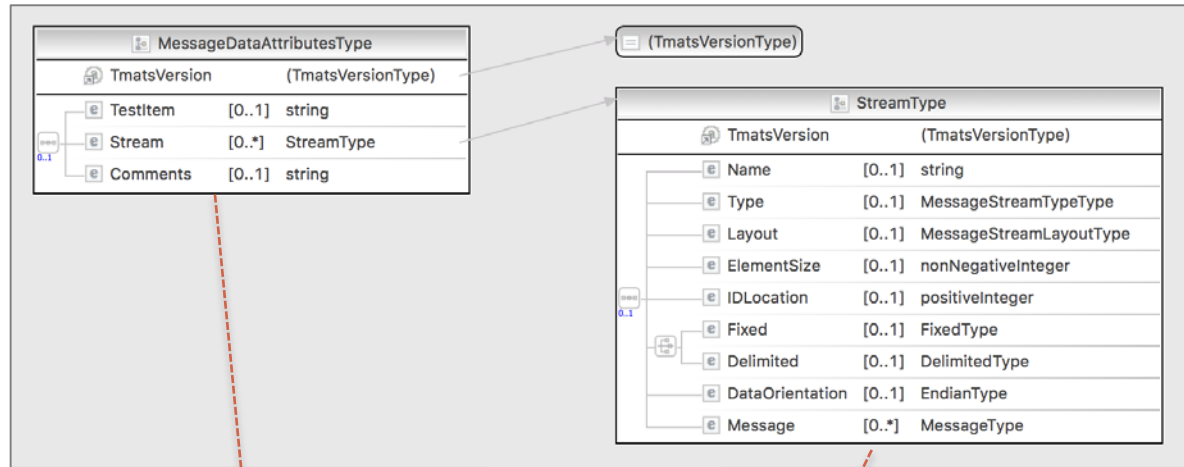
- VISTology (lead) and SwRI (sub) are funded via a Phase II SBIR (AF141-227)
 - Full description can be found here (look for “AF141-227”):
<http://www.acq.osd.mil/osbp/sbir/solicitations/sbir20141/af141.htm>
- Objective:
 - *Develop methods for capturing semantic rules of Test & Evaluation metadata and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

- 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

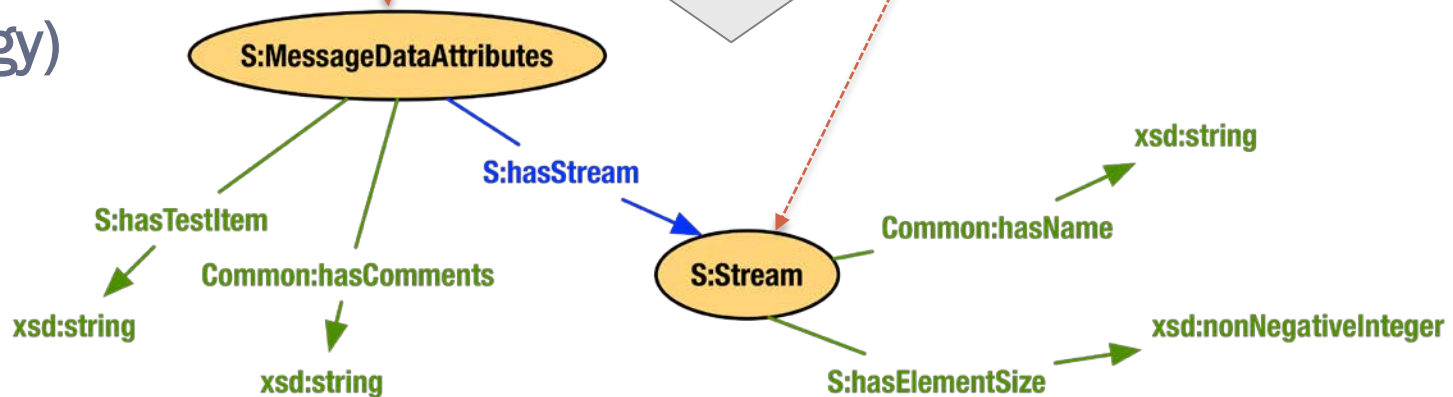
From T&E XML to a Semantic Graph



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

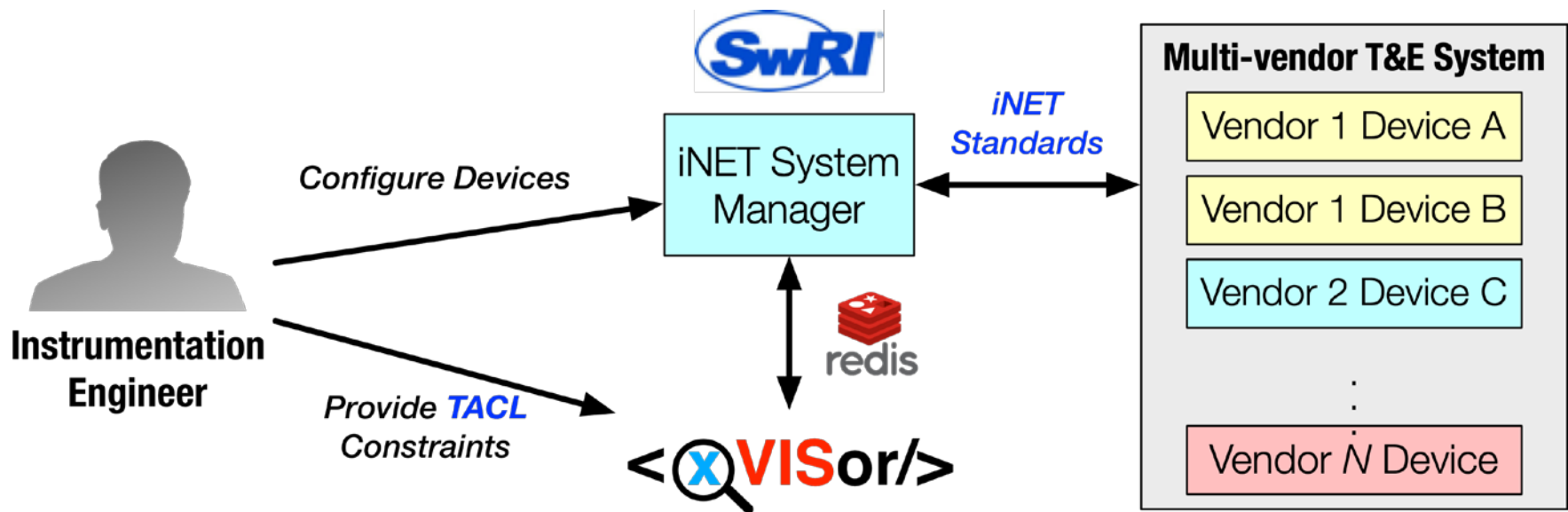
Any SHACL constraints are validated with a standard W3C SHACL engine.

They do not require changes in the engine.

- 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

- SHACL Core contains filters that are entirely domain-independent (~ XSD):
 - Property X must have a value that is \geq 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

- 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 bogged 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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