Multi-class Applications for Parallel Usage of a Guaranteed Rate and a Scavenger Service

Markus Fidler
fidler@informatik.rwth-aachen.de

Volker Sander
sander@fz.juelich.de

- Guaranteed Rate Service
- Performance Limits
- Scavenger Service
- Multi-class Applications
- Conclusions

Motivation

Networking requirements of distributed teleimmersion applications

Flow	Latency	Bandwidth	Reliable	Dynamic
Control	< 30 ms	64 kb/s	Yes	Low
Text	< 100 ms	64 kb/s	Yes	Low
Audio	< 30 ms	128 kb/s	No	Medium
Video	< 100 ms	5 Mb/s	No	Medium
Tracking	< 10 ms	128 kb/s	No	Medium
Database	< 100 ms	> 1 Gb/s	Yes	High
Simulation	< 30 ms	> 1 Gb/s	Mixed	High
Haptic	< 10 ms	> 1 Gb/s	Mixed	High
Rendering	< 30 ms	> 1 Gb/s	No	Medium

Combination of elastic and non-elastic flows with a heterogeneous service demand $\Rightarrow$ Requirement for Network Quality of Service

Differentiated Services Building Blocks

- ## Scalable aggregation of micro-flows to traffic classes

- ## Ingress/Egress Router

  - ### Per micro-flow based metering, marking, and even dropping

  - ### Optional traffic shaping

- ## Core Router

  - ### Per class based forwarding treatment

  - ### Per-Hop Behaviors

    - Expedited Forwarding

    - Assured Forwarding

    - Best-Effort

Ingress/Egress Router
Per-Flow Treatment

Core Router
Aggregate
Scheduling
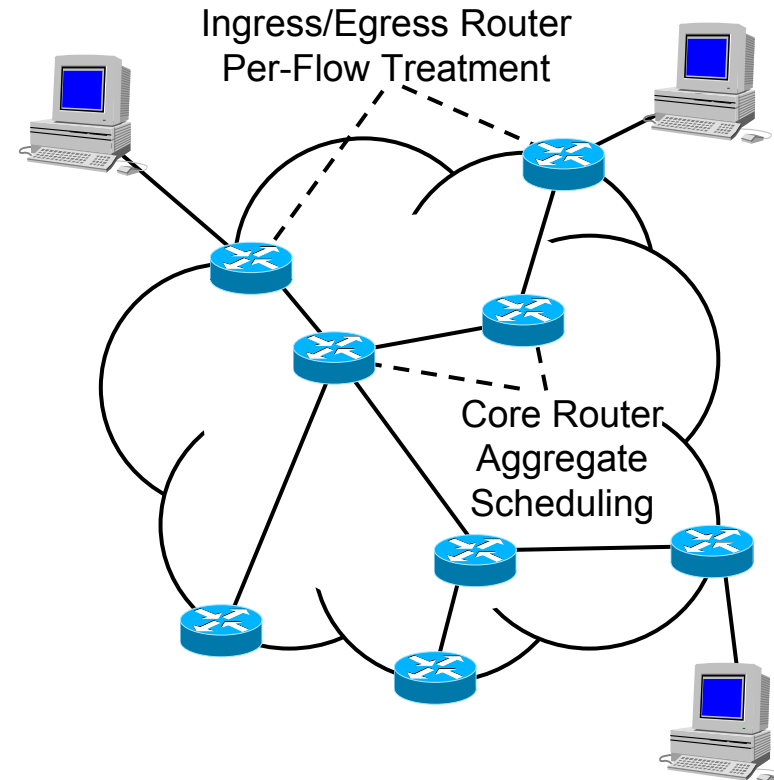
- Services can be built based on admission control and the provision of appropriate Per-Hop Behaviors

- A middleware is introduced to perform admission control, and to dynamically update ingress router configurations on demand: Bandwidth Broker

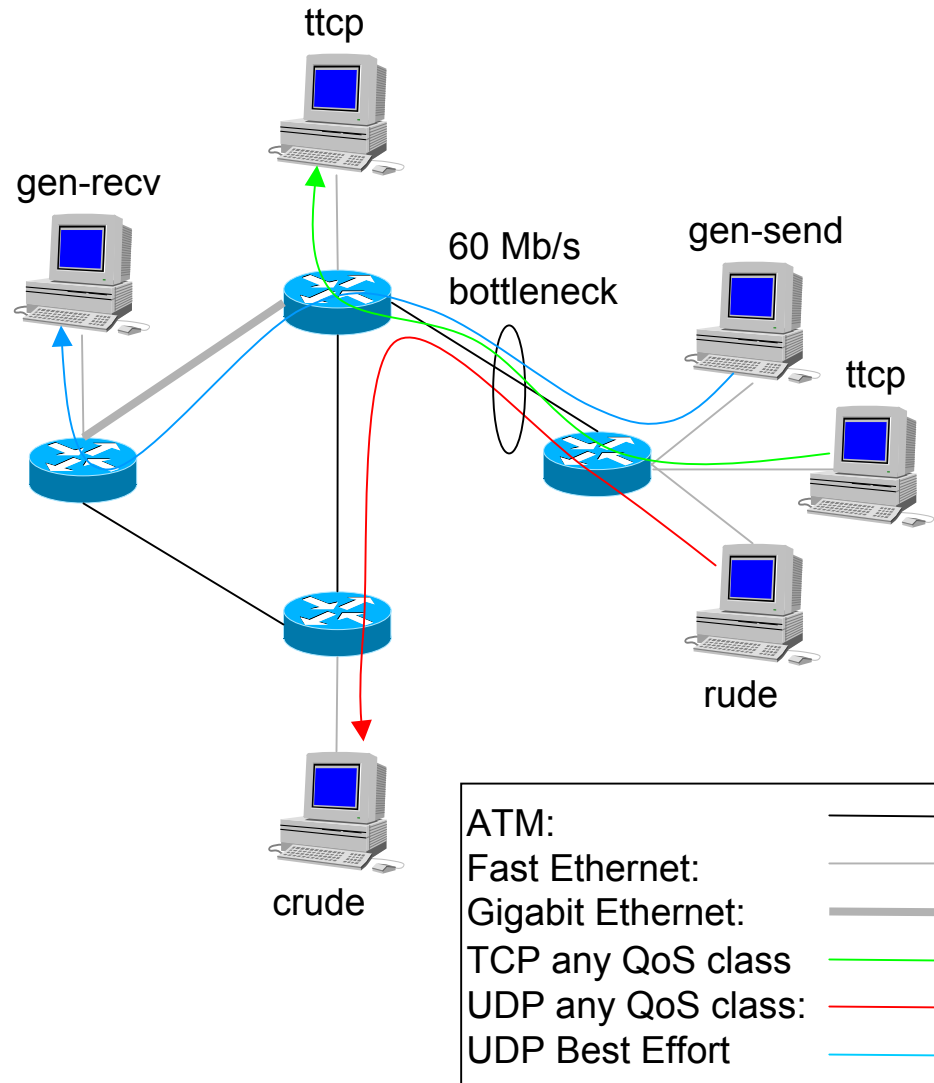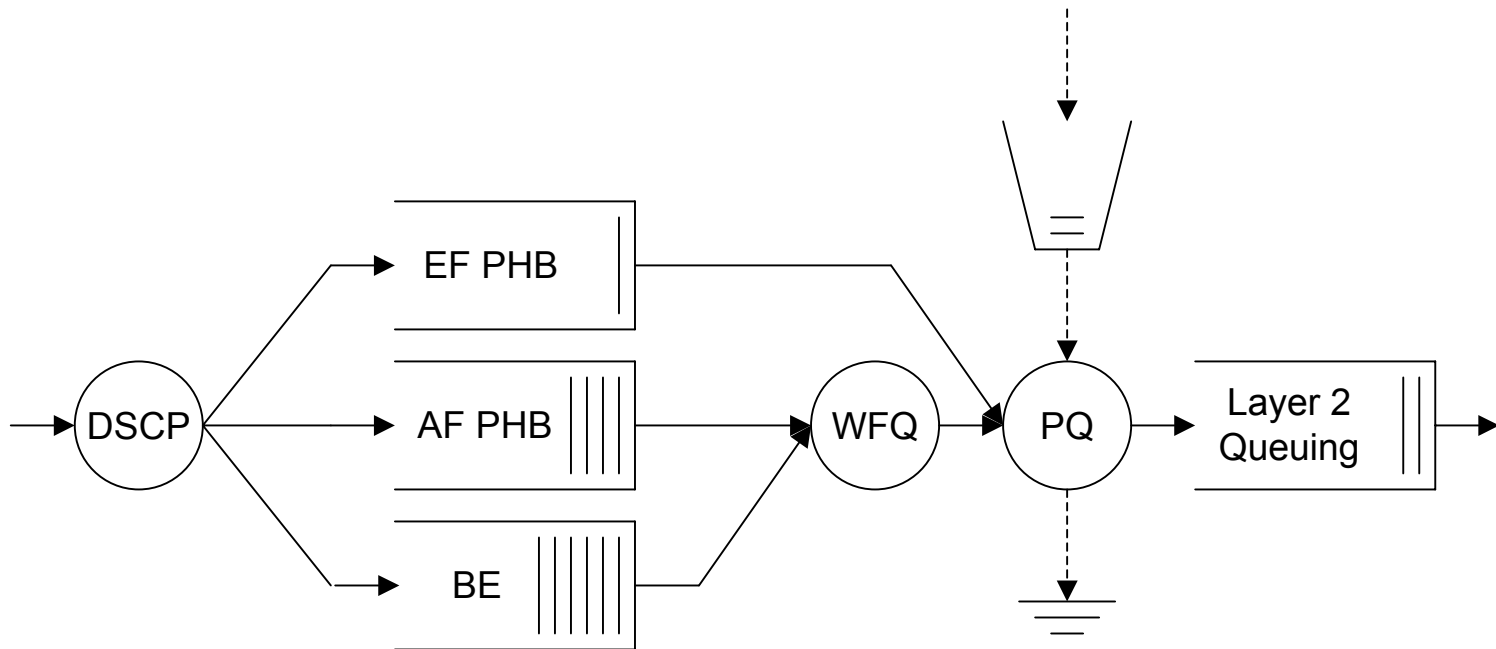- A Guaranteed Rate service can be based either on Expedited Forwarding or on Assured Forwarding

Dynamic Edge Configuration

Static Core Configuration

load

time

Differentiated Services Laboratory Testbed
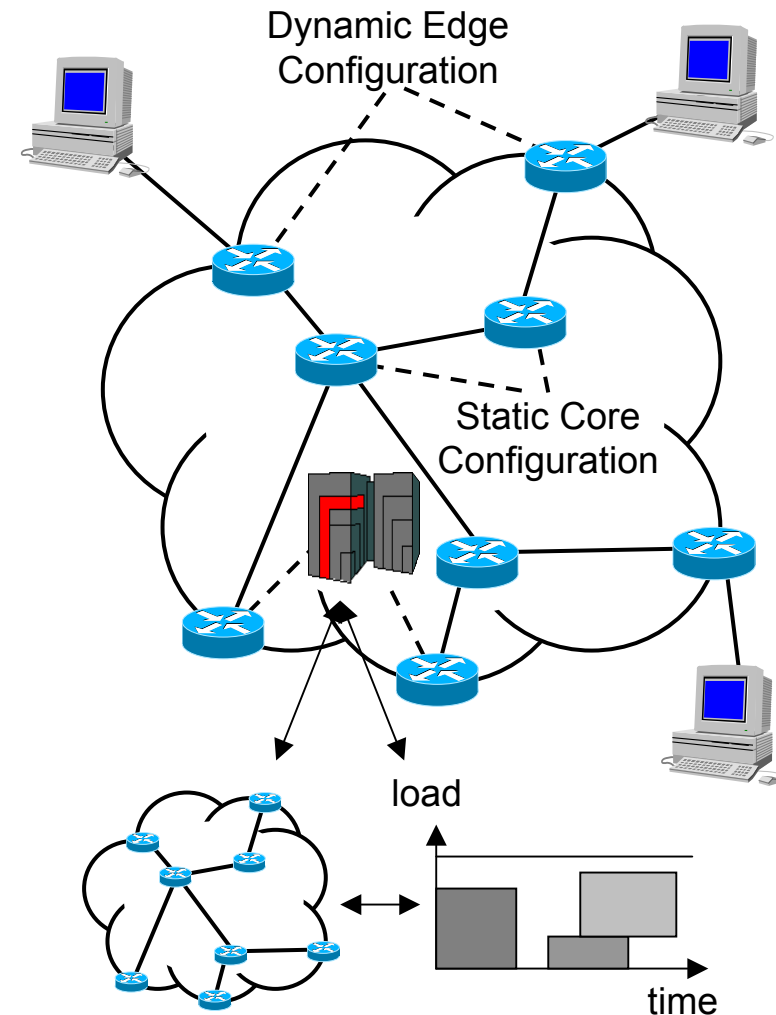
Hardware

- CISCO series 7200 router
- Solaris/Linux end systems

Software

- modified ttcp
  - TCP traffic generator
  - Rate control function added
  - Any QoS traffic class
- gen-send/gen-recv
  - UDP traffic generator
  - Best-Effort traffic
- rude/crude
  - UDP traffic generator
  - Video trace script files
  - Any QoS traffic class

ttcp

gen-recv

60 Mb/s bottleneck

gen-send

ttcp

rude

crude

Legend	
ATM:	
Fast Ethernet:	
Gigabit Ethernet:	
TCP any QoS class	
UDP any QoS class:	
UDP Best Effort	

# Deploying Per-Hop Behaviors

DSCP: Differentiated Services Codepoint
PHB: Per Hop Behavior
EF: Expedited Forwarding
AF: Assured Forwarding
BE: Best Effort
WFQ: Weighted Fair Queuing
PQ: Priority Queuing

TCP Congestion Control

- Window based congestion control
  - throughput = congestion window/round-trip time

- Bandwidth-Delay Product
  - capacity of the pipe = bandwidth · round-trip time

- Congestion window *cwnd* in units of TCP segments
  - Initialization: $cwnd \leftarrow 1$
  - Ack received:
    - Slow Start: $cwnd \leftarrow cwnd + 1$
    - Congestion Avoidance: $cwnd \leftarrow cwnd + 1/cwnd$
  - Segment lost:
    - Three duplicate Acks: $cwnd \leftarrow cwnd/2$
    - Timeout: $cwnd \leftarrow 1$

Guaranteed Rate Service based on Expedited Forwarding

- Strict policing at ingress routers, dropping of excess traffic
- Throughput is bound by the ingress router, no excess is traffic allowed
- TCP congestion control reduces the achieved throughput
- Actual throughput falls below the defined guaranteed rate
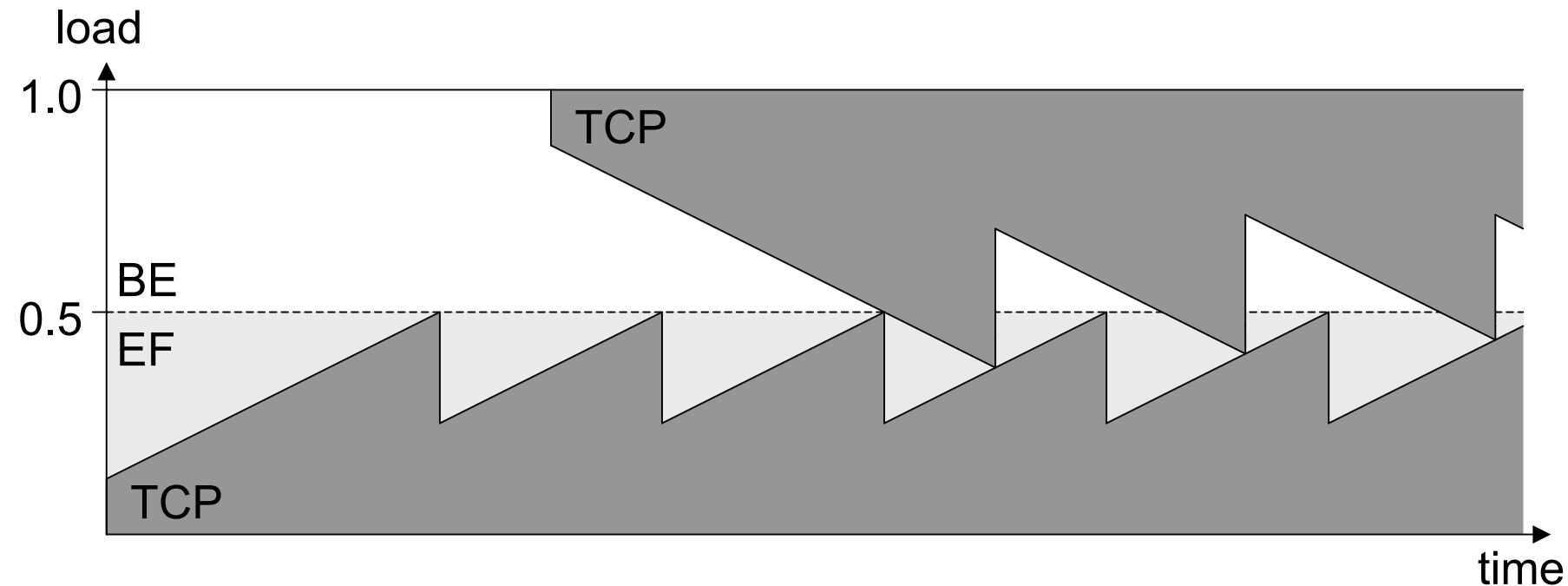
Guaranteed Rate Service based on Assured Forwarding

- Excess traffic is allowed, but at the cost of a higher drop probability
- Weighted Fair Queuing distributes the available resources
- TCP congestion control reduces the achieved throughput
- Throughput can be higher or lower than the defined guaranteed rate
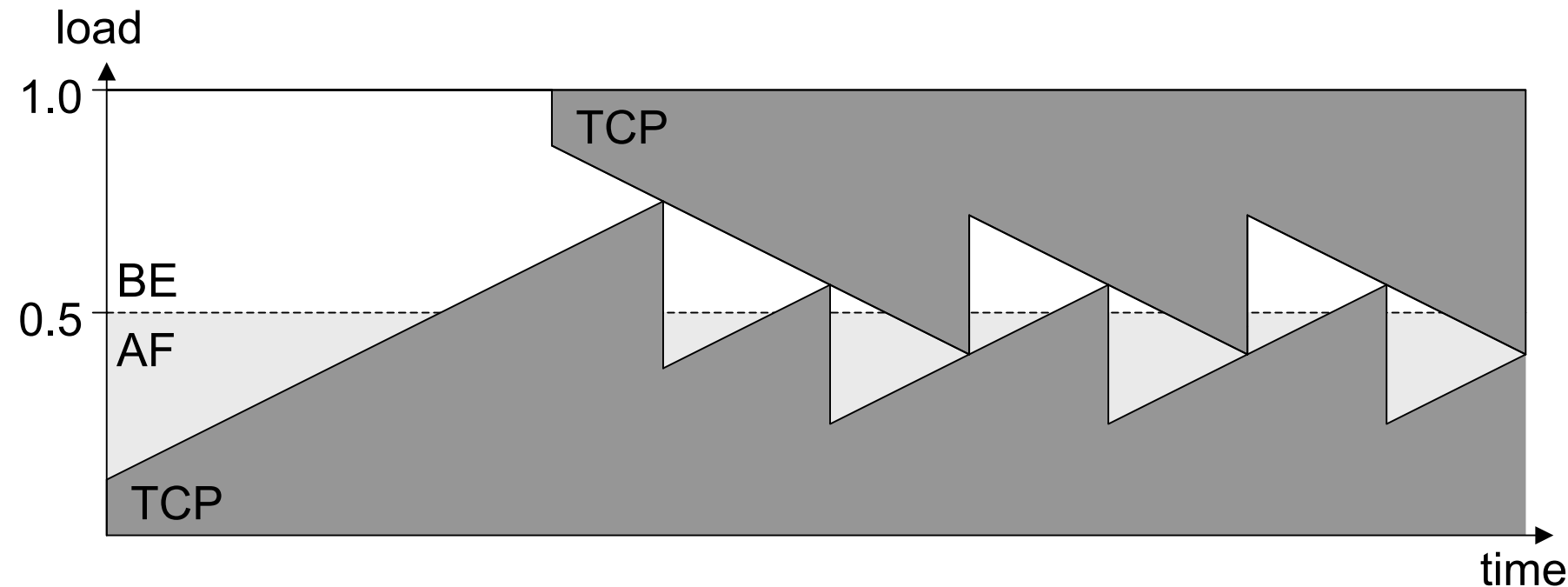
## Guaranteed Rate Service combined with traffic shaping

- Traffic is injected into the network at a defined rate
- Excess traffic is queued at the ingress router
- Delay added by shaping regulates TCP congestion control
- Throughput is bound by the defined guaranteed rate or shaping rate

Traffic Shaping
15 MTU Socket Buffer
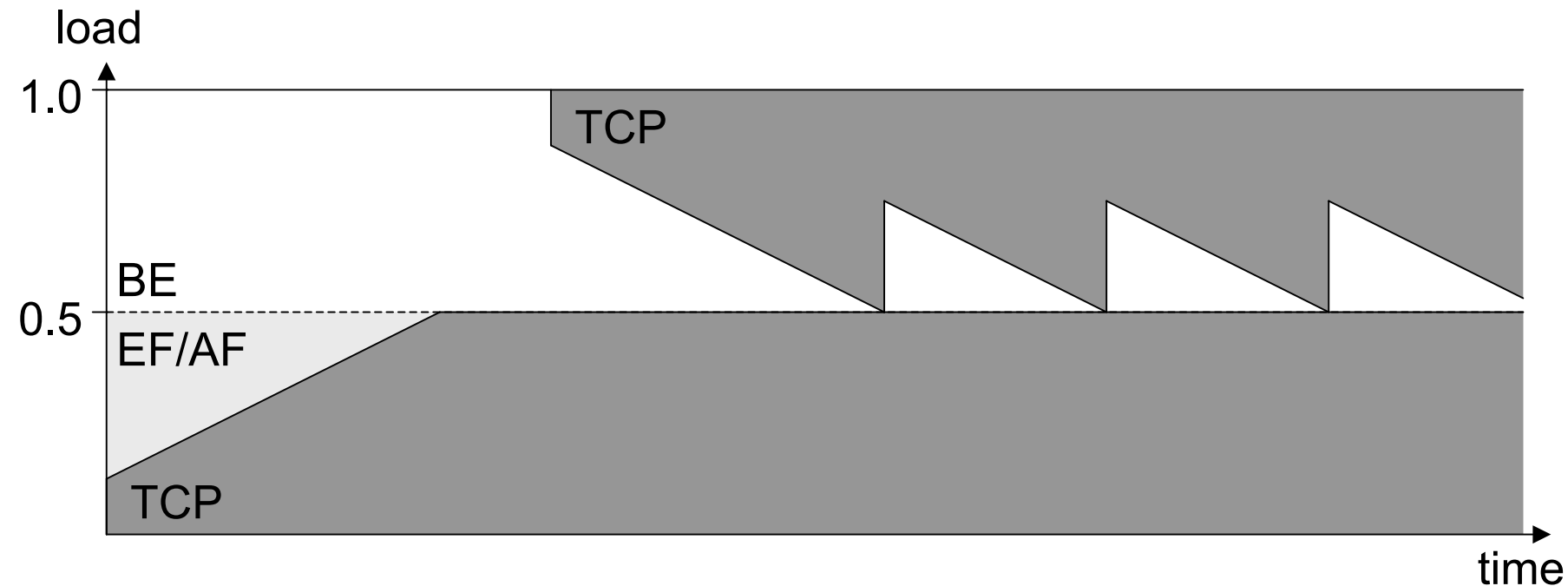
- Offered data rate ~ 15 Mb/s, Target shaping rate ~ 13 Mb/s

- 15 MTU TCP socket buffer, Ethernet MTU = 1500 byte

- throughput = congestion window/round-trip time

- RTT = 15 MTU/13 Mb/s ~ 14 ms

Traffic Shaping
32 MTU Socket Buffer
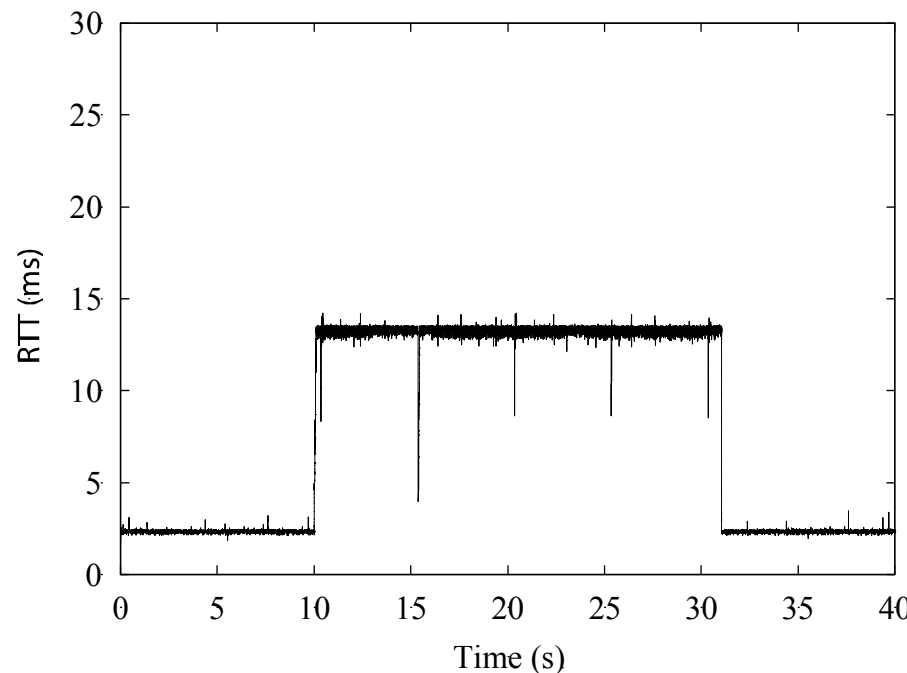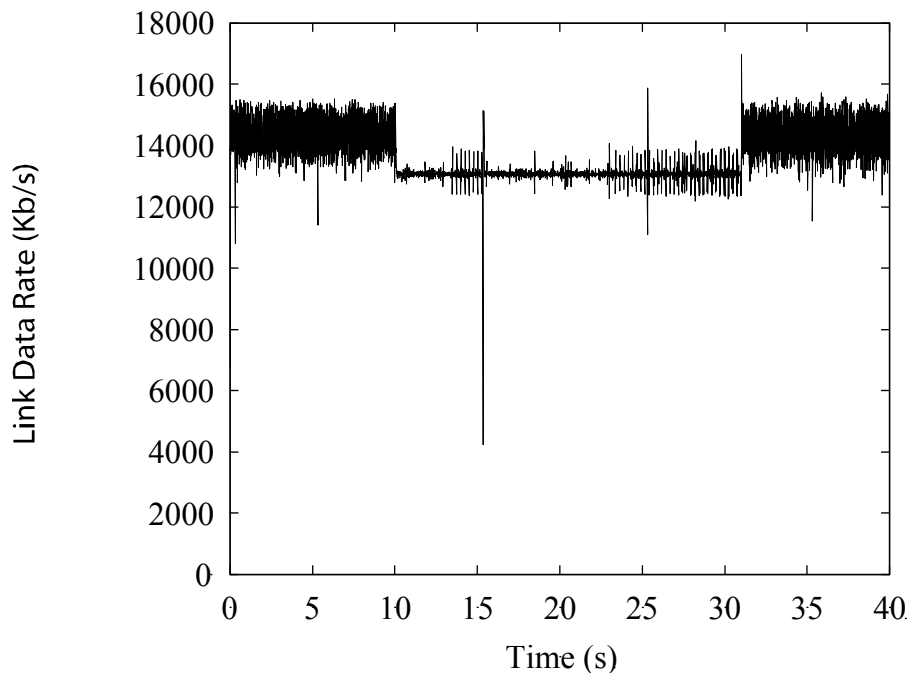
- Offered data rate ~ 15 Mb/s, Target shaping rate ~ 13 Mb/s

- 32 MTU TCP socket buffer, Ethernet MTU = 1500 byte

- throughput = congestion window/round-trip time

- RTT = 32 MTU/13 Mb/s ~ 29.5 ms

Concept of Scavenger Service
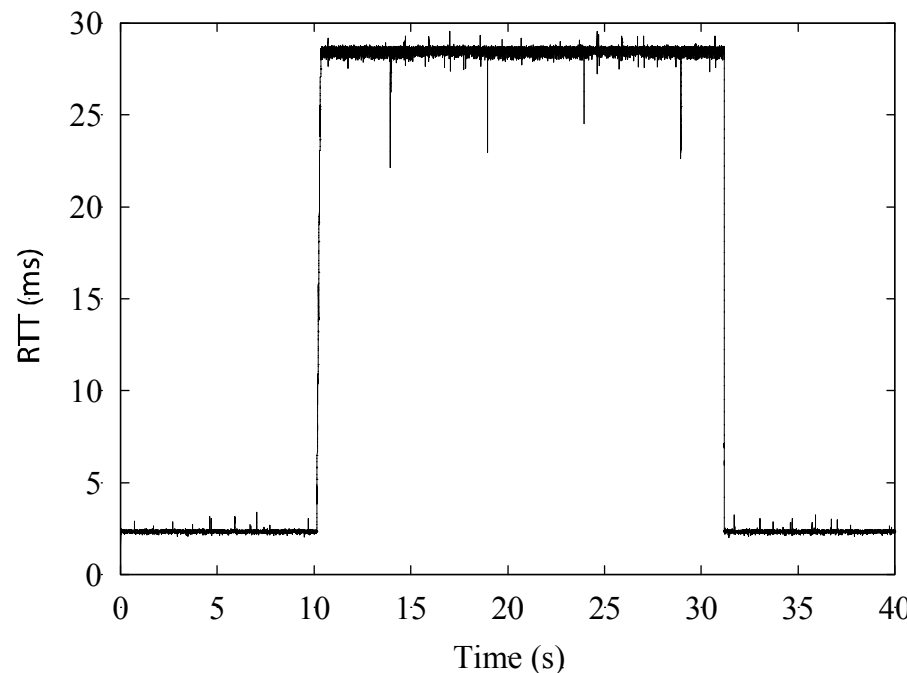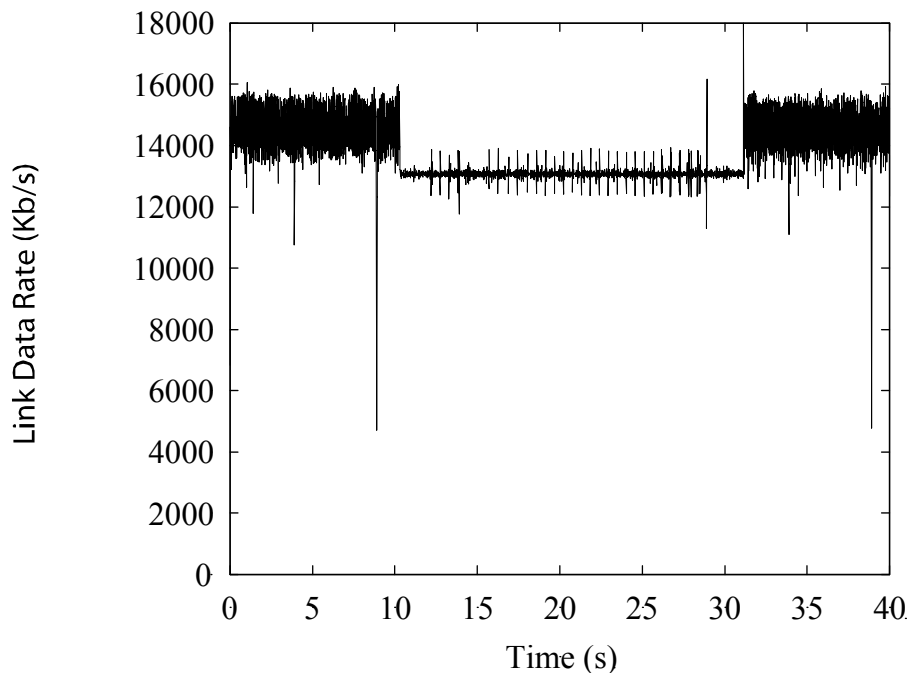
Less than Best Effort Scavenger Service

- Can scavenge any unused transmission capacity
- Cannot preempt any other service
- Can be starved by any other service
- Applicable for background file transfer traffic, peer-to-peer traffic, ...
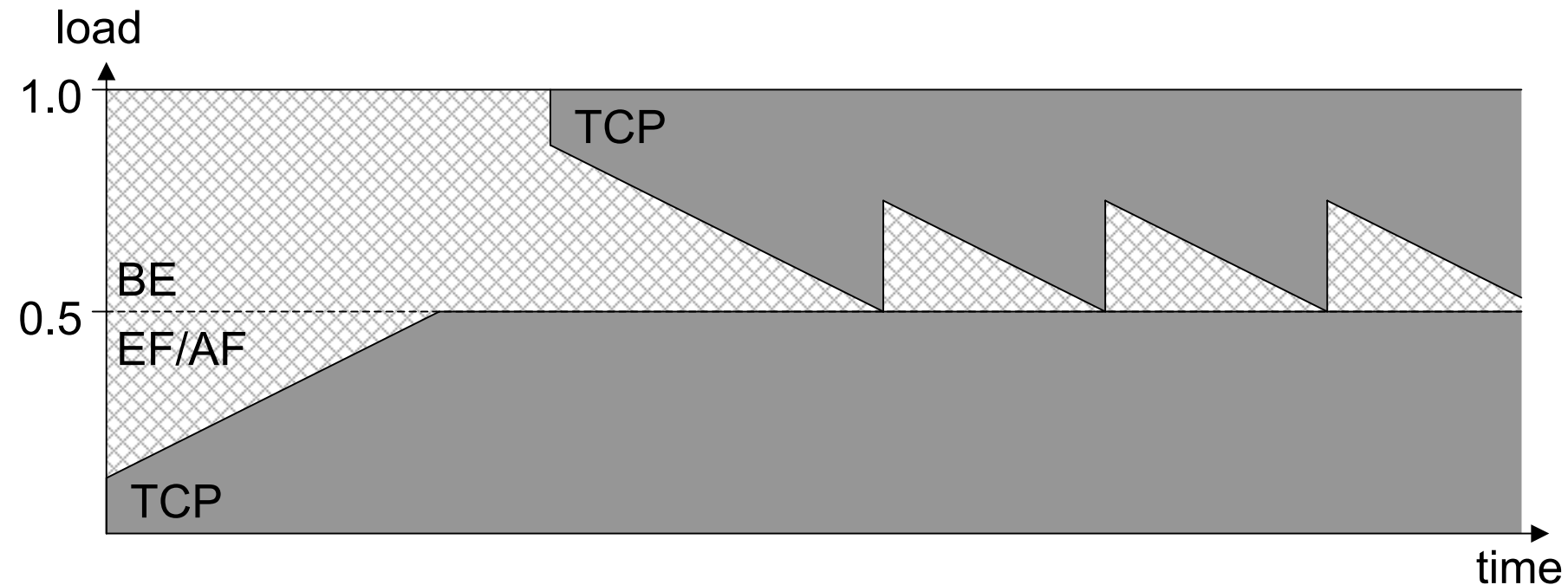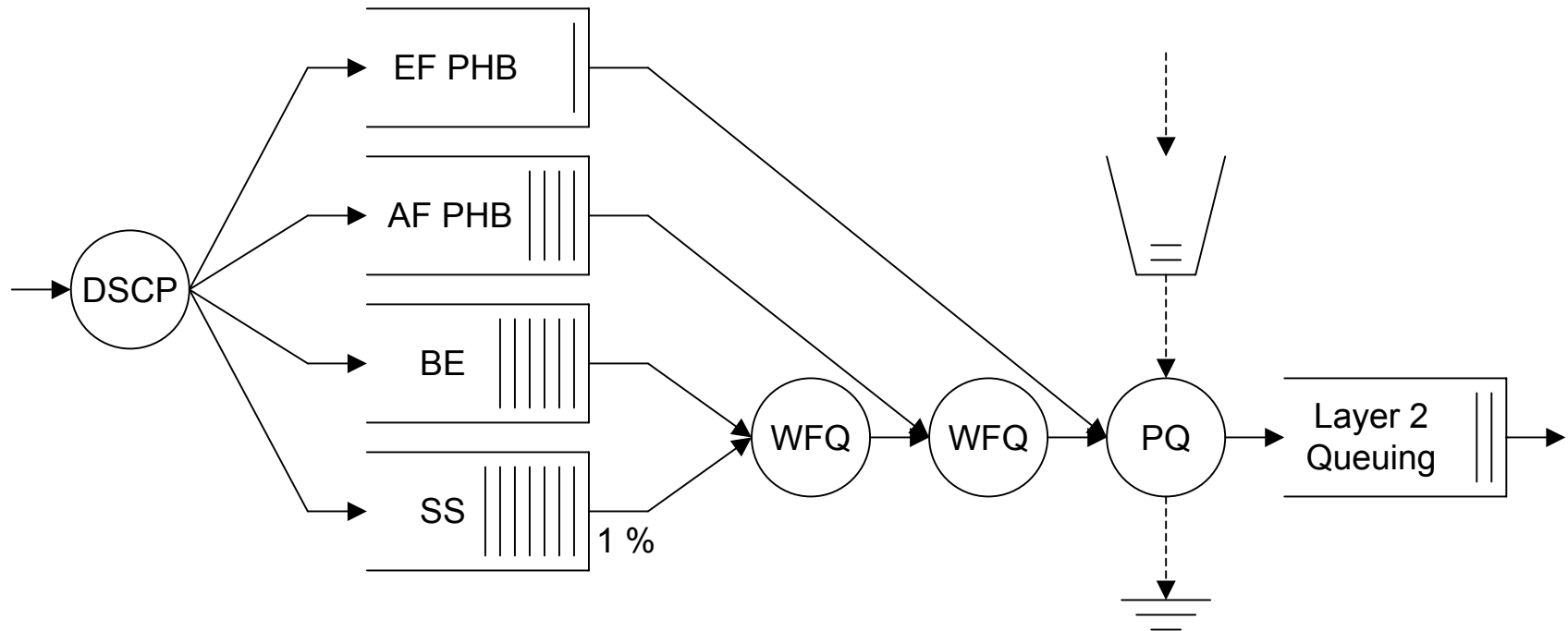
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DSCP:	Differentiated Services Codepoint
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SS:	Scavenger Service
WFQ:	Weighted Fair Queuing
PQ:	Priority Queuing

Application Scenario
Grid FTP

- Grid FTP applies striped sockets to increase throughput
  - TCP congestion control achieves fairness among competing TCP connections
  - Applying parallel TCP connections circumvents this mechanism and is considered to be TCP-unfriendly
  - TCP-friendly congestion control is mandatory when applying the Best-Effort Service
- Best-Effort Service cannot give performance guarantees
  - Deadline file transfer
  - Guaranteed Rate Service
- The proposed solution is a multi-class Grid FTP
  - Guaranteed Rate Service
  - Scavenger Service
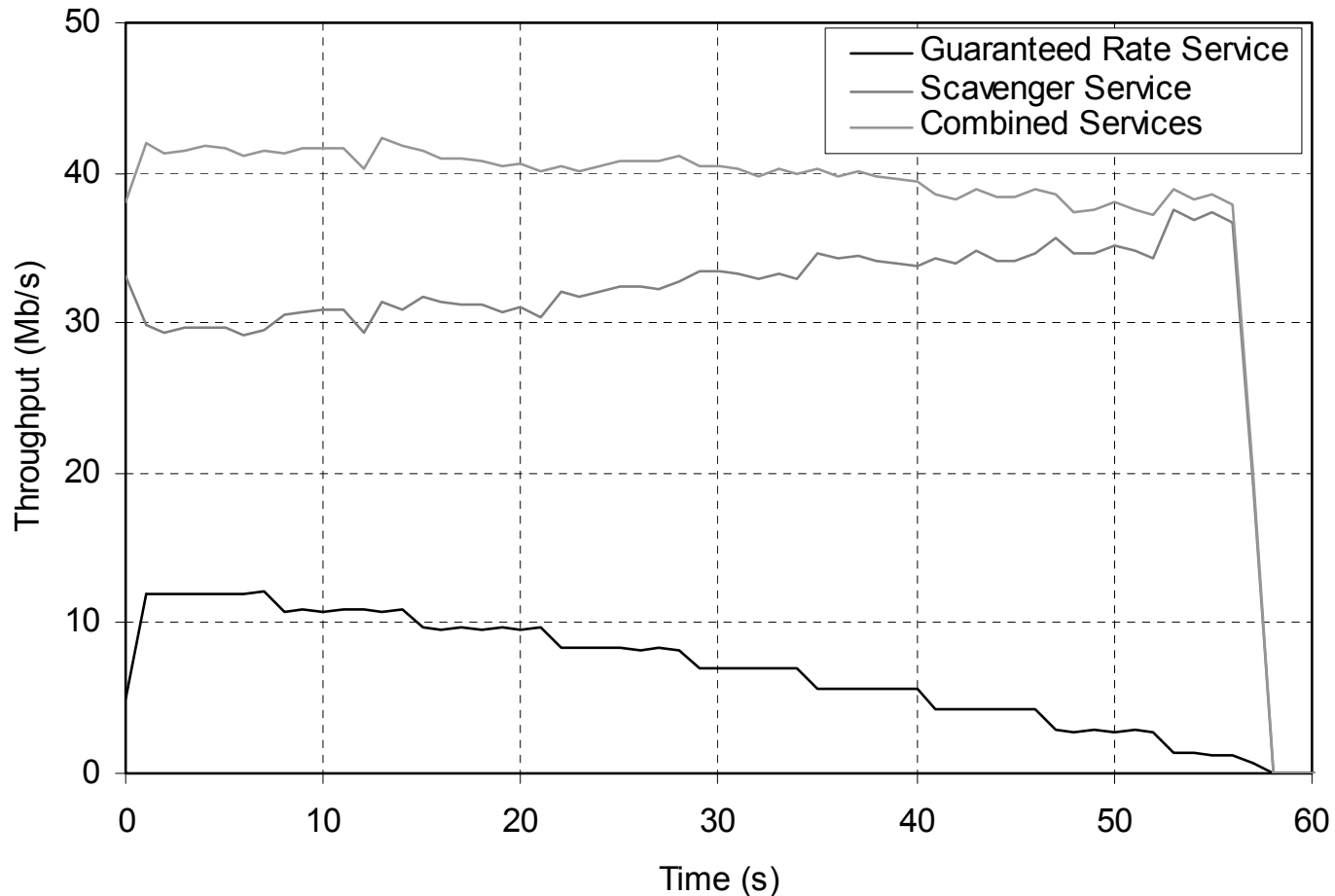
Multi-Class Grid FTP Without BE Congestion

Deadline file transfer (280 Mbyte file / 200 s deadline = 12 Mb/s guaranteed rate)
Guaranteed Rate update for each 25 Mbyte of Scavenger data

Multi-Class Grid FTP With BE Congestion

Deadline file transfer (280 Mbyte file / 200 s deadline = 12 Mb/s guaranteed rate)
Guaranteed Rate update for each 25 Mbyte of Scavenger data

Conclusions
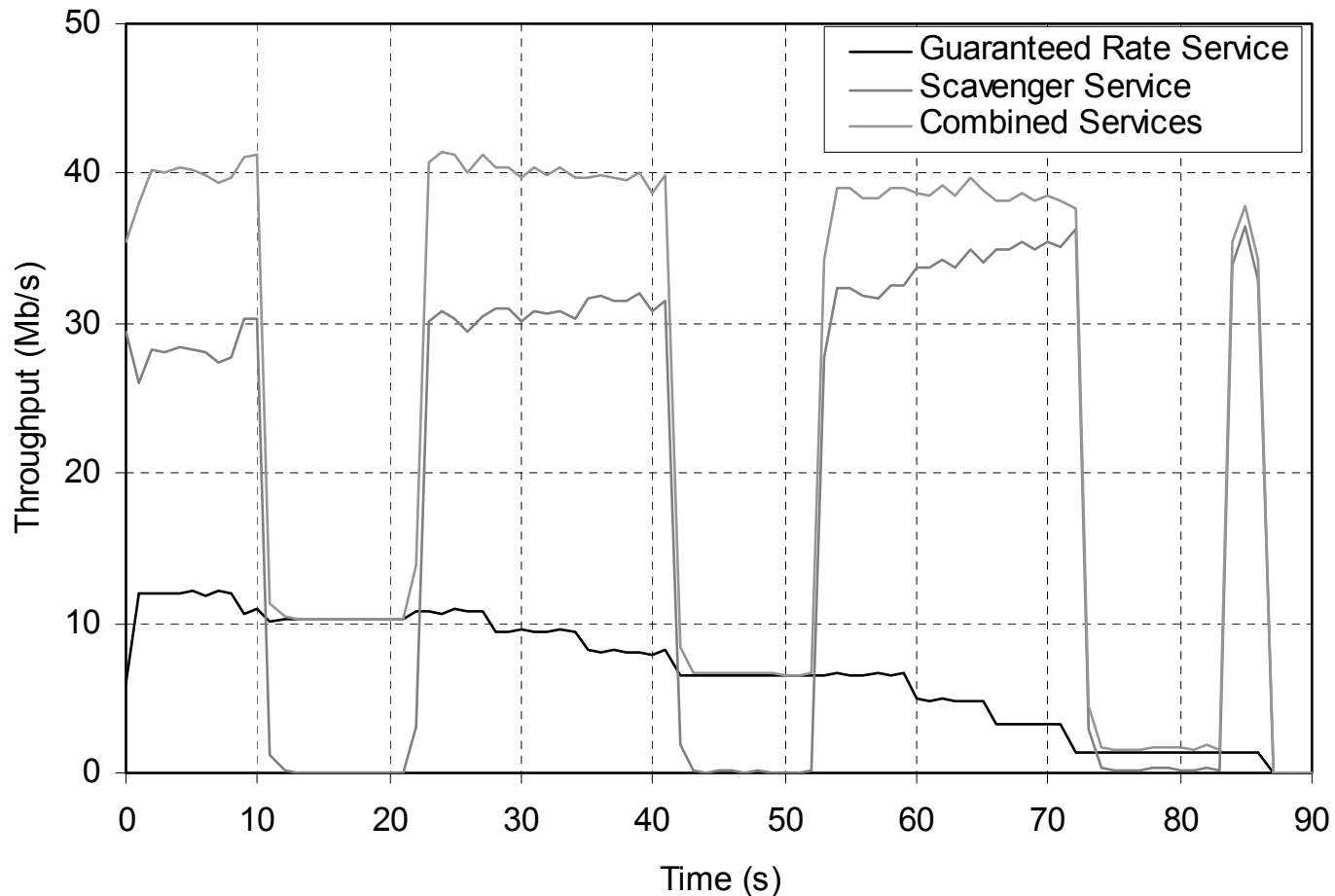
- ## Guaranteed Rate Service
  - Requires a thorough fine-tuning for TCP based applications
    - Prevent from packet loss and congestion window reduction
    - Traffic shaping or rate adaptation at application level
  - Performance Bounds
    - TCP throughput matches the guaranteed rate
    - Any higher rate can result in packet loss and performance degradation

- ## Scavenger Services
  - Scavenge unused resources
  - Best-Effort friendly
  - Cost-effective

- ## Multi-class applications
  - Deadline File Transfer - TCP based
  - Layered Video Transmission - RTP/UDP based