论文研讨 - Lightyear: Using Modularity to Scale BGP Control Plane Verification

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Pre-Background...

Properties, repersented by **propositions and predicates**, are syntatical objects.

$$\forall r, s \in \mathbb{Q}, r = s \vee \exists t \in \mathbb{Q}, r < t < s$$

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Two way of reasoning about their correctness:

- Formal deduction
- **Model checking**

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Verifying global properties **globally** is HARD.

- Symbolically: Amount of states grows exponentially, amount of checks grows (at least) quadratically.
- Runtime: Synchronization is costly / hard to do right.

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LIGHTYEAR

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LIGHTYEAR

Given:

- Configuration (Topology and policies)
- Local invariants
- Desirable global properties

Generates:

- Local checks
- Proof that local constraints imply global properties

The language of LIGHTYEAR

Basically the quantifier-free fragment of FOL, specifing behaviors at **locations** (nodes or edges).

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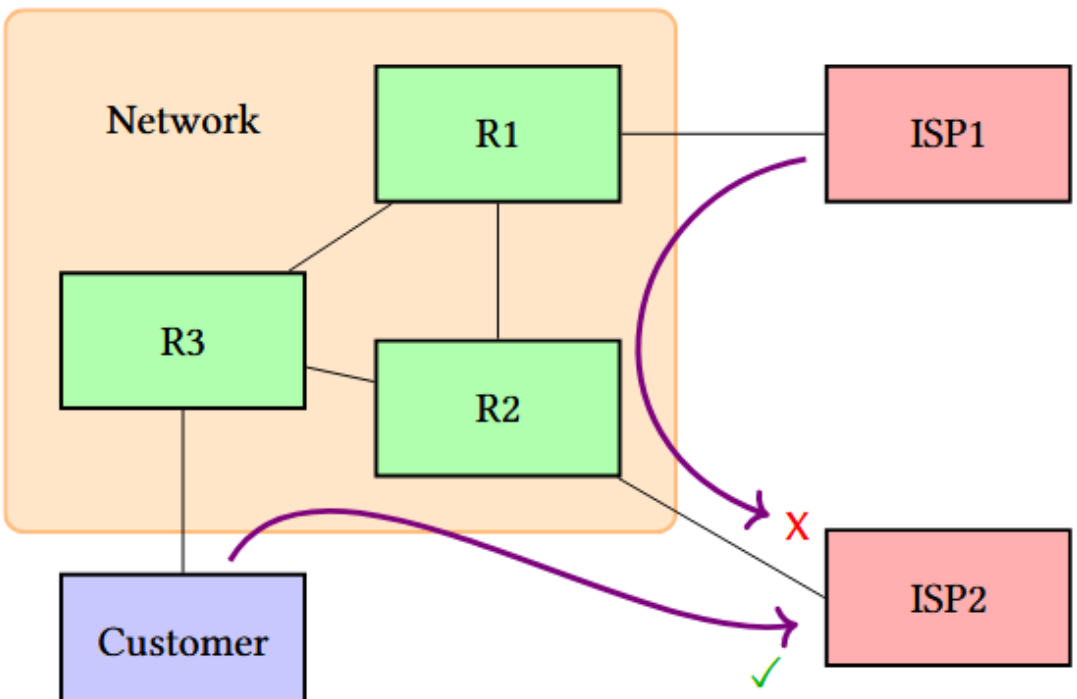
Generated functions: `Import, Export, Originates`

- `Import:` $\texttt{Edge} \times \texttt{Route} \to \texttt{Route} \cup \{\texttt{Reject}\}$

An example...



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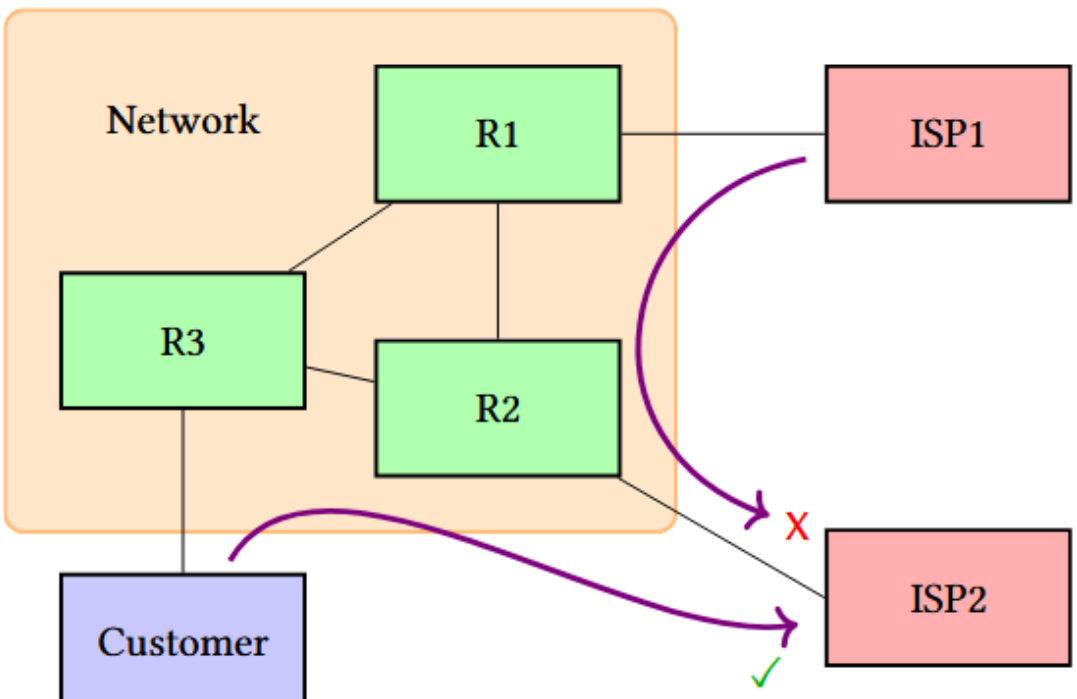

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No routes from ISP1 reaches ISP2

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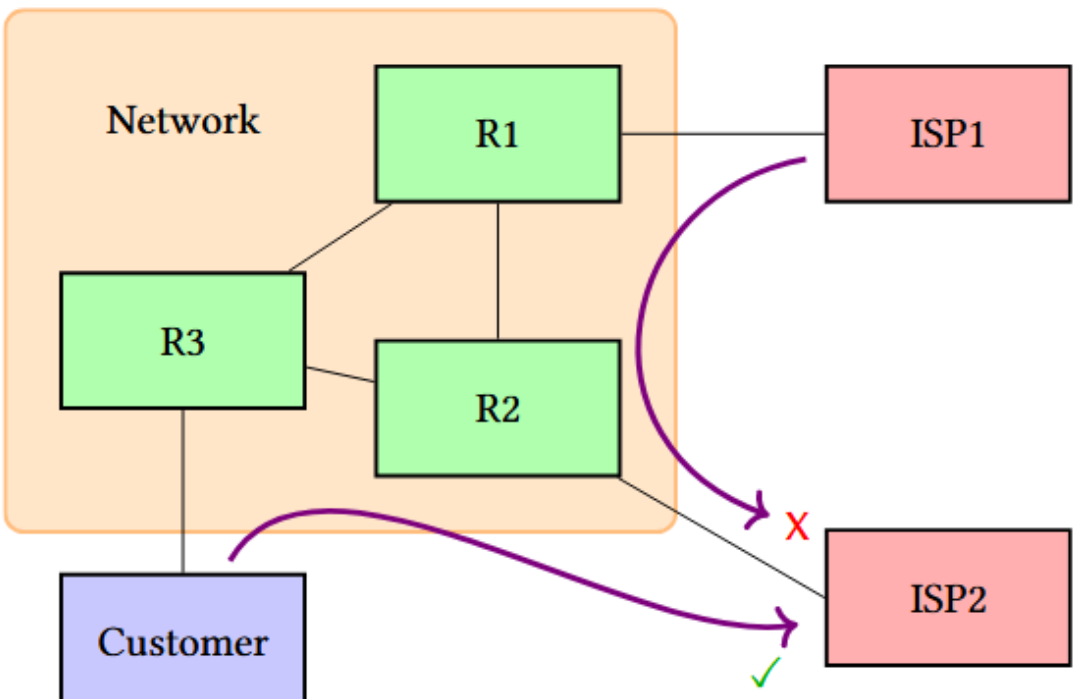

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Liveness

Routes from customer reaches ISP2

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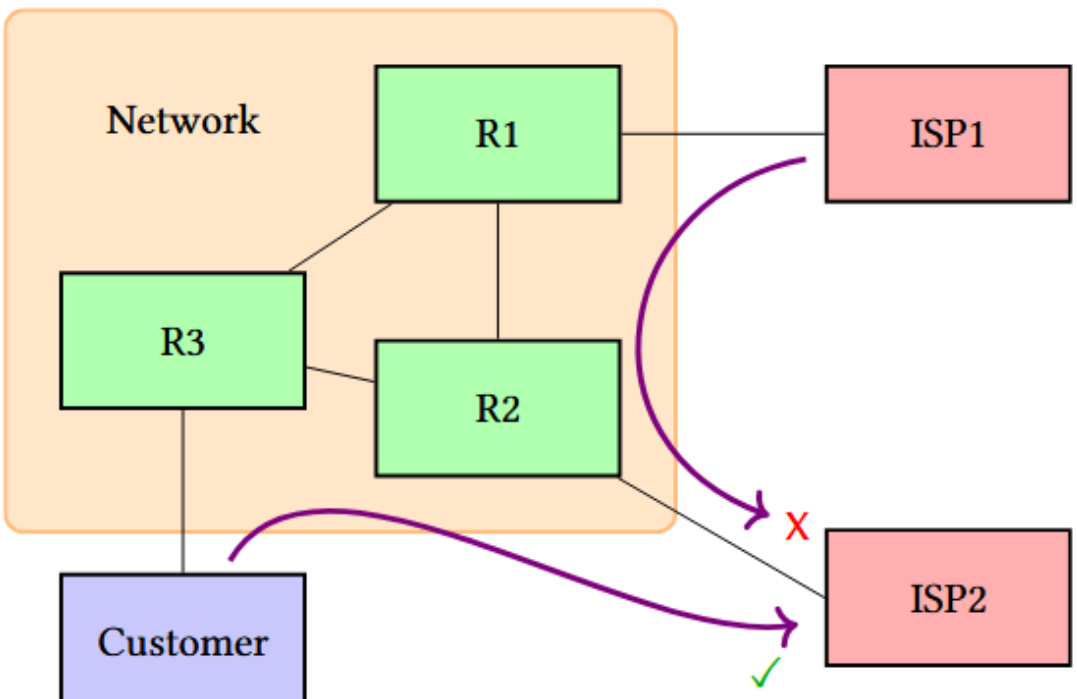

Property: At R2 $\rightarrow$ ISP2

$\neg$ FromISP1(r)

Constraints: At all internal edges:

FromISP1(r)

$\rightarrow 100:1 \in \text{Comm}(r)$

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Topology and policies are fixed, and for liveness checks, the path needs to be provided.

Proof? How?

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SMT

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SMT

For all edge $A \to B$, generates:

$$\left(\bigwedge \mathrm{inv}(\mathrm{A}) \cup \mathrm{inv}(A \to B) \cup \mathrm{inv}(B)\right) \wedge r' = \mathrm{Import}(A \to B, r)$$
$$\to \mathrm{inv}(A \to B)[r/r']$$

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Hundres of routers, tens of thousands of peering sessions.

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11 configuration bugs. Each run takes at most 15 mins.

Conclusion

LIGHTYEAR is a **modular** way to verify global properties of BGP control plane.

- Guaranteed correctness for safety and liveness.
- Constraints are simple to write and understand.
- Implemented in C# which can be directly integrated into existing systems.