Typical versus Worst Case Design in Networking

Nandita Dukkipati

Yashar Ganjali, Rui Zhang-Shen

High Performance Networking Group

Stanford University

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Introduction: Worst-case design

- Preference for worst-case design: packet classification algorithms, switch buffer architectures, congestion control, ...

- Lampson's hint: "... Normal case must be fast. The worst-case must make some progress. "

- Why the preference for worst-case design?

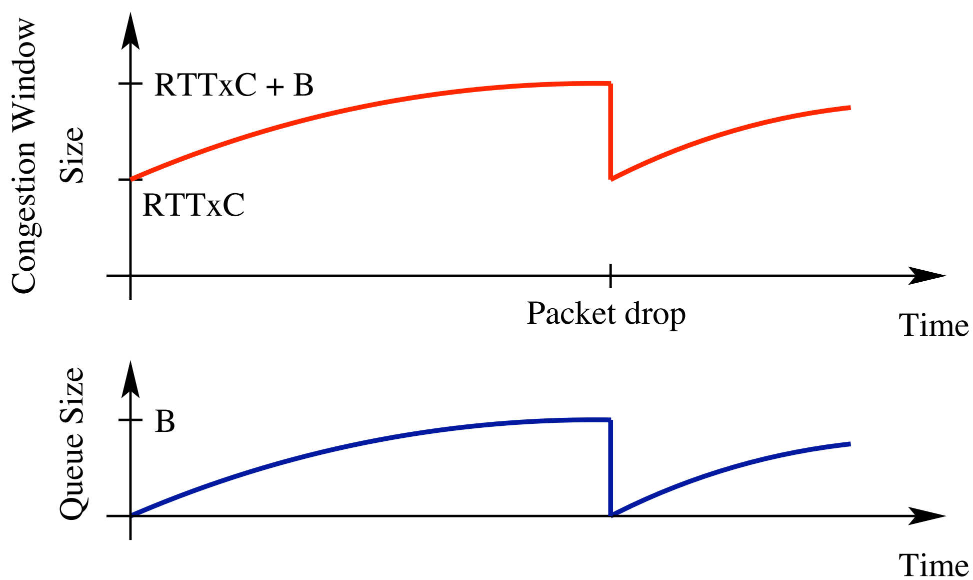
  - Typical case known only after system is deployed
  - Easier to quantify/verify/prove performance
  - Feels good and safe

Introduction: The case for typical-case design

- Worst-case design does not always make sense
- Our position: Design for the typical-case unless designing for the worst-case is absolutely necessary or cheap
- Examples:
    - Buffer sizing in core routers
    - Designing a congestion control algorithm
    - Backbone network design

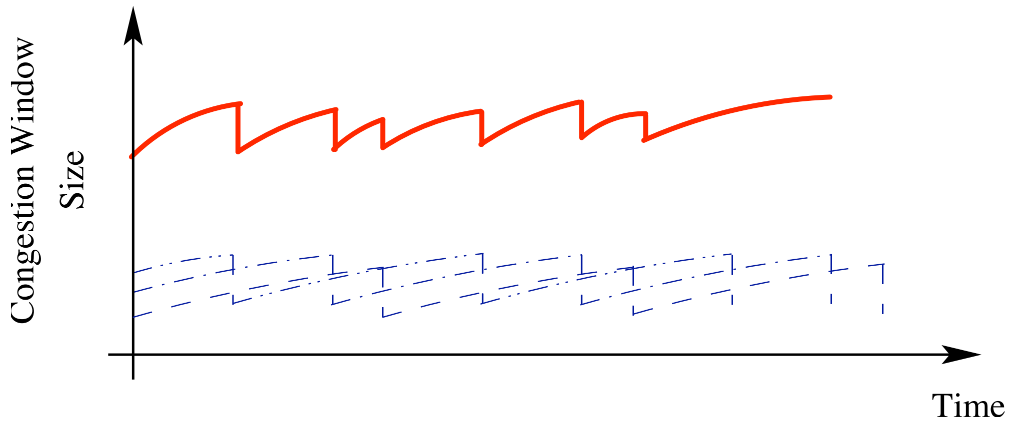
Typical-case Design: Buffer Sizing for Core Routers

- How much buffering do Internet routers need to guarantee near 100% link utilization ?
- Rule of thumb: $C \times \overline{RTT}$
- Example: RTT = 250 ms, C = 40 Gbps, buffer size = 1,250,000 packets
- Rule of thumb holds for single/synchronized flow(s)



Typical-case Design: Small Buffers

- Desynchronized flows: expect less buffering



- Buffering needed: $\frac{C \times \overline{RTT}}{\sqrt{N}}$
- Example: RTT = 250 ms, C = 40 Gbps, N = 10000, buffer size = 12,500 packets
- Worst-case: few flows, Typical-case: thousands of flows
- Benefits: reduced delay and jitter, simplified router architecture

Typical-case Design: Very Small Buffers

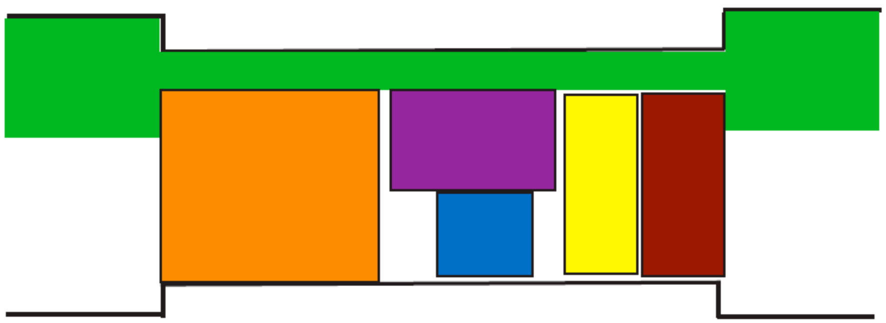
- Worst-case assumption: core link should be 100% utilized
- Recent work: Buffer size 10-20 packets, link utilization 75%
- Five orders magnitude reduction from original rule-of-thumb
- Consequences: all-optical routers, very high capacity network, low power consumption, low delay...

Typical-case Design: Designing Congestion Control

- Congestion control is deliberately designed to be conservative
  - Starts flows slowly: helps in flash crowd scenarios
  - Works well when most or all flows are long-lived

mean flow size >= "pipe" size

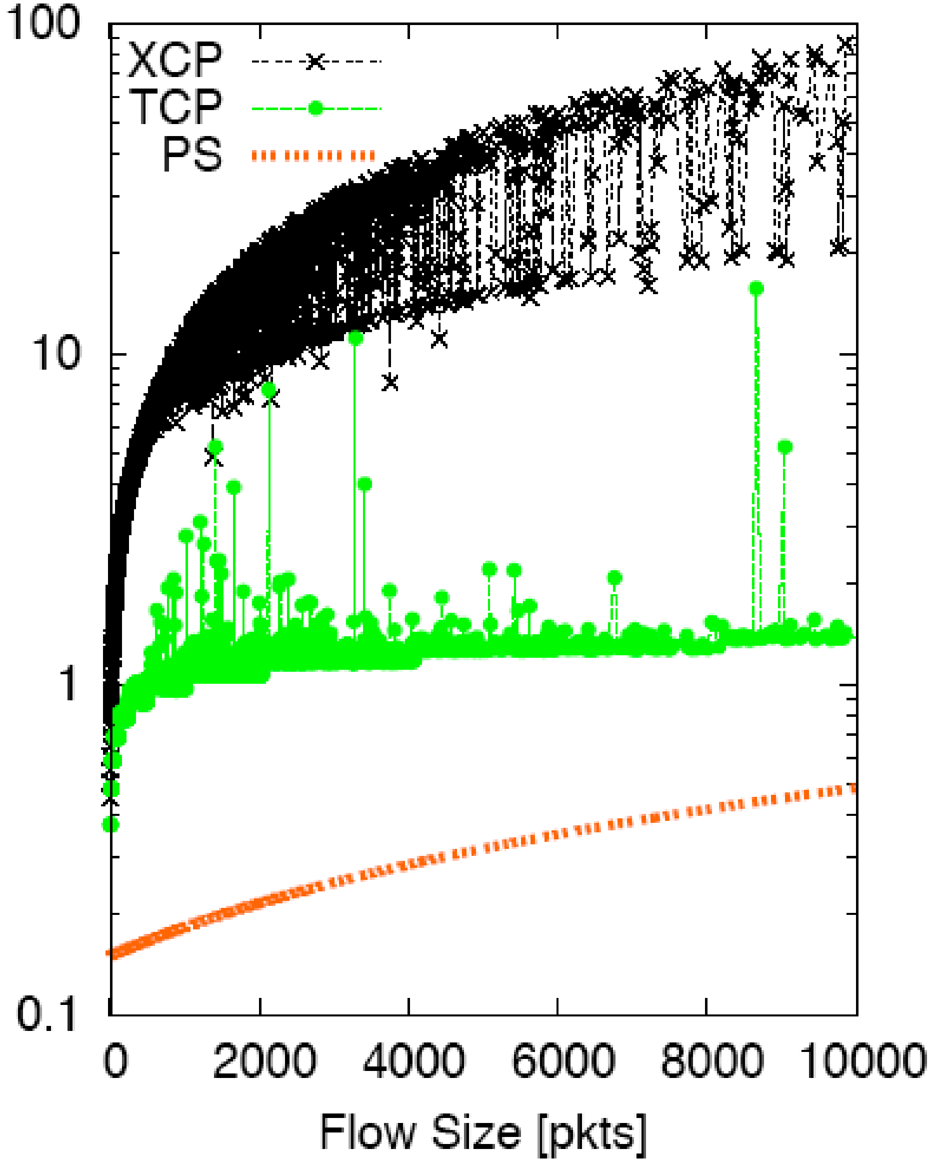
- Typical case:



mean flow size << "pipe" size

Typical-case Design: Designing Congestion Control

Flow Duration (secs) vs. Flow Size

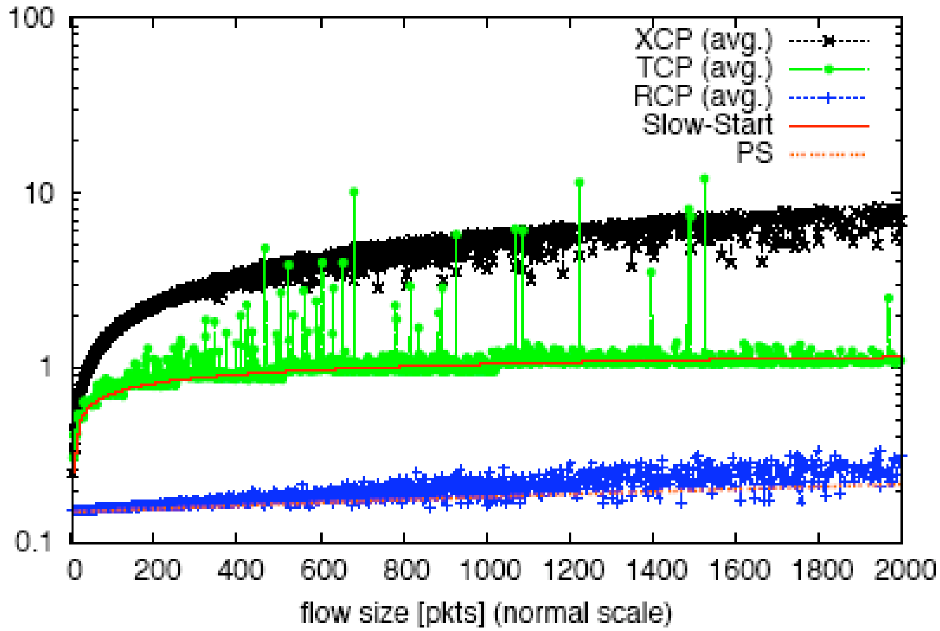


- Flows arrive in a Poisson process and have a heavy-tailed flow-size distribution
- Consequence: Makes flows last many times longer than necessary in the typical case

Typical-case Design: Rate Control Protocol (RCP)

- Rate Control Protocol (RCP): Designed for fast Flow Completion times --- close to ideal processor sharing

$$R(t) = R(t-T)\left[1 + \frac{\frac{T}{d_0}\left(\alpha(C - y(t)) - \beta\frac{q(t)}{d_0}\right)}{C}\right]$$



Typical case: One/two orders of magnitude reduction in Flow Completion Time

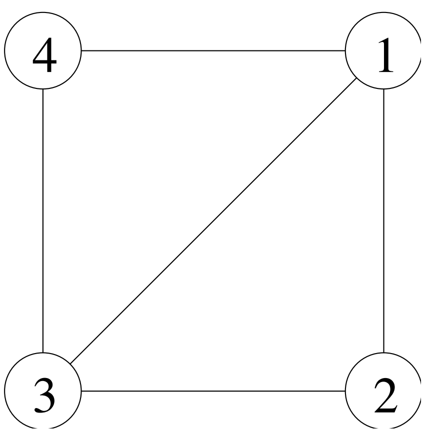
Worst case: Flash crowds

When Worst-case Design makes sense

- Worst-case guarantees are required
- Cheap to design for worst case and it doesn't overly hurt the typical case
- Don't know the typical-case or it is likely to change faster than you expect to change your design

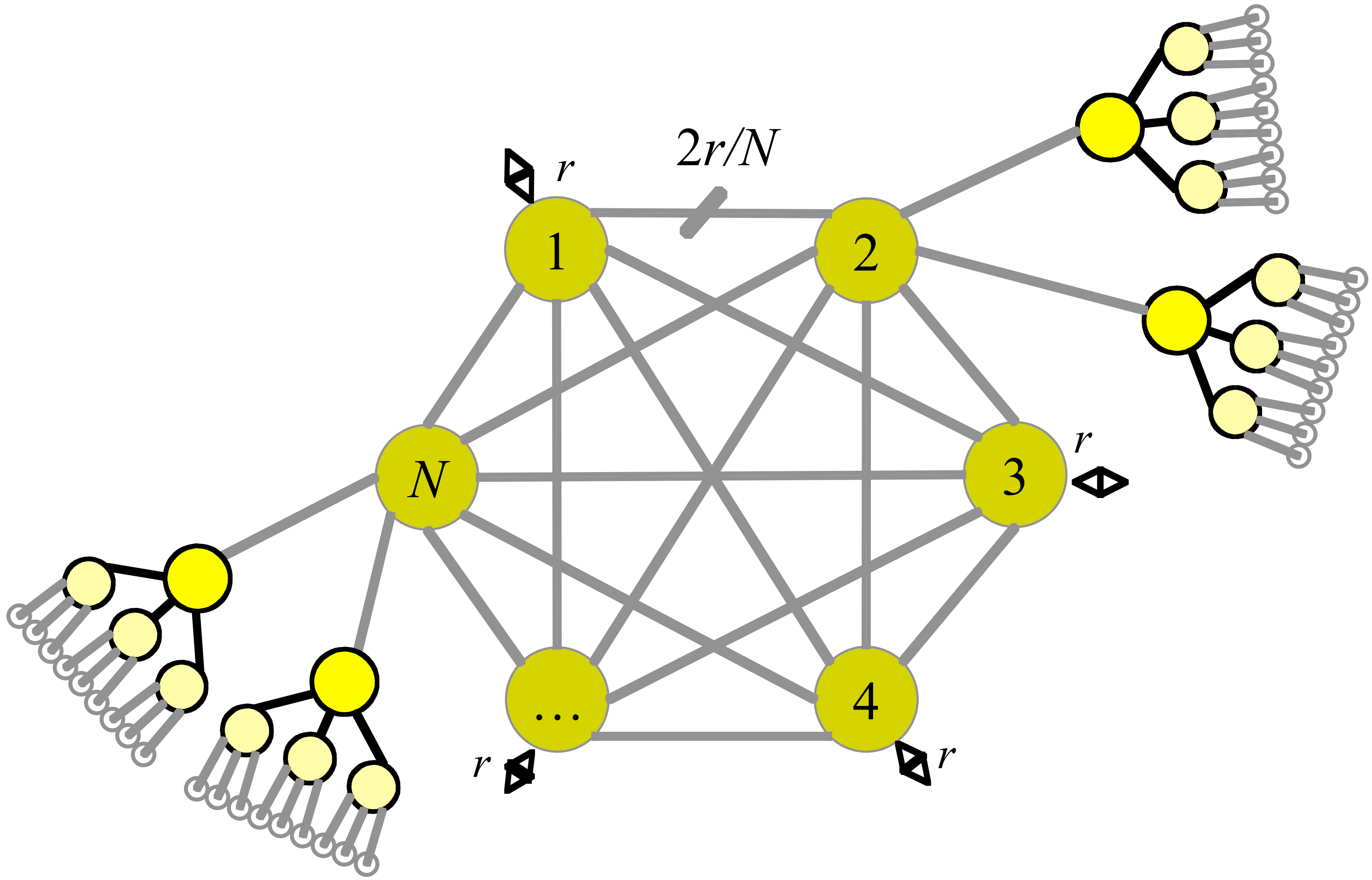
Worst-case Design: Backbone Network Design

- What makes network design hard ?
  - Inaccurate design input
  - No guarantees on handling deviant matrices
  - Need to provision for failures
- Example: $$\mathcal{T} = \{\Lambda | \sum_j \lambda_{ij} \leq R_i, \forall i; \ \sum_j \lambda_{ji} \leq R_i, \forall i\}$$



% over-provision	% traffic-matrices
0%	0.20%
25%	2.59%
50%	15.09%

Worst-case Design: Valiant Load Balancing



Worst-case Design: VLB Characteristics

- Worst-case guarantees
  - Can support all feasible traffic-matrices
  - Is provably the most efficient in supporting all traffic
  - Empirical study: About the same cost as conventional network
- Typical-case:
  - Max. propagation delay bounded by 2x network diameter
  - Only load-balance when necessary
  - There are "express paths"

Conclusion

- Blindly designing for worst-case does not make sense
- Immense benefits in typical-case design in terms of performance, cost and complexity
- Design for typical-case unless typical-case is not known or the worst-case design is absolutely necessary or is cheap.