Efficiently Delivering Online Services over Integrated Infrastructure

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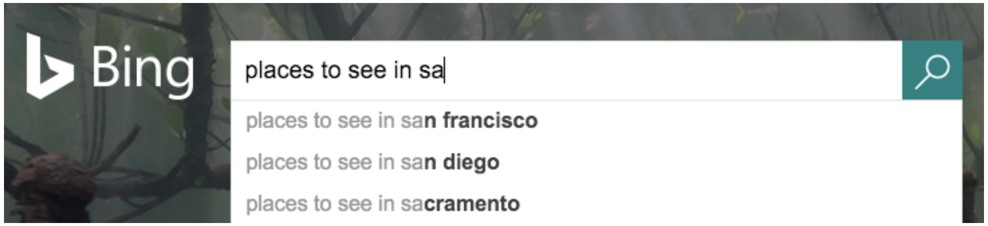
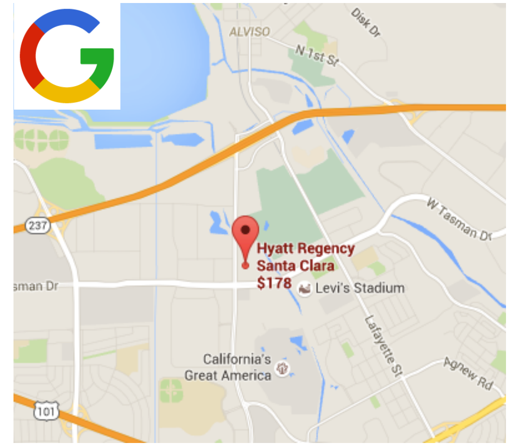
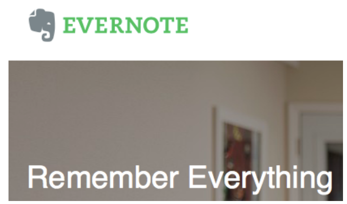
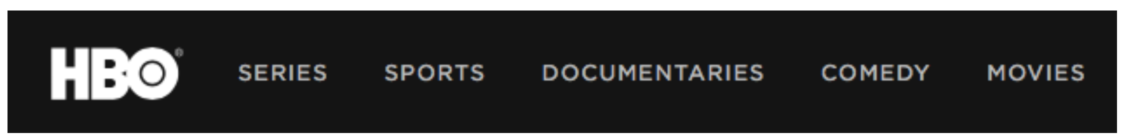
Online Services

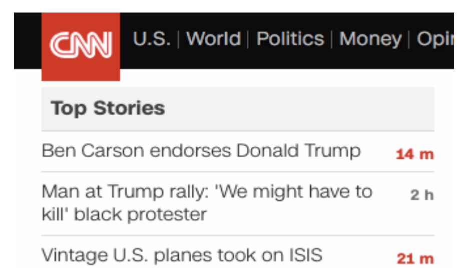


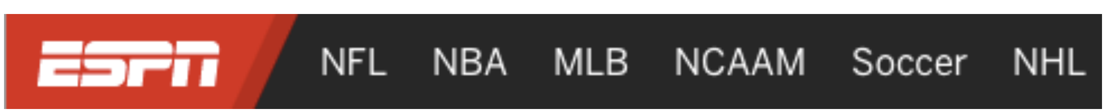




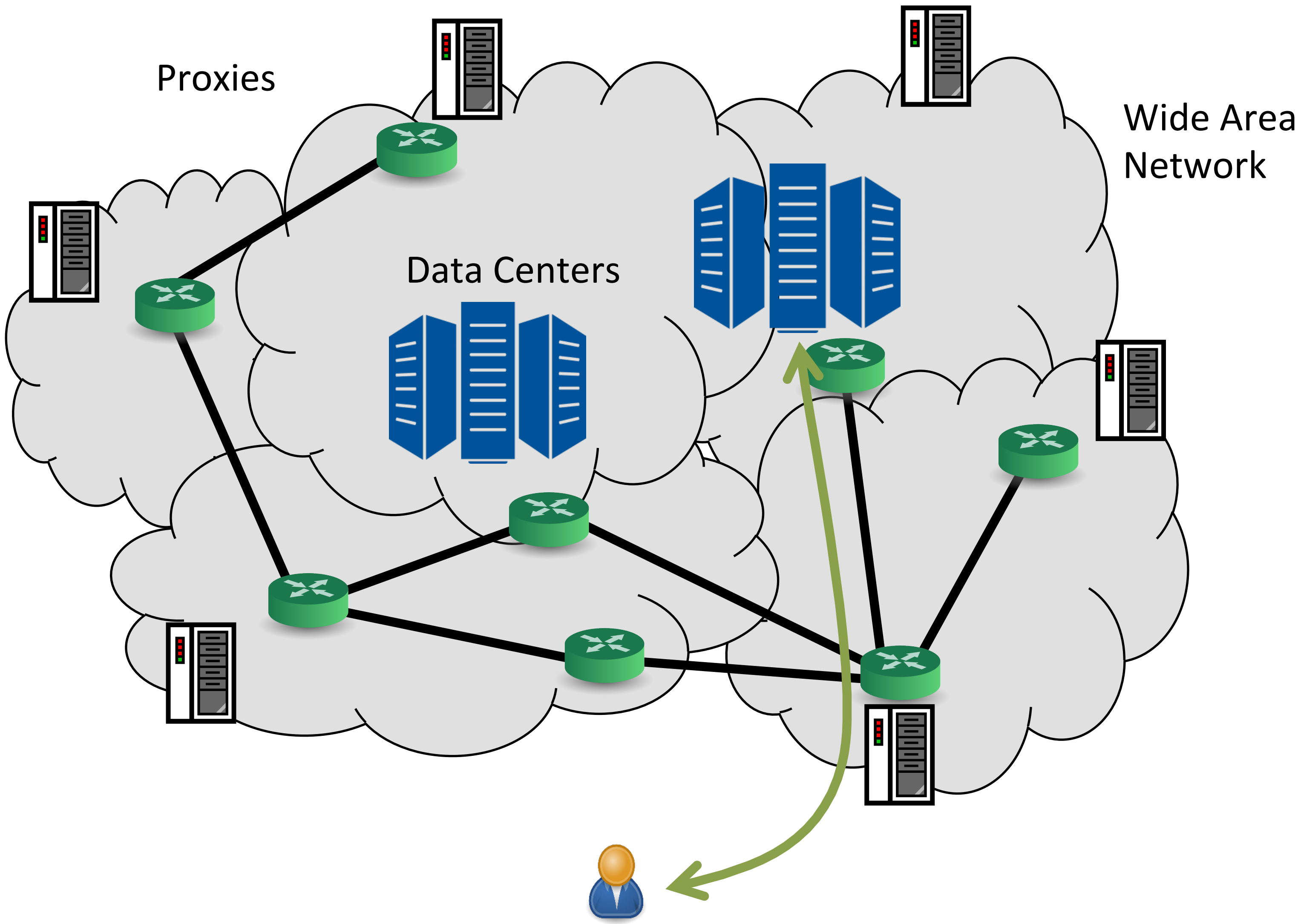


stackoverflow

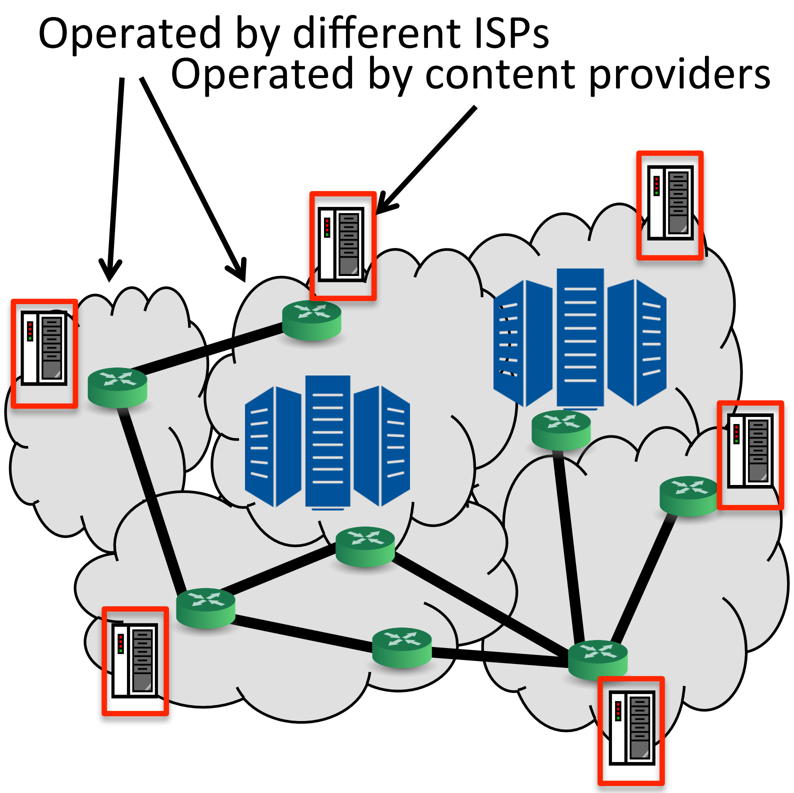




Online Service Delivery Infrastructure

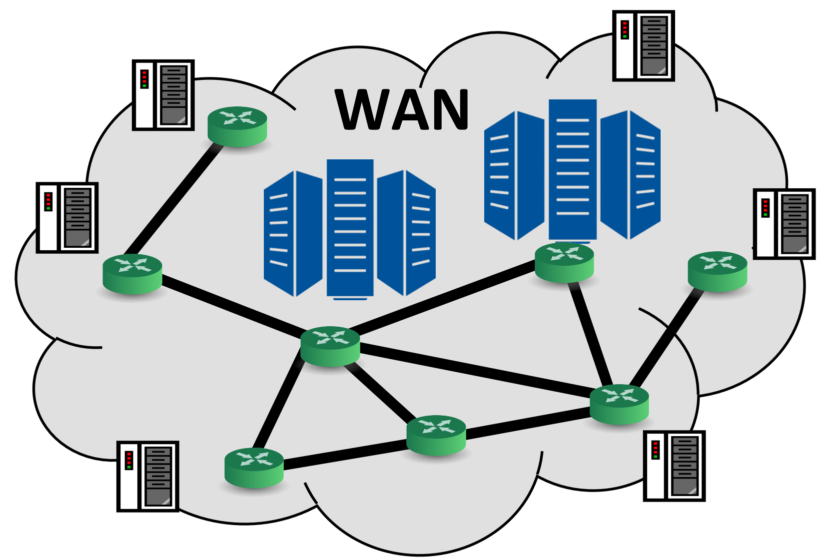


Online Service Delivery is Evolving



Multiple owners

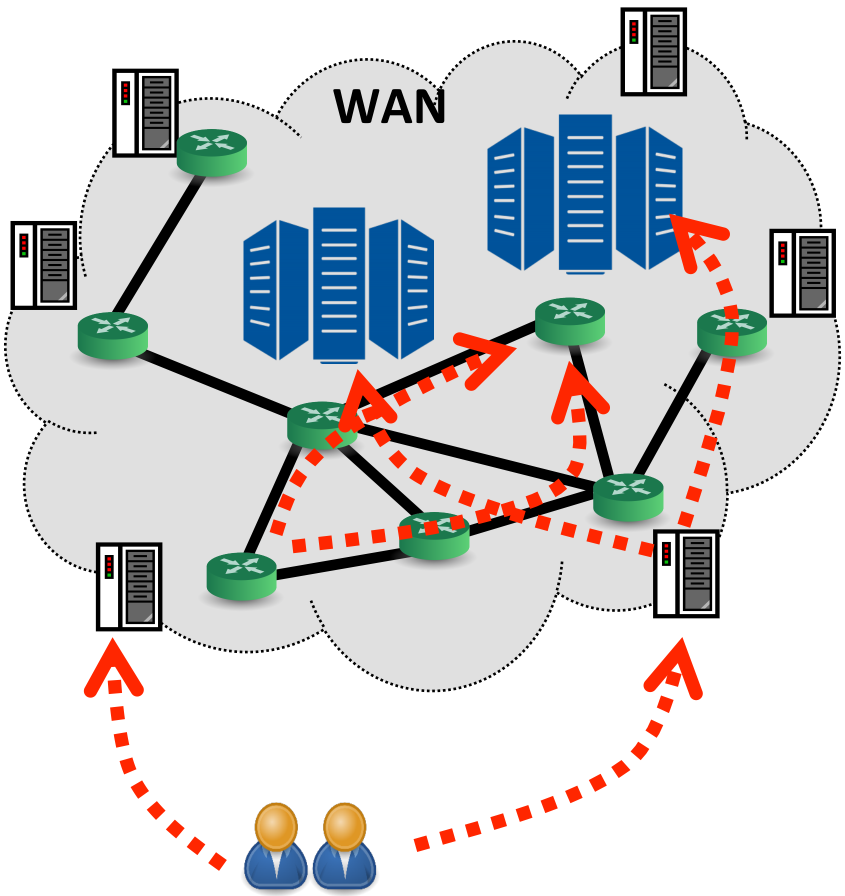
Traditional infrastructure



Owned by a single entity

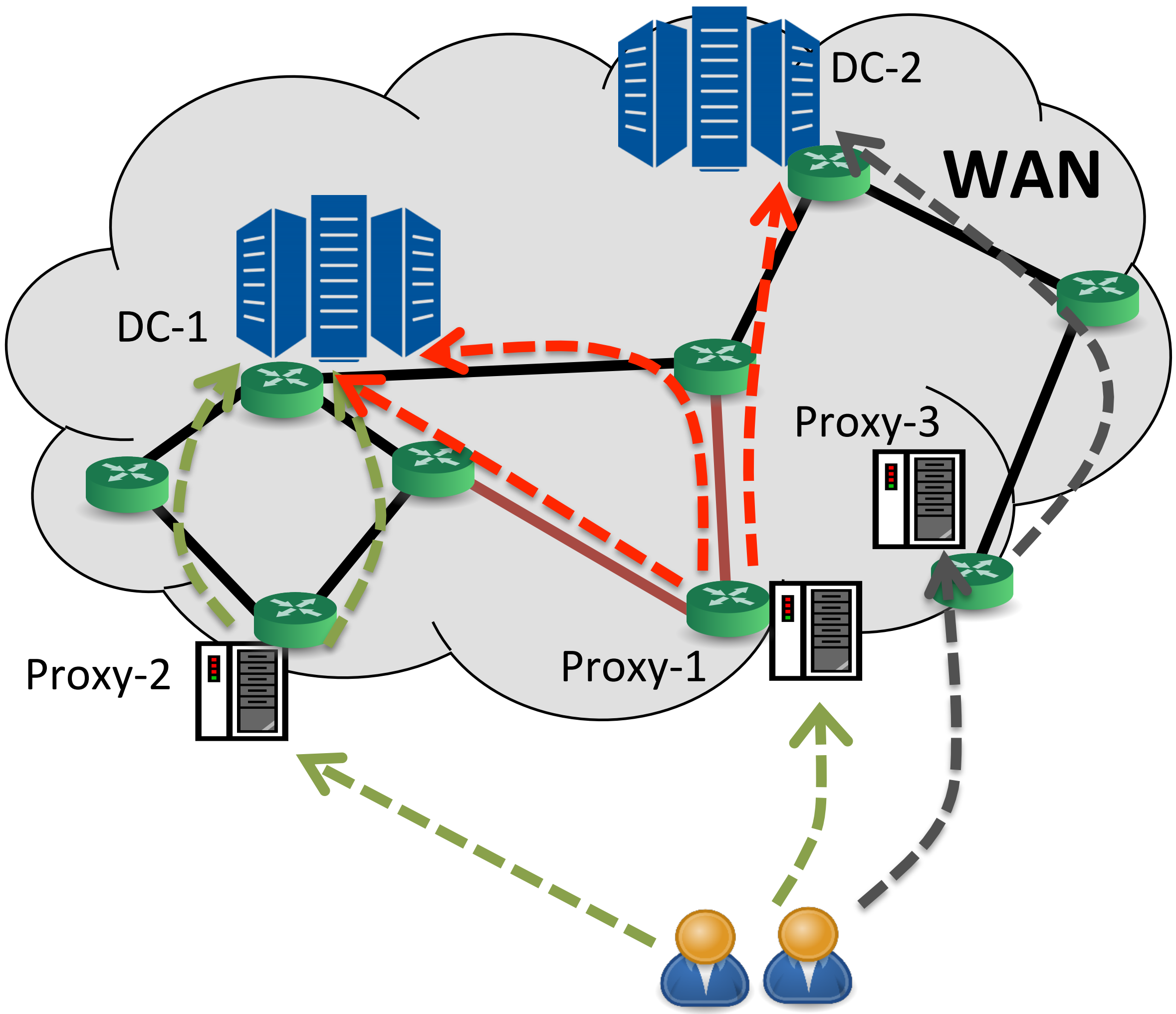
Integrated infrastructure

Integrated Infrastructure Enables Joint Control of All Decisions



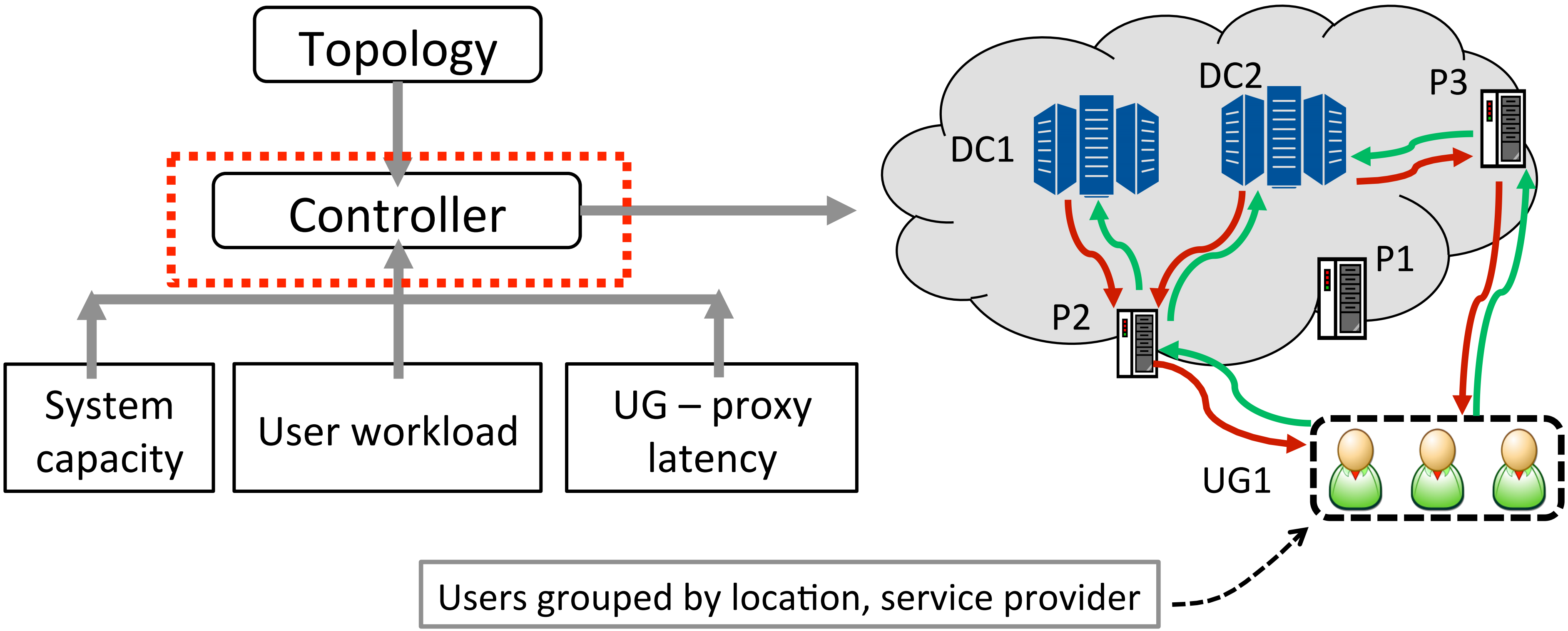
1. User – Proxy mapping
2. Proxy – DC mapping
3. Paths in the wide area network

Advantages of Joint Control



- Increase **efficiency**: total traffic without congestion
- Improve **performance**: aggregate end-to-end latency

Footprint: Jointly Controls the Integrated Infrastructure



Control decisions for a user group:

- UG—proxy mapping
- proxy—DC mapping
- network paths

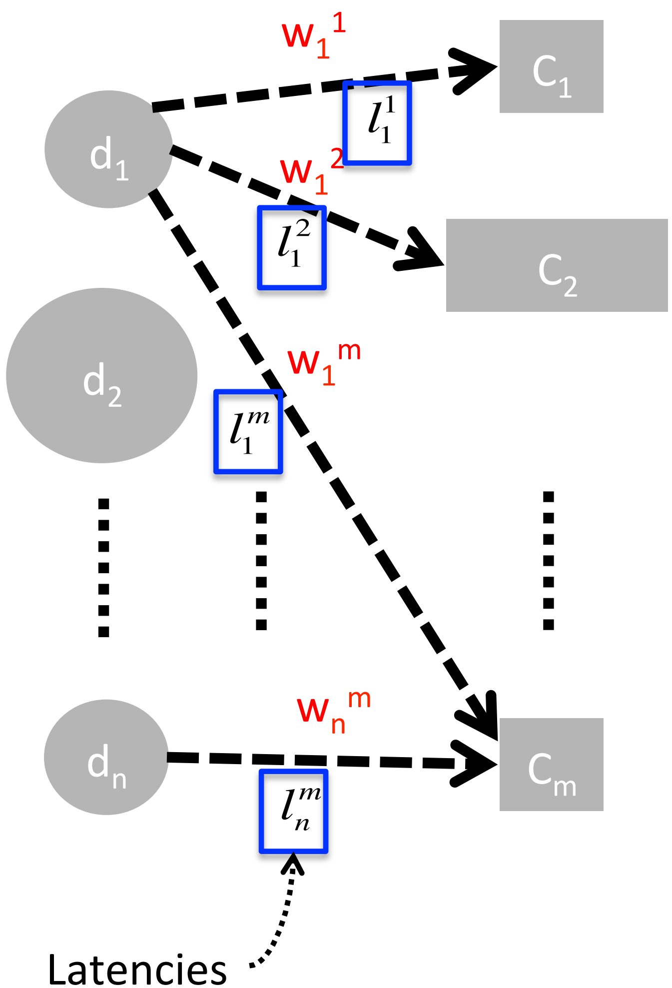
Goals:

- Maximize congestion free traffic
- Minimize end-to-end latency

Outline

- Challenges in computing forwarding configuration
- Other challenges in realizing Footprint
- Evaluation

Computing Configuration: Basic Approach



Estimated user demands for an epoch

$$\{d_1, d_2, \ldots, d_n\}$$

Resource capacities

$$\{C_1, C_2, \ldots, C_m\}$$

Estimated load from user ‘u’ on resource ‘r’

$$n_u^r = d_u . w_u^r$$

Capacity constraint for resource ‘r’

$$n^r = \sum_u n_u^r \leq C_r$$

Linear Program

Objective

maximize $$\sum_u \sum_r n_u^r - \sum_u \sum_r l_u^r n_u^r$$

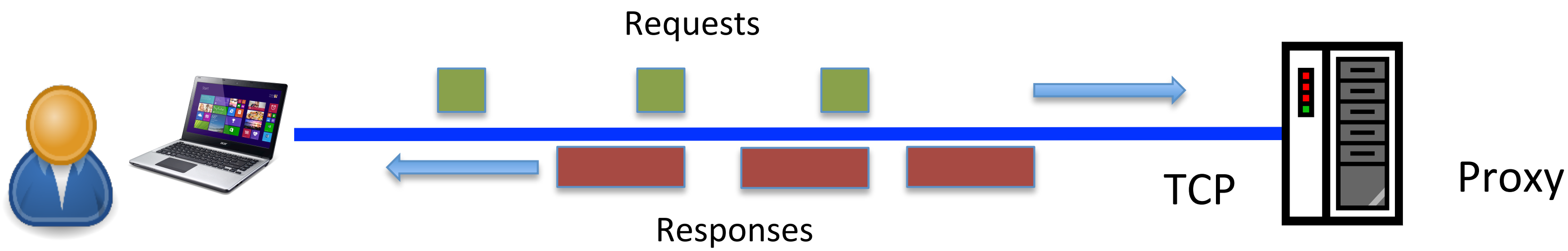
Does such a simple model suffice ?

No

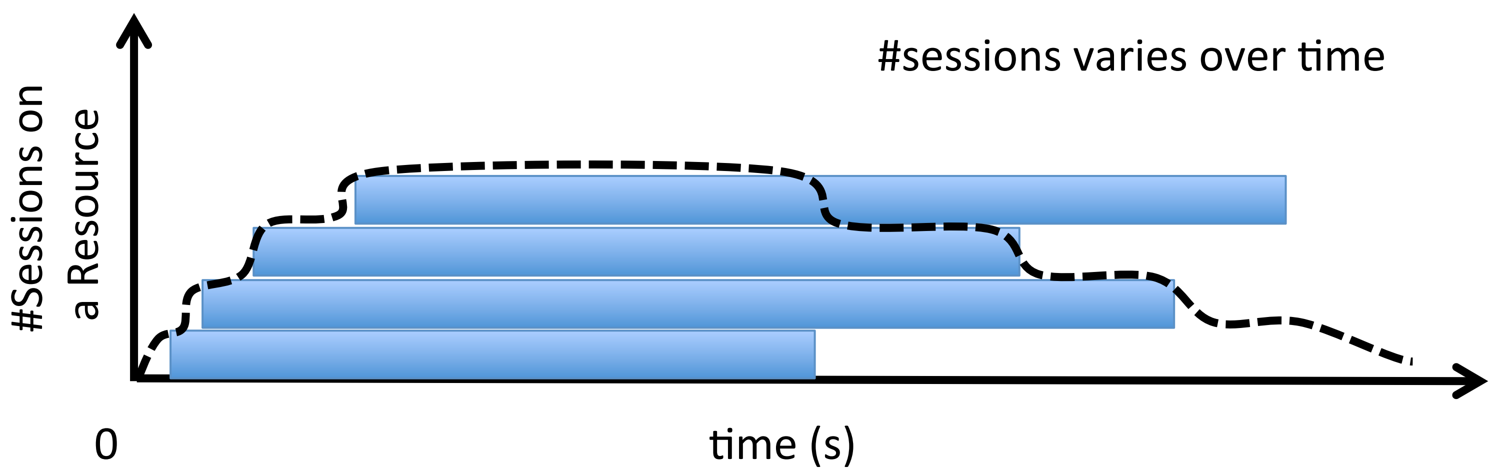
Because of the nature of traffic from different online applications

User Traffic Arrives over Sessions

- Multiple requests and responses over a single session

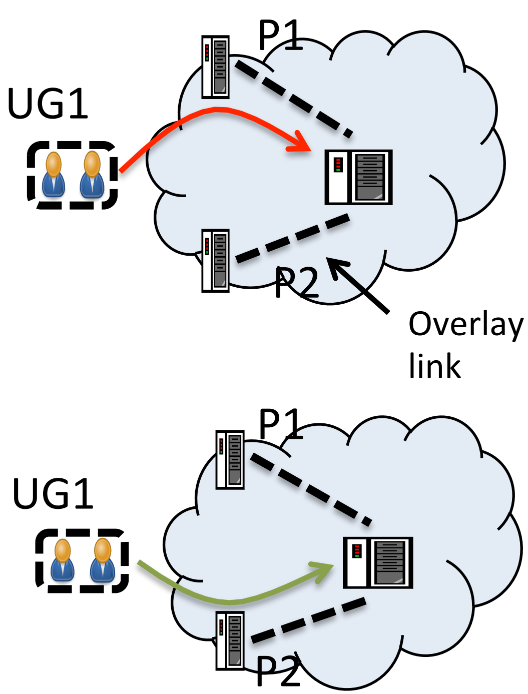


- Sessions are long-lived and arrive all through the duration of an epoch

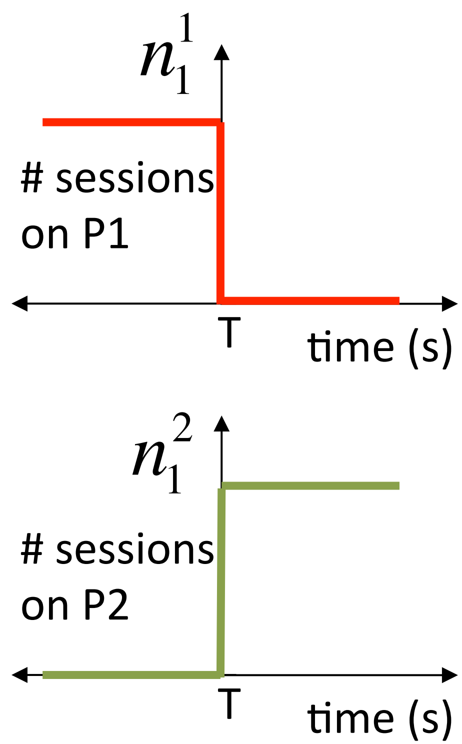


Session Stickiness

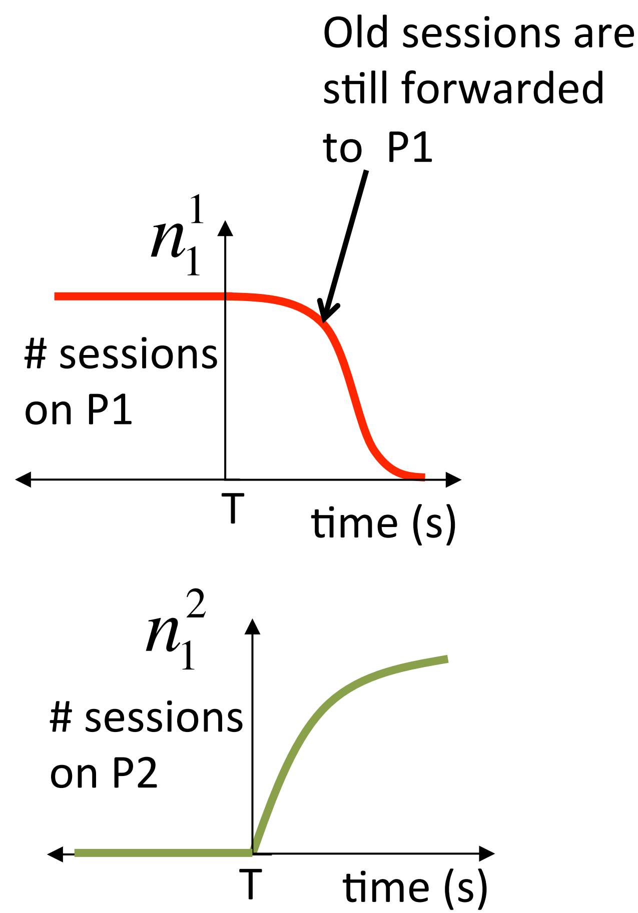
Sessions **stick** to proxy and DC
- Long lived TCP sessions
- No fresh DNS query in the middle of a session



Switch traffic at t = T



Non-sticky sessions



Sticky sessions

Challenge: Temporal Variation of Load

1. Non-zero session lifetime
2. Session stickiness

$\Big\}$ **Gradually varying** load from a user group to a resource

- Resource capacity constraints should be satisfied during entire epoch

$$\sum_u n_u^r \le C_r \longrightarrow \sum_u n_u^r \boxed{(t)} \le C_r$$

- Computationally infeasible if $n_u^r(t)$ does not have a closed form
  - Applications have arbitrary session life distributions

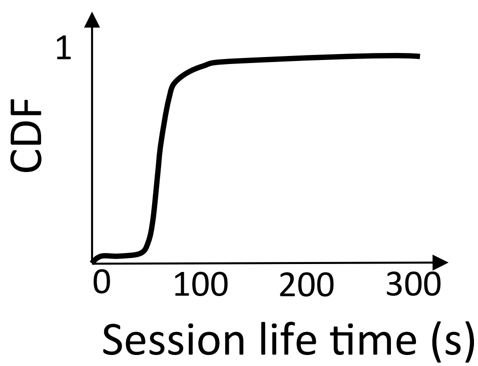
How to guarantee congestion free delivery for traffic on sessions?

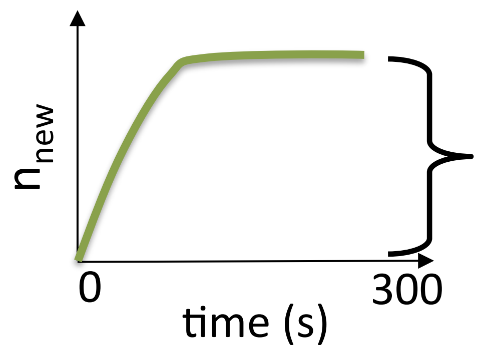
High Fidelity Modeling of Load

$$n^r(t) = n^r_{new}(t) + n^r_{old}(t)$$

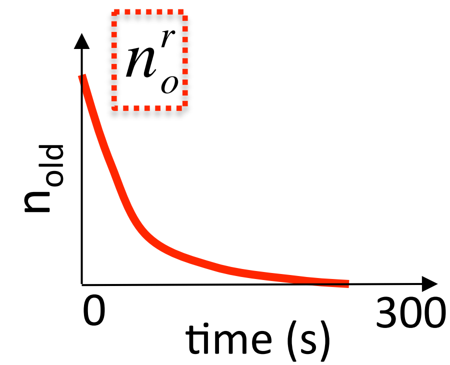
current previous

Always holds this pattern





Proportional to arrival rate of new sessions



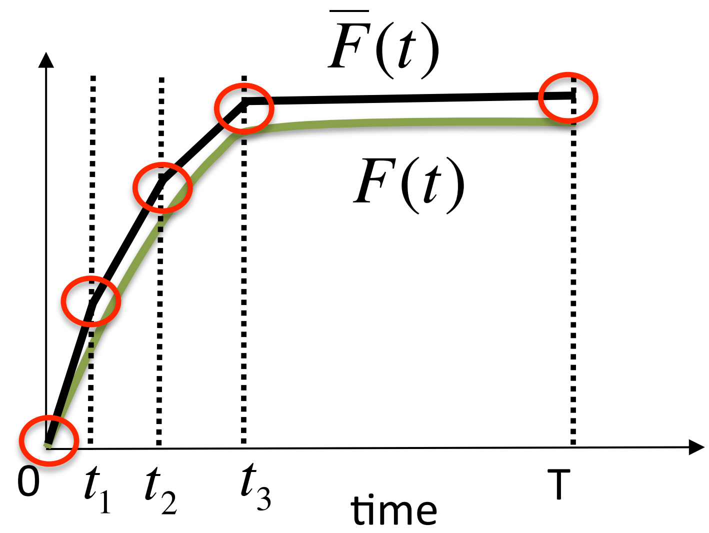
$$n^r(t) = \boxed{\lambda^r} F(t) + n^r_o G(t)$$

Arrival rate of sessions (decision variable)

Pattern Functions ← Session length distribution

Discretizing the Temporal Model

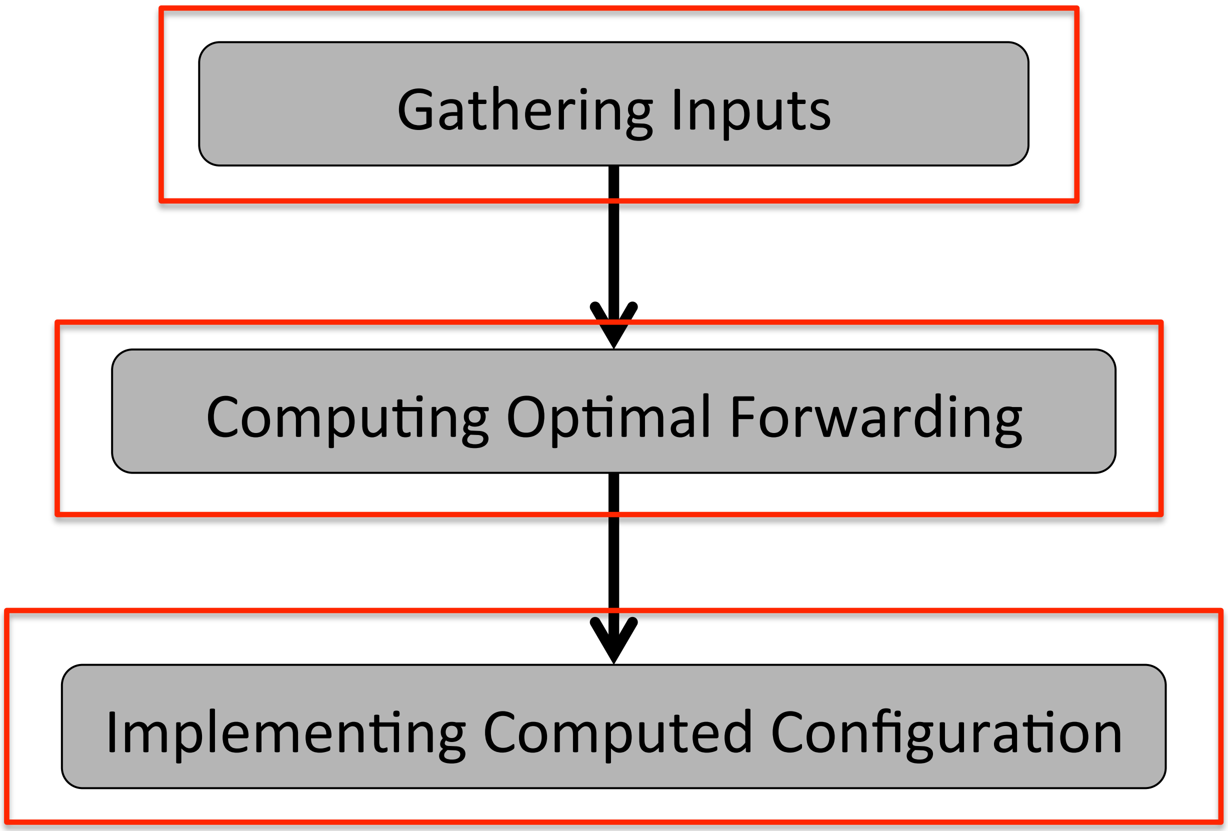
Approximate $F(t)$ by a tight piecewise linear **upper bound,** $\overline{F}(t)$



$$n^r(t) \le \overline{n}^r(t) = \lambda^r \overline{F}(t) + n_0^r G(t)$$

- $\overline{n}^r(t)$ has maximum at one of the corners
- Capacity constraints have to be checked only at fixed set of points
- **Optimal** λ^r's obtained by solving a **linear program**

Footprint: System Implementation



Footprint: Inputs to the controller

- Input data collected every 5 minutes
- Inputs:
  - User group – proxy latency measurements
    - Piggy-back on end-host applications
    - Instrumented JavaScript on bing.com webpage [Calder *et al.,* IMC 2015]
  - User workload
    - Estimated using observed workload in prior epochs
  - System health status
    - From Microsoft internal system monitoring pipelines
- Deployed in production

Implementing Computed Configuration

- UG—proxy mapping: DNS (BIND)
- Proxy—DC mapping: Custom software to change configuration
- WAN path selection: OpenFlow
- Prototyped on a modest-sized testbed

Evaluation

1. Joint Decisions

2. Temporal Modeling

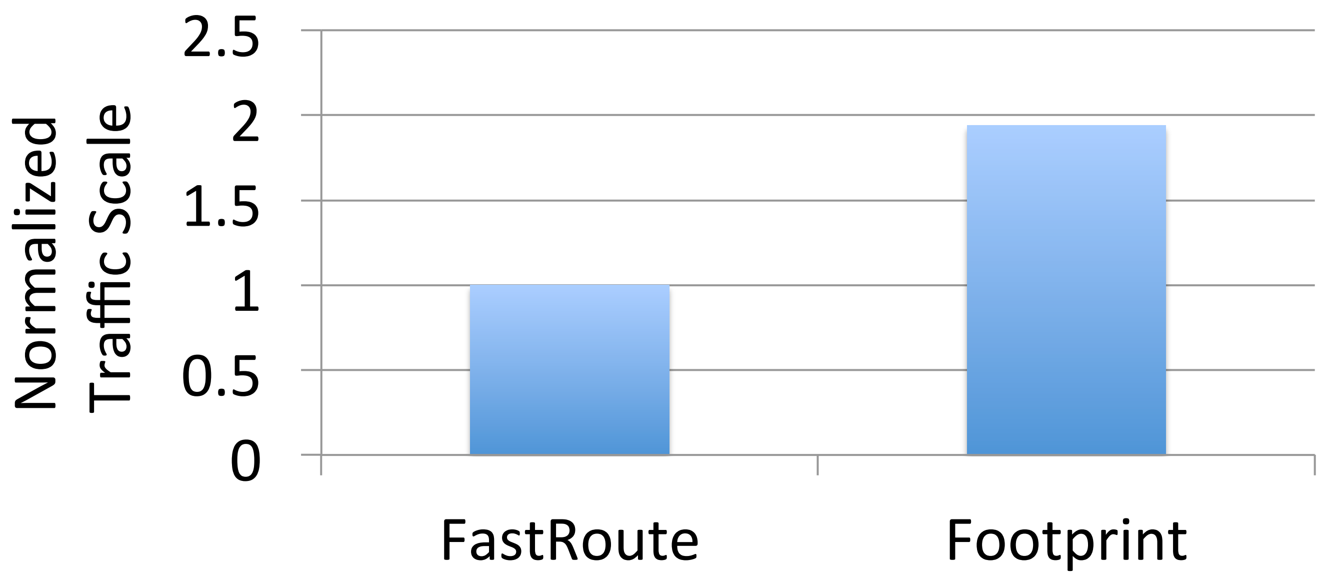
Evaluation Setup

- Trace driven simulations
- Data
  - Taken from production deployment of Footprint
  - One week worth of data
  - Multiple topologies (North America, Europe)
- Scale
  - O(10k) user groups
  - O(100) routers and links
  - O(100) proxies
  - O(10) data centers
- Metric
  - Efficiency: Maximum traffic with no congestion
  - Performance: Aggregated end-to-end latency

Evaluation: Efficiency of Joint Control

FastRoute [Flavel *et al.*, NSDI 2015]

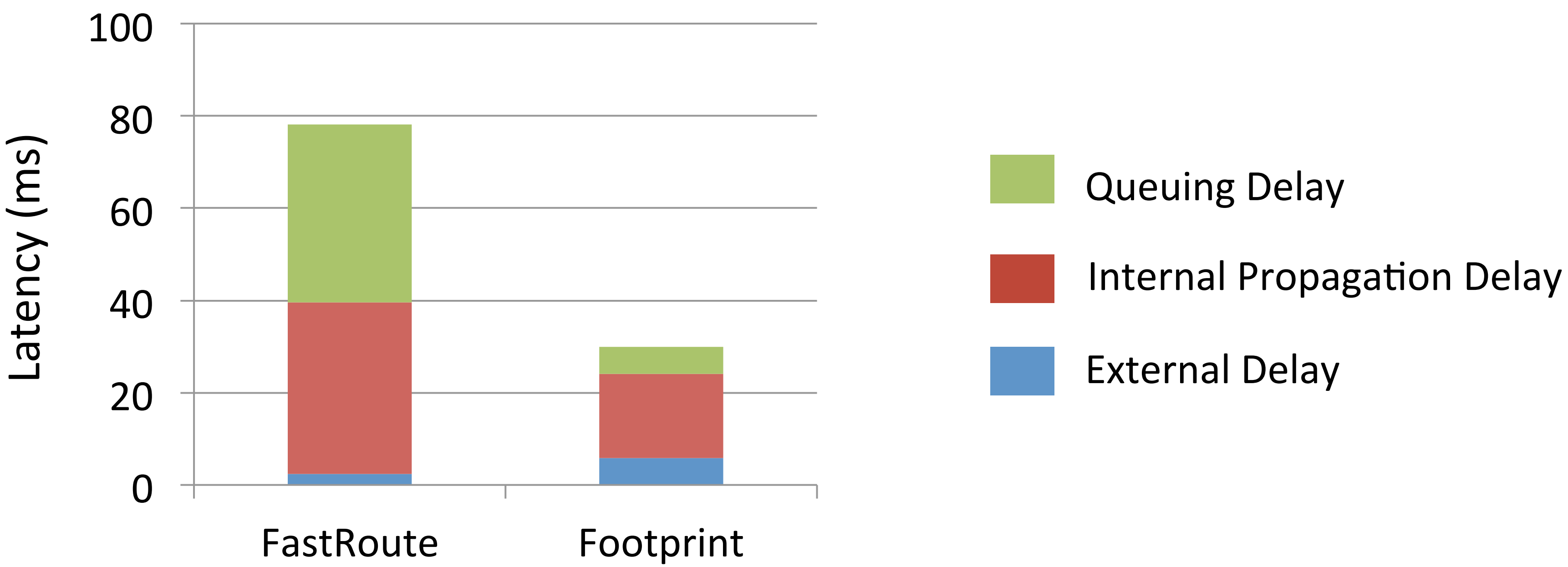
- UG—proxy: Closest proxy decided by Anycast routing
- Proxy—DC: Closest proxy based on active measurements
- WAN path selection: Independent traffic engineering module



- **Footprint can carry 2x more load** because user traffic is diverted to resources with unused capacity

Evaluation: Latency Improvement

Compare end-to-end latency at 70% capacity of FastRoute



Footprint decreases overall latency by ~60%

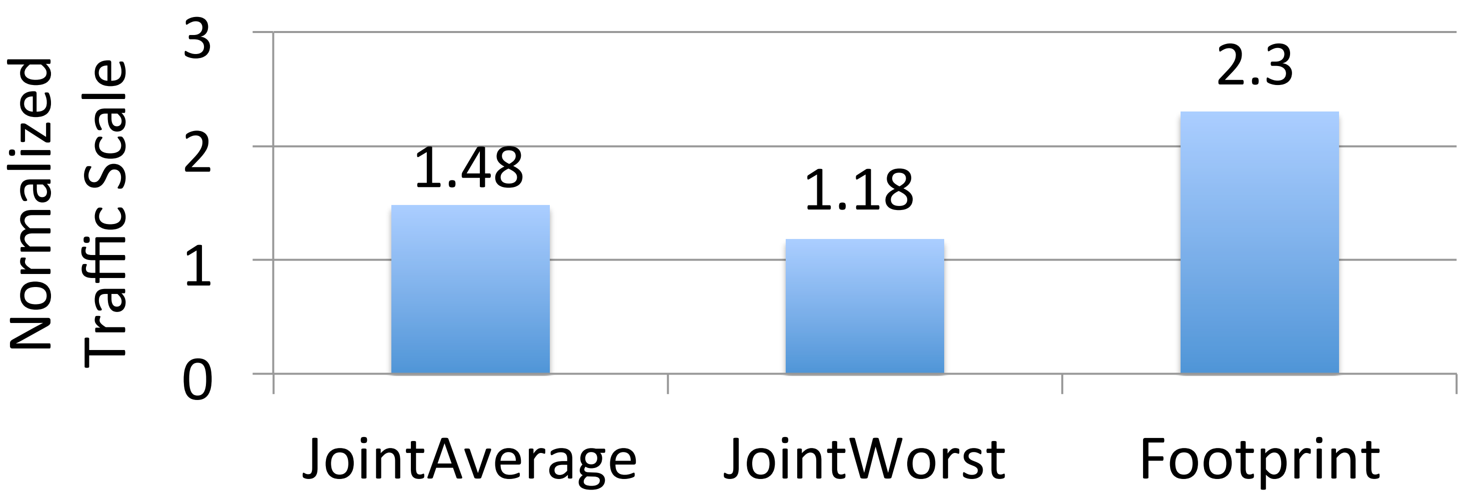
Evaluation: Efficiency of Temporal Modeling

- Compare with non-temporal models
  - **JointAverage**:

$$n^r(t) = \lambda \text{ x Average session length}$$

  - **JointWorst:**

$$n^r(t) = \max_t (\#\text{old sessions}) + \max_t (\#\text{new sessions})$$



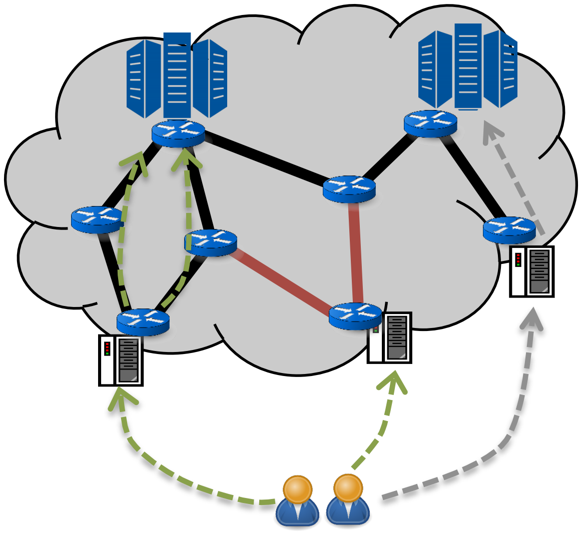
More than 50% gains with respect to non-temporal models.

Related Work

- To coordinate or not to coordinate? [Narayana *et. al*, SIGMETRICS 2012]
- Cooperative world *vs* Single entity world
- Show importance of temporal load modeling

Summary

- ***Joint decision*** for proxy, DC and WAN path selection
  - 100% increase in supported users, and,
  - 60% reduction in end-to-end latency



- High fidelity temporal models 50% efficient than non-temporal models