Facilitating Network Management with Software Defined Networking

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http://projectbismark.net/

Software Defined Network *Management*

- Software defined networking (SDN) makes it easier for network operators to evolve network capabilities

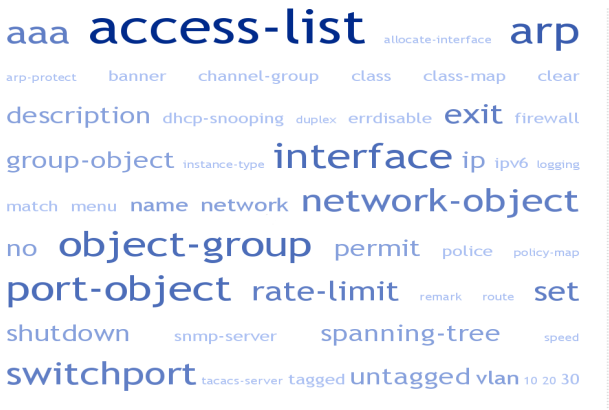
- Can SDN also help network operators manage their networks, once they are deployed?
  - Home networks
  - Campus/Enterprise networks

Why is network management so hard?

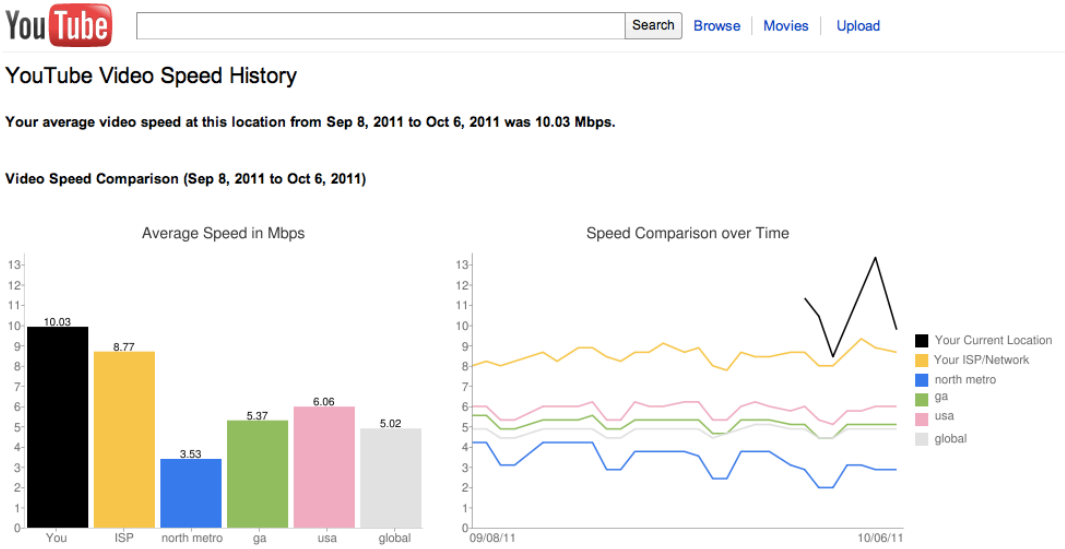
Changes are Frequent, Unwieldy

- Changes to the network configuration occur daily
  - **Errors are frequent**
- Operators must determine
  - **What will happen** in response to a configuration change
  - Whether the configuration is **correct**

Georgia Tech	*add*	*del*	*mod*	Total
Routers (16)	31,178	27,064	262,216	326,458
Firewalls (365)	249,595	118,571	171,005	539,171
Switches (716)	216,958	20,185	116,277	353,420
Rtr avg. per device	2,324	1,692	16,389	20,404
FW avg. per device	684	325	469	1,477
Swt avg. per device	303	28	162	494



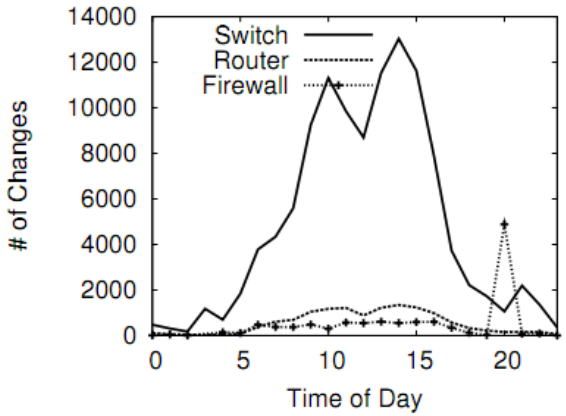
Minimal Visibility Into Performance

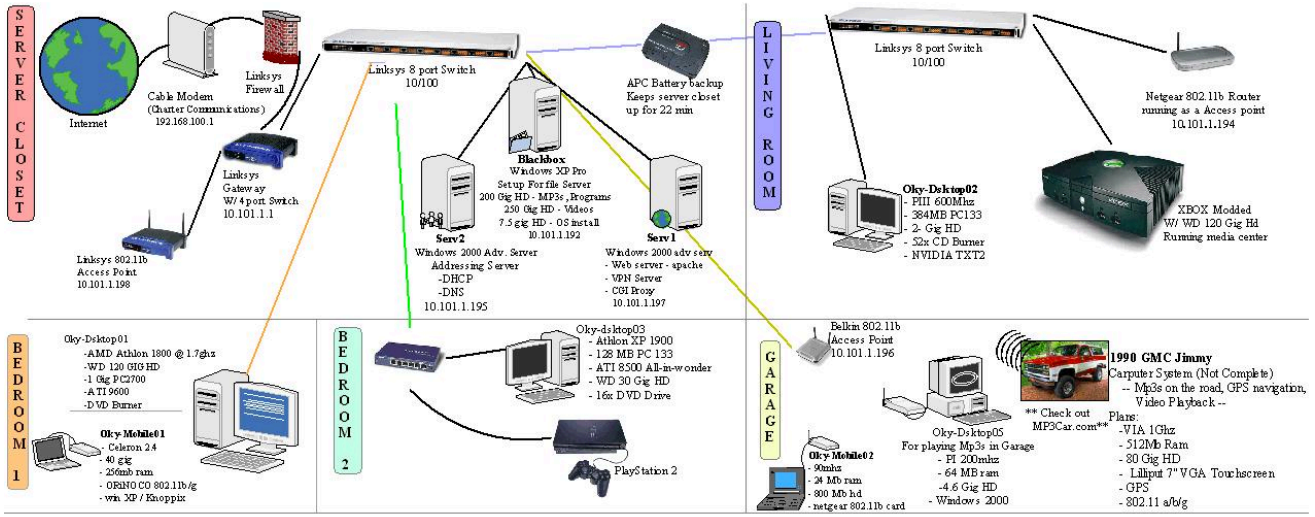


- **Access ISPs**
  - What performance are customers seeing?
  - Can they gain better visibility into downtimes?
  - Can visibility into problems help reduce service calls?
- **Content Providers**
  - How do content routing or traffic engineering decisions affect end user performance
- Also, consumers and regulators

Configuration is Complex, Low-Level

- A campus network may have
  - More than one million lines of configuration
  - Thousands of devices
  - Hundreds of thousands of changes every year
- Home networks can be complex, too

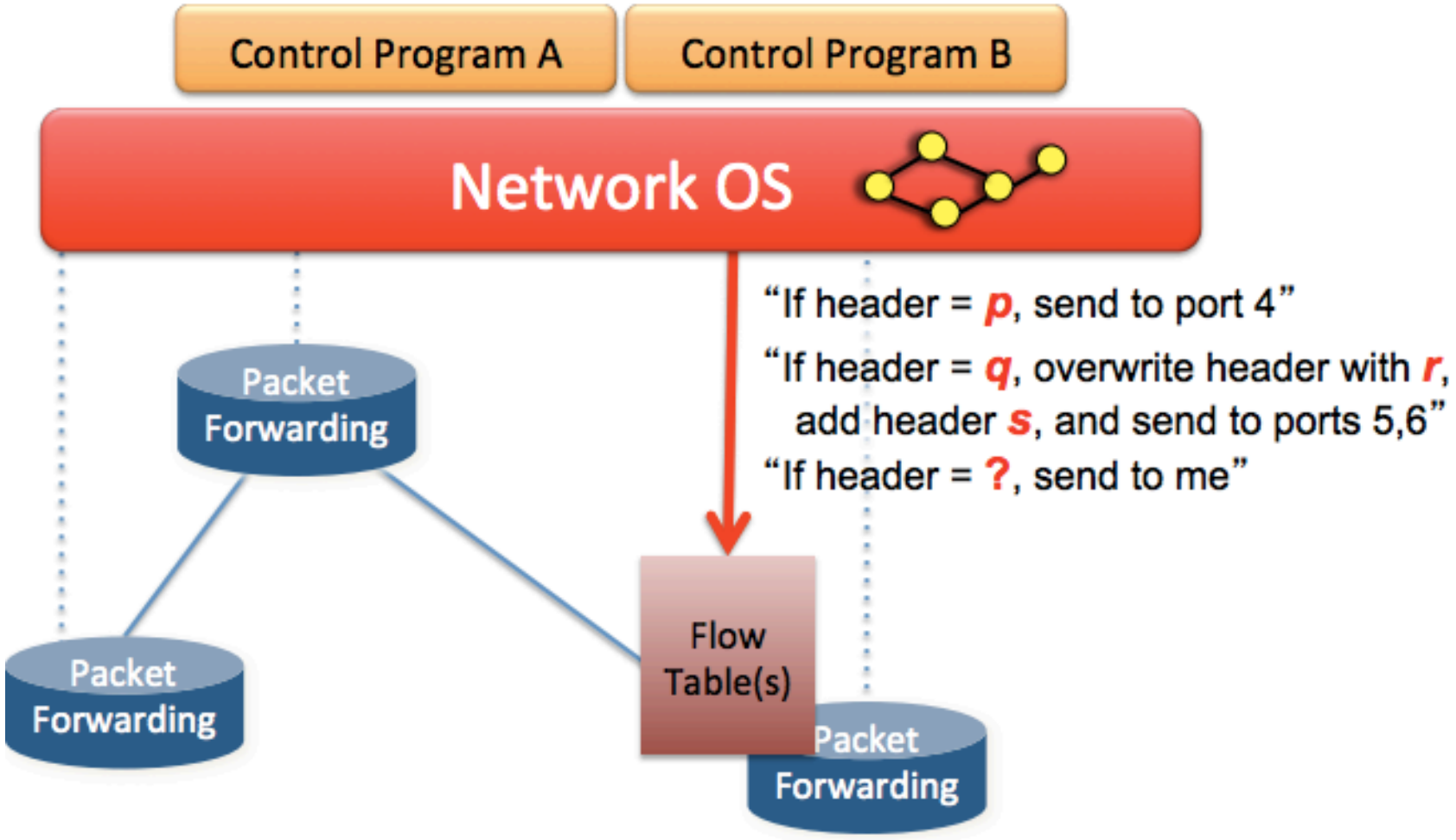




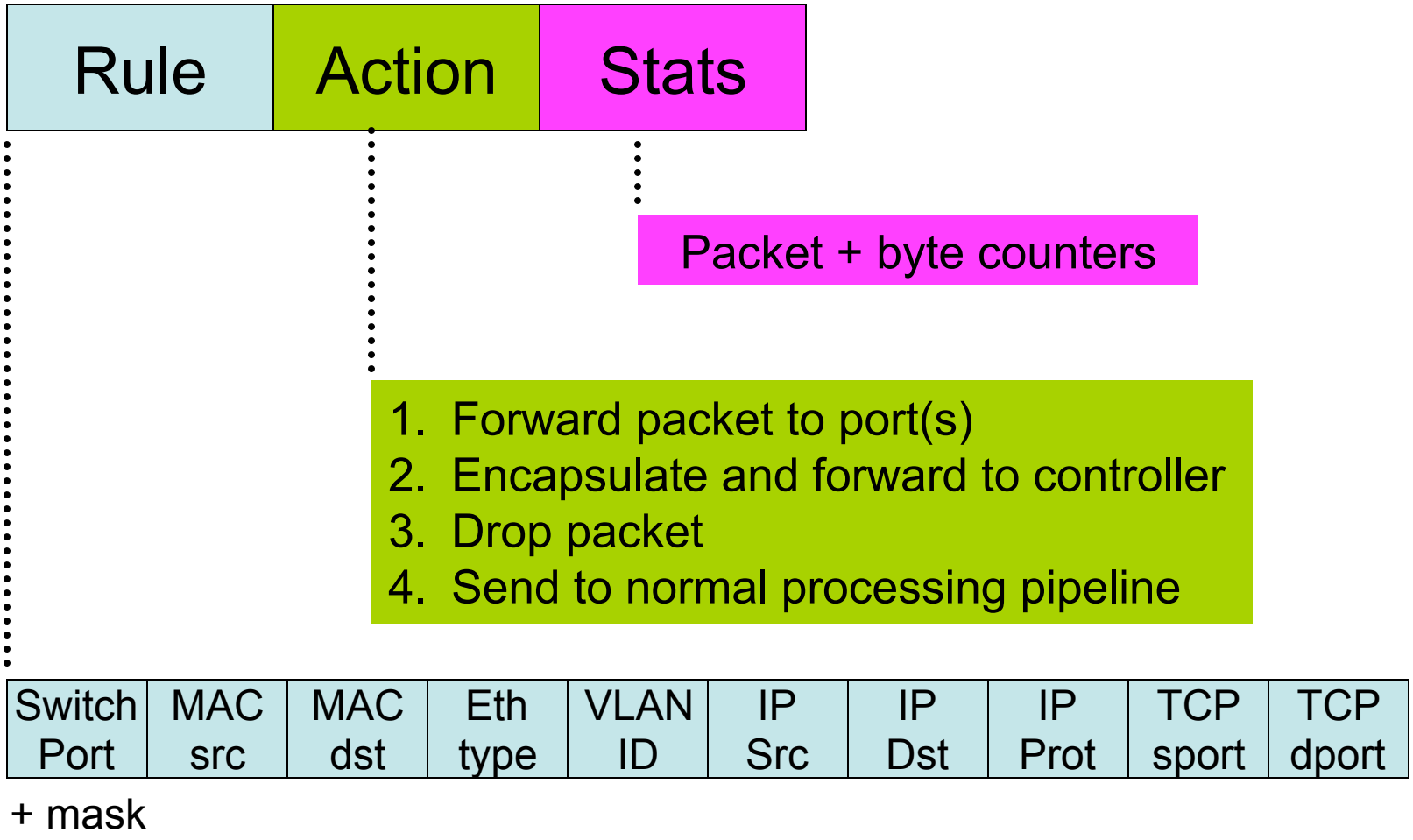
Addressing the Challenges

Challenge	Approach	System
Minimal Visibility and Control	Programmable Measurement Platform	BISmark
Frequent Changes	Event-Based Network Control	Lithium
Low-Level Configuration	High-Level Policy Language	Procera

SDN Forwarding Abstraction



OpenFlow 1.0 Flow Table Entry



Big Problem: Configuration Changes Frequently

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  - **Errors are also frequent**

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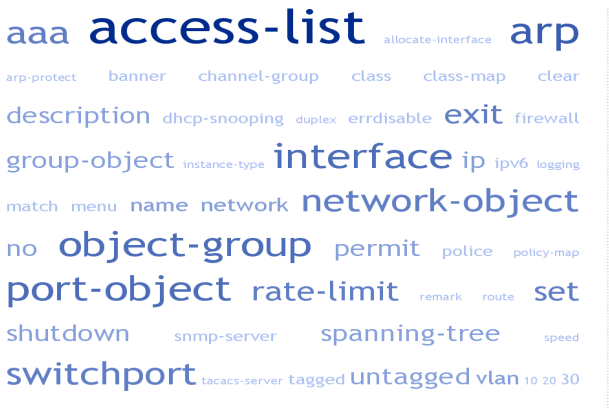


But, Network Configuration is Really Just Event Processing!

- Rate limit all Bittorrent traffic between the hours of 9 a.m. and 5 p.m.
- Do not use more than 100 GB of my monthly allocation for Netflix traffic
- If a host becomes infected, re-direct it to a captive portal with software patches
- …

BISmark: Bringing SDN Home

- Better monitoring and management of home and access networks
- **Deployment:** 225 Routers in ~30 countries

BISmark

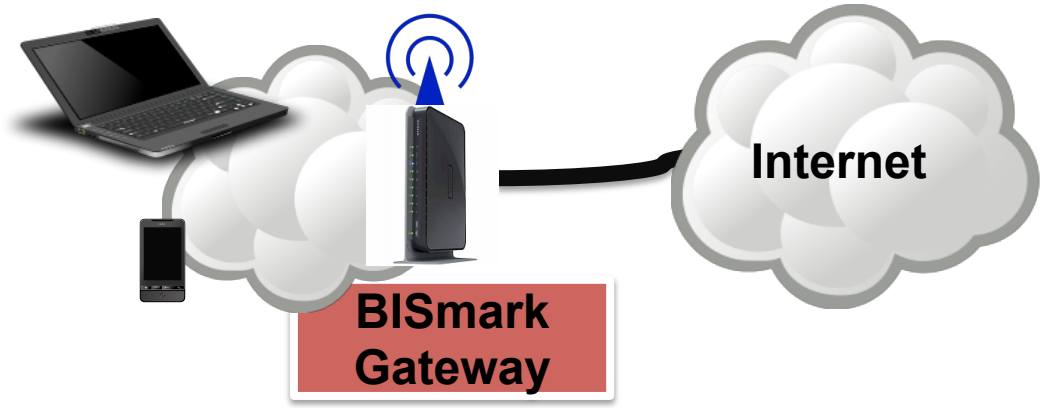
http://projectbismark.net/

BISmark: Better Home Networks

- **Monitoring and Measurement**
  - ISP performance
  - Wireless characteristics and interference
  - Traffic use inside the home
  - Security
  - Human activity patterns

- **Control (with Software Defined Networking)**
  - Usage cap management (ongoing w/HCI researchers)
  - Traffic prioritization (e.g., ensure file sharing does not clobber critical traffic)
  - Parental controls

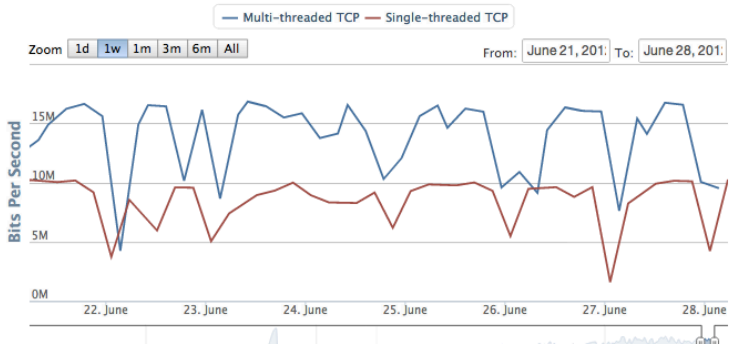
Better Visibility & Control



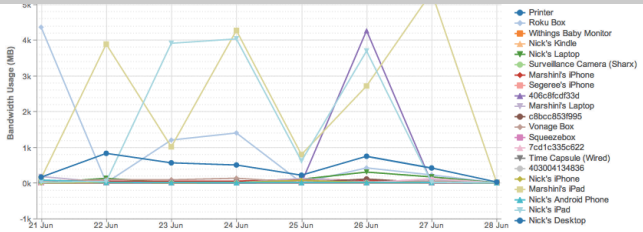
- Better visibility: Continuous performance monitoring
  - Network and application-level monitoring

- Better control: SDN
  - Control applications with simple programs and interfaces

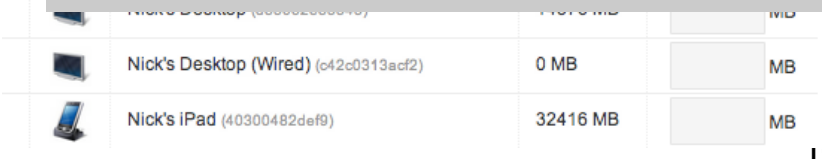
What is the network performance?



How do users use apps and devices?



Can we manage resource allocation ?

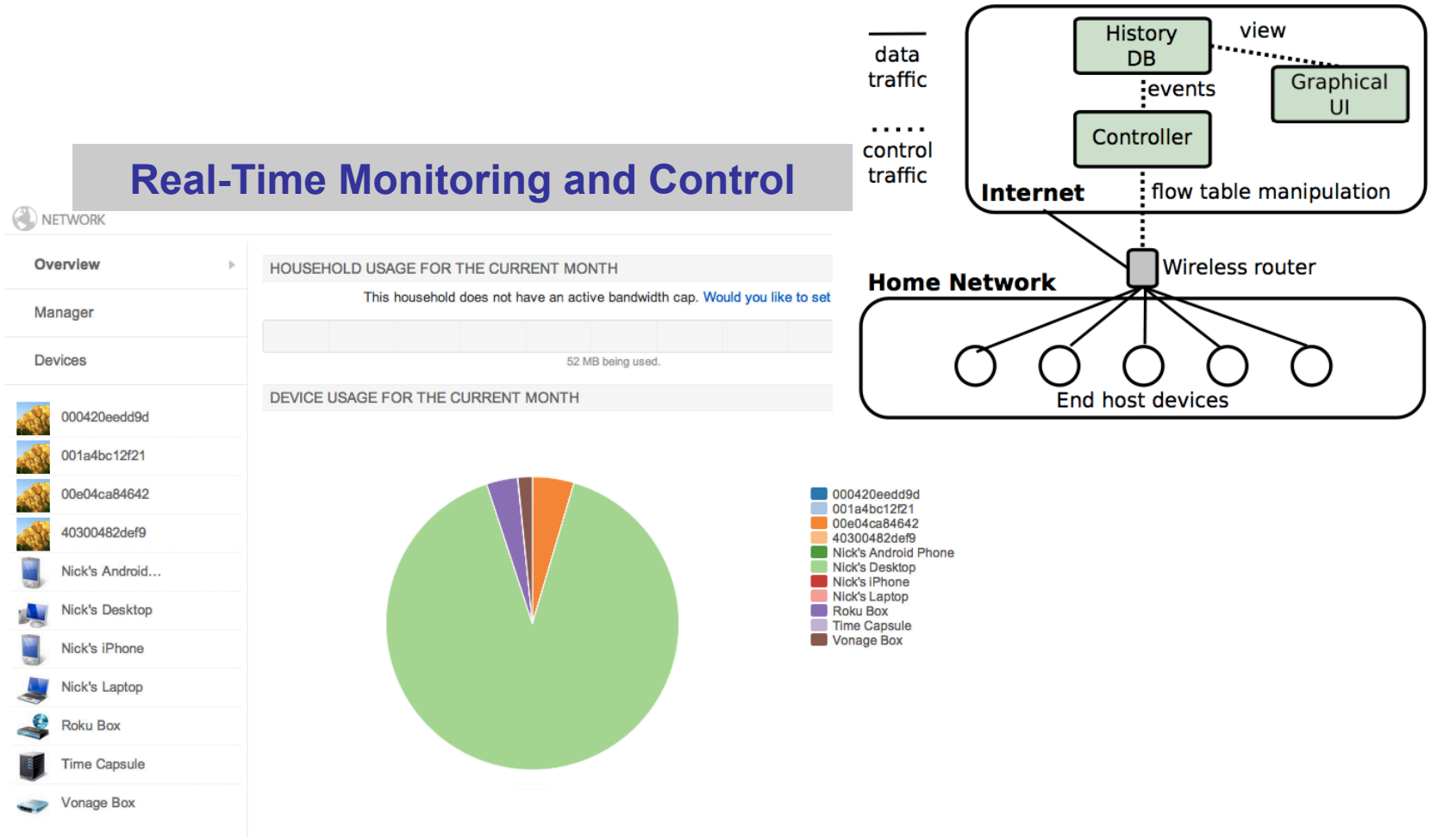


Usage Control in Home Networks

- Network management in homes is challenging
- One aspect of management: **usage control**
  - Usage cap management
  - Parental control
  - Bandwidth management

- **Idea:** Outsource network management/control
  - Home router runs OpenFlow switch
  - Usage reported to off-site controller
  - Controller adjusts behavior of traffic flows

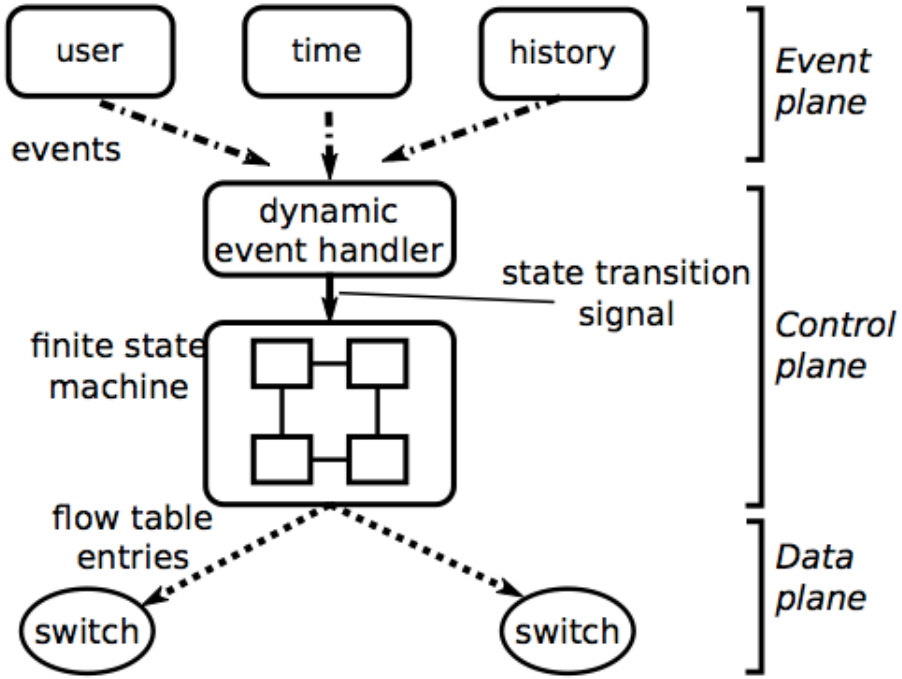
Control: SDN + Intuitive Interfaces



Joint work with Boris de Souza, Bethany Sumner, Marshini Chetty.

Lithium: Event-Based Network Control

Main Idea: Express network policies as event-based programs.

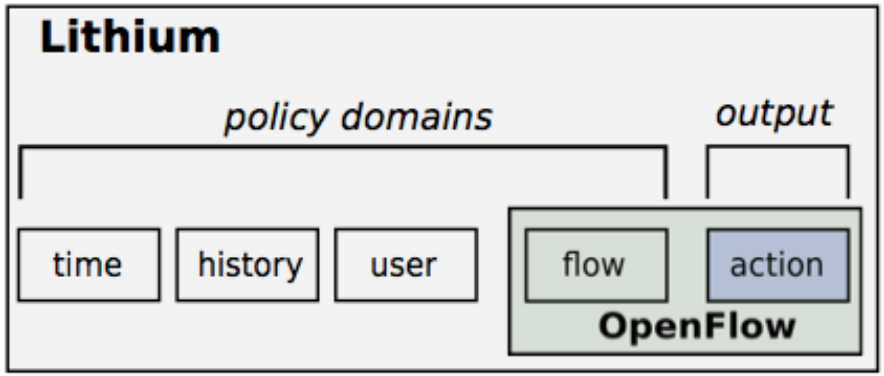


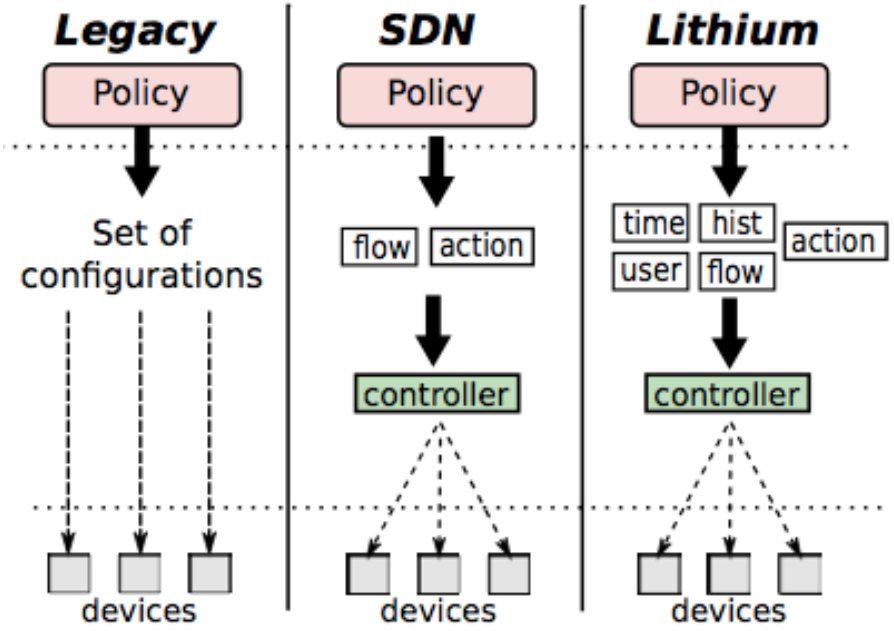
Resonance: Inference-Based Access Control for Enterprise Networks. Nayak, Reimers, Feamster, Clark. *ACM SIGCOMM Workshop on Enterprise Networks*. August 2009.

Extending the Control Model

- OpenFlow only operates on flow properties

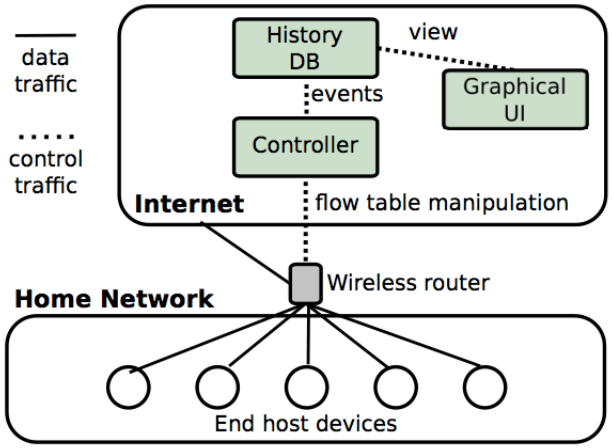
- Lithium **extends the control model** so that actions can be taken on **time**, **history**, and **user**

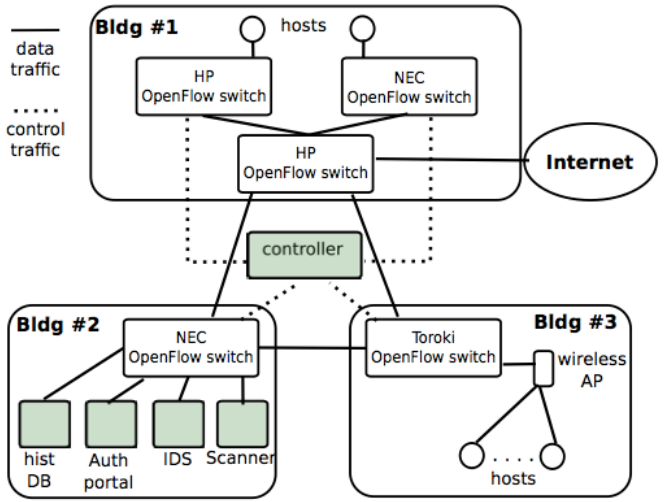




Two Real-World Deployments

- **Usage control in home networks**
  - Implementation of user controls (e.g., usage cap management, parental controls) in home networks
  - **Today:** Not possible
  - **With SDN:** Intuitive, simple
- **Access control in enterprise networks**
  - Re-implementation of access control on the Georgia Tech campus network
  - **Today:** Complicated, low-level
  - **With SDN:** Simpler, more flexible





Deployment Status

- Over 300 routers deployed in home networks “in the wild”
- Collaboration with Measurement Lab on monitoring network performance from various regions and ISPs.
- Ongoing trials with several ISPs as part of private deployments

- Firmware
  - OpenWrt, with luci web interface
  - IPv6-capable
- Netgear 3800 router
  - Atheros chipset
  - MIPS processor, 16 MB flash, 64 MB RAM
  - Gigabit ethernet
  - 2.4 GHz *and* 5 GHz radio

Ongoing Extensions

- **More measurements:** Denser deployments (e.g., apartments)
- **Broader scope:** More measurements (e.g., integration with Tor's OONI project)
- **Sensor fusion:** Tighter integration with other in-home, *in situ* sensing capabilities (e.g., phones)
- **Open programming interface:** Enable other researchers to perform measurements

The Need for a Policy Language

- Network policies
  - Are **dynamic**
  - Depend on **temporal conditions** defined in terms of external events
- Need a way to configure these policies **without resorting to general-purpose programming** of a network controller
- Intuitive user interfaces can ultimately be built on top of this language

The Need for Reactive Control

- Simple policies are doable in FML: “Ban the device if usage exceeds 10 GB in the last 5 days”

```
deny(Us, Hs, As, Ut, Ht, At, Prot, Req) <- over(Hs).
over(Hs) <- usage(Hs,lastDays(5),amt), amt > 10.
```

  - But, adding **temporal predicates** is difficult!
    - “Remove the ban if usage drops below 10 GB.”
    - “Remove the ban when an administrator resets.”

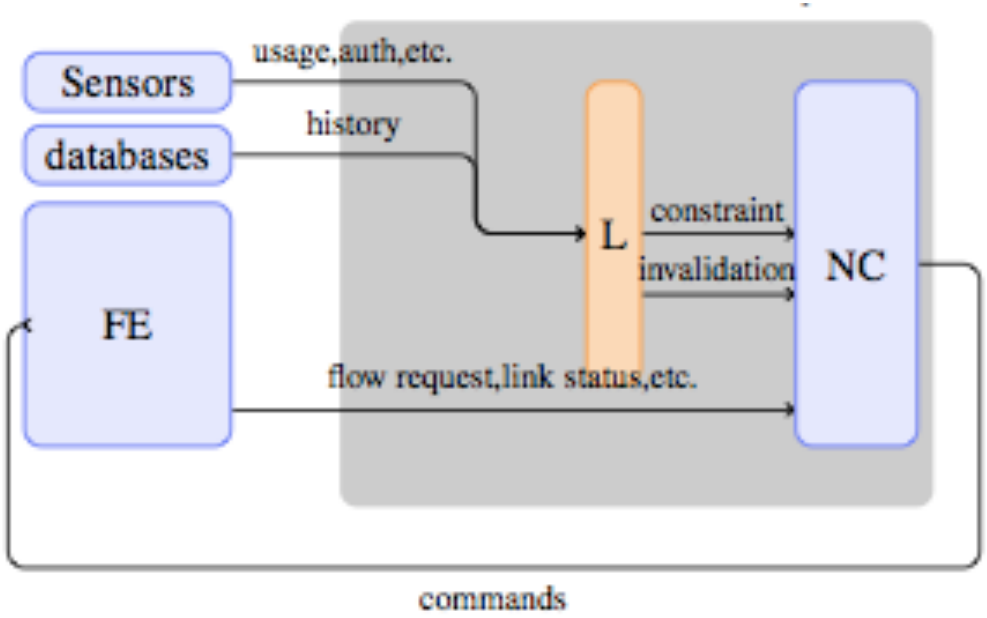
  - Each condition requires a new predicate.

```
over(Hs) <- usageOnceExceeded(Hs,lastDays(5),10).
```

Language Design Goals

- **Declarative Reactivity:** Describing when events happen, what changes they trigger, and how permissions change over time.
- **Expressive and Compositional Operators:** Building reactive permissions out of smaller re-active components.
- **Well-defined Semantics:** Simple semantics, simplifying policy specification.
- **Error Checking & Conflict Resolution:** Leveraging well-defined, mathematical semantics.

Procera: Programming Reactive, Event-Based Network Control



Define a signal function for a device going over (or under) the usage cap:

```
overUnderEvent =
  proc env → do
    capMap ← capTracker ⪻ env
    usagedb ← usageTracker ⪻ env
    usageChanges ← usageChangesTracker ⪻ env
    let now = calendarTime env
    let over src =
      monthlyUsage usagedb now > capMap ! src
    condSplit over ⪻ usageChanges
```

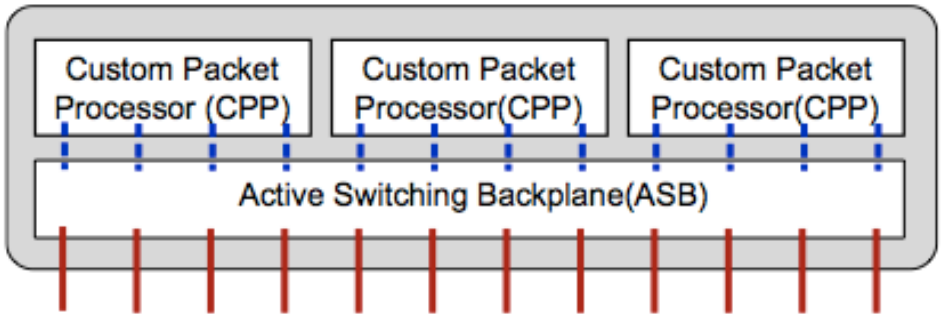
Define the set of devices over the cap:

```
overSetStream =
  proc env → do
    (over, under) ← overUnderEvent ⪻ env
    toSetStream ⪻ (over, under)
```

- **Controller:** signal functions and a flow constraint function
- Receives **input signals** from environment
- Periodically updates a **flow constraint function** that controls the forwarding elements

Next Steps: Faster, Programmable Data Plane

- Augment OpenFlow switches with **custom packet processors**
- **Device abstraction layer** to allow programmability of this substrate
  - Single device
  - Network wide
- **Applications**
  - Big data applications
  - On-the fly encryption, transcoding, classification
  - Selective deep packet inspection



Summary

- Software Defined Networking can simplify network monitoring and management, but we still need new control models.

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- **BISmark:** Better visibility and control of home networks
- **Lithium:** Event-based network control
- **Procera:** Policy language for SDNs
- Next
  - A fast, programmable data plane for SDN