NetSum: Mining Summaries of Network Configuration Changes

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Problem Statement and Goals

Motivation: networks require near-constant configuration changes [1]

- 20% of network operators make changes once per day
- 80% of network operators are concerned changes will introduce problems with existing functionality
- Operators need a way to vet changes at a high level

Goals:

- Mine succinct summaries of configuration changes
- Understand low-level configuration changes: infer high-level intention
- Verify operational updates: confirm compliance with intention and network policy

Path Change Summaries:

A configuration change can encompass many tasks (re-routing traffic, updating ACLs, modifying interface/port settings). Initially, we focus on *path changes* and summarize each change in the form:

`pc: old_path => new_path`

- `pc`: a *packet class*, an equivalence class where every packet is forward the same way [3]
- `old_path, new_path`: *regular expressions* defining a path in the previous network and the current network, respectively

Generalizing Useful Path Expressions

Key Challenge: deriving a regular expression that describes the path change at the right level of abstraction

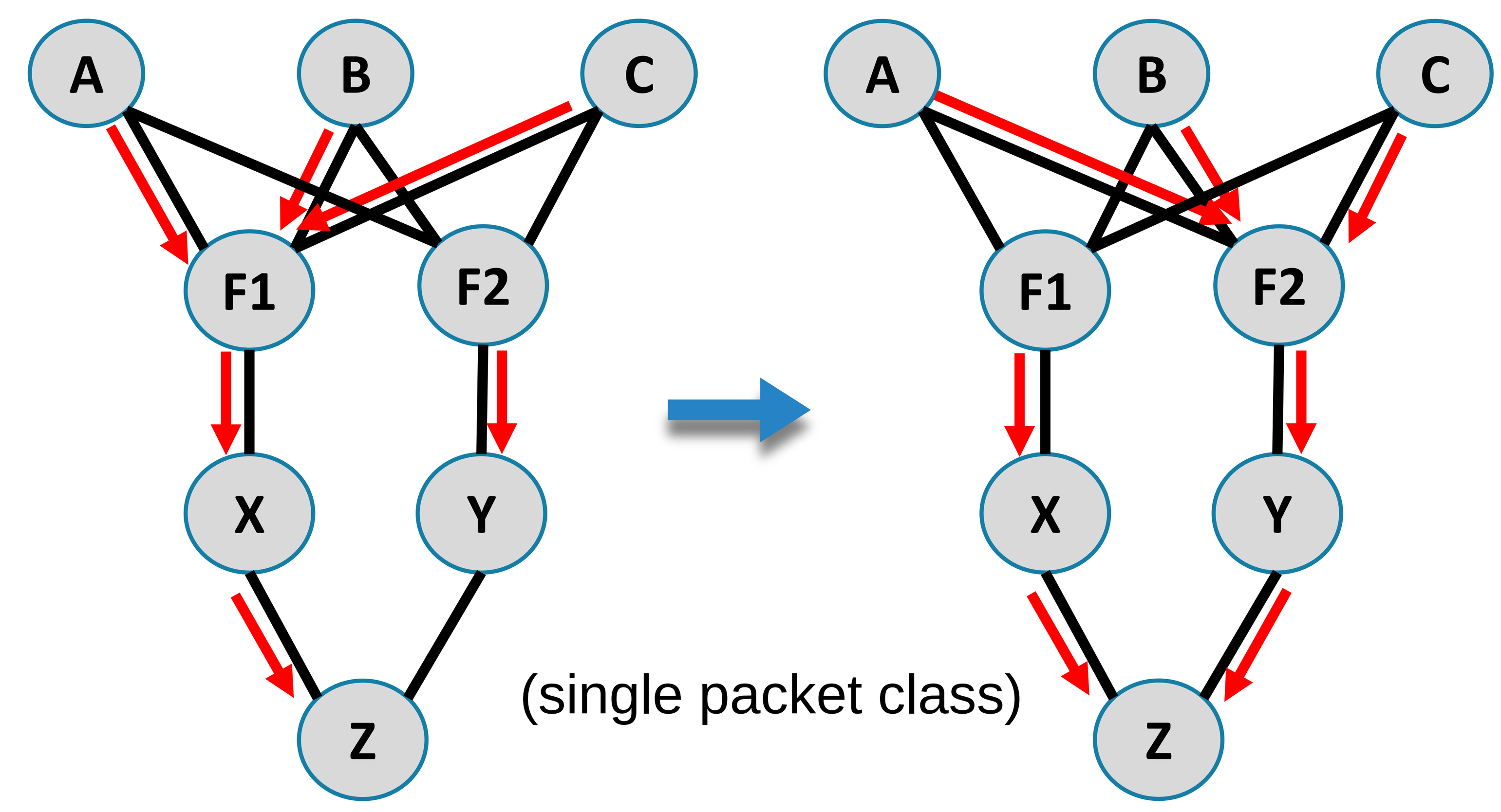
- *Precise*: informative enough to capture the impact of the configuration change
  - `new_path`: `.*` - not precise enough to describe impact
- *Concise*: uncover the high-level intention of the configuration change
  - `old_path`: `.*` - concisely matches all previous paths

Mining Strategies:

- *Correctness:* the expression correctly identifies the change and could be used to synthesize a change [2]
- *Minimality*: bias toward expressions with fewer terms (Occam's razor)
- *Topology restrictions:* if only a single path exists between nodes n_1 and n_2, ignore intermediate hops
- *Non-empty path change*: the difference between `old_path` and `new_path` is non-empty
- *Indistinguishable nodes:* automatically inferred or user-defined sets of nodes with similar function

Motivating Example

Input: two network configurations: ***N* → *N'***
Output: summary of each changed path, as a regular expression

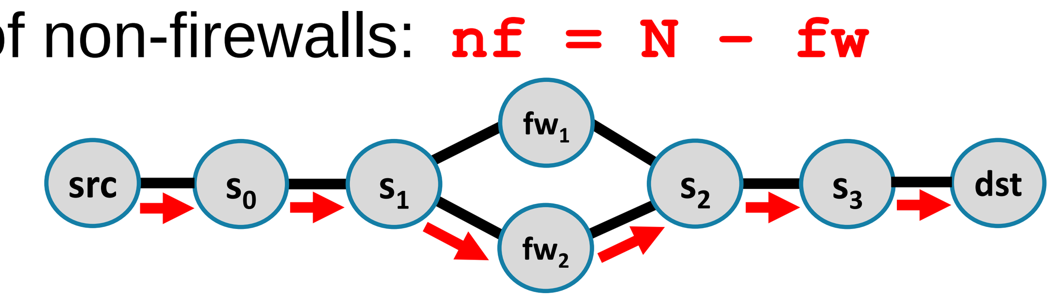


- The most generic expression does not capture the intention of the configuration change:
  `.* => .*`
- An explicit expression is too verbose:
  `(A+B+C) F1 X Z => (A+B+C) F2 Y Z`
- **Goal:** a concise, useful expression:
  `.* F1 .* => .* F2 .*`

Application of Mining Strategies

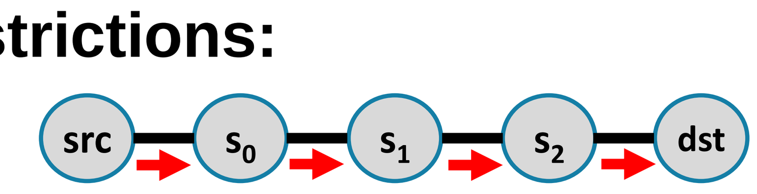
Indistinguishable nodes: automatically infer and cluster together devices with similar functionality

- N = all nodes in the network
- Set of firewalls: $fw = \{fw_1, fw_2\}$
- Set of non-firewalls: `nf = N – fw`



- Summarized path: `src nf* fw nf* dst`

Topology restrictions:



- Summarized path: `src .* dst`

References

[1] H. Kim, J. Reich, A. Gupta, M. Shahbaz, N. Feamster, R. Clark. Kinetic: Verifiable Dynamic Network Control. In USENIX Symposium on Networked Systems Design and Implementation (NSDI '15), 2015.
[2] S. Saha, S. Prabhu, P. Madhusudan. NetGen: Synthesizing Data-Plane Configurations for Network Policies. In Symposium on Software Defined Networking Research (SOSR '16), 2016.
[3] A. Khurshid, X. Zou, W. Zhou, M. Caesar, P. Godfrey. VeriFlow: Verifying Network-Wide Invariants in Real Time. In USENIX Symposium on Networked Systems Design and Implementation (NSDI '13), 2013.