Towards Validated Network Configurations with NCGuard

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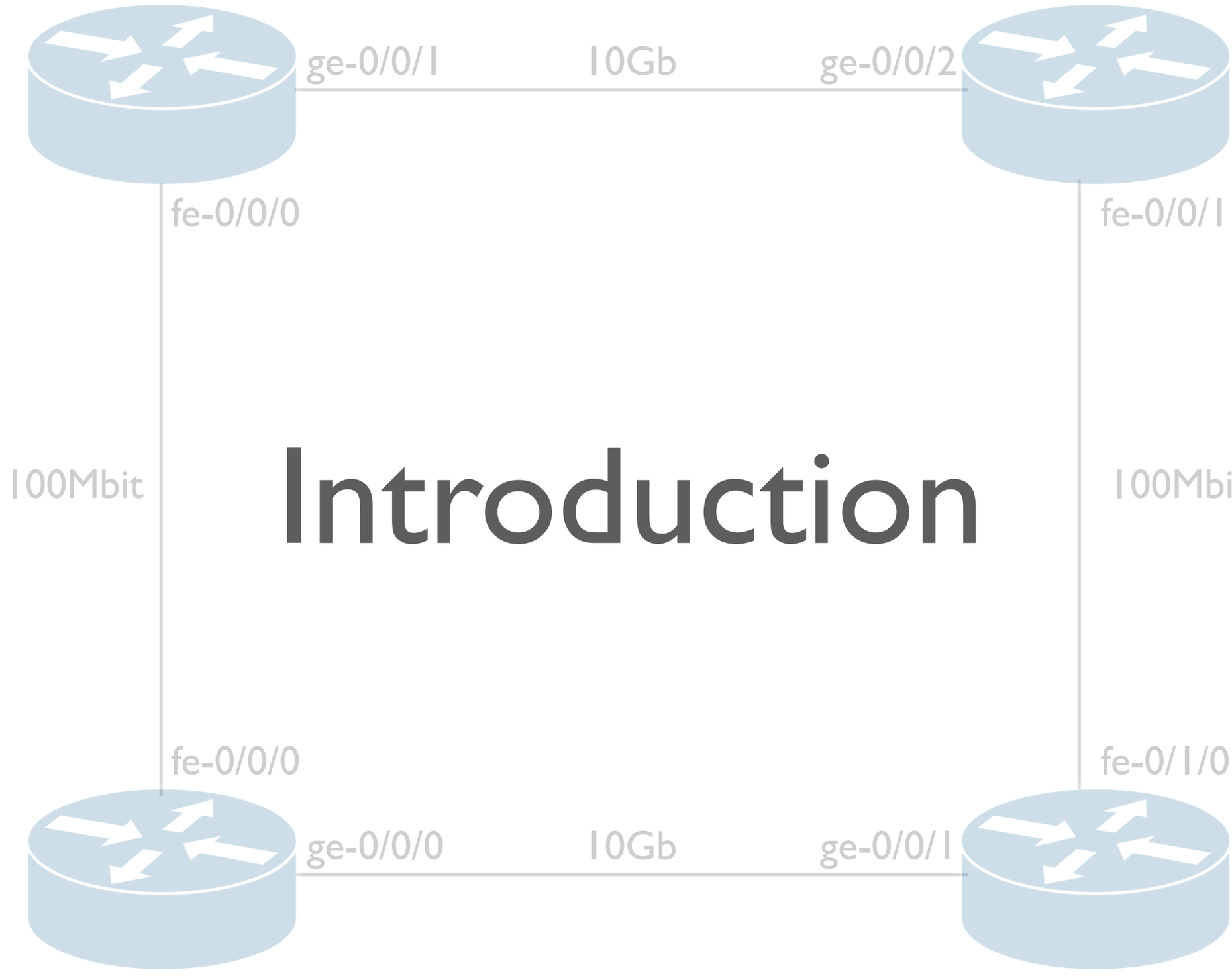
Université catholique de Louvain (UCL), Belgium

Internet Network Management Workshop
October 19, 2008

Agenda

- Introduction
  - State-of-the art in network configuration
- NCGuard: *Towards new configuration paradigm*
  - High-level representation
  - Validation
  - Generation
- Conclusion
- Demo session (1:30pm - 2:30pm)



Introduction

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- Configuring networks is **complex**, **costly**, and **error-prone**
  - Networks can be composed of hundreds to thousands of devices
  - **Manual** configuration, *equipment-by-equipment*
  - *Trial-and-error* approach

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- Configuring networks is **complex**, **costly**, and **error-prone**
  - Networks can be composed of hundreds to thousands of devices
    - **Manual** configuration, *equipment-by-equipment*
    - *Trial-and-error* approach
- **Diversity** of vendor-specific languages (IOS, JunOS, etc.)
  - Syntax, semantic, and supported features sets are different
  - **Low-level** configuration languages
    - Lot of code duplication

Consequences

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    - Misconfigurations have led and **still lead** to large scale problems (e.g., YouTube in 2008)
- Management costs **keep growing** due to the increasing complexity of network architectures

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Current Approaches: Static Analysis

- Use **pattern matching** on configurations to detect misconfigurations [1]

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Current Approaches: Static Analysis

- Use **pattern matching** on configurations to detect misconfigurations [1]
- Compare configurations to given **specifications** [2]
- Pro & Con:
  - Very effective to detect some critical problems
  - Need a *a priori* specifications of what a valid network is
  - Difficulties encountered when analyzing heterogenous networks
    - Solution: use of an intermediate representation

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- **Infer** network-specific policies, then perform **deviation** analysis [2]
- Pro & Con:
  - Completely independent of *a priori* validity specifications
  - Too verbose, people are flooded with non-error messages.
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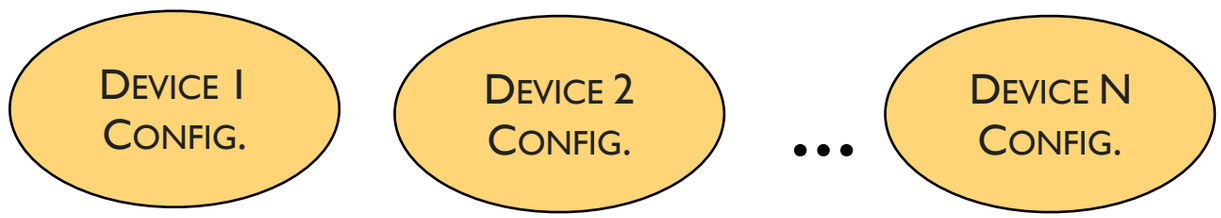

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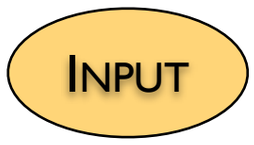

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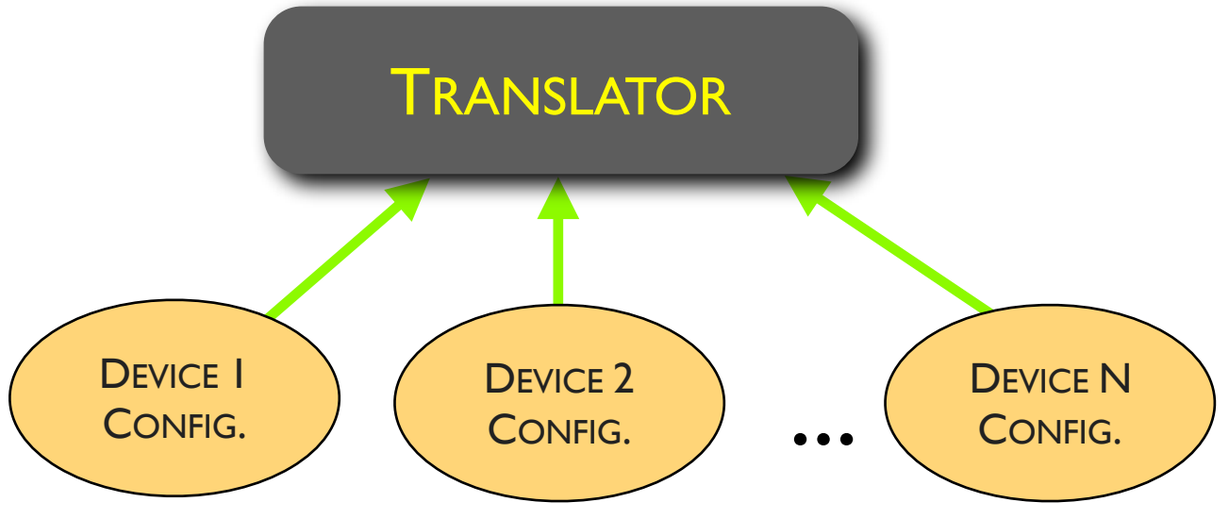

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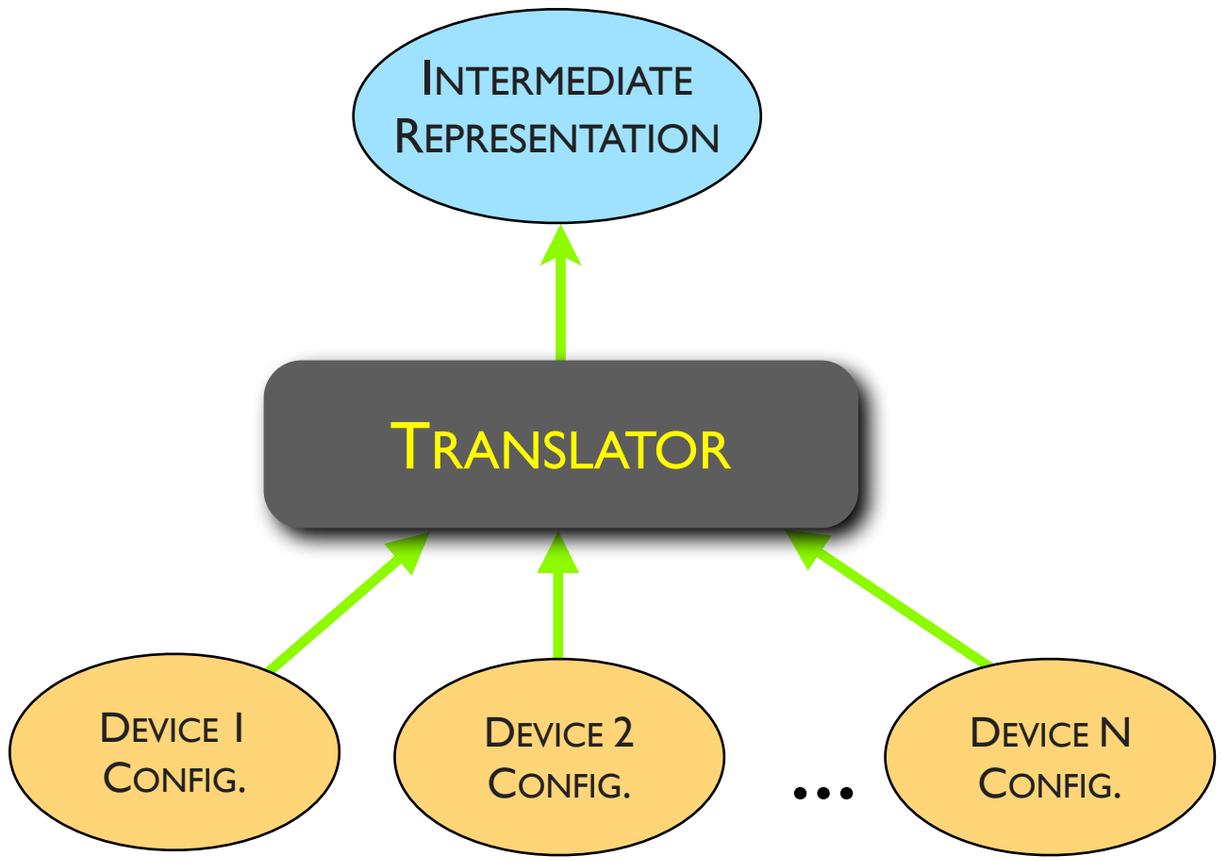

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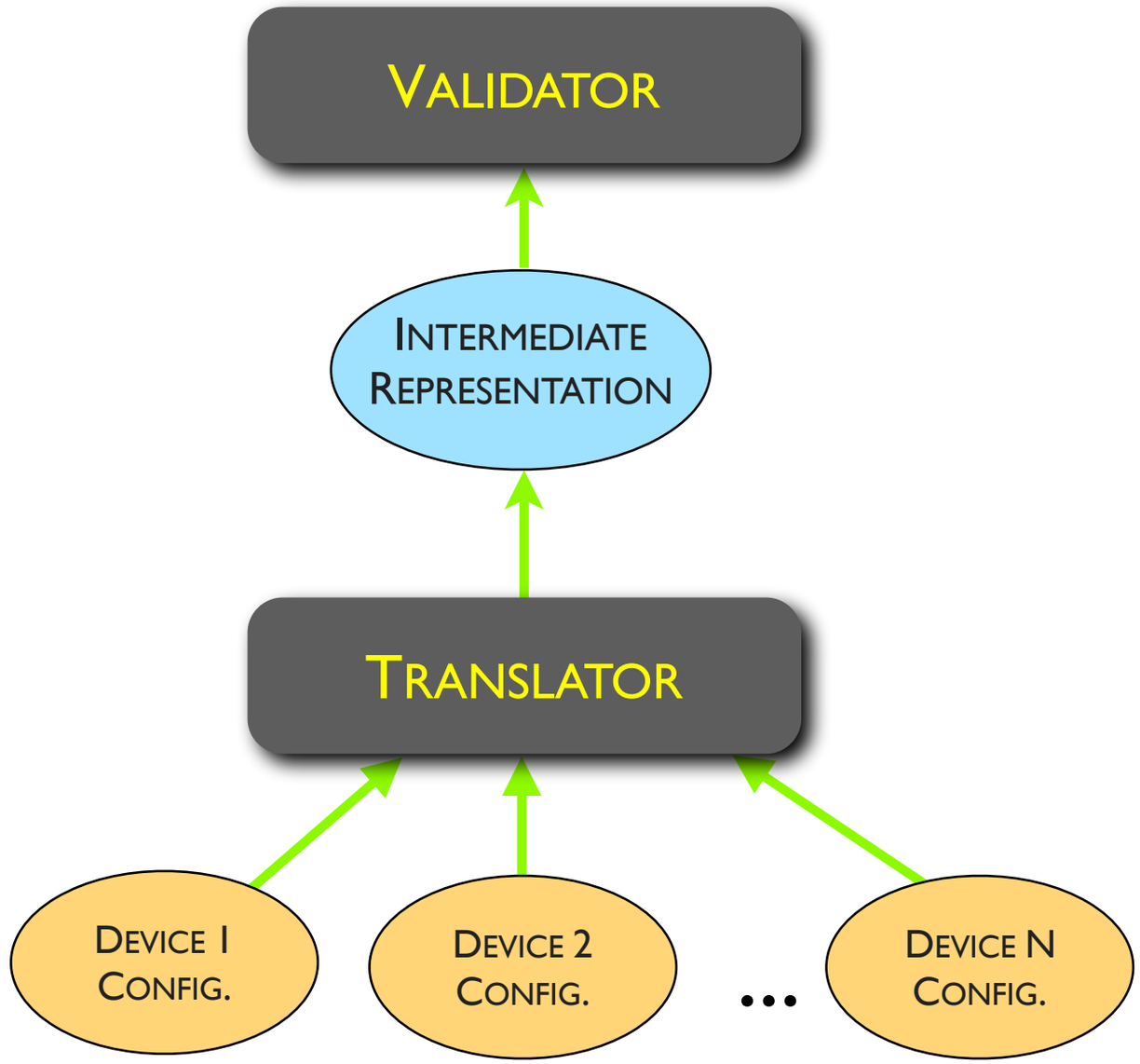

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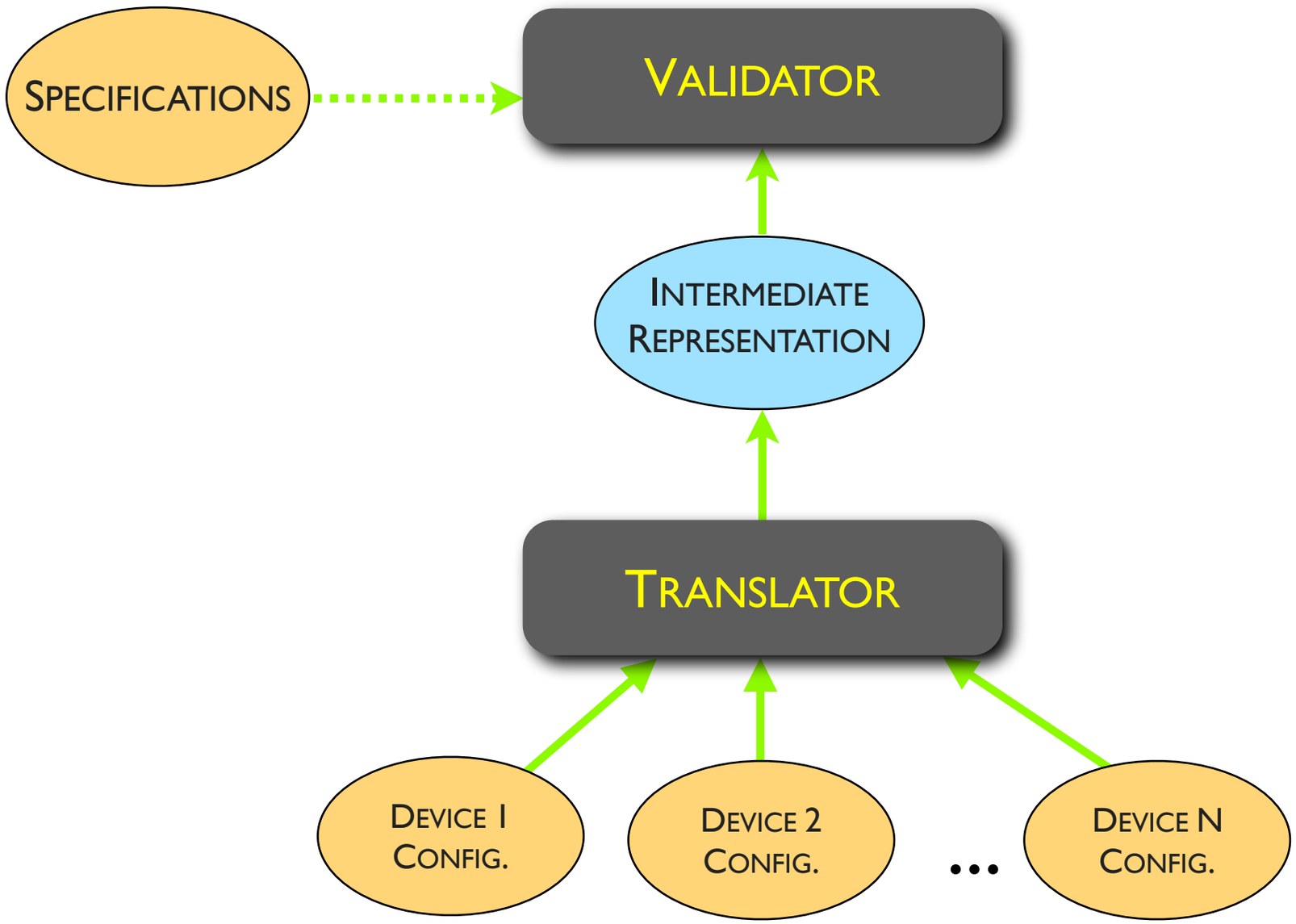

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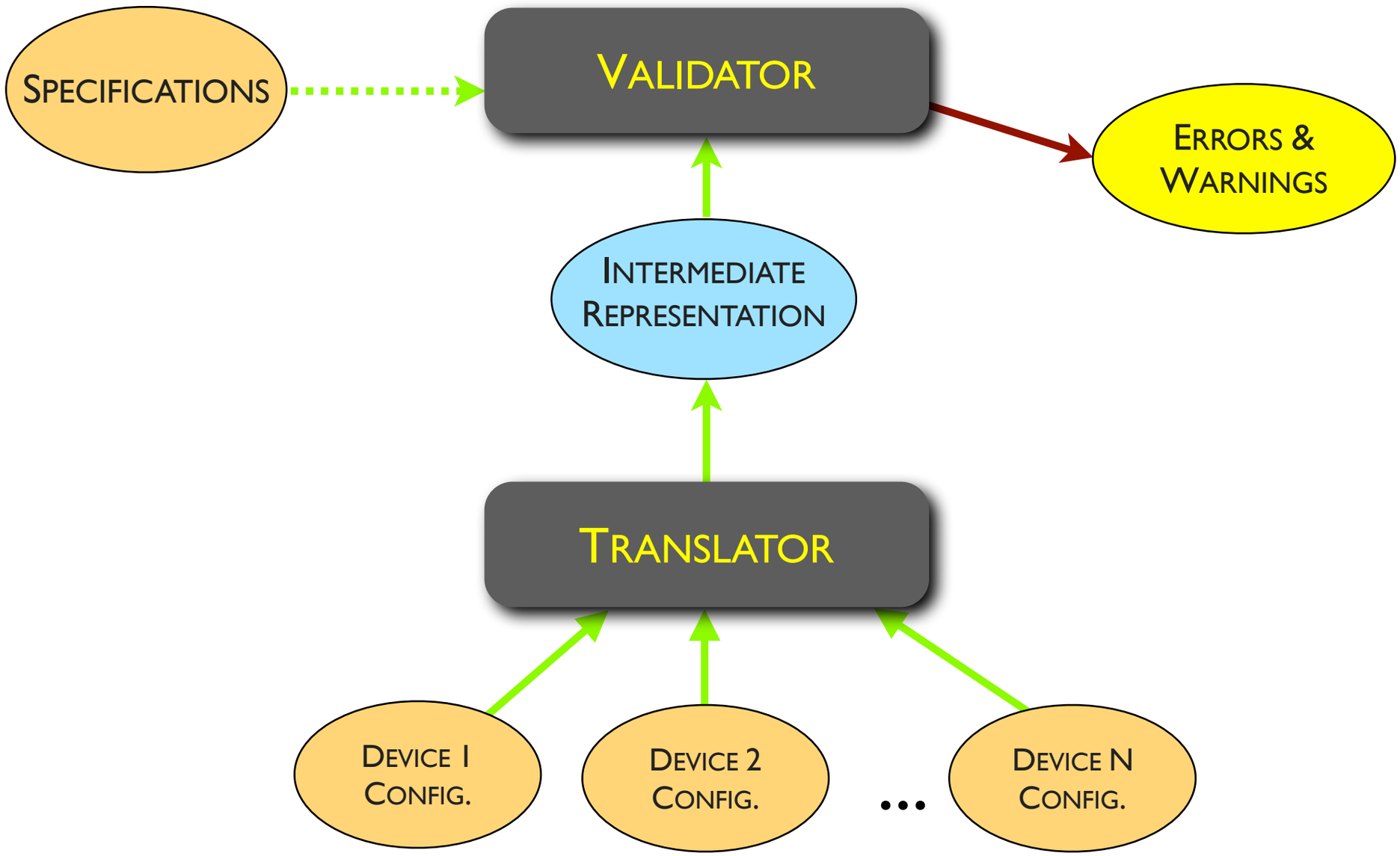

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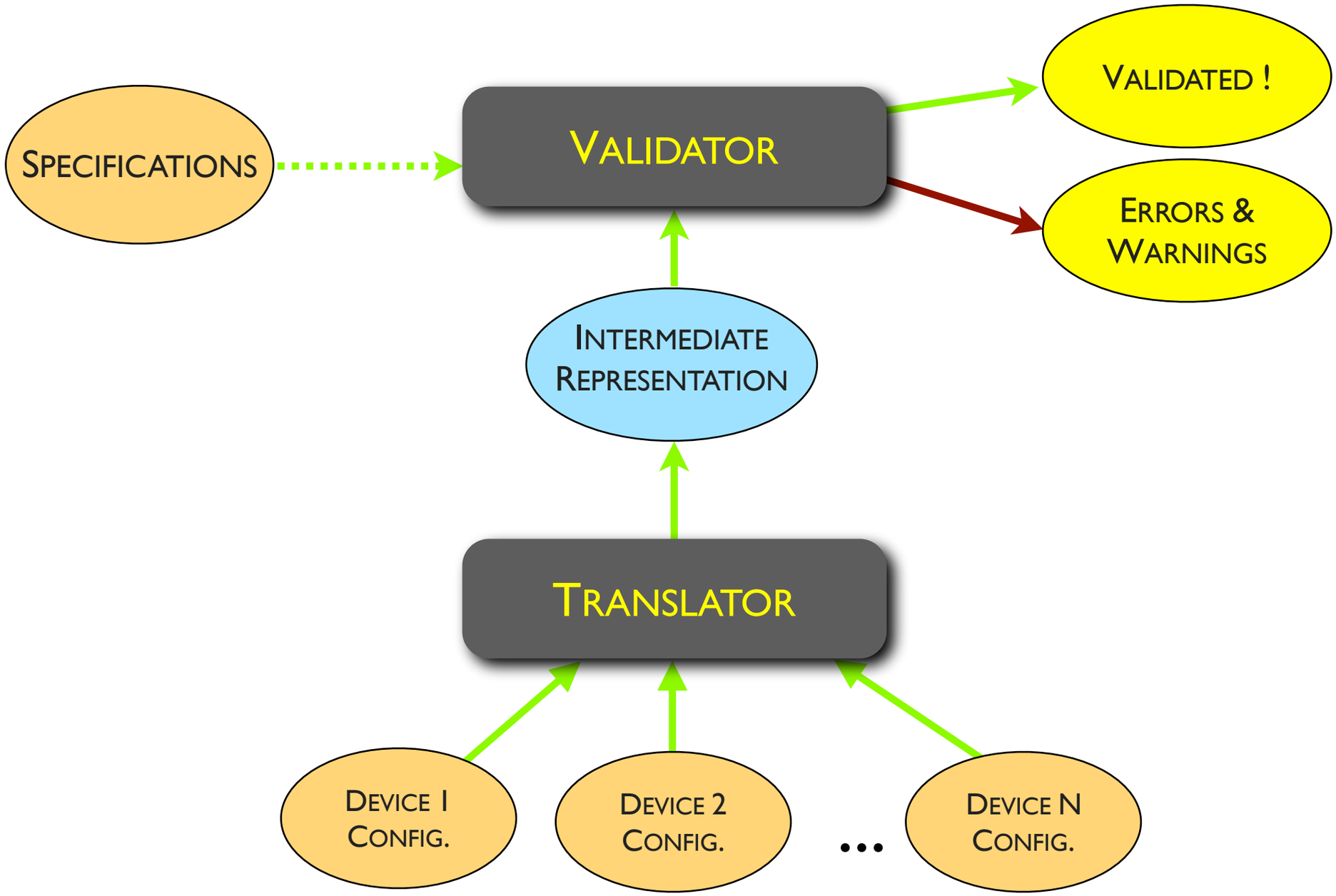

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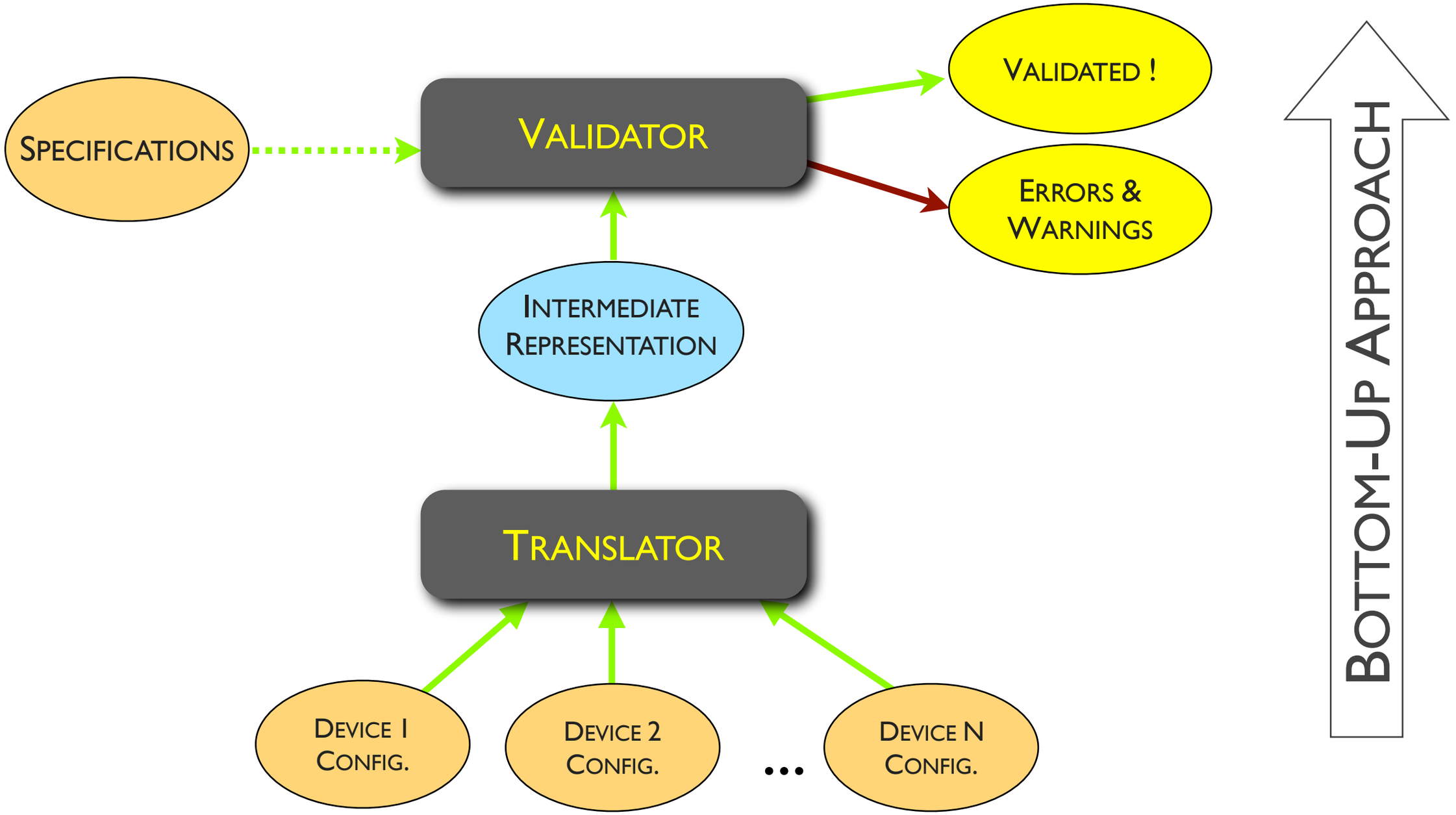

Legend: INPUT PROCESS OUTPUT

```
bgp {
  group ibgp {
    type internal;
    peer-as 100;
    local-address 200.1.1.1;
    neighbor 200.1.1.2;
```

NCGuard: *Towards new configuration paradigm*[1]

```
  group ebgp {
    type external;
    peer-as 200;
    neighbor 172.13.43.2;
  }
```

[1] http://inl.info.ucl.ac.be/softwares/ncguard-network-configuration-safeguard

Starting point

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- Network configuration contrasts with numerous progress in **software engineering**
  - Requirements, specifications, verification, validation, new development schemes, etc.
  - In comparison, network configuration is like *writing a distributed program in assembly language* [1]

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- Current approaches do **not solve** the problem
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- Why not **apply** software engineering techniques to network configurations ?

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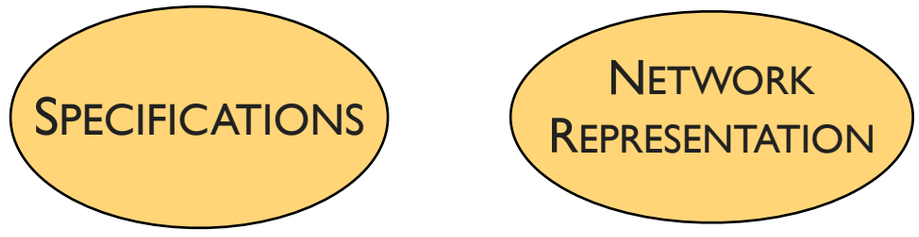

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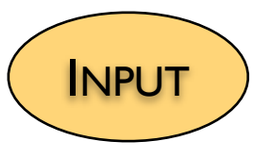

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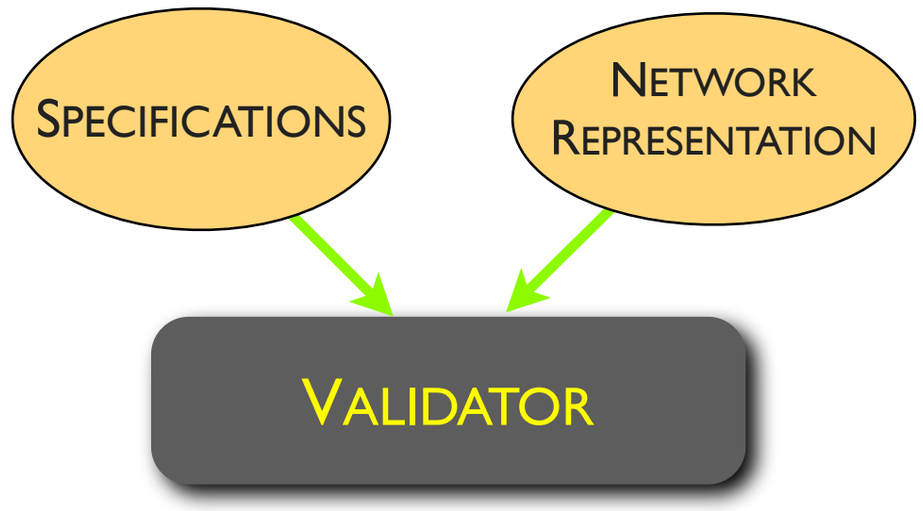

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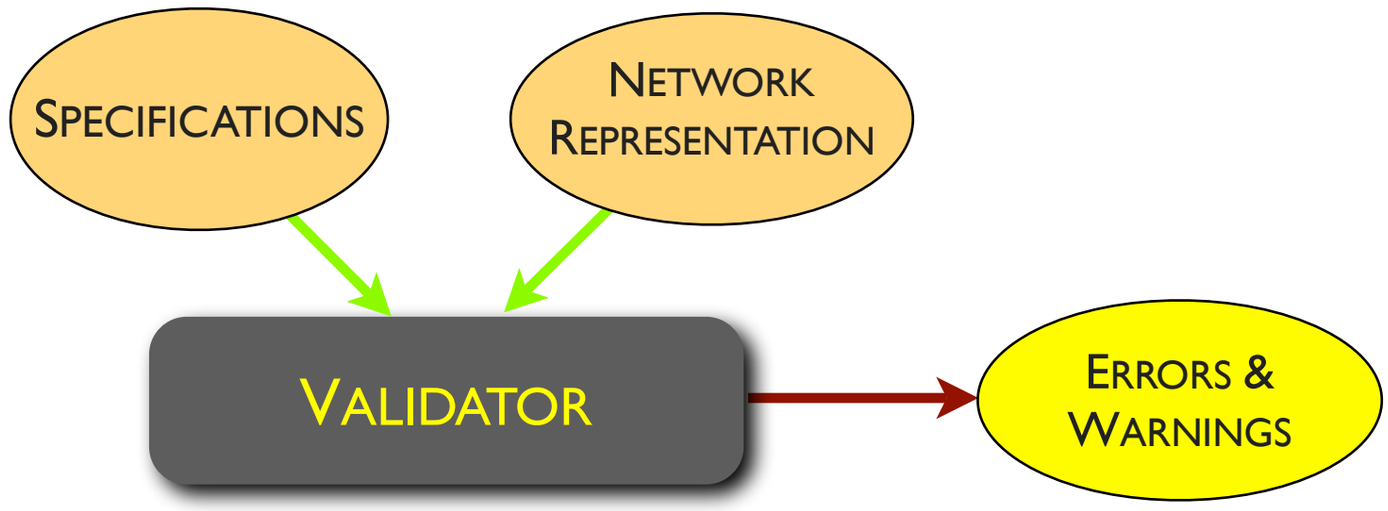

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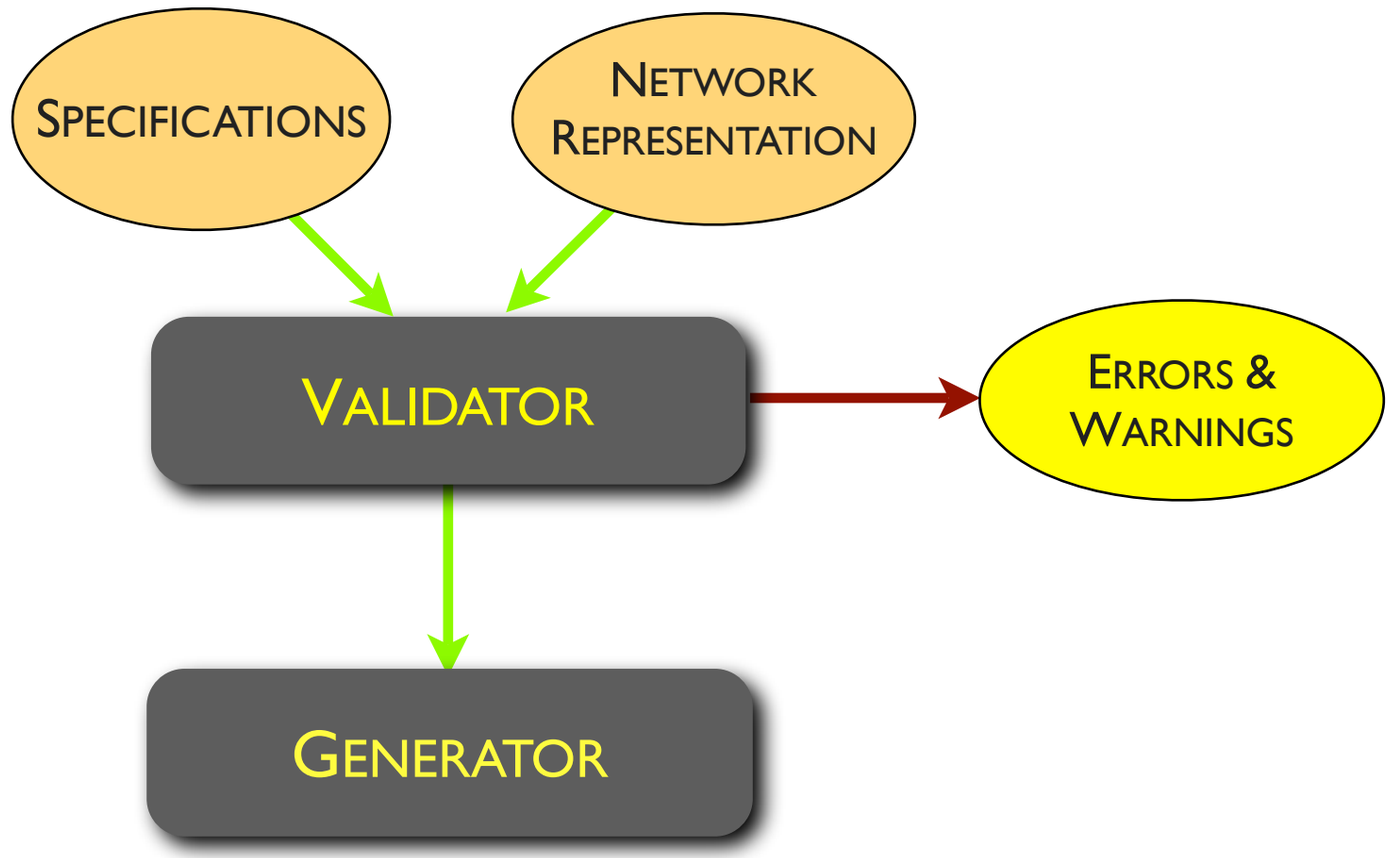

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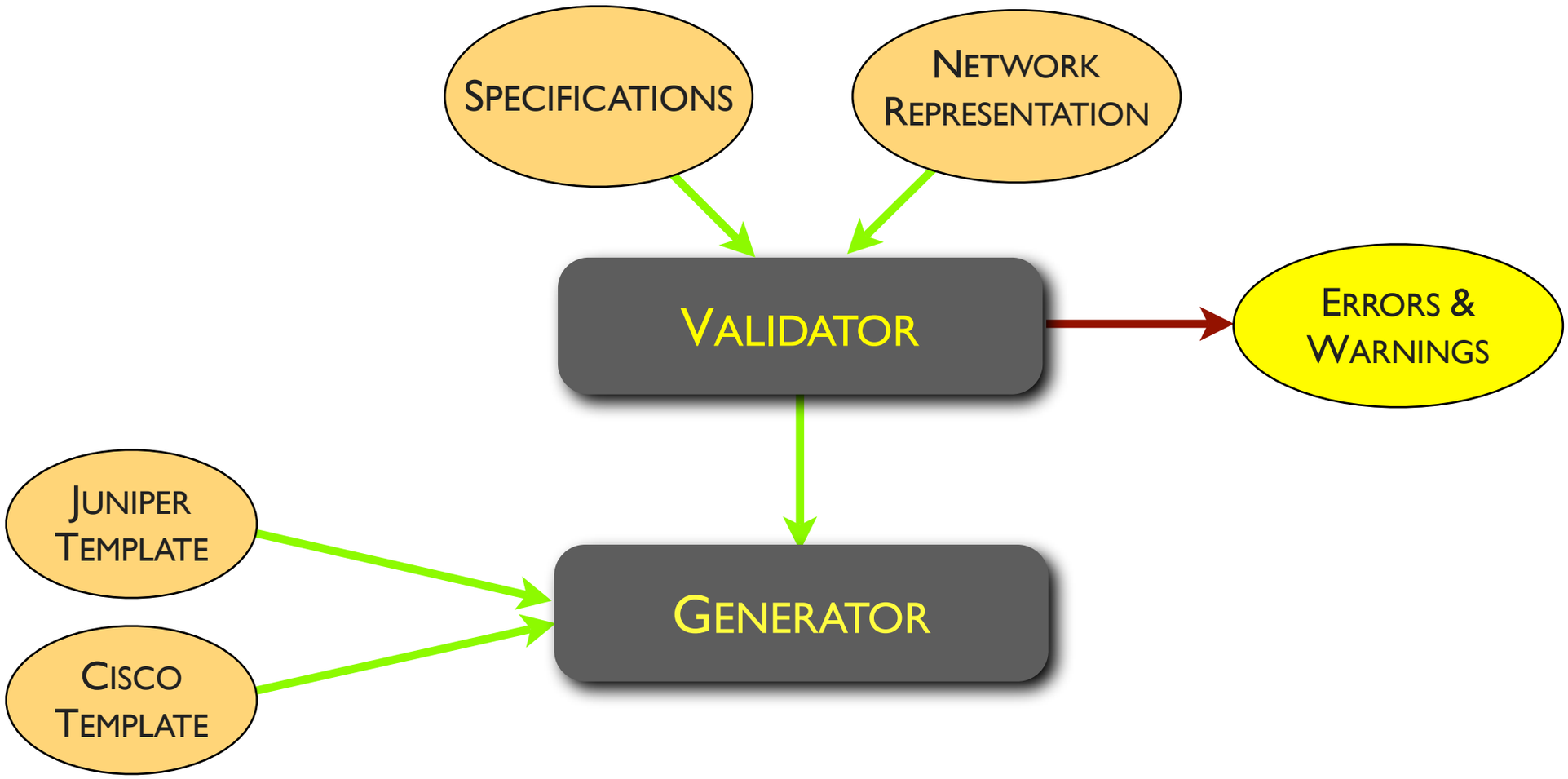

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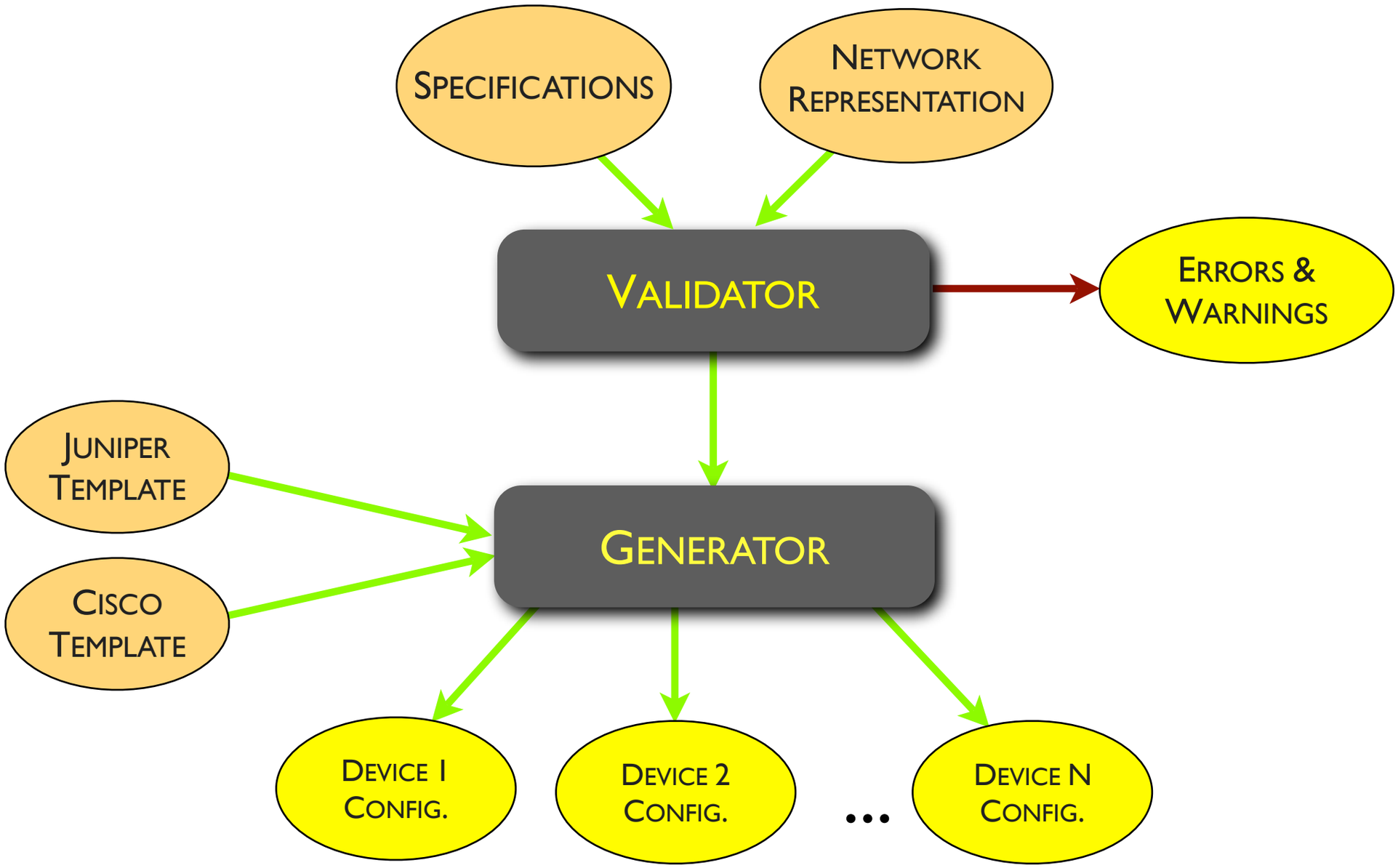

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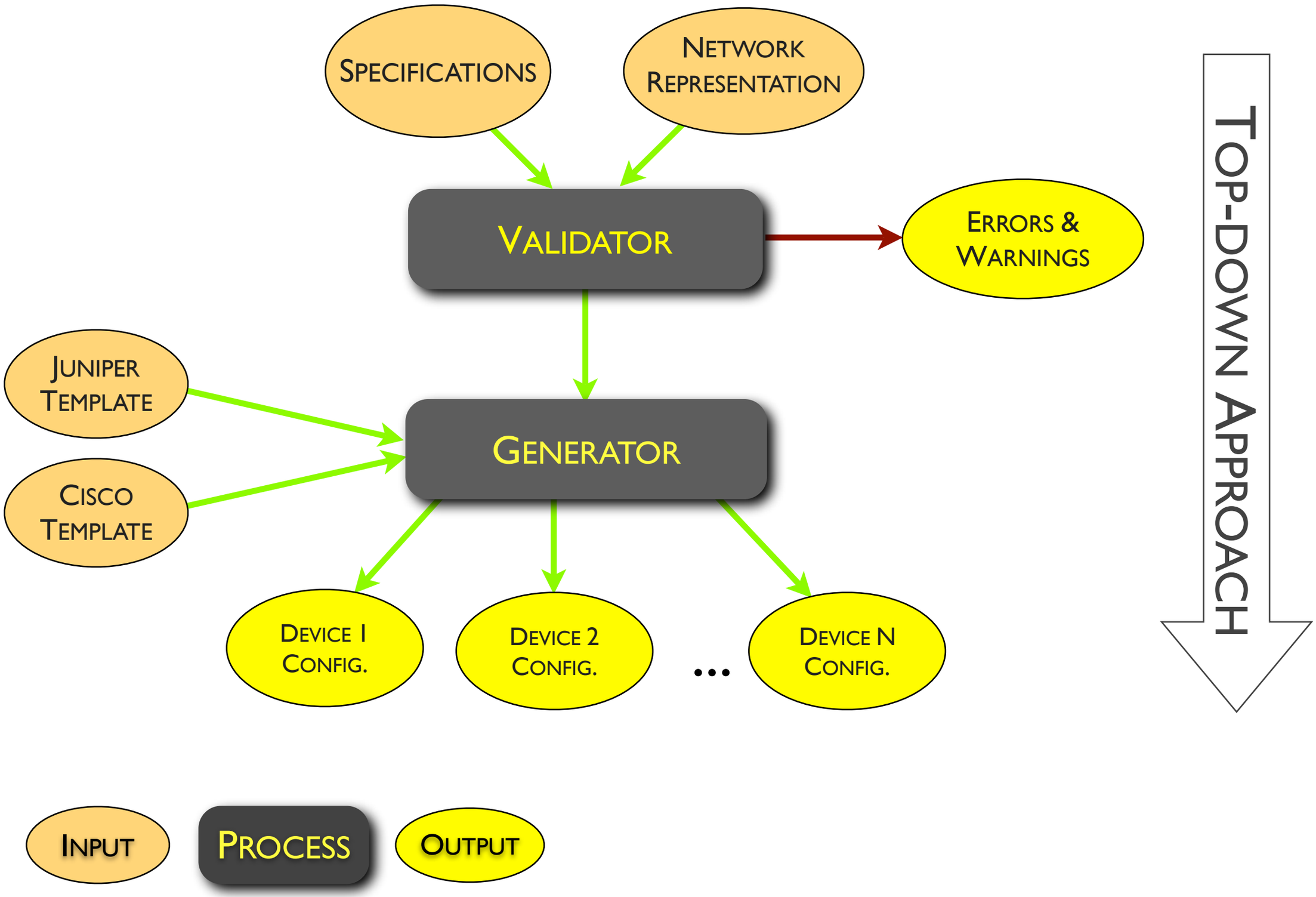

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    - Flexible way of adding rules
3. **Generation** engine
    - Produce the configuration of each device in its own configuration language

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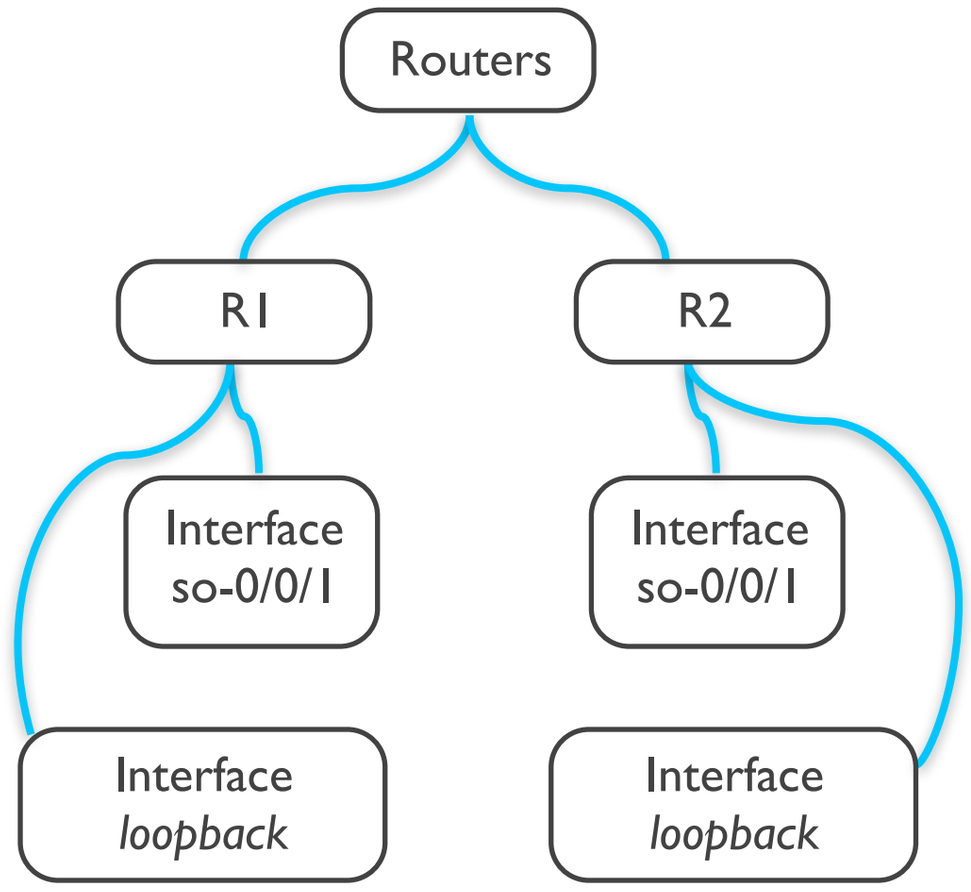
  - Symmetry
- If a rule cannot be expressed as one of them:
  - Custom (*e.g.*, connexity test, network redundancy test, etc.)

Rules representation



: Configuration node

Rules are expressed formally by using the notions of **scope** and its **descendants**

- A configuration node is an element of the high-level representation
  - Composed of fields
- A *scope* is a set of configuration nodes
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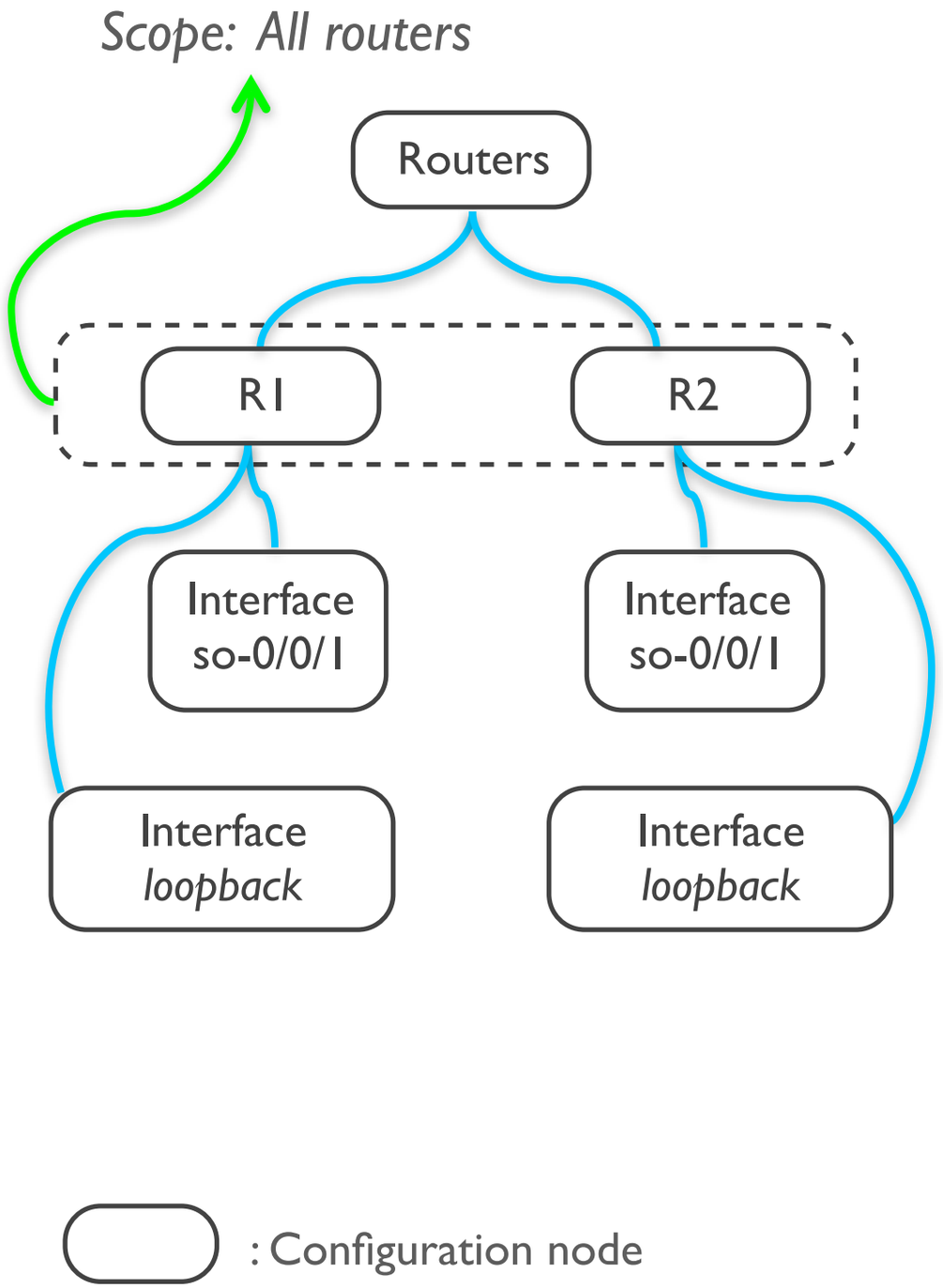

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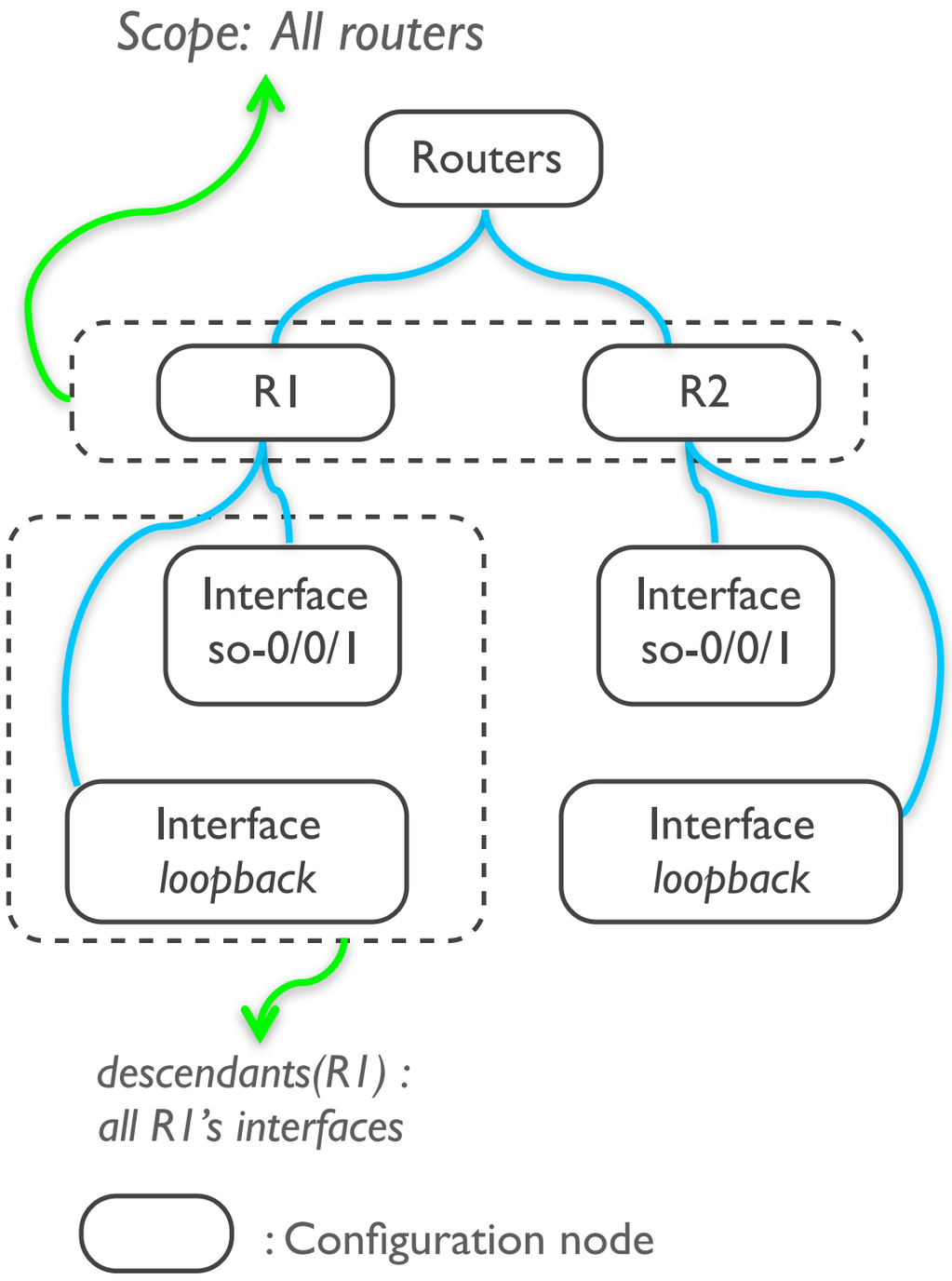

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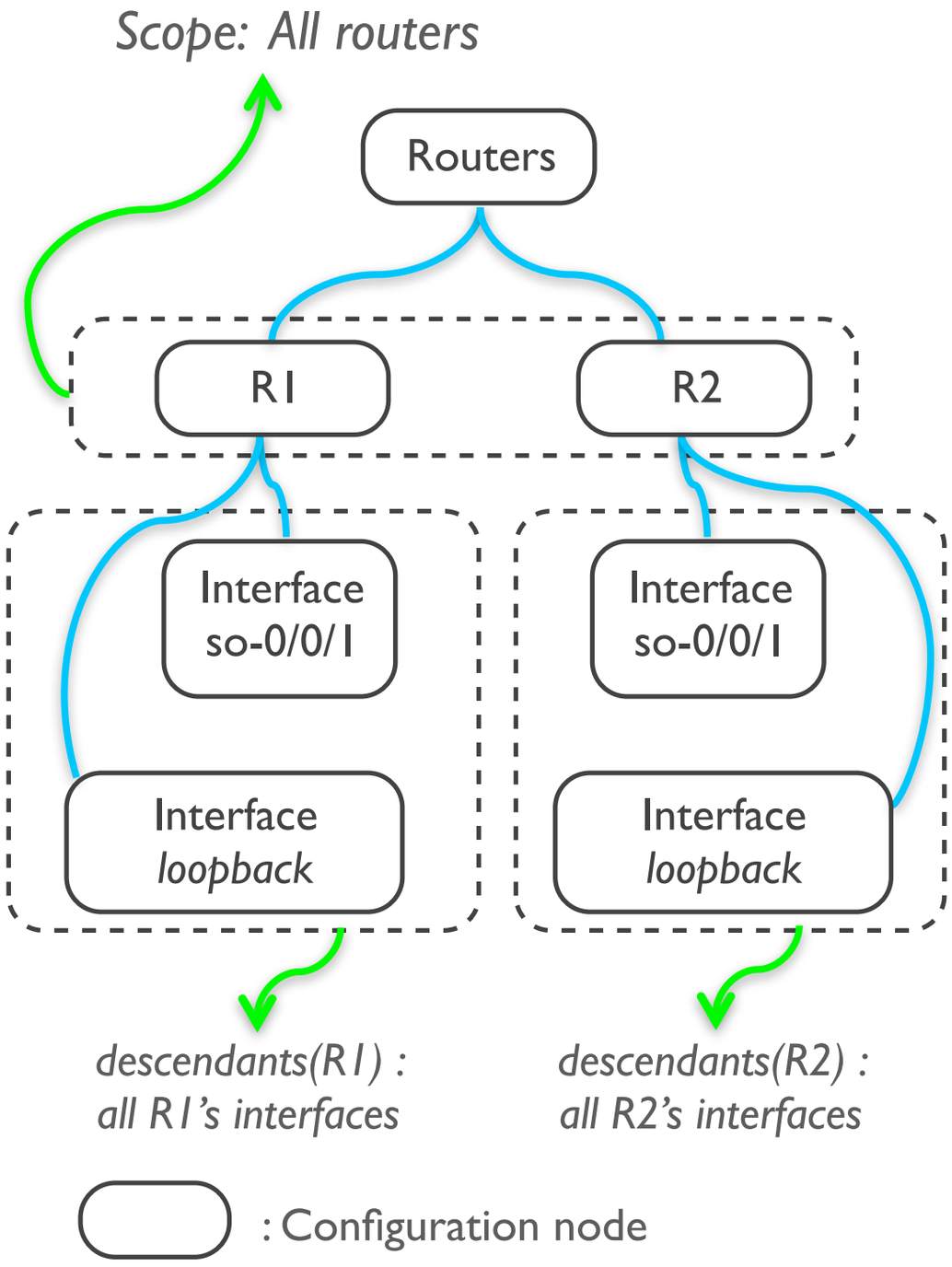

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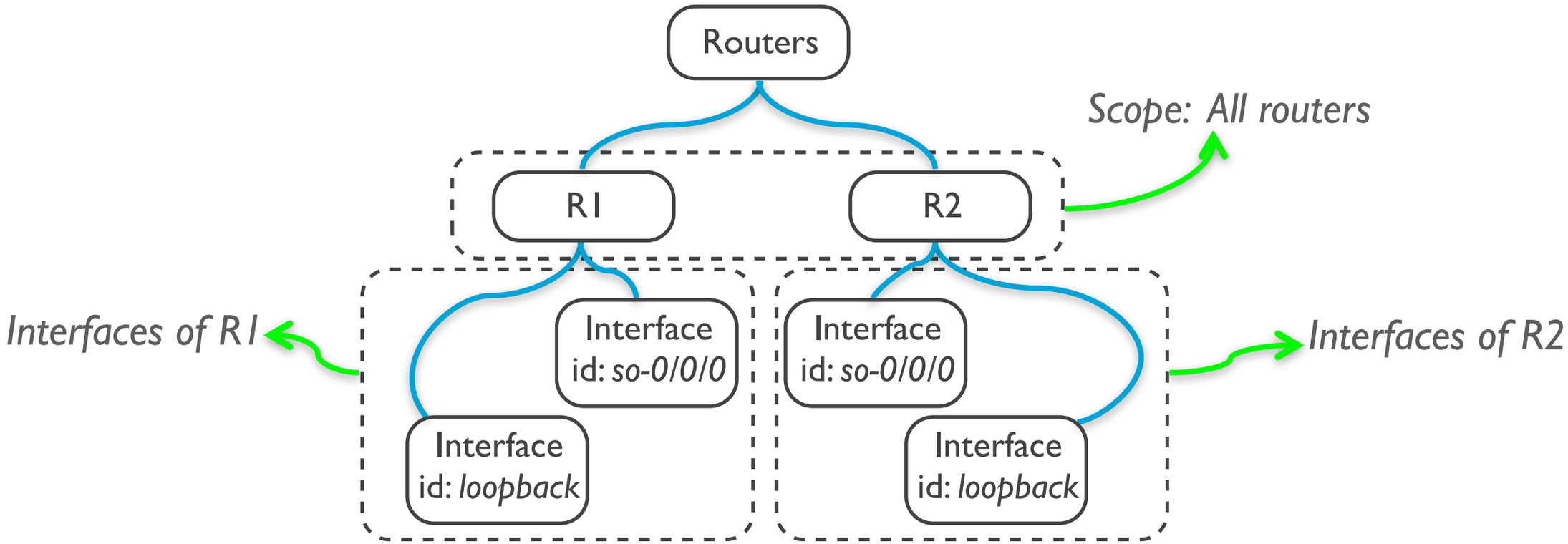
Presence rule

- Check if certain configuration nodes are in the representation

  Example: each router ***must*** have a loopback interface



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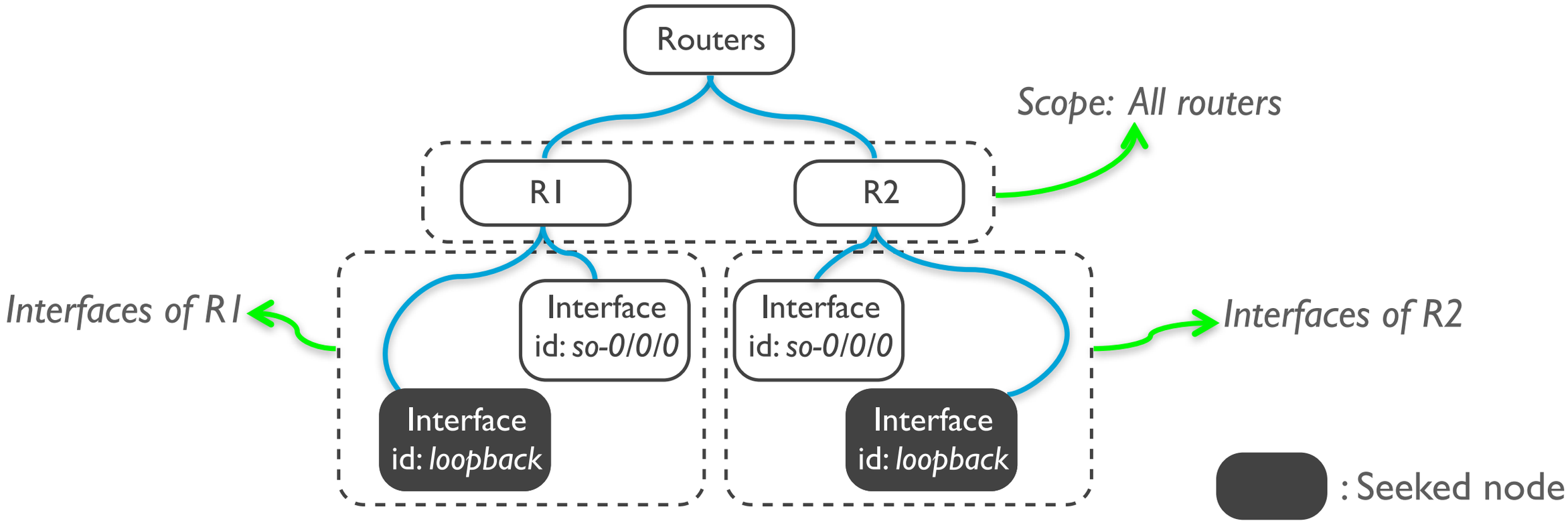

Presence rule

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

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

Example : each router **must** have a loopback interface

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

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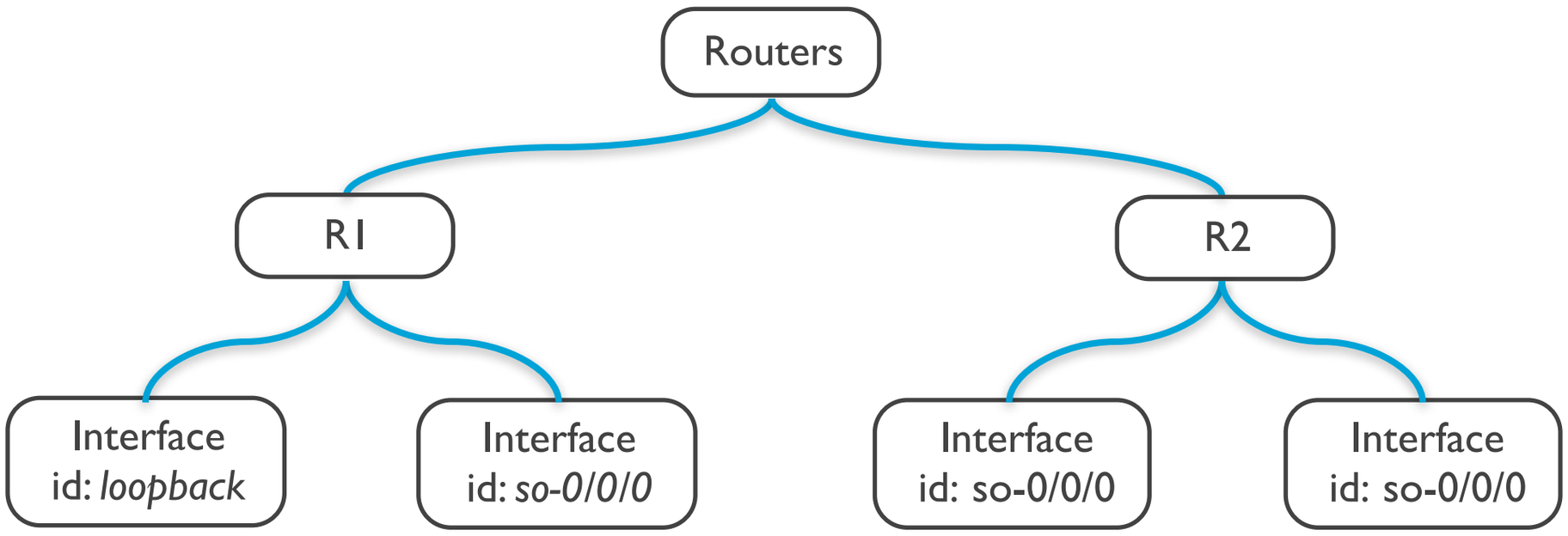
Uniqueness rule

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

Example : uniqueness of routers interfaces identifiers



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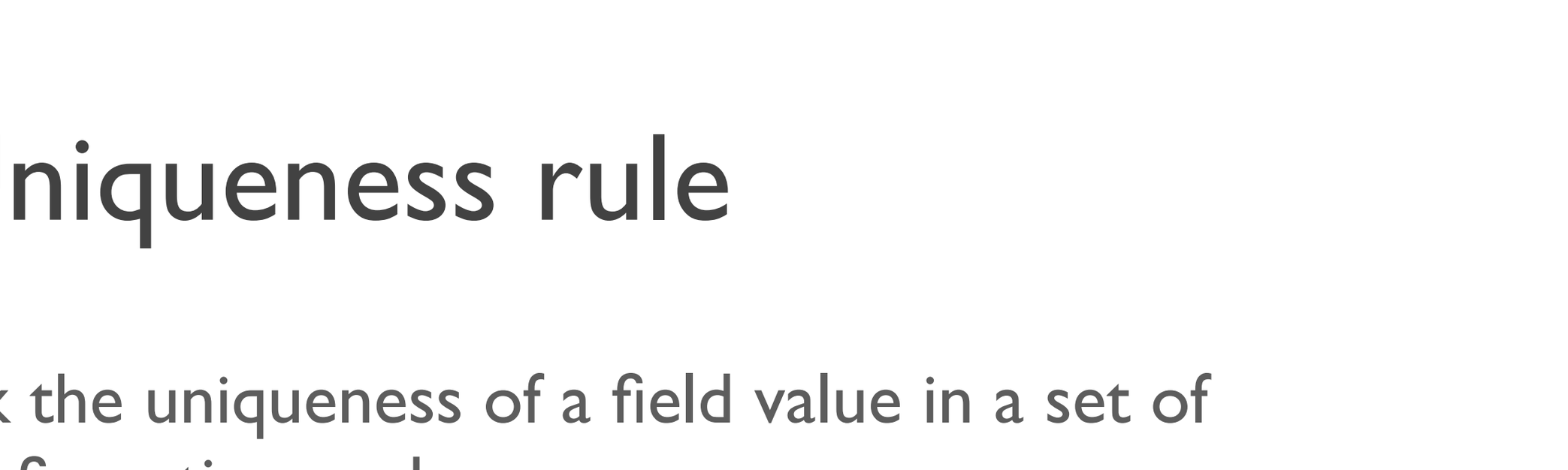

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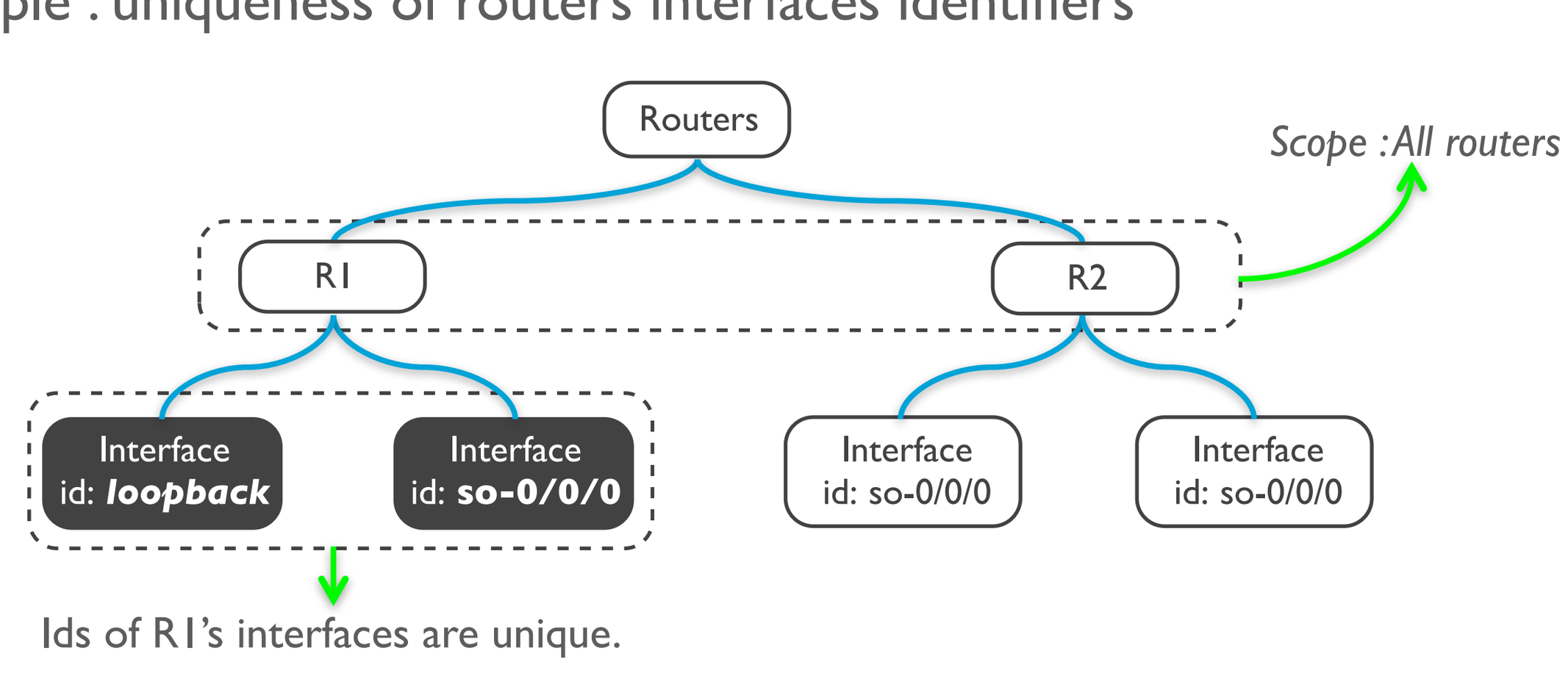

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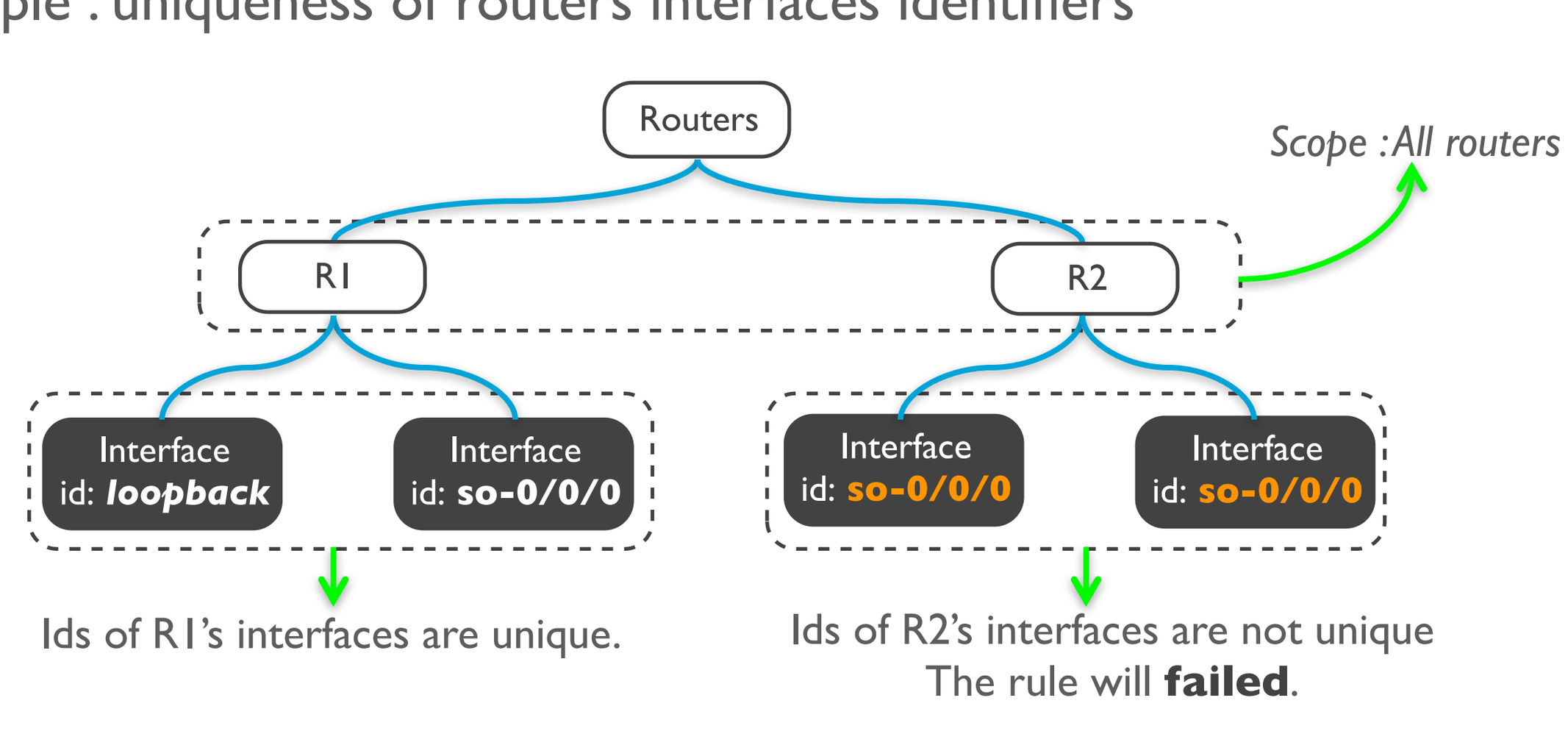

Uniqueness rule

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

$$\forall x \in \text{SCOPE}\, \forall y \in \mathtt{d}(x)\ : \neg(\exists z_{\neq y} \in \mathtt{d}(x) : y.field = z.field)$$

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Uniqueness rule

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

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- Such rules can be checked **implicitly** by the high-level representation
- Example: MTU must be equal on both ends of a link
  - Automatically checked by modeling it once at the link level
    - Instead of twice at the interfaces level
  - Hypothesis: duplication phase is correct

Custom rule

- Used to check **advanced** conditions
  - Expressed in a query or programming language

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>
```

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- High level representation is not designed to be translated into low level language
  - **Intermediate** representations are needed
- **Templates** translate those intermediates representations into configuration files
  - Support of any configuration or modeling language (e.g., Cisco IOS, Juniper JunOS, etc.)

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>
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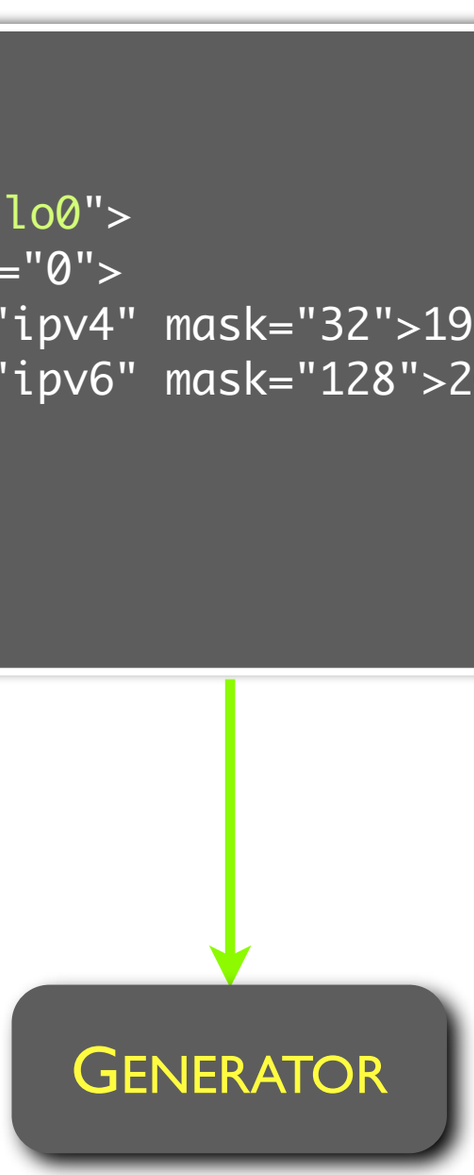

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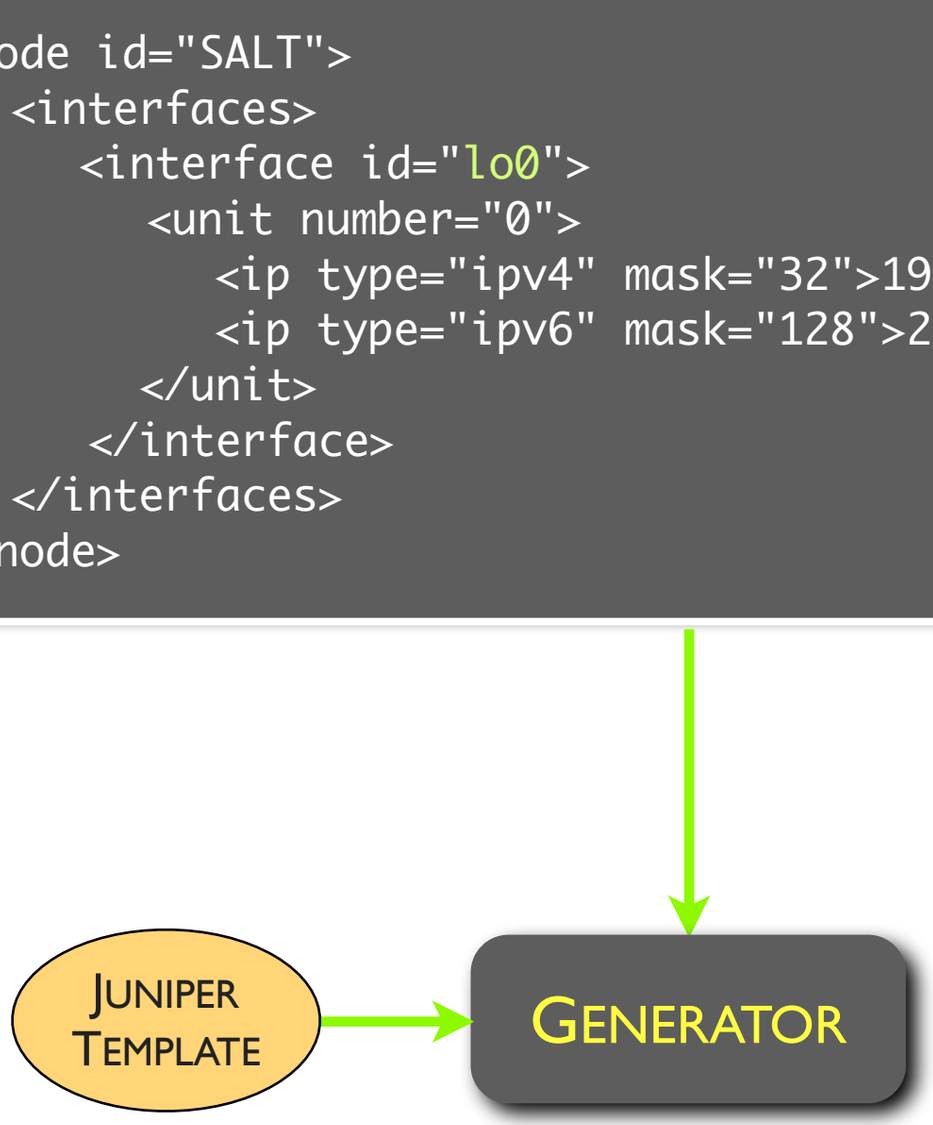

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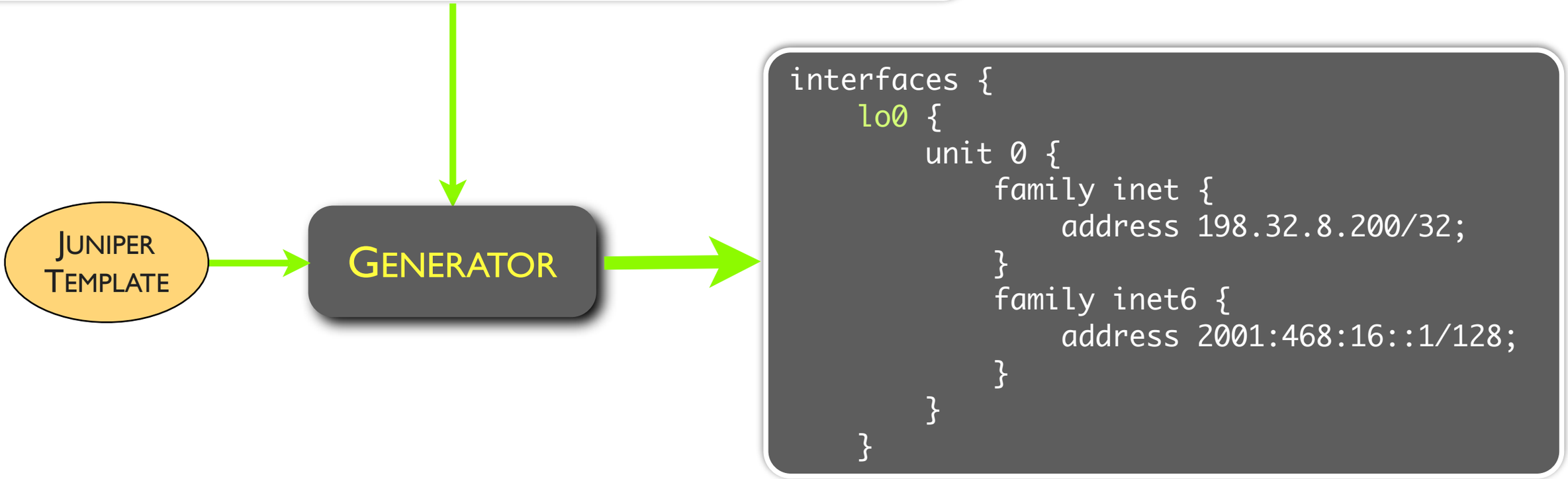

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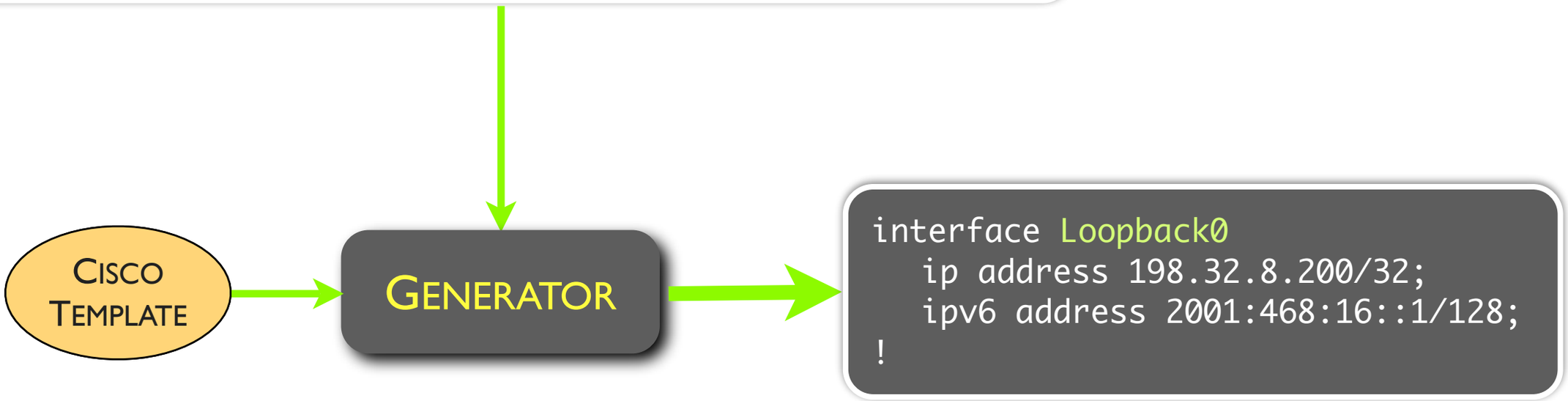

Conclusion

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- NCGuard is a **first step** towards an *extensible*, and *easy* way of designing and configuring *correct* networks.
  - **Easy** to:
    - Add new protocols, equipments, parameters, etc.
    - Add rules to check specific needs or new features
    - Add new templates to generate appropriate configlets
- Further works:
  - Extends the prototype to a broader range of case
  - Allow VNG to interact directly with the routers

Any Questions ?