A Synthesis Approach Towards Automated Management in Software-defined Networks

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Network Management

- Current computer networks
  - Network fabrics become more powerful
  - Emerging applications demand more reliable and complex services

- Network management
  - Manual, low-level, unpredictable process
  - Silent failures and hidden dependencies common

- SDN makes management worse
  - Software-defined network (SDN): programmable network behavior
    - Forces management at an individual switch level
    - Various sizes emerging applications (cloud, datacenter)
      - Makes management intimidating

Lacking formalization & tool support

Dynamic Control Logic Construction

- Two families of network management
  - Formalize
    - Network
    - Environment

- Prior invariant:
  - Output: A winning strategy that reduces complexity

- Virtual network
  - A: Algorithm for finding
  - Environment player e triggers transition

- Management solution:
  - Solves as a twoplayer, temporal-logic approach

- Synthesis for abstract network
  - For emerging applications demand more reliable and robust network management

- SCD is a special case of DCC when network state change is not presented

- Find a control logic satisfying given network
  - Goal: scalable yet rigorous management
  - New proposal: Synthesizing provably correct solutions for two families of control logic construction problems
    - Static control logic construction (SCC)
      - Find a control logic satisfying given network-wide requirement and prior network-wide constraints
      - Solve as a reachability problem
    - Dynamic control logic construction (DCC)
      - Find a strategy that updates control logic in response to network state changes
      - Solve as a two-player game
    - SCD is a special case of DCC when network state change is not presented
    - Automated through model checking and game solvers (e.g., nuSMV, JTLV, TuLiP,...)

Static Control Logic Construction

- Controls: Configuration 1
  - Type: S, F
    - Action: Allow, Deny
  - Flows: U, G, F, I

- Controls: Configuration 2
  - Type: S, F
    - Action: Allow, Deny
  - Flows: U, G, I

- Enforcement: Configuration 1
  - Enforce a security policy that denies SSH traffic for untrustworthy hosts, allows all rest

- Enforcement: Configuration 2
  - Management solution: an ordering of rule updates that achieves requirement, while satisfying invariant in all transient states

- Synthesis solution
  - Solve reachability problem in model checker
  - Special case of DCD synthesis

Scaling by Abstraction

- SDN networks are amenable to abstraction
  - Centralized logical view
  - Network-wide property hierarchical in nature: high-level property abstracts away switch-level details

Abstraction for network management

- Partitions large problem into multiple small ones
- Synthesis for abstract network
- Implementation on concrete sub-networks

Abstraction for Control Logic Construction

- A larger dynamic control logic construction problem

- Topology-based abstraction by grouping nodes

- Synthesize solution for the abstract problem
- Map solution to concrete network

Conclusion

- Contributions
  - Formalize two families of network management problems
  - Propose a synthesis approach for provably-correct automation
  - Investigate abstraction technique for scaling

- Future Work
  - Distributed controllers in SDN
  - Contract-based synthesis, contract discovery
  - Virtual network – killer application in SDN
  - Bi-simulation framework

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