Traffic Handling and Network Capacity in Multi-Service Networks

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Outline

- Introduction and Motivation
- Network Analysis
- Significance
- Future Work

Introduction and Motivation

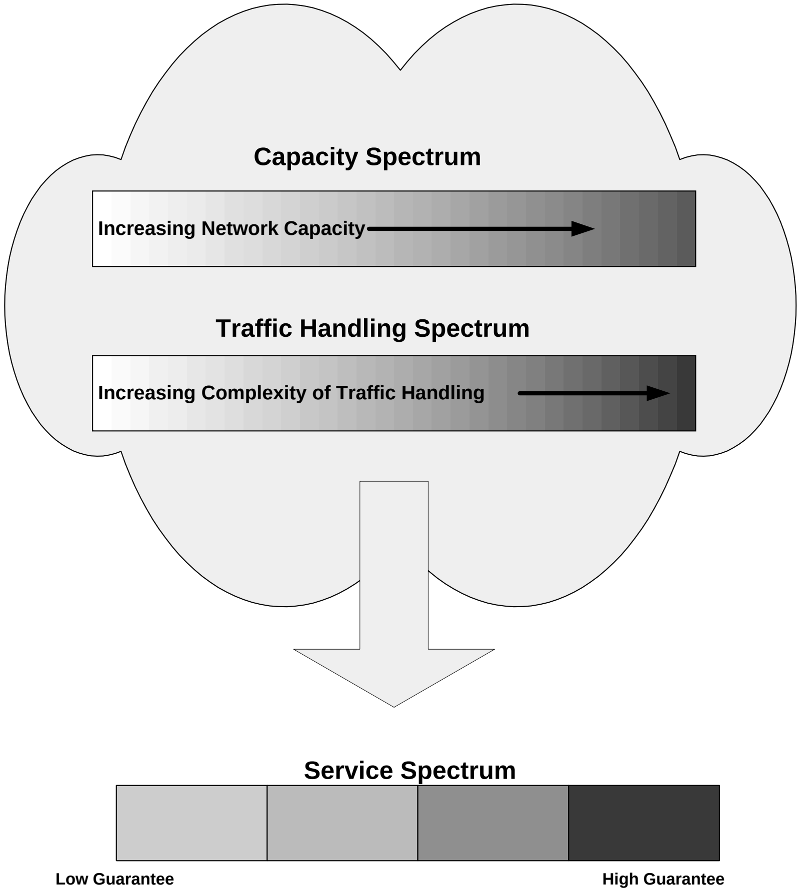
Introduction

- Evolution of Internet from research to commercial
- Growth in volume and diversity of traffic
  - $=>$ redesign of Internet architecture
  - $=>$ revision of engineering rules

Introduction and Motivation

The Network Spectrum

- Aggregate handling + abundant capacity
- Semi-aggregate handling + simpler traffic management + moderate capacity
- Per-flow handling + complex traffic management + minimal capacity



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Introduction and Motivation

The Problem

- Given the varying levels of complexity and differing capacity requirements of aggregate, semi-aggregate and per-flow traffic handling, how can one evaluate and quantify the trade-off between the three approaches?
- For the same level of performance, what is the difference in required capacity between the three approaches and how can this be used to justify the choice of one approach over another?

Questions

- How much more network capacity is needed with aggregate versus per-flow handling?
- How does the complexity of per-flow handling compare to capacity costs of aggregate traffic handling?
- How sensitive are the capacity requirements to variations in delay requirements?

Introduction and Motivation

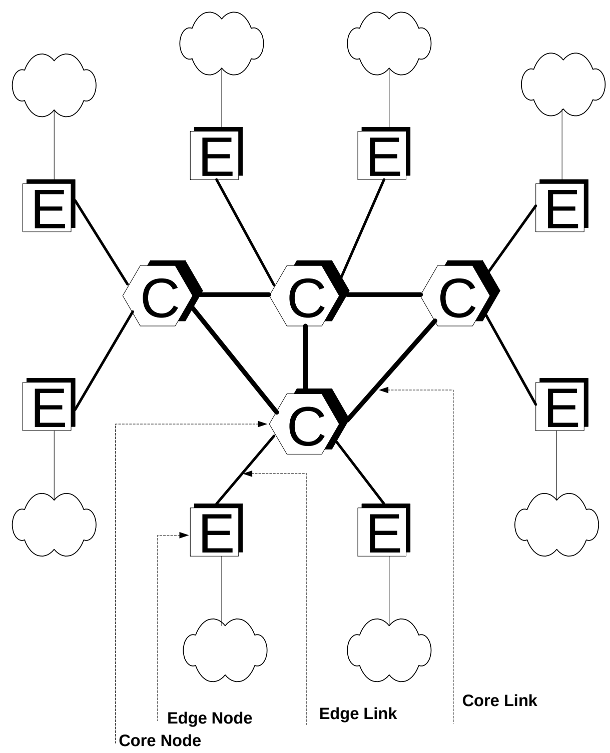
Approach

- Alternatives
  - Simulation
  - Stochastic Analysis
  - Deterministic Analysis
- Chose deterministic analysis using network calculus to provide bounds on capacity
  - Not dependent on traffic models
  - Suitable for architectural comparisons

Edge-Core Network Analysis

Edge-Core Topology

- Topology defined by # of core nodes N_{core} & # of links per core node n_{link}
- $(N_{core} - 2)$ possible topologies per N_{core}
- Full-mesh: $n_{link} = (N_{core} - 1)$
- Fixed # of sources per edge node



Edge-Core Network Analysis

Scheduling Mechanisms

- Weighted Fair Queueing (WFQ)
  - Single flow per queue
- Class-Based Queueing (CBQ)
  - Two per-class queues: RT and NRT
  - WFQ between the class queues
- Strict Priority Queueing (PQ)
  - Two priorities : RT high, NRT low priority
- First-In-First-Out Queueing (FIFO)

Edge-Core Network Analysis

Applications

Application	RT/NRT	Avg. Rate (Mbps)	Burstiness (Bytes)	Packet Size (Bytes)	E2E Delay (msec)
Telephony	RT	0.064	64	64	20
Interactive Video	RT	1.5	8000	512	50
E-mail	NRT	0.128	3072	512	500
WWW	NRT	1.0	40960	1500	500

- Email and WWW are delay-tolerant BUT may require some guaranteed bandwidth to prevent starvation

Edge-Core Network Analysis

Analysis of Capacity Requirements

- Use a network with WFQ in both the edge and core as the reference
- Calculate the amount of traffic that can be supported in a WFQ network
- Compare the capacity required for various combinations of traffic handling schemes in the edge and core

Edge-core Network Results

Parameters

- Number of edge nodes per core node $N_{edge} = 60/N_{core}$, $N_{core} = 3..20$
- Routes set-up within the core using Djikstra's shortest path algorithm
- Traffic within the core was distributed symmetrically
- Maximum load on each edge link $w_T = $ 90%

Edge-Core Network Results

Network Capacity for 20-node Full-Mesh

		Core Traffic Handling			
		WFQ	**CBQ**	**PQ**	**FIFO**
Edge Traffic Handling	**WFQ**	107	201	144	1497
	CBQ	191	256	195	1818
	PQ	146	210	149	1700
	FIFO	1212	1269	1224	2318

- Network capacity in equivalent OC-3 links
- All-FIFO capacity $\approx$ 22x all-WFQ network
- All-CBQ capacity $\approx$ 2.5x all-WFQ network
- All-PQ capacity $\approx$ 1.5x all-WFQ network

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Edge-Core Network Results

Impact of Network Diameter with WFQ Edge

Max Hops	C^{WFQ} **(x OC3)**	C^{CBQ}/C^{WFQ}	C^{PQ}/C^{WFQ}	C^{FIFO}/C^{WFQ}
1 (full-mesh)	54	2.8	1.72	28.5
2	85	3.52	2.17	40.08
3	102	3.96	2.24	40.21
4	113	4.0	2.47	46.06
5	156	4.66	2.8	51.8
7	198	5.27	3.36	62.6
10	281	6.17	4.11	74.6

- Utilization decreases with increasing diameter
  - WFQ: 0.73 - 0.14, CBQ: 0.25 - 0.02, FIFO: 0.025 - 0.001
  - More links => smaller diameter => higher per-node delay => smaller capacity

Edge-Core Network Results

Impact of Delay Bound with FIFO Edge

Voice Delay Bound	$C^{WFQ}(Mbps)$	C^{CBQ}/C^{WFQ}	C^{PQ}/C^{WFQ}	C^{FIFO}/C^{WFQ}
0.01	110	2.47	1.89	31.02
0.015	113	1.99	1.42	20.4
0.02	116	1.76	1.2	15
0.025	119	1.63	1.08	11.96
0.03	122	1.55	1.01	9.89

- 10 core nodes
- WFQ capacity increases with increasing voice delay
  - Due to increased burstiness in FIFO edge
- CBQ, PQ and FIFO capacity decreases with increasing voice delay

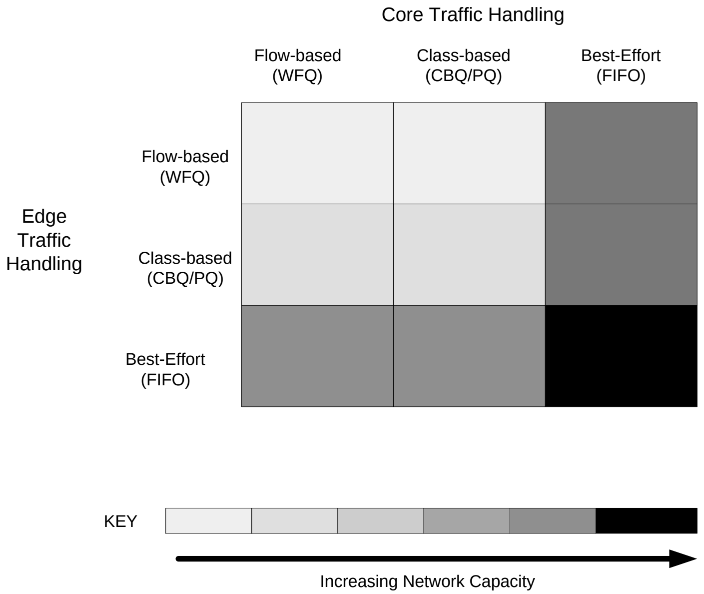
Lessons Learned

- Can quantify comparison of capacity requirements
  - CBQ & PQ network capacity $\approx$ WFQ capacity
- Importance of network architecture in comparing traffic handling approaches
  - Edge-core traffic handling combinations
  - Path vs non-path aggregation
- Sensitivity analysis helps to identify critical parameters affecting capacity requirements

Significance of Results

Network Architecture

- All-WFQ = small capacity + high complexity
- Combination of WFQ, CBQ, PQ = small capacity + medium to high complexity
- All-FIFO = huge capacity + least complexity
- FIFO + (WFQ,CBQ,PQ) = moderate capacity + medium to high complexity



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