Evolution of Internet Routing

Ahmed Saeed

Limitations of BGP

- In terms of route control
  - BGP provides more control to packet source
  - An AS can pick the next hop of a packet but has little control over how packets arrive to it
- In terms of traffic characteristics
  - BGP captures only destination IP-prefixes
  - Video, web, and teleconference traffic all treated the same
- In terms of policy
  - BGP provides indirect expression of policies
  - An AS can set MED and local preference as a proxy for monetary cost

Gupta, et al. "SDX: A software defined internet exchange." SIGCOMM ‘14
Zhao, et al. “Unison: Enabling Content Provider/ISP Collaboration using a vSwitch Abstraction.” ICNP ‘19

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Recall that BGP is simple because it is the minimal interface between all Internet participants that everyone has to agree on

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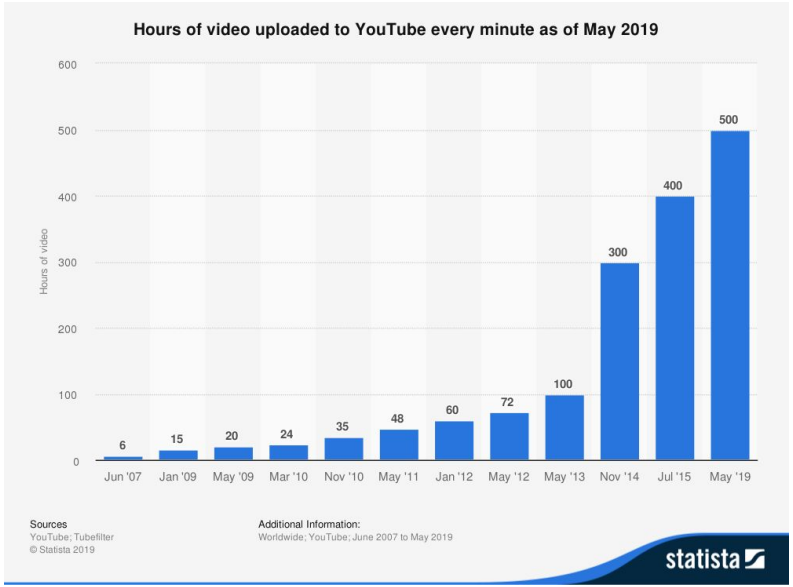
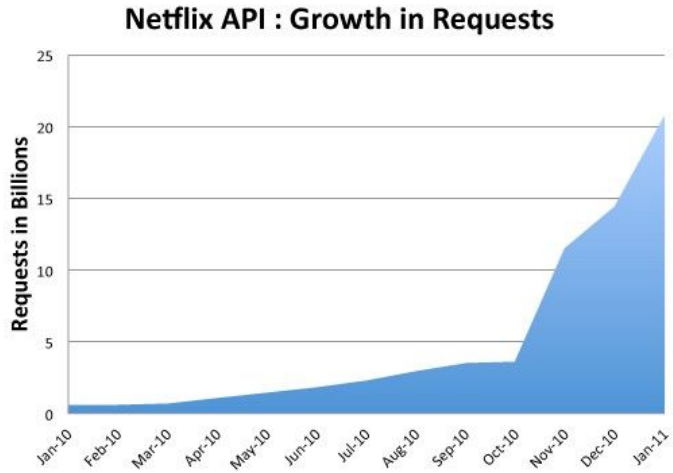
What changed?

Video came along ...



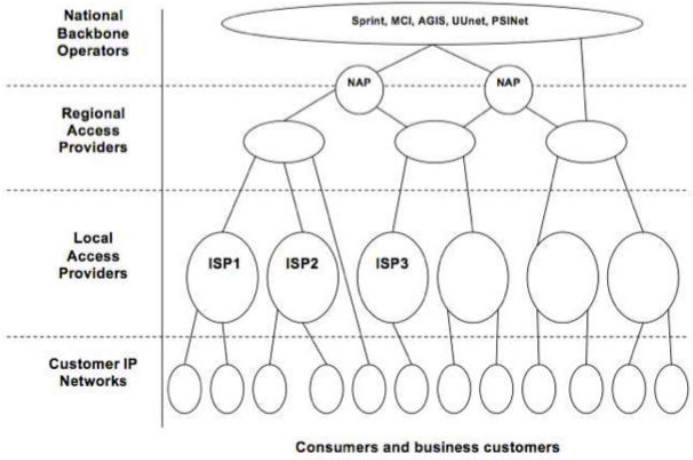
Source: statista based on youtube reported statistics
https://www.statista.com/statistics/259477/hours-of-video-uploaded-to-youtube-every-minute/

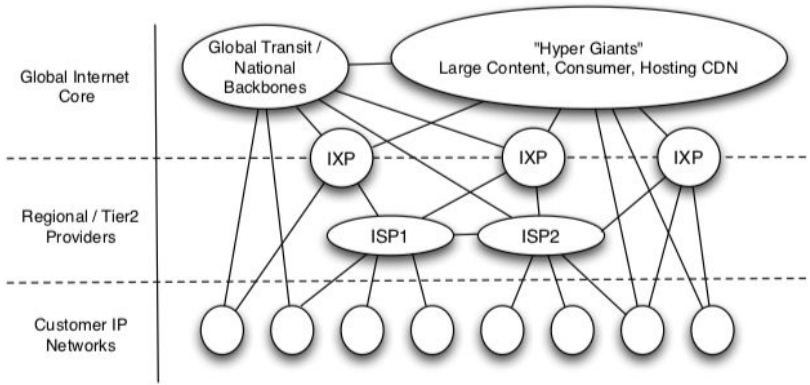


Source: The Netflix Tech Blog
https://medium.com/netflix-techblog/redesigning-the-netflix-api-db5a7221fcff

Changes in Internet Topology

- Internet is becoming more flat
  - ASes are directly connected through peering links forming a peering mesh





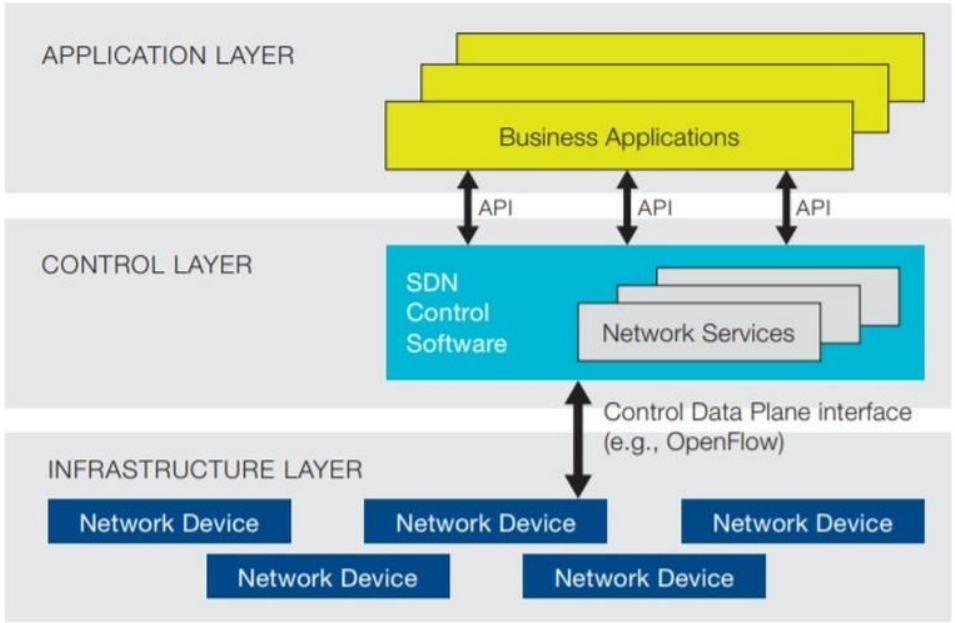
Sketch of Internet topology till around 2007

Sketch of Internet topology starting around 2009

Main result: Dhamdhere and Dovrolis. "The Internet is flat: modeling the transition from a transit hierarchy to a peering mesh." CoNEXT ‘10
Sketches from: Labovitz, et al. "Internet inter-domain traffic." SIGCOMM ‘10

Software Defined Networks

- SDN allows for explicit expression of policies in the form of applications
- Applications are translated into forwarding rules that are executed by the network devices
- SDN has been deployed with remarkable success within several large autonomous systems



Source: https://www.zdnet.com/article/software-defined-networking-101-what-sdn-is-and-where-its-going/

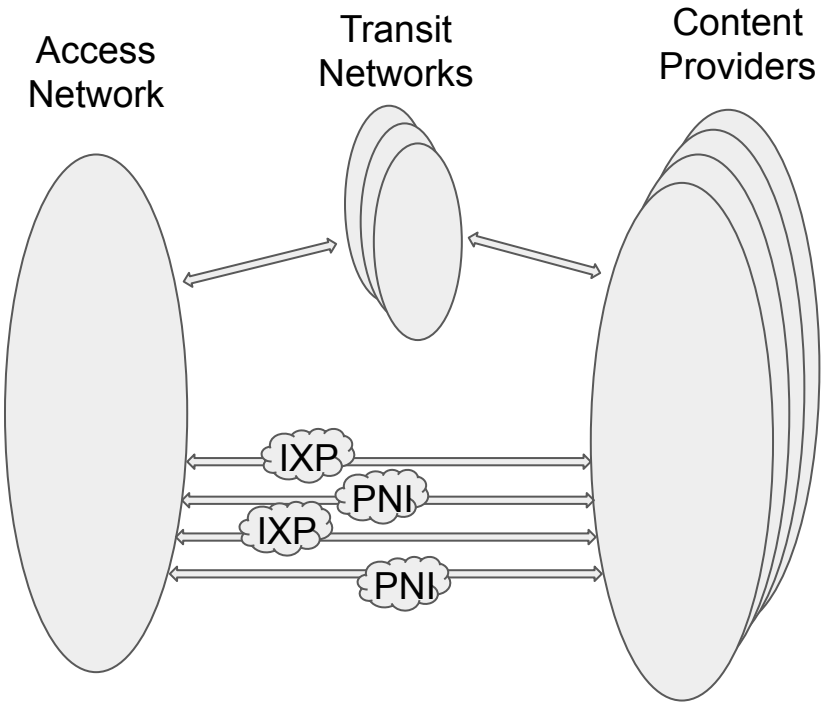
How do we redesign Internet routing?

Internet Routing Should Capture ...

- Per-application requirements
- Load balancing
- Differentiation of service
- Congestion control
- ...

Architecture

- A flat Internet has Access Networks connected directly to Content Providers
  - Content Providers encourage this through open peering policies
- Direct connection is done through Internet Exchange Points (IXPs) or Private Network Interconnection (PNI)



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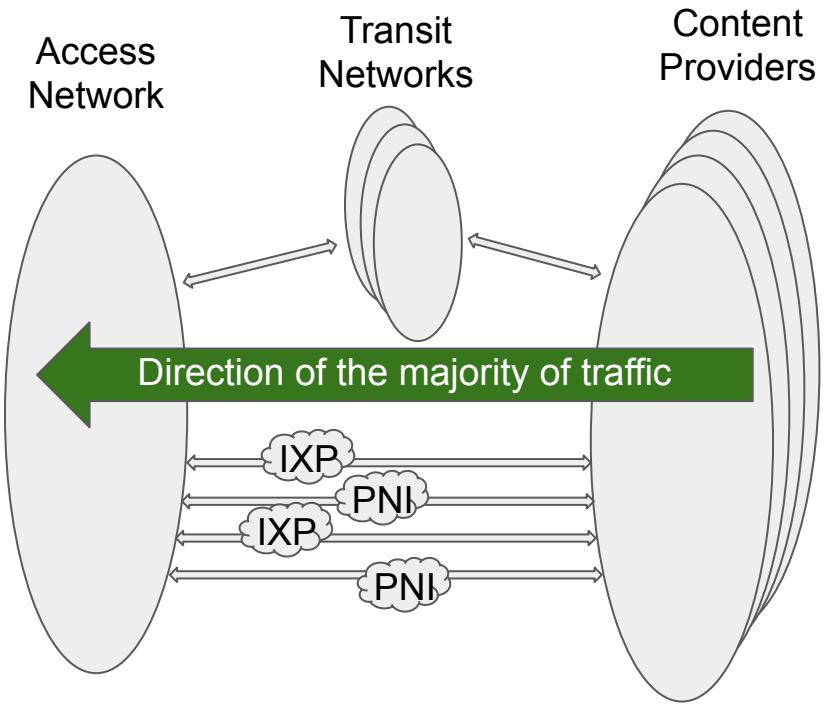

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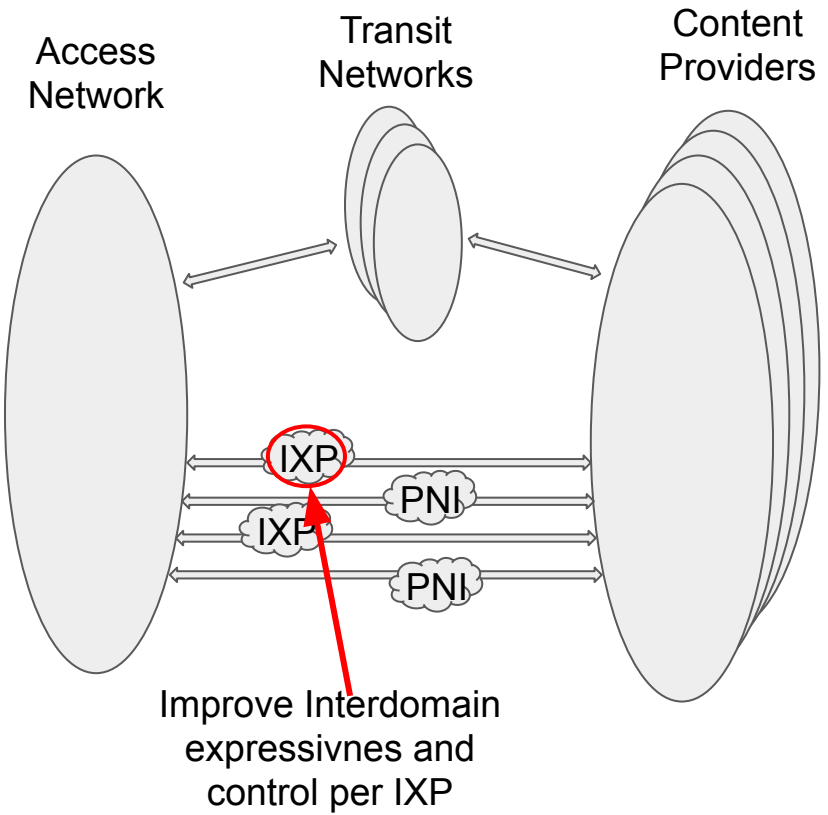

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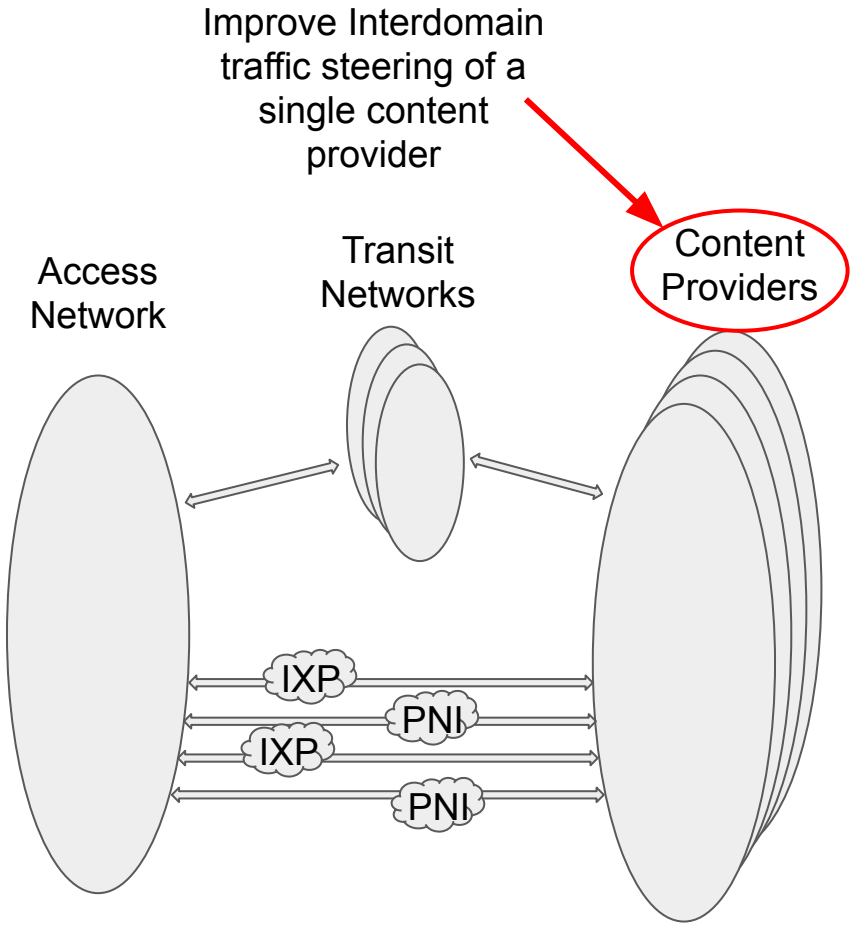

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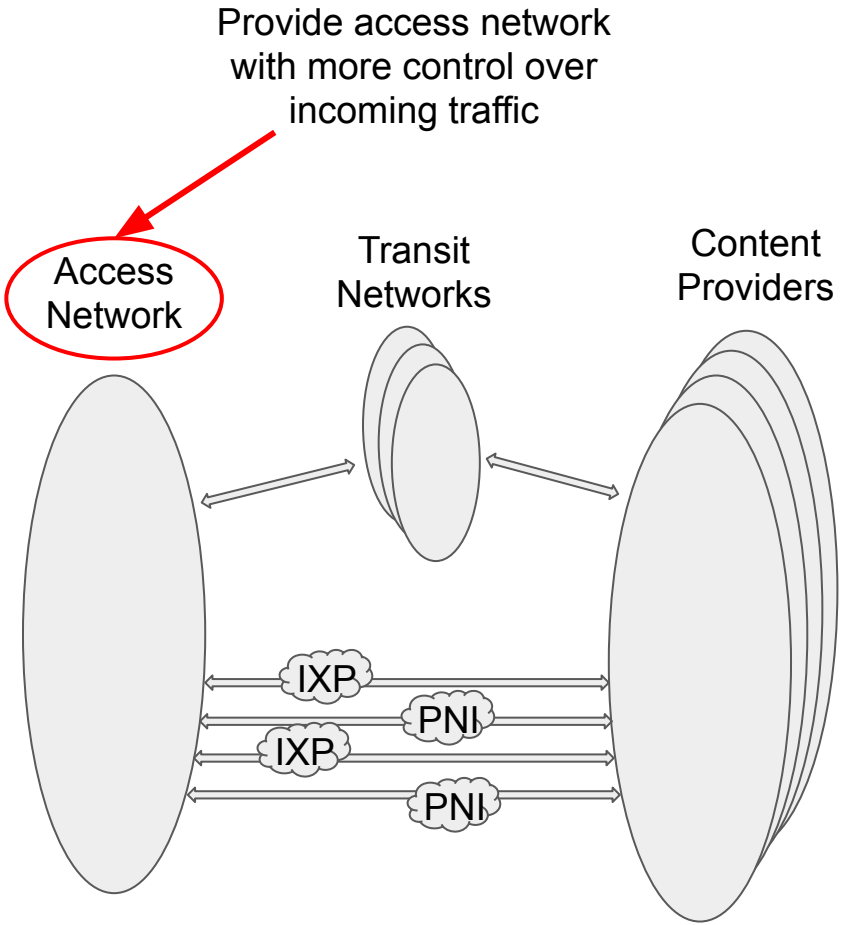
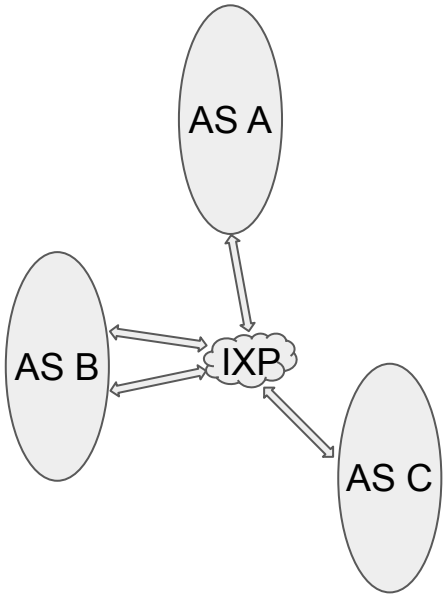
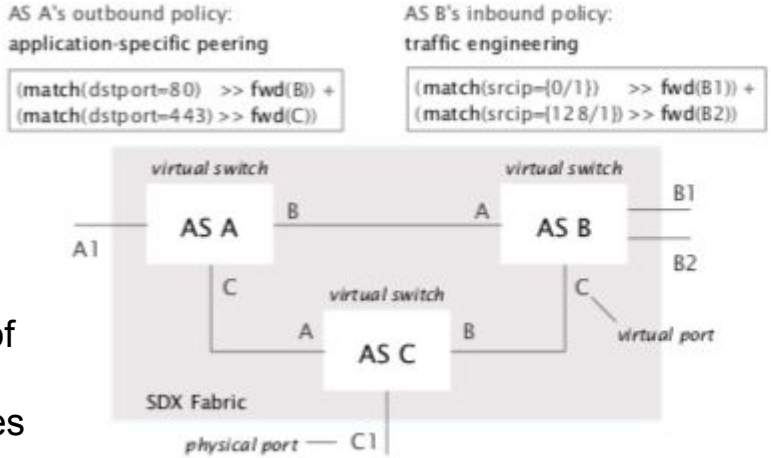


SDX: A Software Defined Internet Exchange



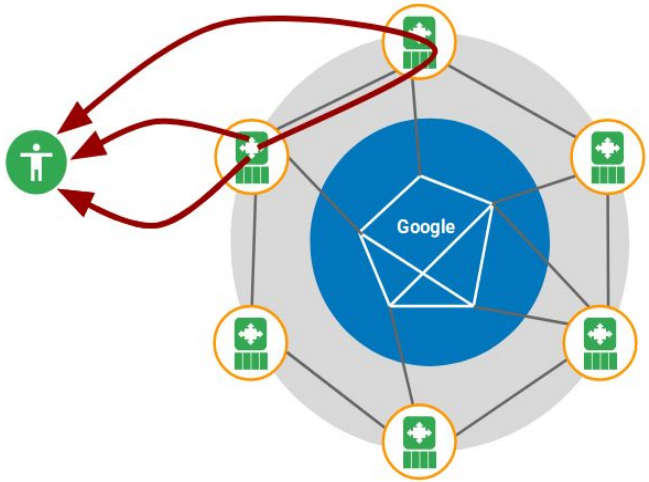
Abstracts this topology as a set of virtual switches that can be programmed using SDN primitives



Gupta, et al. "SDX: A software defined internet exchange." SIGCOMM '14

Content Provider

- A content provider can observe different available routes to a user and choose the best route
  - Route selection can be done centrally per packet across the entire AS (Google's approach)
  - Route selection can be done on a per-PoP basis limiting the choices to links with the PoP



Yap, Kok-Kiong, et al. "Taking the edge off with espresso: Scale, reliability and programmability for global internet peering." SIGCOMM '17

Should the decision be made solely by the CP?

- A content provider picks between many alternative routes

Zhao, et al. “Unison: Enabling Content Provider/ISP Collaboration using a vSwitch Abstraction.” ICNP ‘19

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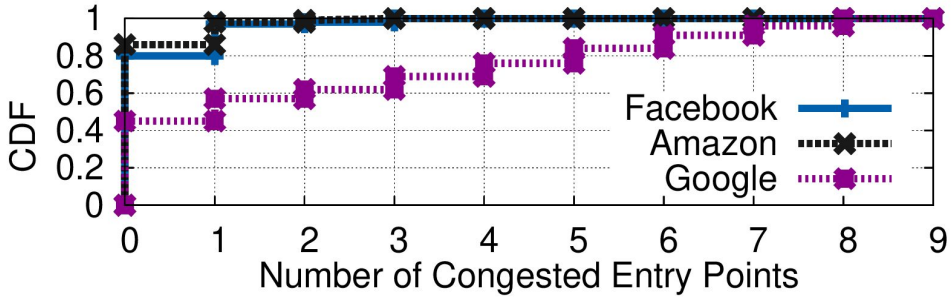

- How can the Content Provider assess the state and choose between routes within the access network?

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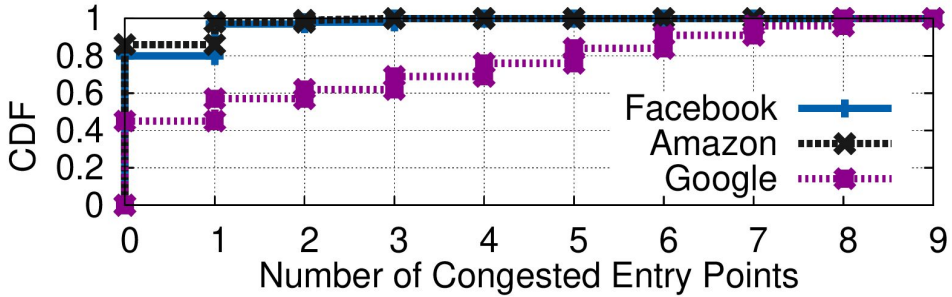

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The Access Network can help the Content Provider choose between alternative routes and even optimize its own network to react to such choices

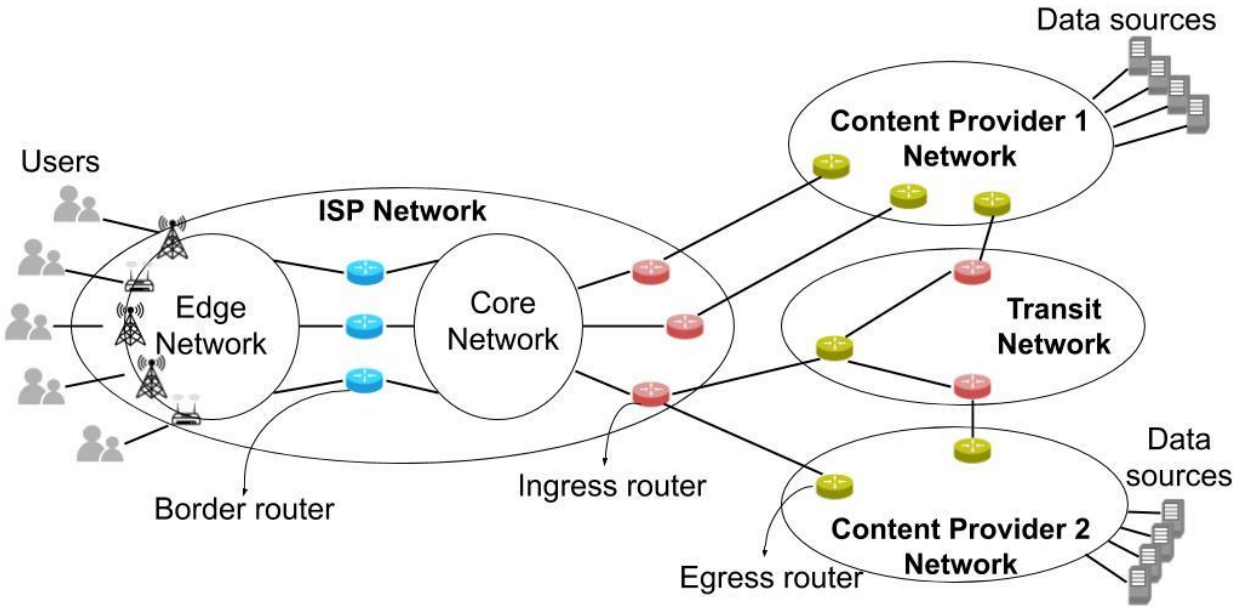
Zhao, et al. “Unison: Enabling Content Provider/ISP Collaboration using a vSwitch Abstraction.” ICNP ‘19

Enabling ISP/CP Collaboration

- Design goals
  - Benefit both CPs and ISP
  - Limited info disclosure
  - Not all CPs have to cooperate

- Solution: Provide an abstraction of the ISP network that can be programmed based on CP preferences that is then used to guide CP routing decisions

Abstracting the ISP Network



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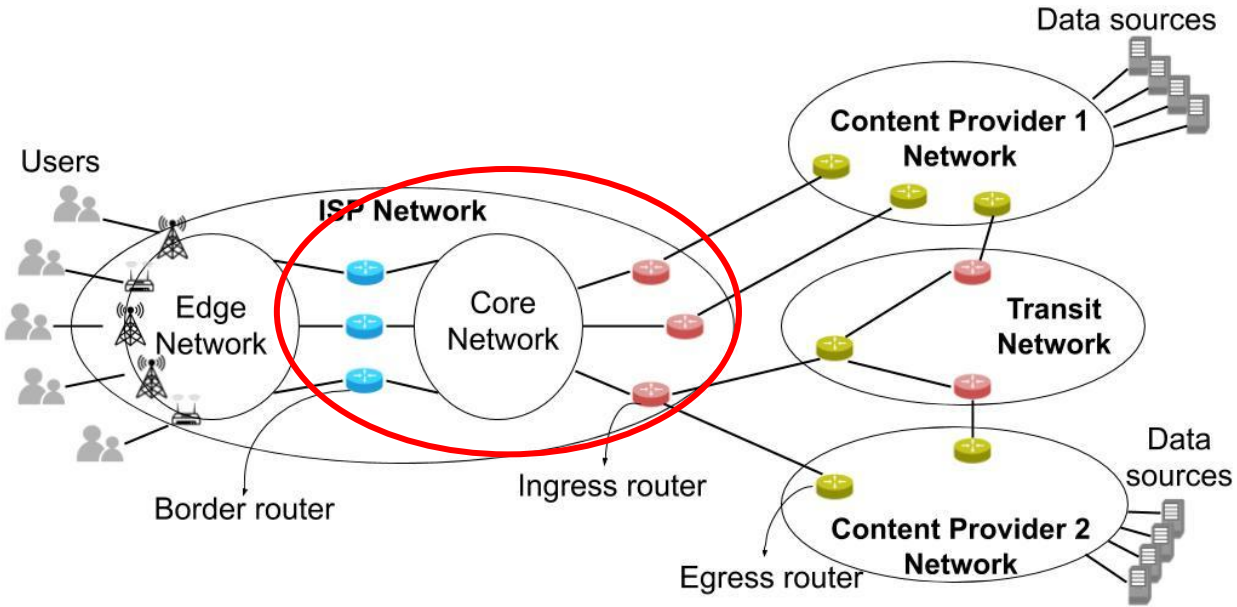

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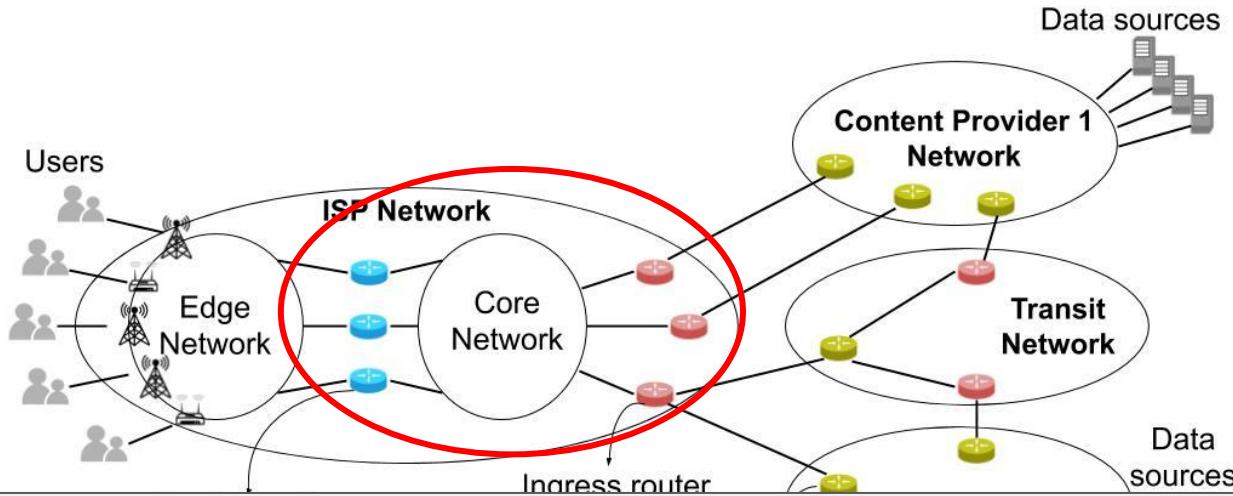
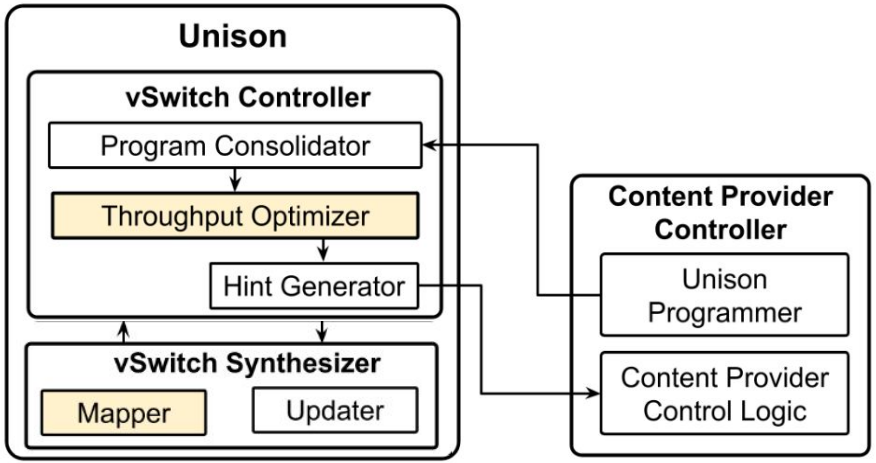
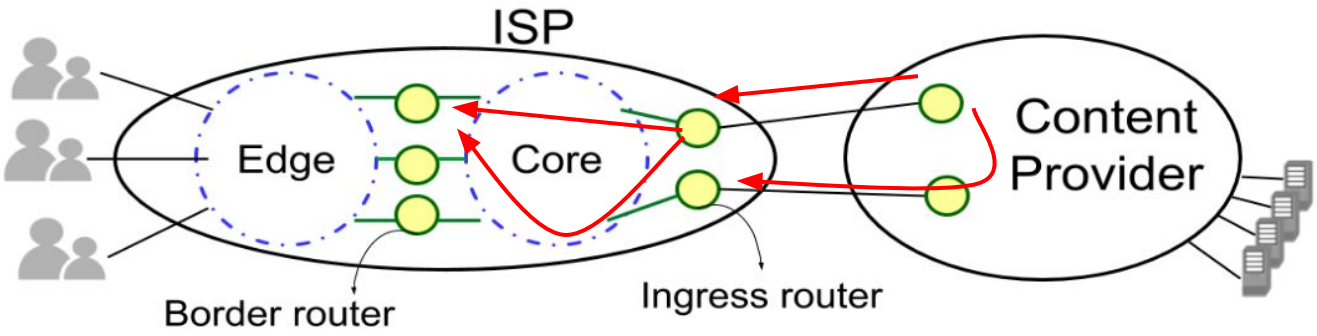


The Core Network can be viewed as a switch with ingress routers as input ports and egress routers as output ports

Unison Overview

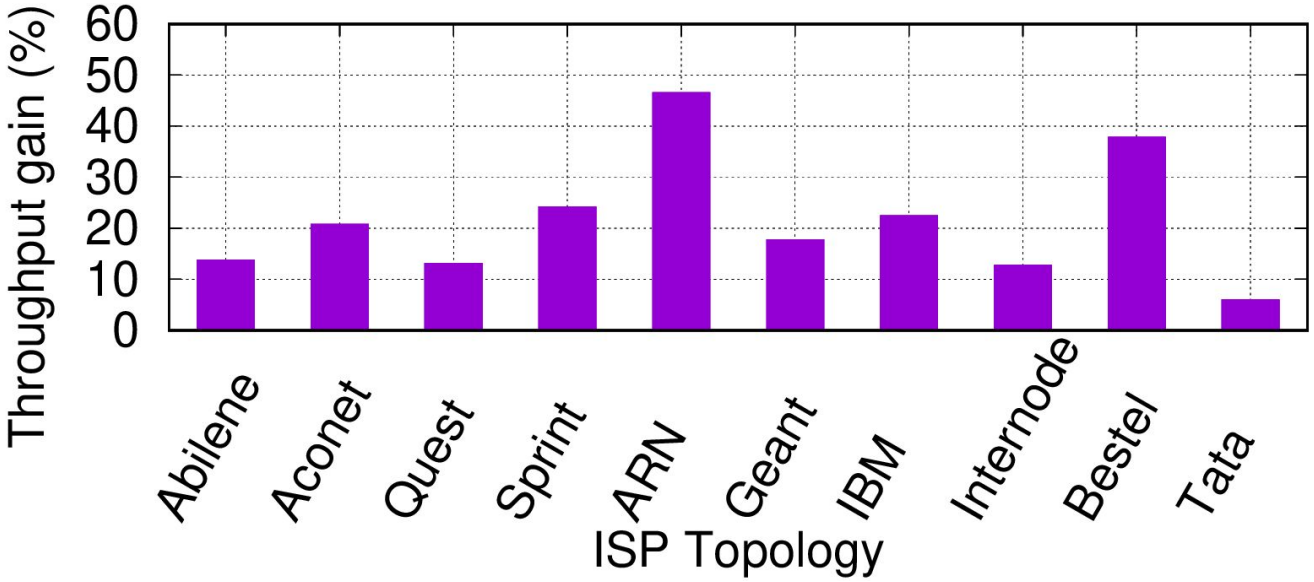




Example of a Unison Application

- Objective: maximize total bandwidth of an ISP
- Constraints:
  - No link capacity is exceed
  - Weighted fairness among CP allocation
- Handle non-cooperating CPs
  - Estimate traffic matrix
  - Optimize intra-domain v.s. not optimize intra-domain routing
- Heuristic algorithm for weighted bandwidth allocation

Simulation Results



Jointly optimizing inter-intra-domain routing improves ISP throughput

Takeaways

- Internet topology is evolving, making control over an important segment of Internet traffic easier
- Technology is improving, providing better tools to express policies and automatically control traffic
- It is time to rethink how Internet routing is performed which is becoming feasible at least for the flat part of the Internet