A Cost-Benefit Framework for Judicious Enterprise Network Redesign

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Why Redesigning Enterprise Networks is Necessary

- **Enterprise networks constantly evolve.**
  - Changes to the design are made on daily basis [Infocom 2010]

- **Evolution leads to “kludgy” designs.**
  - Poor performance [Infocom 2010], high complexity [NSDI 2009], etc.

- **Redesign can improve network quality.**
  - “…*redesigning subnets brings better network efficiency.*”
    Purdue Engineering Computer Network Document Archives.
Why Such Redesign Can Be Costly

Network-wide high-level goals in:
• Performance
• Cost
• security
• …

Thousands of devices (switches, routers, etc)

Complex device dependencies!
What This Paper is About

• Investigate a systematic redesign approach

1. Identify
   Network-wide
   Abstractions

   Requirement in performance, cost, etc

2. Formulate the
   Requirements

   Benefits & costs of redesign
   Correctness & feasibility criteria

3. Solve Formulated
   Problems

   Redesign strategy

• Focus on Virtual Local Area Networks (VLANs) as a case study.
Virtual Local Area Networks (VLANs)

- Desirable to organize user hosts as logical groups based on their roles ("categories")
  - Example categories: Sales, payroll, ECE, CS, etc.
- A VLAN groups hosts into a single broadcast domain, even when they are at physically disparate locations.
- Each VLAN runs a separate spanning tree protocol
- Each VLAN is assigned a subnet address (e.g., a /24 IP block)
Considerations in VLAN Design

• **Correctness criterion:** Hosts belonging to different categories (i.e. logical groups) must be put in different VLANs

• **Feasibility criterion:** The total number of VLANs may be created is subject to the hardware capacity.
  – Maintaining VLAN spanning trees place load on switch CPU and memory

• **Performance criterion:** keep broadcast traffic small
  – Break large categories into multiple VLANs

• **Previous works** are in the context of “green-field” networks[CoNext 2008, Infocom 2010]. We go beyond in two aspects:
  – We show evolution can lead to performance degradation, making redesign necessary
  – We introduce the **Cost criterion**, unique to redesign.
Evolution Leads to Performance Degradation

All hosts shown here belong to the same category.
Redesign Can Improve Performance

- Possible redesign: re-assigning hosts to VLANs

Reassigned from pink to purple

Reassigned from purple to pink

CDF on fraction of VLANs with a certain broadcast traffic

More VLANs with high broadcast traffic

CDF on Broadcast Traffic [pkt/s]

76 out of 112 VLANs see growth of broadcast traffic.
Cost Associated with Redesign: Reconfiguration Effort

- Example: re-configuration costs associated with re-assigning hosts:
  - Hosts IPs will be changed -> need to update DNS servers, security & routing policies, etc.
  - Hosts may change their gateway router -> need to reinstall policies on the new paths

- Reconfiguration cost reflects the probability of configuration errors and amount of potential down time

- Cost criterion: must keep the amount of re-configuration effort small.
Modeling Re-configuration Cost

• **Our Approach: coarser models**
  – Metrics
    • # of hosts re-assigned by the redesign strategy
    • # of VLANs with root-bridges changed
  – Reasonable approximation: the amount of re-configuration effort required is proportional to these measures.

• **Finer-grained models:**
  – E.g., # of configuration lines/blocks that need to be changed
  – Potentially more accurate
  – But requires more detailed domain knowledge to obtain
Framing the VLAN Redesign Problem

• Frame the VLAN redesign problem as to identify the best set of redesign actions:
  – *Objective*: minimize manual reconfiguration effort required
  – *Constraints*:
    • broadcast traffic < *Threshold* (set by the operators)
    • *Correctness & feasibility* criteria

• Solve the problem by applying greedy techniques
  – Algorithm details are in the paper.
Effectiveness of Our Approach

- Comparing our approach with a cost-agnostic approach [CoNext 2008]

![Bar chart showing max broadcast traffic before & after redesign](chart1)

![Bar chart showing # of hosts moved by the two redesign approaches](chart2)
Conclusion

• Feasible to redesign networks to achieve significant performance benefit, while keeping reconfiguration costs low.
  – Focusing on VLANs as a case study

• A framework for systematically trading off redesign benefit VS. costs
  – Cut max broadcast traffic by a factor of ~3
  – While incurring only ~15% of the reconfiguration cost compared to a cost-agnostic approach

• Evaluation on a large-scale campus network using longitudinal data-set