Design et implémentation d'un logiciel de validation et de génération de configurations réseaux

Grégory PARDOEN et Laurent VANBEVER

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Promoteur : Professeur Olivier BONAVENTURE

INL: IP Networking Lab
UCL, Louvain-la-Neuve, Belgium

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Introduction

Some facts

- Today, most networks are still configured on a "router-by-router" basis (telnet approach)
  - This is error-prone and leads to misconfigurations (*e.g.*, AS7007 incident in '97, AS3561 in '01, YouTube in '08...)
  - Network manufacturers encourage engineers to manually apply configurations changes
  - Management costs keeps growing due to the increasing complexity of network architectures

A **new** vision of network configuration is **needed** !

Main objectives

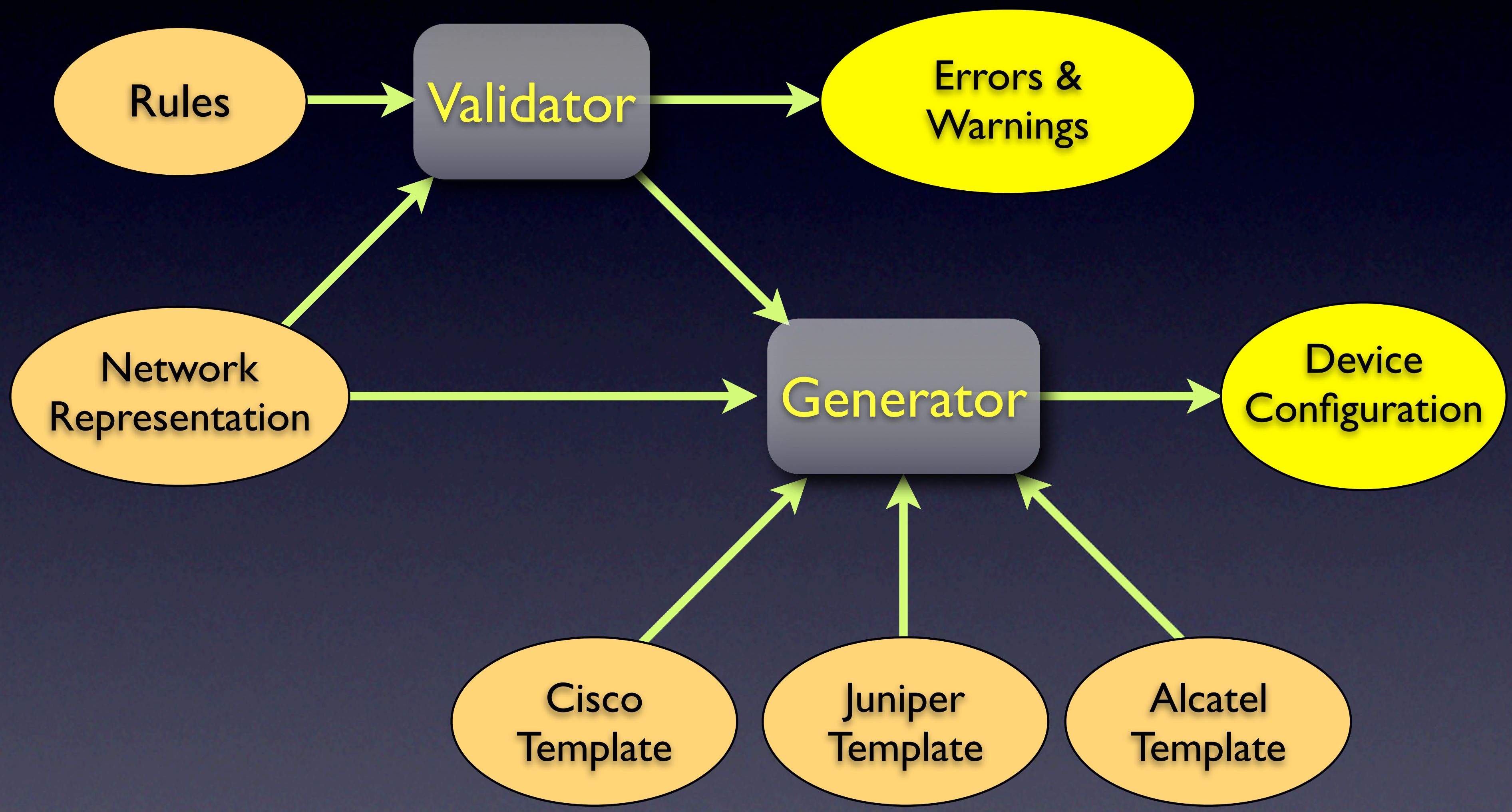
- A ***extensible*** and ***easy*** way of designing and configuring ***correct*** networks
  - Extensibility to be able to add and check new network features
  - Easy because network configuration tends to be harder and time consuming
  - Correct according to given specifications
- Similar to **software engineering** techniques applied to network configurations

Principles

- **Rules** allow a network architect to specify formally his objectives
  - High-level objectives are design decisions (*e.g.*, enforce route reflectors redundancy)
  - Low-level objectives are related to routers configurations details (*e.g.*, same MTU on both ends of a link)
- **High-level language** allows the writing of an entire network configuration in a single entity
- Implemented in a software: Validated Network Generator or **VNG**

VNG architecture

Design



Legend: INPUT PROCESS OUTPUT

Checking correctness

Rule based approach

- A rule represents a **condition** that must be met by the network (like in software engineering)
- Rules check the **correctness** of the high level representation
- Rules are applied on configuration nodes
- Rules are defined in a XML document

High-level representation

- A single entity represents the whole network
- **Avoid** as much as possible **redundancy** (e.g. link parameters, protocols configurations)
  - Eliminate duplication errors and reduce typing faults
- Represented using a **flexible** and hierarchical language: XML
- Structural constraints are defined in a XML Schema

Checking correctness

Rule based approach

- Four **types** of rules were identified:
  1. *Presence*
  2. *Non-presence*
  3. *Uniqueness*
  4. *Symmetry*
- If a rule cannot be expressed as one of them:
  - *Custom*

Checking correctness

Rule based approach

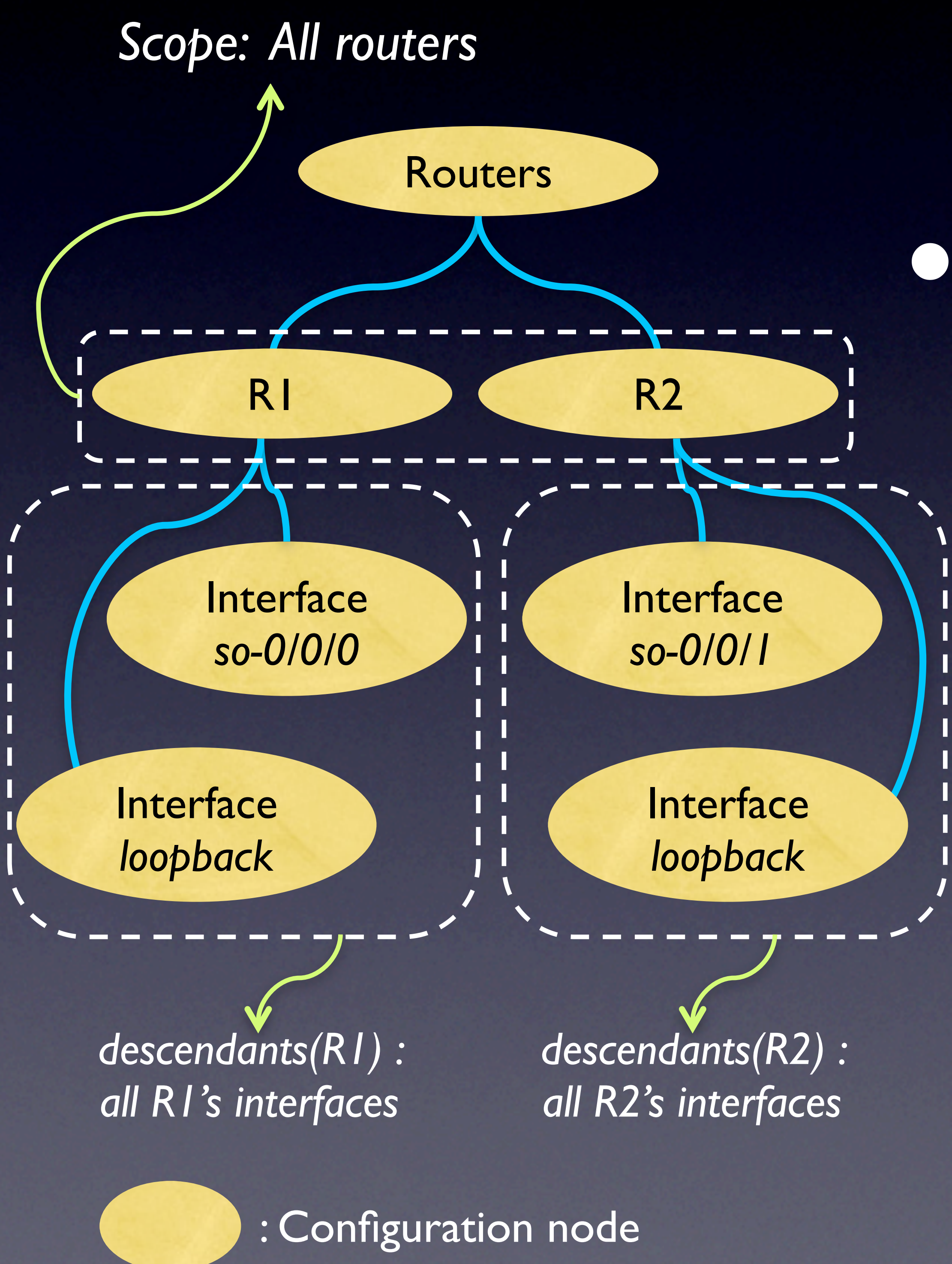
- Rules can be checked by using three **techniques**:

1. Structural constraints (XML Schema): **Structural rules**
2. Queries on the representation (XQuery): **Query rules**
3. A programming language (Java): **Language rules**

	PRESENCE NON-PRESENCE	UNIQUENESS	SYMMETRY	CUSTOM
STRUCTURAL RULES	✓	✓	✓	
QUERY RULES	✓	✓	✓	✓
LANGUAGE RULES				✓

Table 1. Type of rule in function of the advised technique

Checking correctness



- The rules are expressed formally by using the notions of **scope** and its **descendants**
  - A *scope* is a set of configuration nodes
  - *descendants(x)* is a set of selected descendants of the scope's element *x*

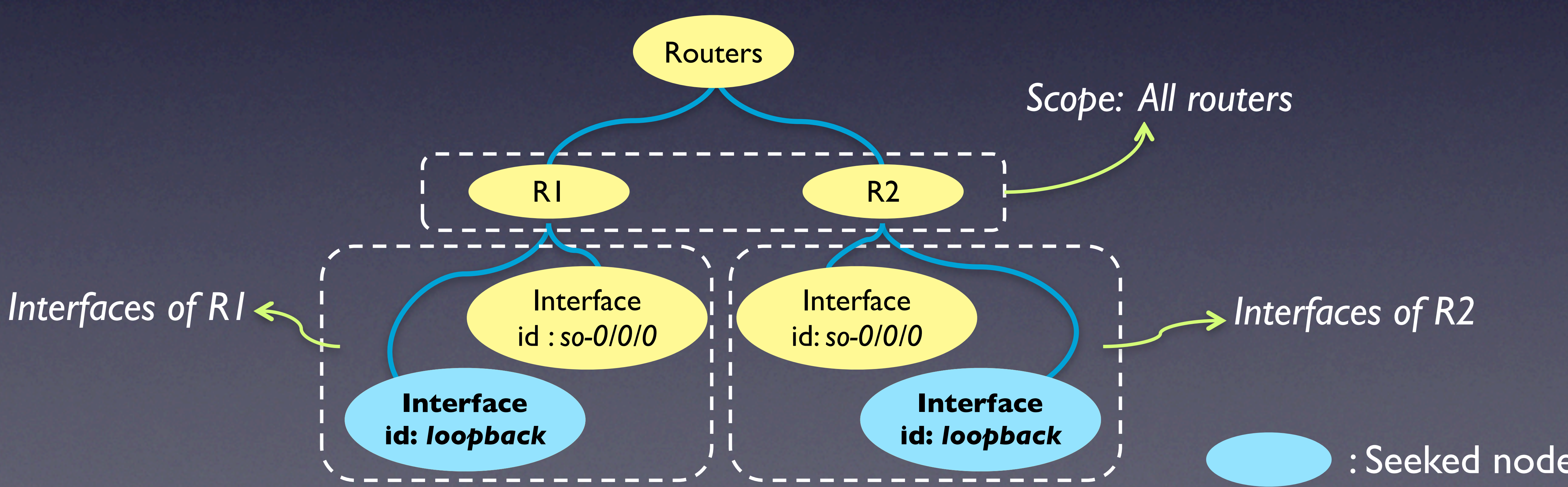
Checking correctness

presence rules

Check if certain configuration nodes are in the representation

Example: each router *must* have a loopback interface

$$\forall x \in \text{ROUTERS}\, \exists y \in \texttt{interfaces}(x) : y.id = loopback$$



Checking correctness

presence rules

Check if there is at least one configuration node respecting a given condition in each *descendants* set.

$$\forall x \in \textsc{scope},\ \exists y \in \texttt{descendants}(x) : C_{\text{presence}}(T, y)$$

Example : each router must have a loopback interface

$$\forall x \in \textsc{routers}\ \exists y \in \texttt{interfaces}(x) : y.id = loopback$$

Query Rules are defined in a XML document

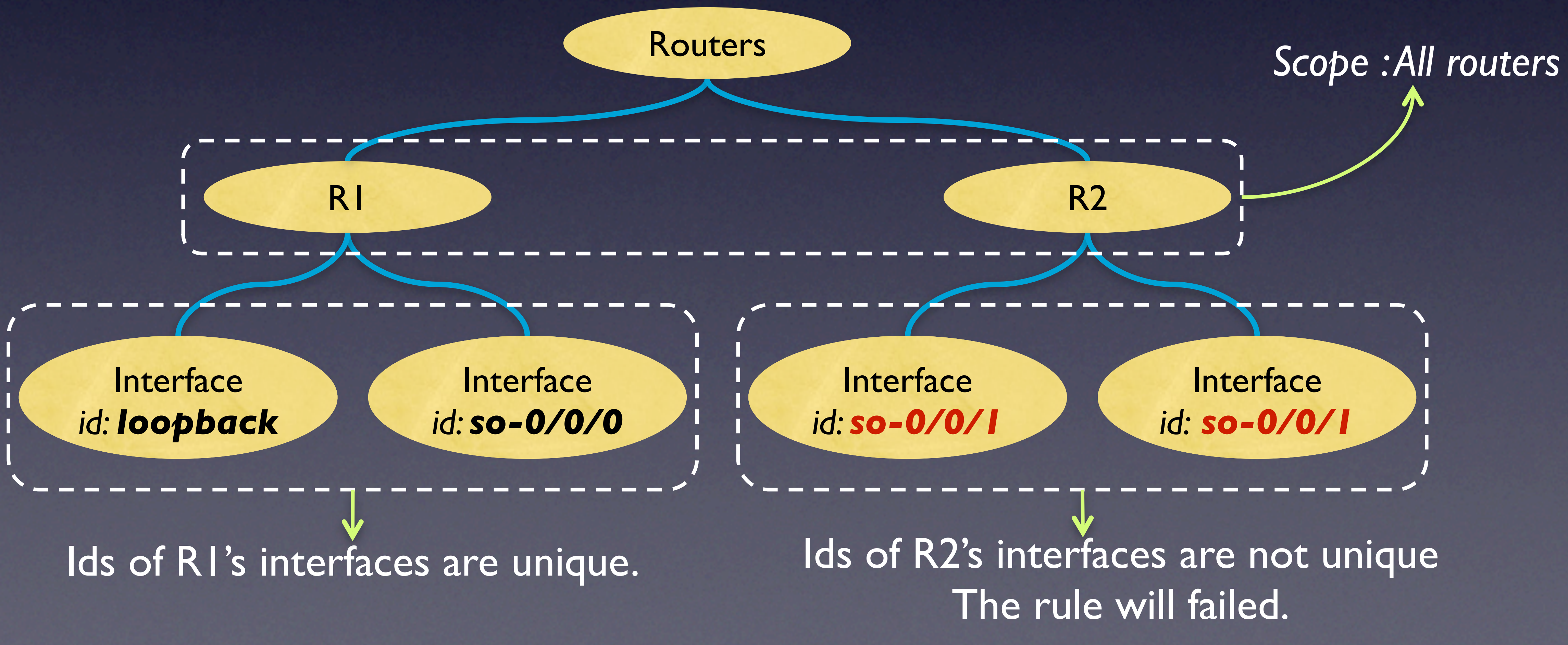
```
<rule id="LOOPBACK_INTERFACE_ON_EACH_NODE" type="presence">
<presence>
        <scope>ALL_NODES</scope>
        <descendants>interfaces/interface</descendants>
        <condition>@id='loopback'</condition>
</presence>
</rule>
```

Checking correctness

uniqueness rules

Check the uniqueness of a field value in a set of configuration nodes

Example : uniqueness of routers interfaces' identifiers



Checking correctness

uniqueness rules

Check if there is no two configuration nodes with an identical value of *field*

$$\forall x \in \textsc{scope}\, \forall y \in \texttt{descendants}(x)\ :\neg(\exists z_{\neq y} \in \texttt{descendants}(x) : y.field = z.field)$$

Example: uniqueness of interfaces' identifiers

$$\forall x \in \text{ROUTERS}, \forall y \in \texttt{interfaces}(x) : \neg(\exists z_{\neq y} \in \texttt{interfaces}(x) : y.id = z.id)$$

```
<rule id="UNIQUENESS_INTERFACE_ID" type="uniqueness">
<uniqueness>
        <scope>ALL_NODE</scope>
        <descendants>interfaces/interface</descendants>
        <field>@id</field>
</uniqueness>
</rule>
```

Checking correctness

symmetry rules

- Check the equality of fields of configuration nodes
- Such rules can be checked **implicitly** by the high level representation (*i.e.*, using *structural* rules)
- Example : MTU must be equal on both ends of a link
  - It can be checked by representing the MTU once on the link level instead of twice at the interfaces level
  - Hypothesis: the duplication phase is correct

Checking correctness

custom rules

- *Custom* rules are needed because some expressions are complicated and cannot be written easily

Example: All OSPFs areas must be connected to the backbone

```
<rule id="ALL_AREAS_CONNECTED_TO_BACKBONE_AREA" type="custom">
    <custom>
        <xquery>
            for $area in /domain/ospf/areas/area[@id!="0.0.0.0"]
            let $nodes := $area/nodes/node
            where count(/domain/ospf/areas/area) > 1
            and not(some $y in $nodes satisfies /domain/ospf/areas/
                    area[@id="0.0.0.0"]/nodes/node[@id=$y/@id])
           return
               <result><area id="{$area/@id}"/></result>
        </xquery>
    </custom>
</rule>
```

Checking correctness

Summary

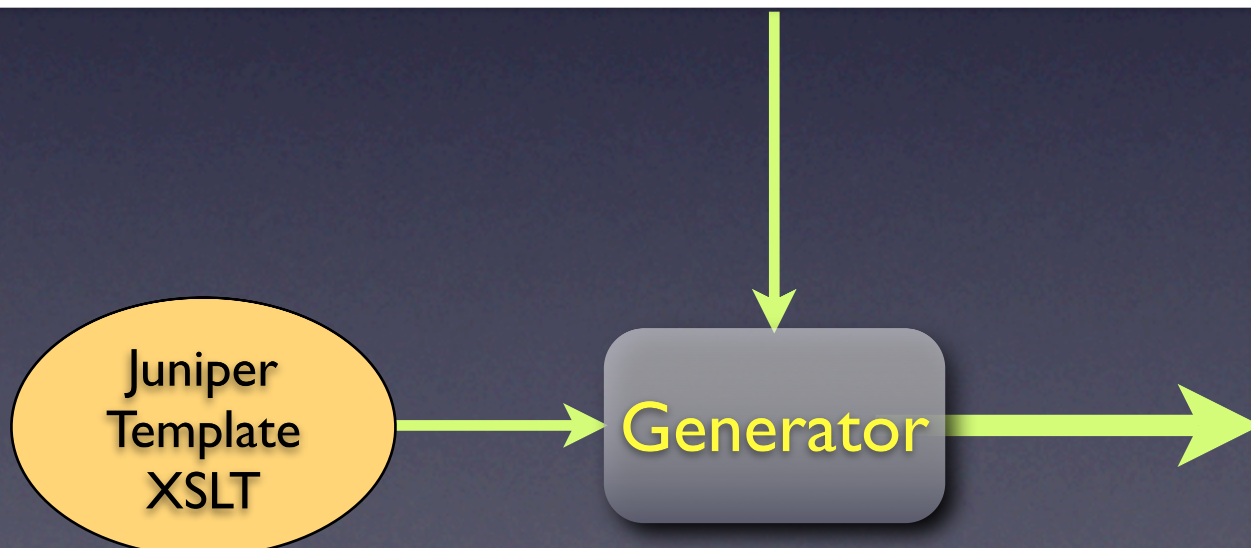
- A rule can be written in **few** lines
- **Simple** XML syntax
- Complex rules can also be expressed
- An operator can write as many rules as he want

Generation

- High level representation is not intended to be translated easily into configuration files
  - **Intermediate** representations are needed
    - It could be seen as the result of a *preprocessing* phase
- **Templates** allow the translation of intermediates representations in configuration files
  - Templates of any configuration or modeling language can be written (e.g., Cisco IOS, Juniper JunOS, etc.)
  - Written in XSLT

Generation

```
<node id="SALT">
  <interfaces>
    <interface id="lo0">
      <unit number="0">
        <ip type="ipv4" mask="32">198.32.8.200</ip>
        <ip type="ipv6" mask="128">2001:468:16::1</ip>
      </unit>
    </interface>
  </interfaces>
</node>
```




```
interfaces {
    lo0 {
        unit 0 {
            family inet {
                address 198.32.8.200/32;
            }
            family inet6 {
                address 2001:468:16::1/128;
            }
        }
```

Demonstration

Conclusion

Conclusion

- Our tool is a **first step** towards a *extensible* and *easy* way of designing and configuring *correct* networks
  - **Easy** to:
    - Add new protocols, equipments, parameters...
    - Add rules to check specific needs or new features
    - Add new constructors to generate appropriate configlets
- Further works
  - Automatically produce high level representation of a network
  - Extend the prototype to a broader range of cases
  - Allow VNG to interact directly with the routers

Any questions ?