A Theorem Proving Approach Towards Declarative Networking

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Motivation

- Challenges to today's Internet: increasing complexity and fragility in Internet routing
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- Runtime verification, model checking: CMC, MaceMC, PiP, D3S
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- We propose *Formally Verifiable Networking* framework
  - *Bridge the gap between verification and design/implementation*

Our Approach: *Formally Verifiable Networking*

- Goal: unifying the design, specification, implementation, and verification of networking protocols within a logic-based framework
- Declarative networking written in Network Datalog (NDlog, distributed variant of Datalog), intermediary layer between logical specification and real implementation
- Property preserving translations, from declarative networking implementation to formal system specifications for verification
- Theorem prover, statically checks properties of formal system specification against network invariants
- Code generation from verified formal specification

Background on Declarative Network

- Declarative specifications of networks using *Network Datalog* (NDlog), a distributed variant of Datalog
- NDLog is compiled to distributed dataflows
- Distributed query processor executes the dataflows to implement the network protocols

```
R1:reachable(@S,D)<-link(@S,D)
R2:reachable(@S,D)<-link(@S,Z),reachable(@Z,D)
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More details on declarative networking

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- `R1:reachable(@S,D)<-link(@S,D)`
  `R2:reachable(@S,D)<-link(@S,Z),reachable(@Z,D)`
  - For all nodes `S,D`: `S` can reach `D` via a link from `S` to `D`

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R1:reachable(@S,D)<-link(@S,D)
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- For all nodes S,D,Z: if there is a link from S to Z, and that Z can reach D, then S can reach D

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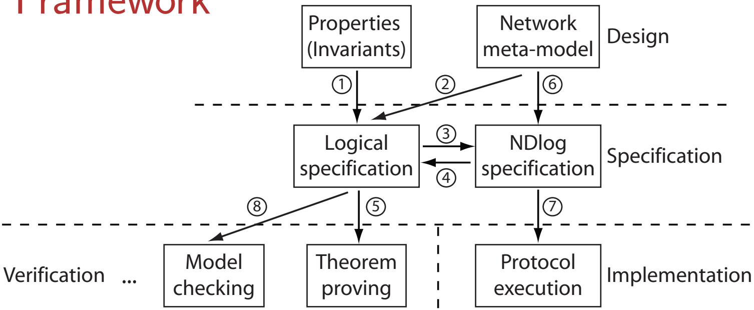
FVN Framework



- Specification: two way property preserving translation
  - Formal system specification generated from NDlog program (arc 4)
  - Declarative network synthesized from verified logical specification (arc 3)
- Verification: proving network invariants against system specifications by interacting in theorem prover
- Implementation: existing distributed query processor executes the NDlog programs

Conclusion

- More details in poster
  - NDlog Program Verification (arc 1,4,5)
  - Generating Equivalent NDlog implementation (arc 3,7)
  - Component Based Verification of BGP System (arc 2,3,5)
- Future Work
  - Network Models and Implementation
    - Relaxed algebraic models, component-based models
  - Modeling Soft-state in Declarative Networking
    - Linear logic, semantic foundation for verification of NDlog programs with soft-state
  - Combining Verification Techniques
    - Theorem proving, declarative networking specific proof strategies/tactics
    - Model checking declarative networking, transitions update routing tables specified in linear logic