FSR: Formal Analysis & Implementation Toolkit for Safe Inter-domain Routing

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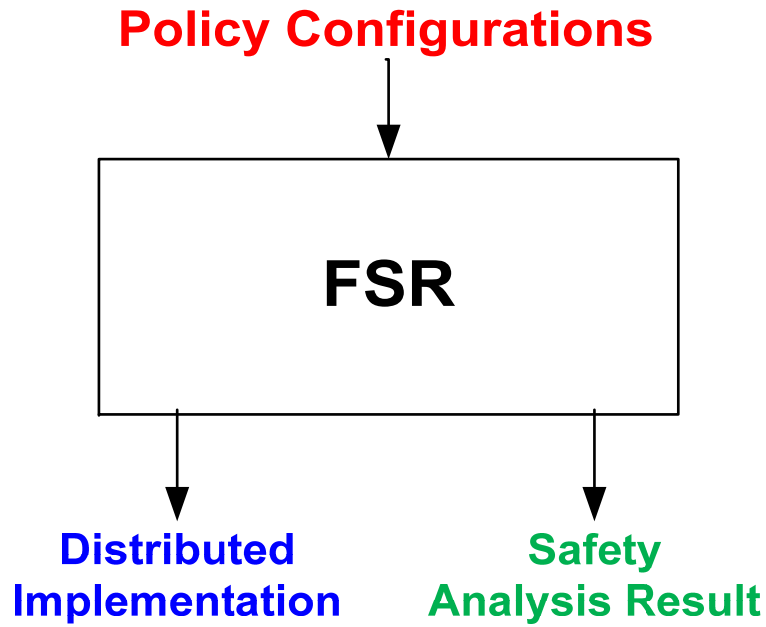
Introduction

- **Today's Internet routing system (BGP) does not guarantee convergence (safety)**
  - Policy configuration largely affect the behavior of BGP
  - Oscillations cause serious performance disruption
- **Limitations of current approaches**
  - Formal theories: Manual proofs or counter-examples
  - Distributed implementation: Simulations for study protocol overhead and transient behavior during protocol execution
- **Goal of FVR: Bridging the formal theories and distributed implementation**

Architecture (10,000 feet)



- **Input: policy configurations (as algebra)**
  - Examples: Gao-Rexford guideline [SIGMETRICS 00], hop-count
- **Formal side: Safety analysis results**
- **Practical side: Distributed implementation**

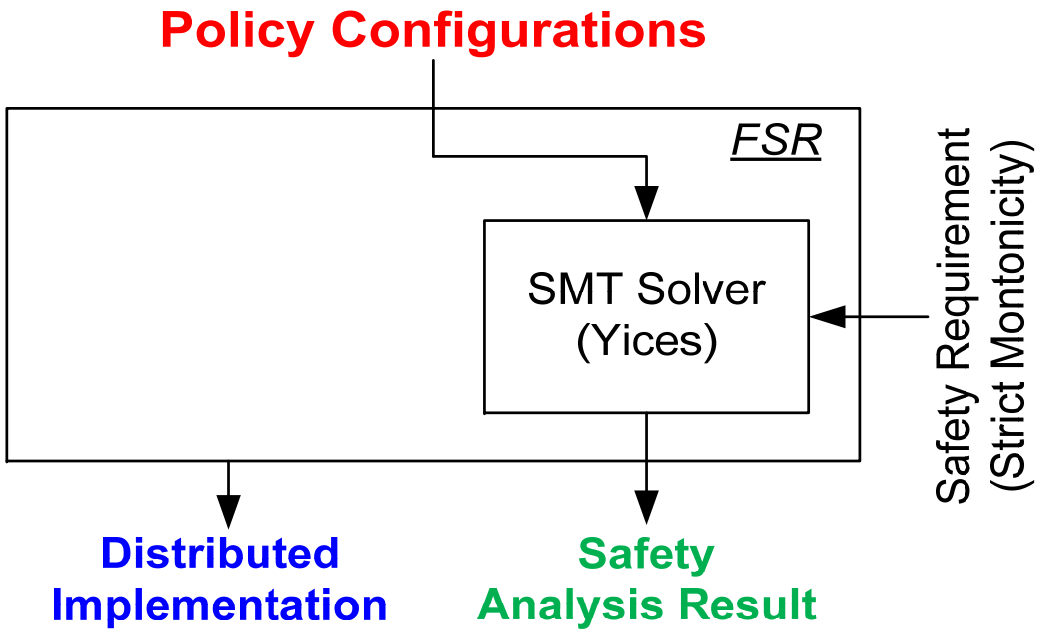
Policy as Routing Algebra

- **An abstract structure $\langle \sum, L, <, \oplus \rangle$**
  - $\sum$, L describe route and link attributes
  - $\oplus$ specifies how to compute new routes
  - $<$ determines how to compare routes
- **Gao-Rexford Guideline**

	Explanation	Algebra instance
$\sum$	Business relationship: customer, peer, provider	{C, R, P, ø}
L	Business relationship between neighboring ASes	{c, r, p}
<	Prefer customer (C) over peer(R) / provider(P)	C < R, C < P
$\oplus$	How a new route attribute depends on existing routes and links; and whether a node exports/imports certain classes of routes	

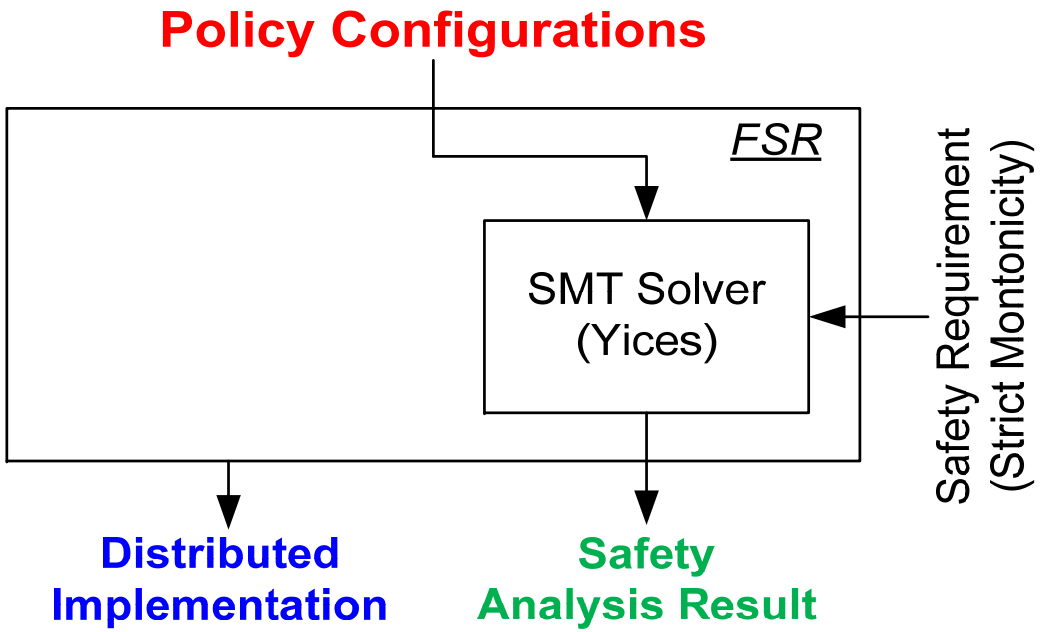
$\oplus$	C	R	P
c	C	ø	ø
r	R	ø	ø
p	P	P	P

Architecture (analysis)



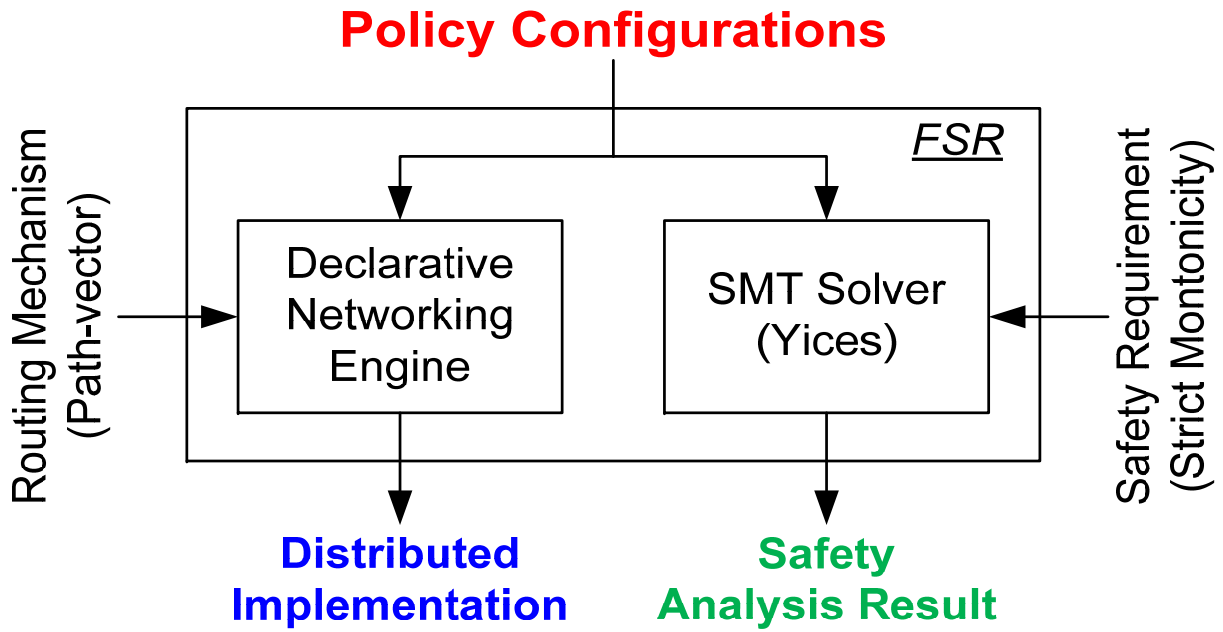
- **Contribution #1: Reduction from safety analysis to SMT solving**
  - Strict monotonicity (SM) implies safety [SIGCOMM 03, 05]
  - Convert policy configuration into Yices (SMT solver) constraints
  - Check if the constraints are satisfiable

Architecture (analysis)



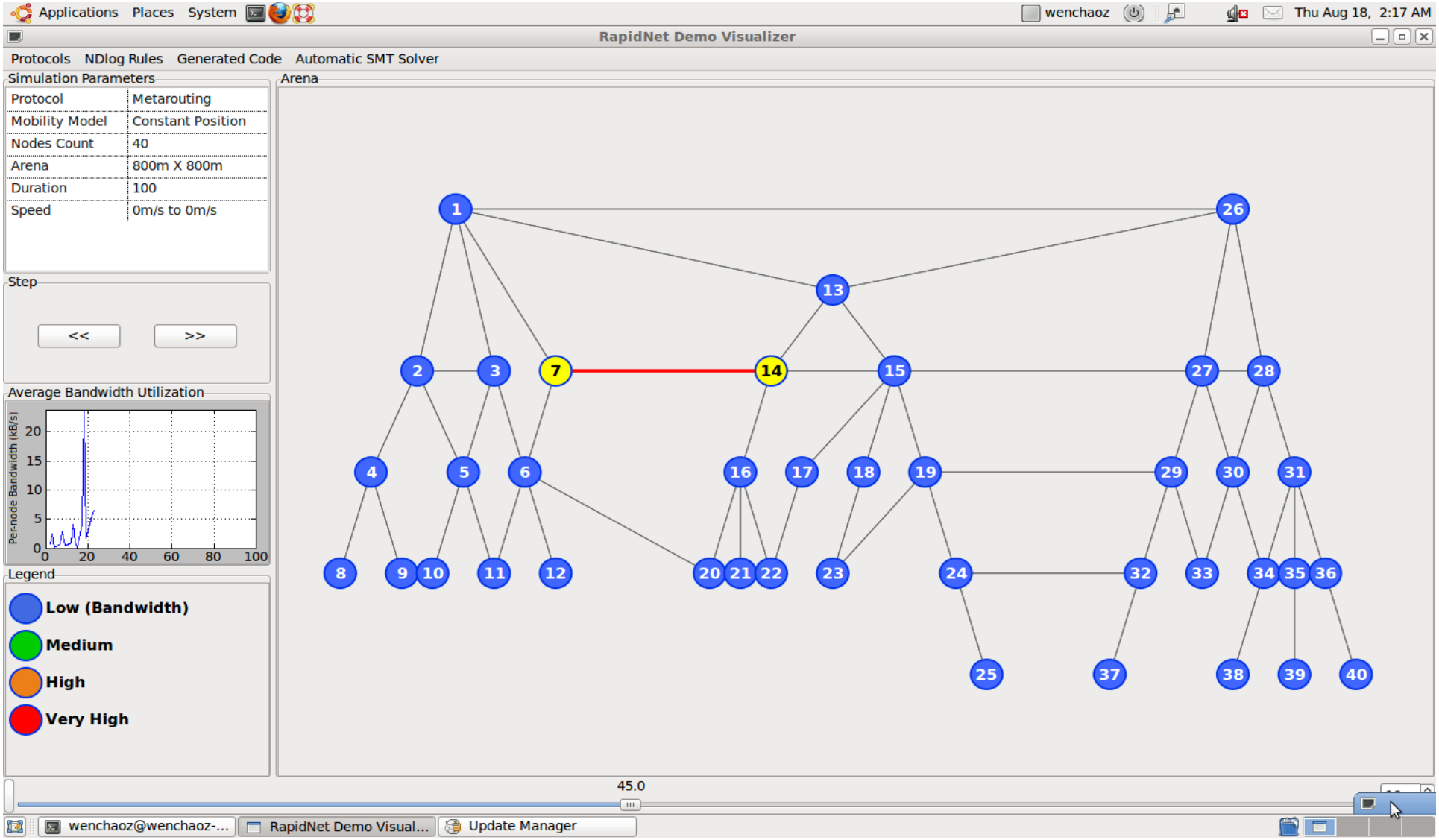
- **Contribution #1: Reduction from safety analysis to SMT solving**
- **Output: Safety analysis result**
  - SAT – ***automatically*** generated proofs
  - UNSAT – an unsatisfiable core (***pinpoint configuration errors***)

Architecture (implementation)

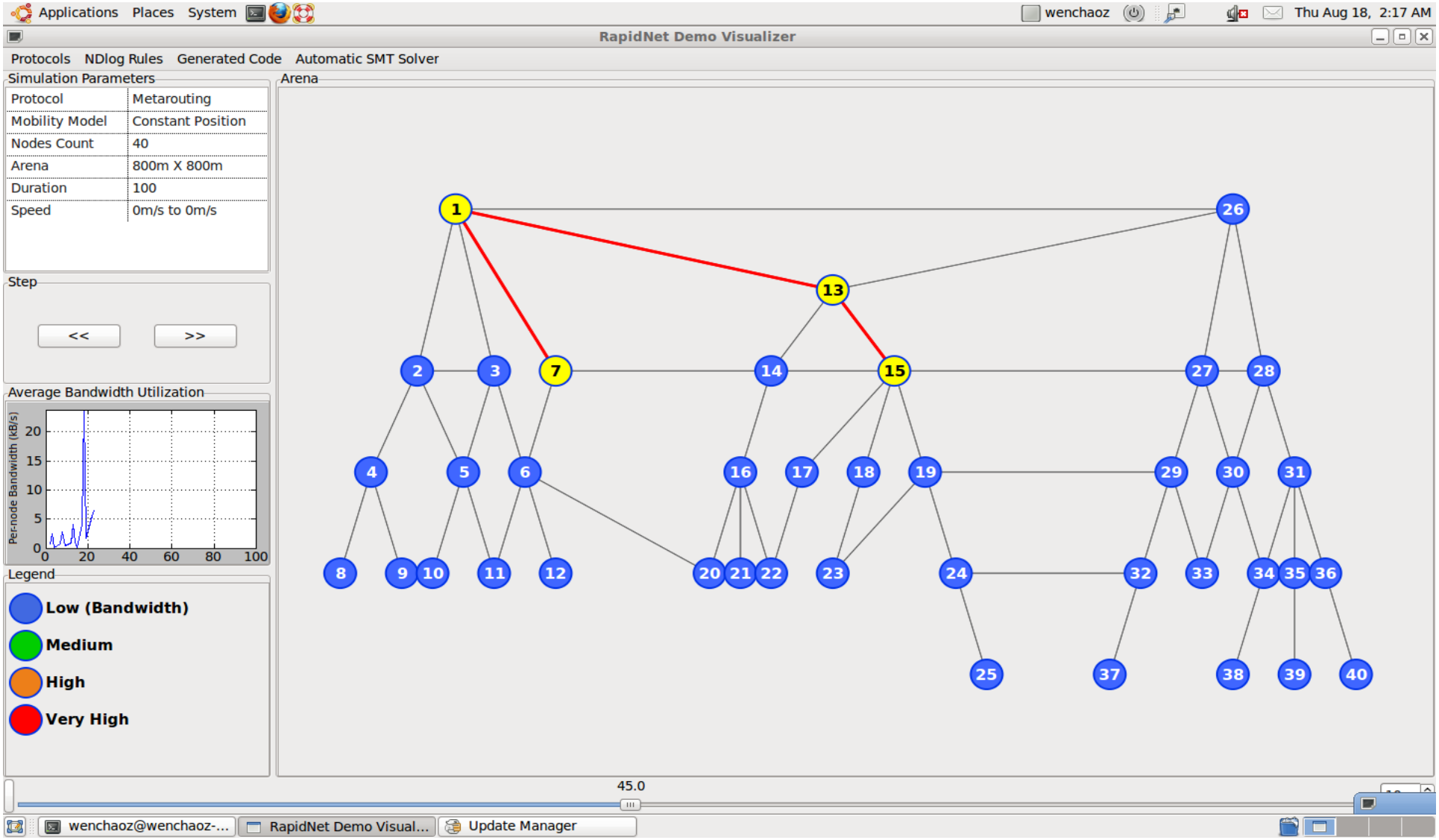


- **Contribution #2: Provably correct distributed implementation**
  - Generalized path vector + policy configuration
  - Generation of *Declarative Networking* program [SIGCOMM 05]
  - Correctness proof for the policy -> NDlog translation

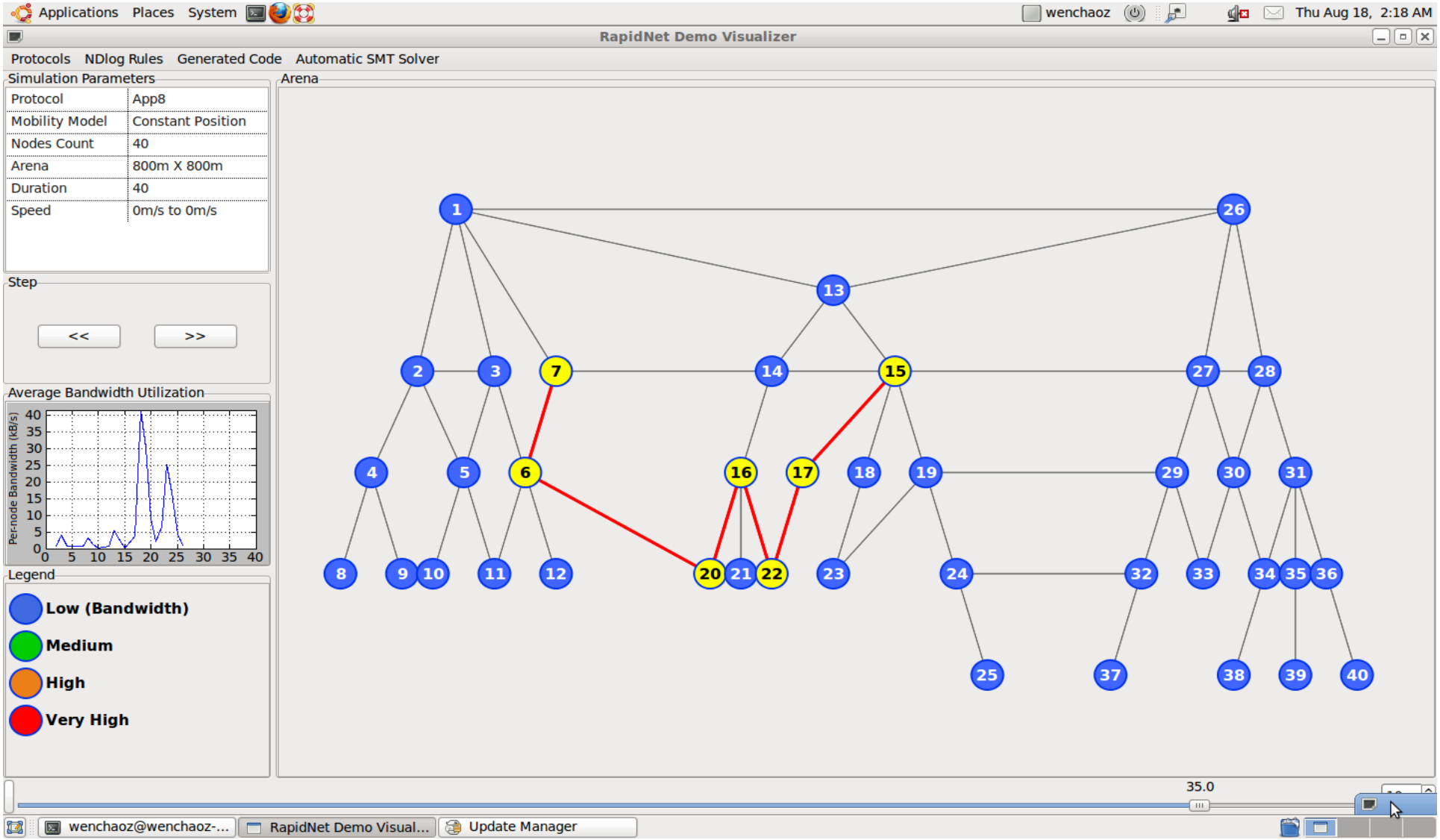
Demo: GR + HopCount



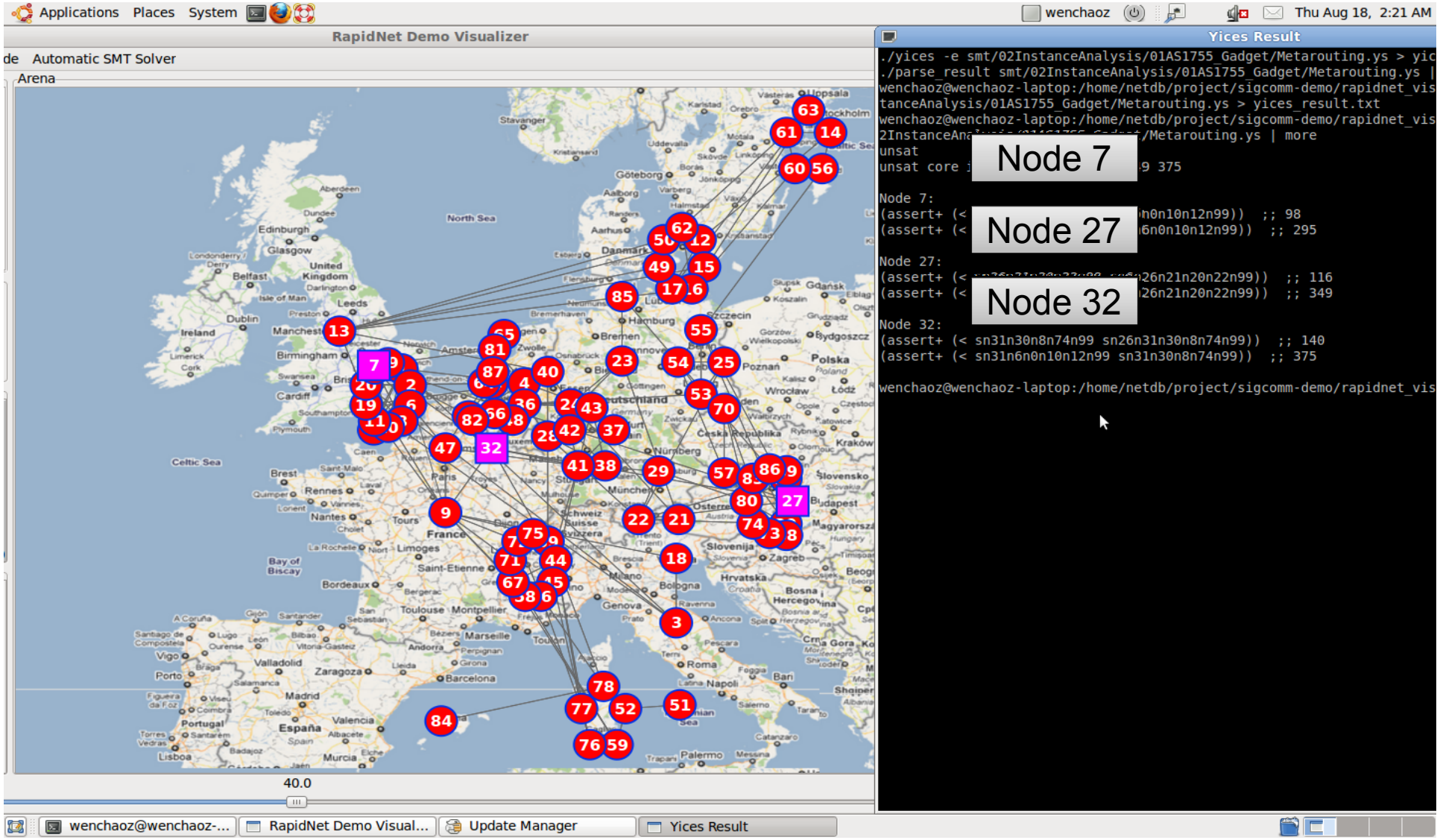
Demo: GR + HopCount



Demo: GR (wrong) + HopCount



Demo: Pinpoint Mis-configuration



Summary

- **Bridging formal theories and implementation**
  - Unified policy specifications (based on routing algebra)
  - Automated safety analysis (reduced to constraint solving)
  - Provably correct distributed implementations

Thank you...

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http://netdb.cis.upenn.edu/fvr/