Ethane: taking control of the enterprise

Martin Casado et al

Giang Nguyen

Motivation

- Enterprise networks are large, and complex, and management is distributed.
- Requires substantial manual configuration. Kerravala (Yankee Group 2002):
  - 62% of network downtime in multi-vendor networks comes from human-error.
  - 80% of IT budget on maintenance and operations.

Motivation (cont)

- Current approaches:
  - Insert middleboxes at network choke points:
    - Problem: traffic might accidentally or is maliciously diverted around the middleboxes
  - Introduce tools/additional protocols/layers:
    - Hide the issue instead of fixing it.
    - Additional complexity (e.g., managing the mgmt tools)

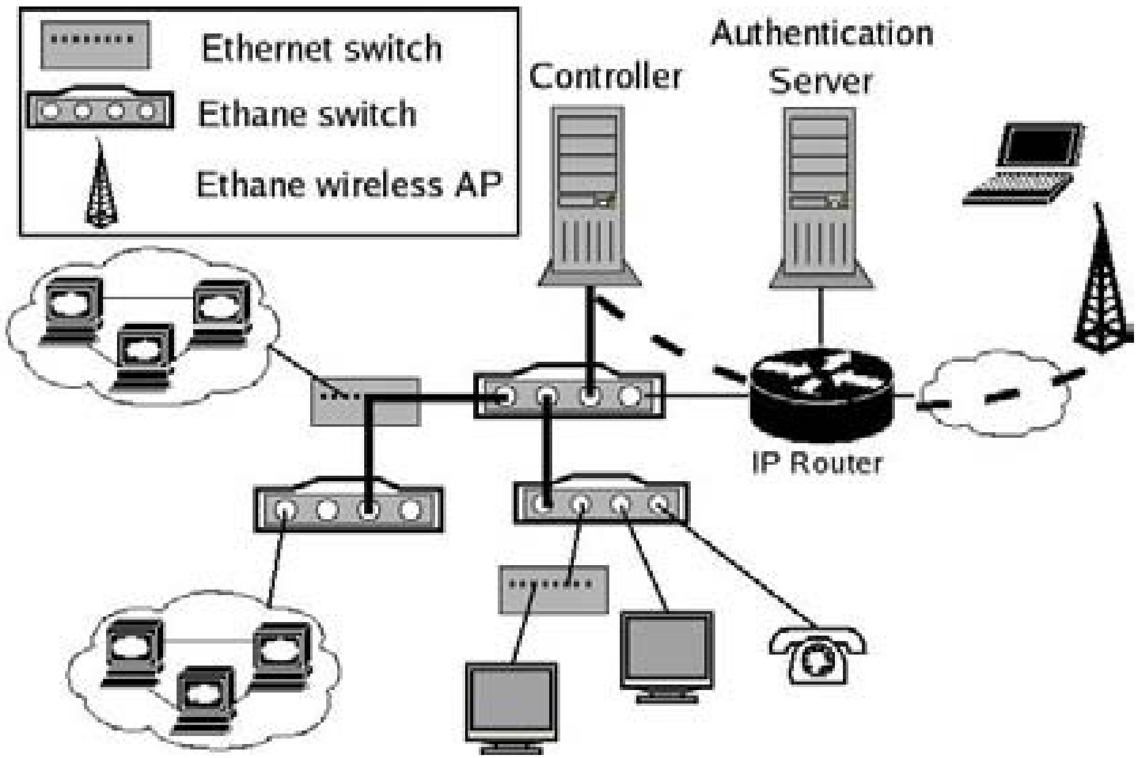
Motivation (cont)

- *"How could we change the enterprise network architecture to make it more manageable?"*
  1. "The network should be governed by policies declared over high-level names."
  2. "Policy should determine the path that packets follow."
  3. "The network should enforce a strong binding between a packet and its origin."

Ethane design overview

1. Central controller
   - Has a global network policy and topology view.
   - From configured rules, decides whether each flow is allowed and how it is routed.
2. Ethane switches
   - Contains simple flow tables.
   - All packets not from known flows are forwarded to controller for decision on “action.”
   - If allowed, then added to flow table and subsequent packets from same flow are forwarded without consulting controller.
3. Names and policy language
   - All users, hosts, switches, protocols etc have names, that are used when writing rules for the controller.

Example deployment

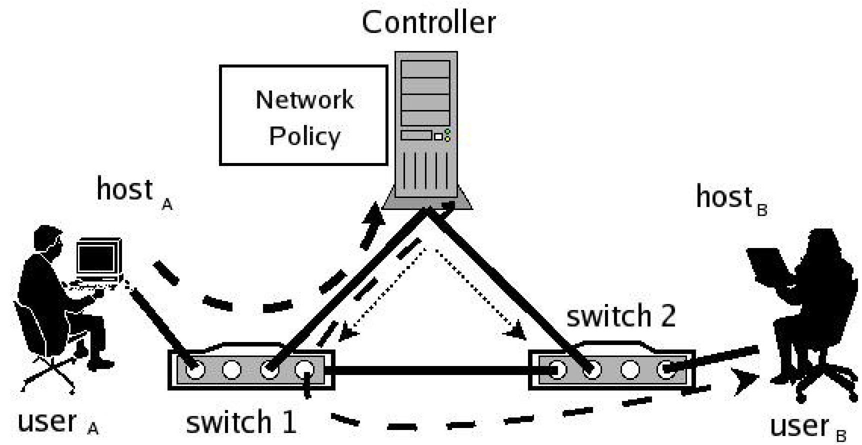


5 basic activities in an Ethane network

1. Registration:
   - All switches, hosts, and users register with the controller.
2. Bootstrapping:
   - Switches maintain secure channels with controller.
   - Minimum spanning tree (MST) rooted at controller.
3. Authentication:
   - A host joining the network is redirected by switch to the controller for authentication (by MAC) when it does DHCP. Controller records bindings host->IP, IP->MAC, MAC->switch port.
   - User is authenticated (e.g. password) via browser. Controller records binding user->host.

5 basic activities in an Ethane network (cont)

1. Flow setup:
   - UserA initiates connection to userB.
   - Switch1 has no matching entry in flow table -> forwards to controller.
   - If controller accepts, computes path and updates all switches along path.
2. Forwarding:
   - Controller sends packet back to switch1, which forwards it and adds new entry in table to allow subsequent packets from this flow without asking the controller.



Ethane switches

- Simpler than Ethernet switches
  - Doesn't need to learn addresses, support VLANs, run routing protocols, etc…
  - Flow table orders of magnitude smaller because only contains active flows.
  - Flow (header) matching is exact, not longest prefix.
- 2 common types of flow table entries:
  - Per-flow: allow action.
  - Per-(misbehaving-)host: drop action.
- Other possible actions/services:
  - Multiple queues, controller tells in which to place flow.
  - NAT: by replacing packet headers.

Ethane controller

- Registration:
  - Hosts, users, Switches, protocols, access points ({Switch, port} pairs) must be registered. Directly, or queried from LDAP etc.
- Authentication:
  - Hosts, users, and Switches must authenticate, (e.g., MAC, password, SSL certs).
- Tracking of bindings:
  - Bindings between users, addresses, and access points are logged.
- Enforcing resource limits:
  - Can direct Switches to rate-limit flows.
  - Can limit number of authentication requests per host per access point.
  - More possibilities.

Ethane controller (cont)

- Fault tolerance:
  - Cold standby: secondary controllers participate in same global MST.
    - After primary controller goes down, will take over when MST converges.
    - Simple, but slow recovery: hosts/users have to re-authenticate.
  - Warm standby: a separate MST for each secondary controller.
    - Controllers monitor one another's liveness.
    - Bindings are replicated across controllers.
    - Complex, but faster recovery.
- Fault tolerance and scalability:
  - Multiple active controllers:
    - Switches need to authenticate with only one controller.
    - Spread flow decision queries across multiple controllers.
    - Complex consistency issues etc.

Multicast and broadcast traffic

- In theory:
  - Switch: keeps for each flow a bitmap of ports to forward.
  - Controller: from computed broad/multicast tree, assigns appropriate bits during path setup.
  - Broadcast are mostly discovery protocols, e.g. ARP, which the controller can reply without creating a new flow or broadcasting.
- In practice:
  - ARP causes a significant load on the controller.
  - Might setup a dedicated ARP server, and controller directs ARP traffic there.
  - But what about other disc protocols? Tradeoff: controller implements common protocols, and broadcasts unknown ones with rate-limit.
  - Doesn’t scale well, but expecting discovery protocols to go away if Ethane is used widely.

Rules

- Network policy is a set of rules:
  - *[<condition(s)>]:action;*
  - Conditions: conjunction of predicates.
  - Actions: allow, deny, waypoints (list of entities to route the flow through), and outbound-only.
  - Example: [(*usrc=“bob”)∧(protocol=“http”)∧(hdst=“websrv”)]:allow;*
  - Means if the user initiating the flow is bob and the flow protocol is http and the destination is host “websrv”, then allow the flow.
  - Rules are independent. First rule that matches is used.
- Rule lookups have to be fast.
  - Can’t simply compile because of huge namespace of users, hosts, etc
  - So use compilation plus just-in-time creation of search functions.

Prototype

- Switches:
  - Wireless access points using WRTSL54GS.
  - 4-port gigabit switches using FPGA.
  - 4-port gigabit switches using desktop PCs.
- Controller:
  - Standard desktop PC.

Deployment

- 100Mb/s network
- 11 wired and 8 wireless Switches.
- ~300 hosts
- Create a network policy that matches existing firewall configs, NATs, router ACLs etc.

- Hosts connected to an Ethane switch port does not require user authentication.

Evaluation: controller scalability

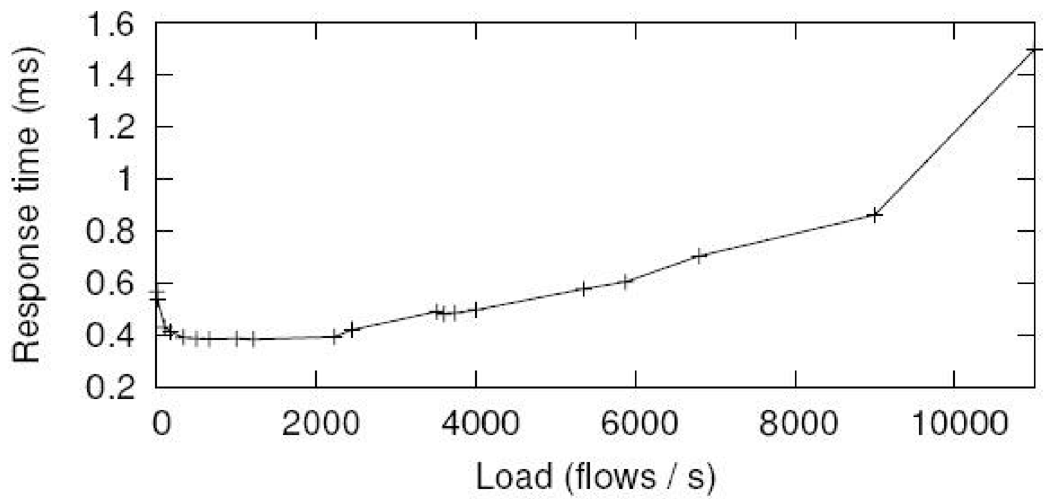


Figure 6: Flow-setup times as a function of Controller load. Packet sizes were 64B, 128B and 256B, evenly distributed.

- A 22,000-host network observed max 9,000 flow requests per second, suggesting that a single controller can handle 20,000 hosts with flow request setup time under 1.5ms.

Evaluation: effect of failures

Failures	0	1	2	3	4
Completion time	26.17s	27.44s	30.45s	36.00s	43.09s

Table 1: Completion time for HTTP GETs of 275 files during which the primary Controller fails zero or more times. Results are averaged over 5 runs.

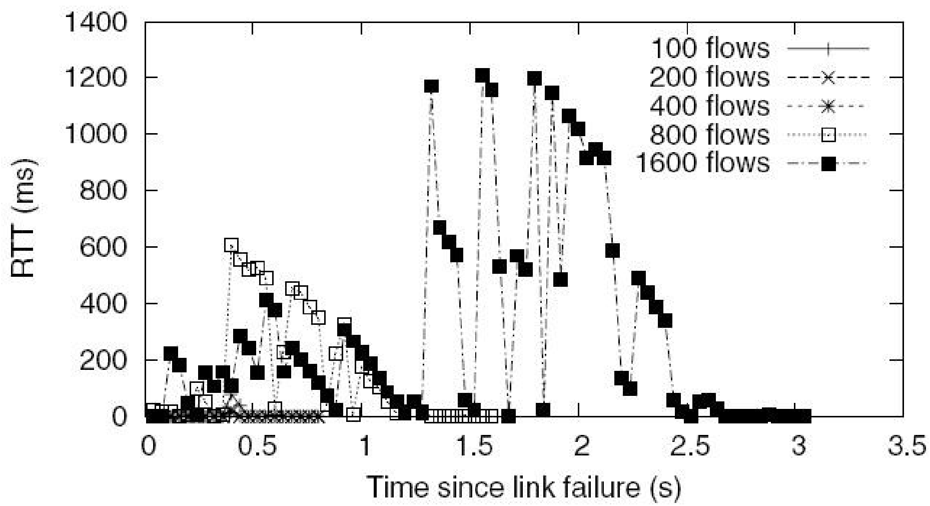


Figure 10: Round-trip latencies experienced by packets through a diamond topology during link failure.

Shortcomings

- Broadcast and discovery protocols.
- Application-layer routing: hostA not allowed to talk to hostC, so hostB can relay hostA’s messages.
- Tunneling other protocols in http.
- Spoofing Ethernet MACs.
  - Physically allow only one host per switch port.
  - Or use 802.1X plus link-level encryption such as 802.1AE.