Scalable Scheduling Support for Loss and Delay Constrained Media Streams

Richard West, Karsten Schwan &
Christian Poellabauer

Georgia Institute of Technology

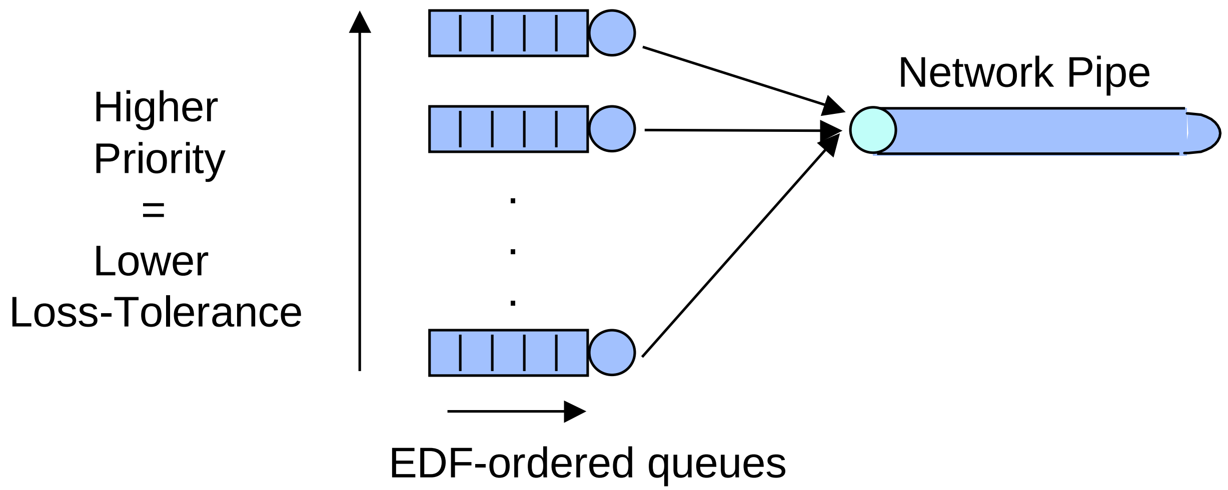
Introduction

- Real-Time media servers need to support 100s (even 1000s) of clients with individual RT (QoS) constraints.
- Need fast/efficient scheduling on such servers.
- We describe Dynamic Window-Constrained Scheduling (DWCS):
  - DWCS limits the number of late packets over finite windows of arrivals requiring service.
  - Focus on a scalable implementation of DWCS.
  - Approximating DWCS trades execution speed for service quality.

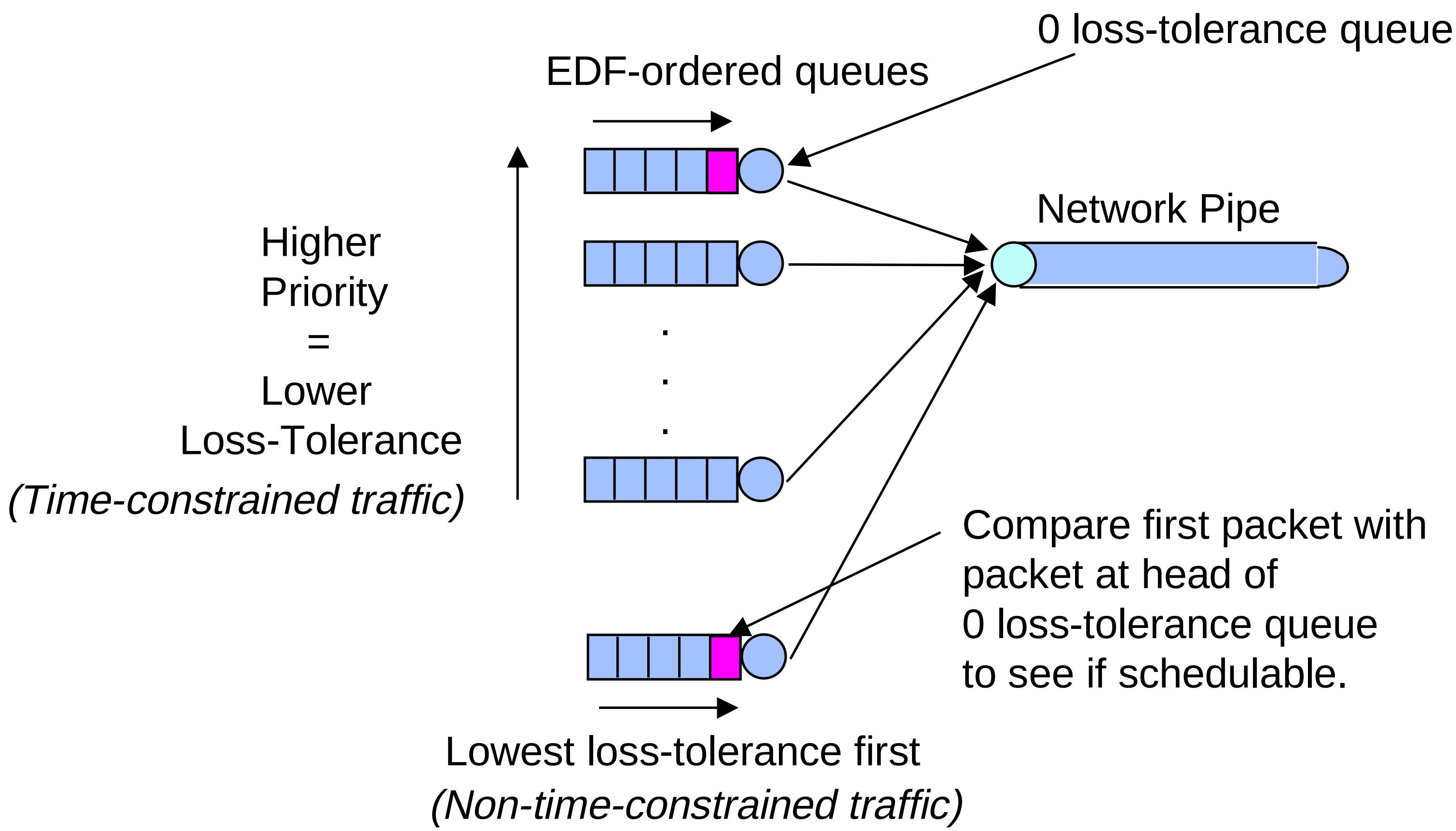
DWCS Packet Scheduling

- Two attributes per packet:
  - Deadline (max inter-packet gap).
  - Loss-tolerance, **x/y**.
    - **x** late/lost packets every **y** arrivals for service from same stream.
- At any time, all packets in the same stream:
  - Have the same current loss-tolerance.
  - Have deadlines offset by a fixed amount from predecessors.

DWCS - Conceptual View



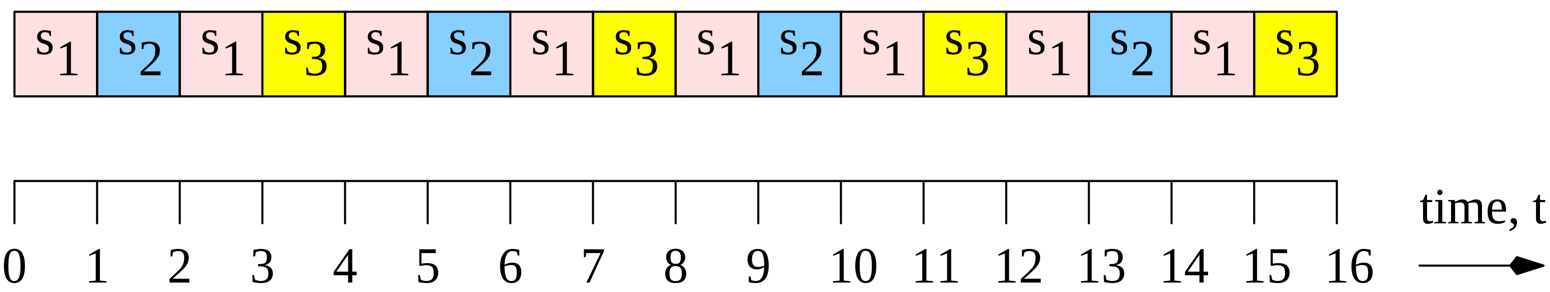
Heterogeneous Scheduling



Pairwise Packet Ordering Table

Precedence amongst pairs of packets
• Lowest loss-tolerance first
• Same non-zero loss-tolerance, order EDF
• Same non-zero loss-tolerance & deadlines, order lowest loss-numerator first
• Zero loss-tolerance and denominators, order EDF
• Zero loss-tolerance, order highest loss-denominator first
• All other cases: first-come-first-serve

Example: L1=1/2, L2=3/4, L3=6/8 D=1, Service Time (C)=1

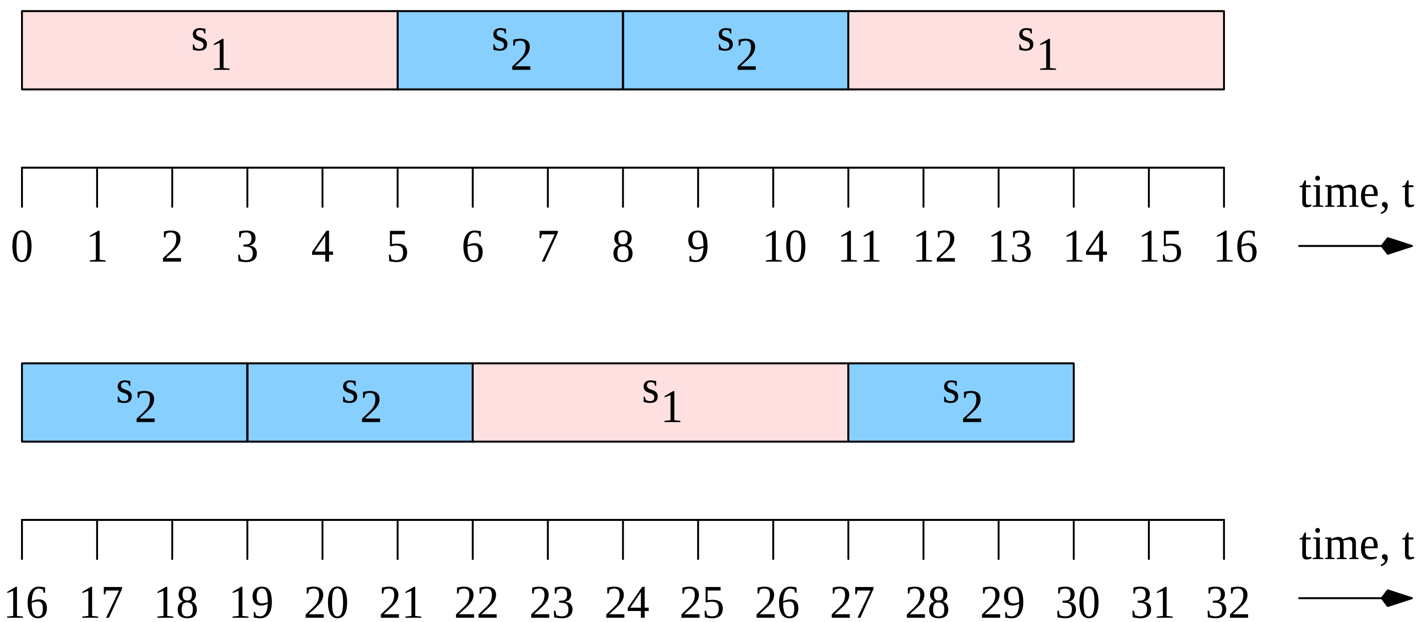


s_1 1/2(0), 1/1(1),1/2(2),1/1(3),1/2(4)...

s_2 3/4(0),2/3(1),2/2(2),1/1(3),3/4(4),2/3(5),2/2(6),1/1(7),3/4(8)...

s_3 6/8(0),5/7(1),4/6(2),3/5(3),3/4(4),2/3(5),1/2(6),0/1(7),6/8(8)...

Example: L1=1/2, L2=1/2, C1=5, C2=3, D1=5, D2=3



s_1 1/2(0),1/1(5),1/2(10),0/1(15),1/2(20),0/1(25),1/2(30)...

s_2 1/2(0),0/1(3),1/4(6),1/3(9),1/2(12),0/1(15),1/4(18),

1/3(21),1/2(24),0/1(27),1/2(30)...

Loss-Tolerance Adjustment (A)

- For stream **i** whose head packet is serviced before its deadline:
  - if ($y_i' > x_i'$) then $y_i' = y_i' - 1$;
  - if ($x_i' = y_i' = 0$) then $x_i' = x_i$; $y_i' = y_i$;
- Where:
  - x_i=Original loss-numerator for stream **i**
  - y_i=Original loss-denominator for stream **i**
  - x_i'=Current loss-numerator for stream **i**
  - y_i'=Current loss-denominator for stream **i**

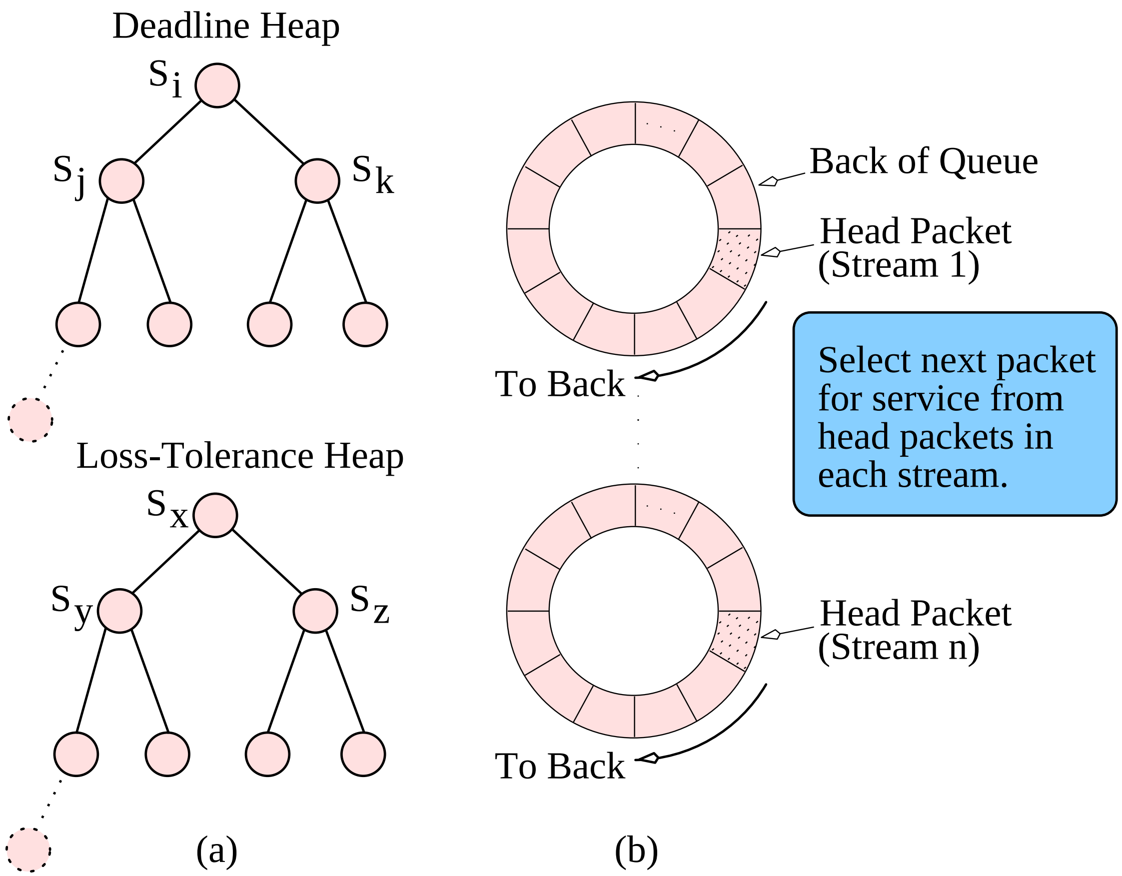
Loss-Tolerance Adjustment (B)

- For stream **j** whose head packet misses its deadline:
  - if ($\mathbf{x_j'} > 0$) then
    - $\mathbf{x_j'}=\mathbf{x_j'}-1$; $\mathbf{y_j'}=\mathbf{y_j'}-1$;
    - if ($\mathbf{x_j'}=\mathbf{y_j'}=0$) then $\mathbf{x_j'}=\mathbf{x_j}$; $\mathbf{y_j'}=\mathbf{y_j}$;
  - else if ($\mathbf{x_j'}=0$) and ($\mathbf{y_j} > 0$) then
    - $\mathbf{x_j'}=2\mathbf{x_j}-1$; $\mathbf{y_j'}=2\mathbf{y_j}+(\mathbf{y_j'}-1)$; (**method 1**)
    - $\mathbf{x_j'}=\mathbf{x_j}$; $\mathbf{y_j'}=\mathbf{y_j}$; (**method 2**)
    - if ($\mathbf{x_j} > 0$) then $\mathbf{y_j'}=\mathbf{y_j'}+\lceil(\mathbf{y_j}-\mathbf{x_j})/\mathbf{x_j}\rceil$; (**method 3**)
    - if ($\mathbf{x_j}=0$) then $\mathbf{y_j'}=\mathbf{y_j'}+\mathbf{y_j}$;

DWCS Algorithm Outline

- While **TRUE**:
  - Find stream **i** with highest priority **(see Table)**
  - Service packet at head of stream **i**
  - Adjust loss-tolerance for **i** according to **(A)**
  - Deadline(**i**) = Deadline(**i**) + Inter-Pkt Gap(**i**)
  - For each stream **j** missing its deadline:
    - While deadline is missed:
      - Adjust loss-tolerance for **j** according to **(B)**
      - Drop head packet of stream **j** if droppable
      - Deadline(**j**) = Deadline(**j**) + Inter-Pkt Gap(**j**)

DWCS Implementation



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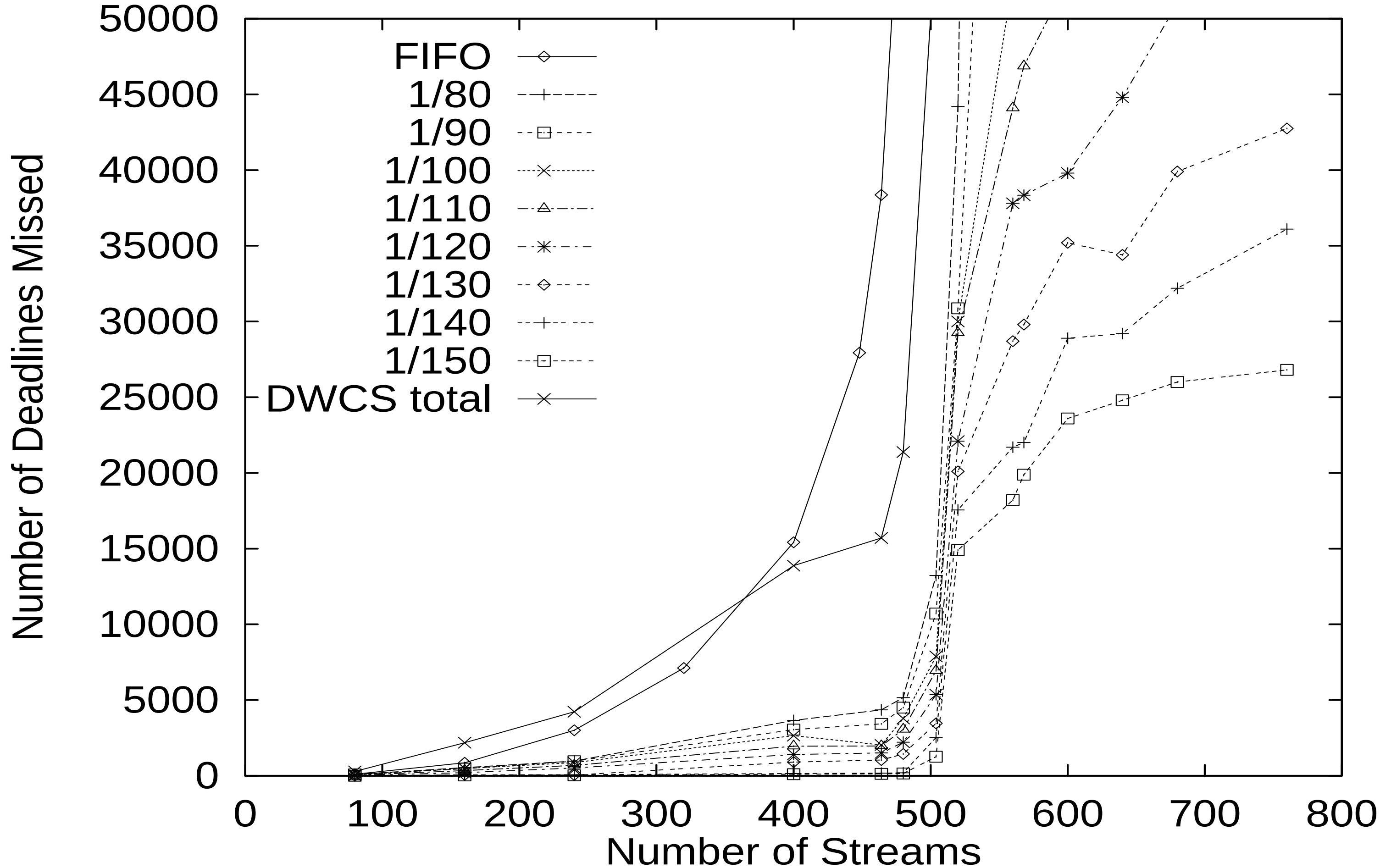
Missed Deadlines (D=500, C=1)



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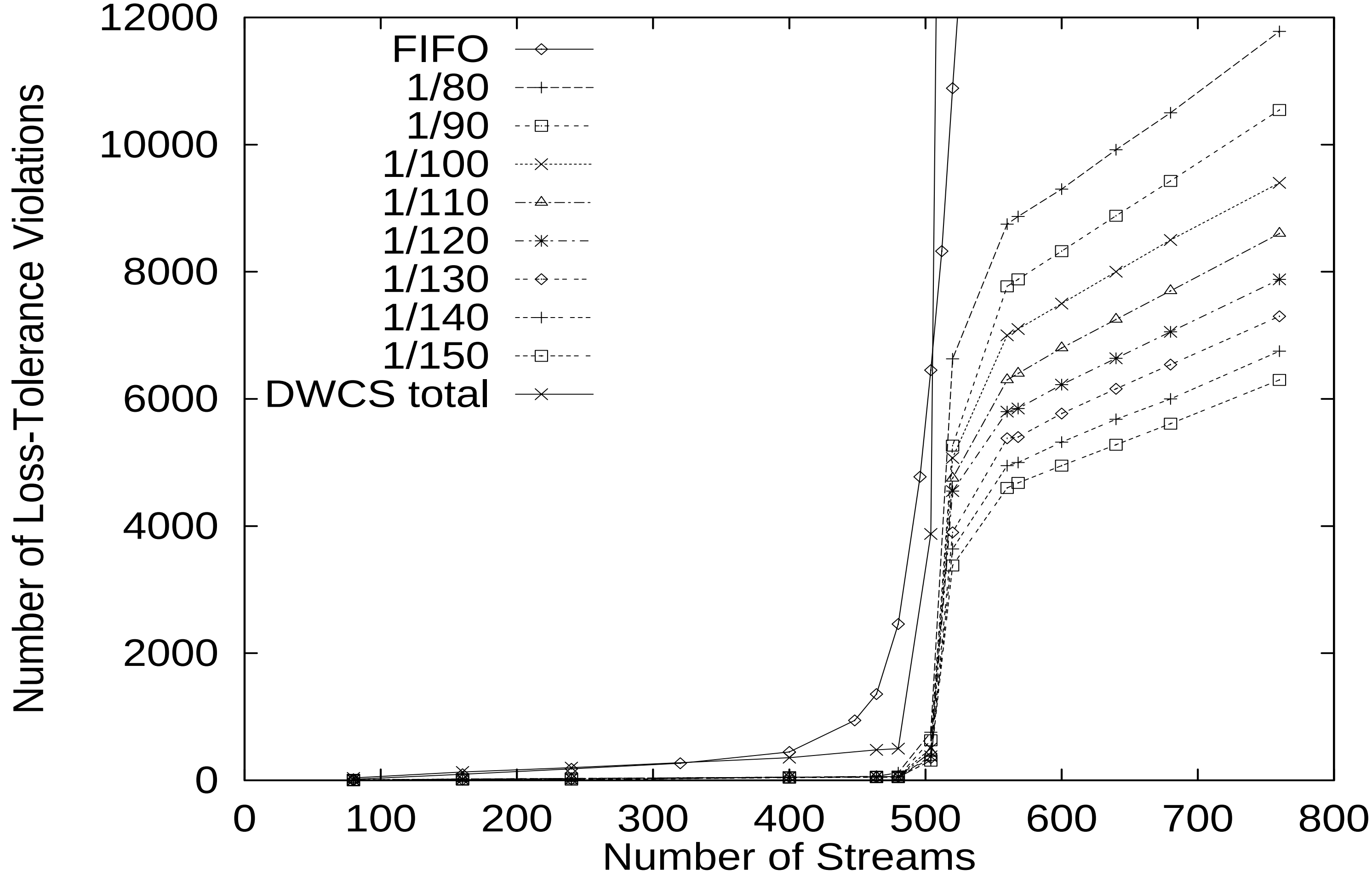
Loss-Tolerance Violations (D=500, C=1)



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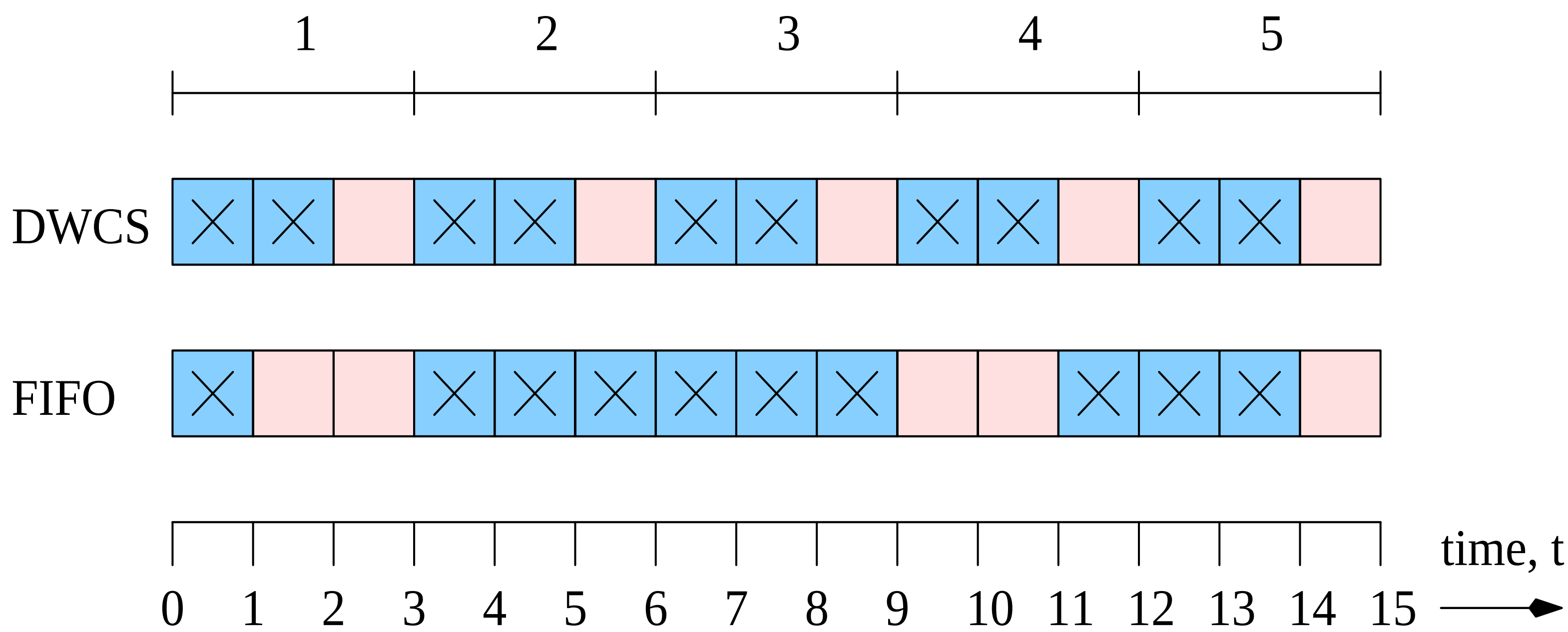
DWCS Spreads Losses



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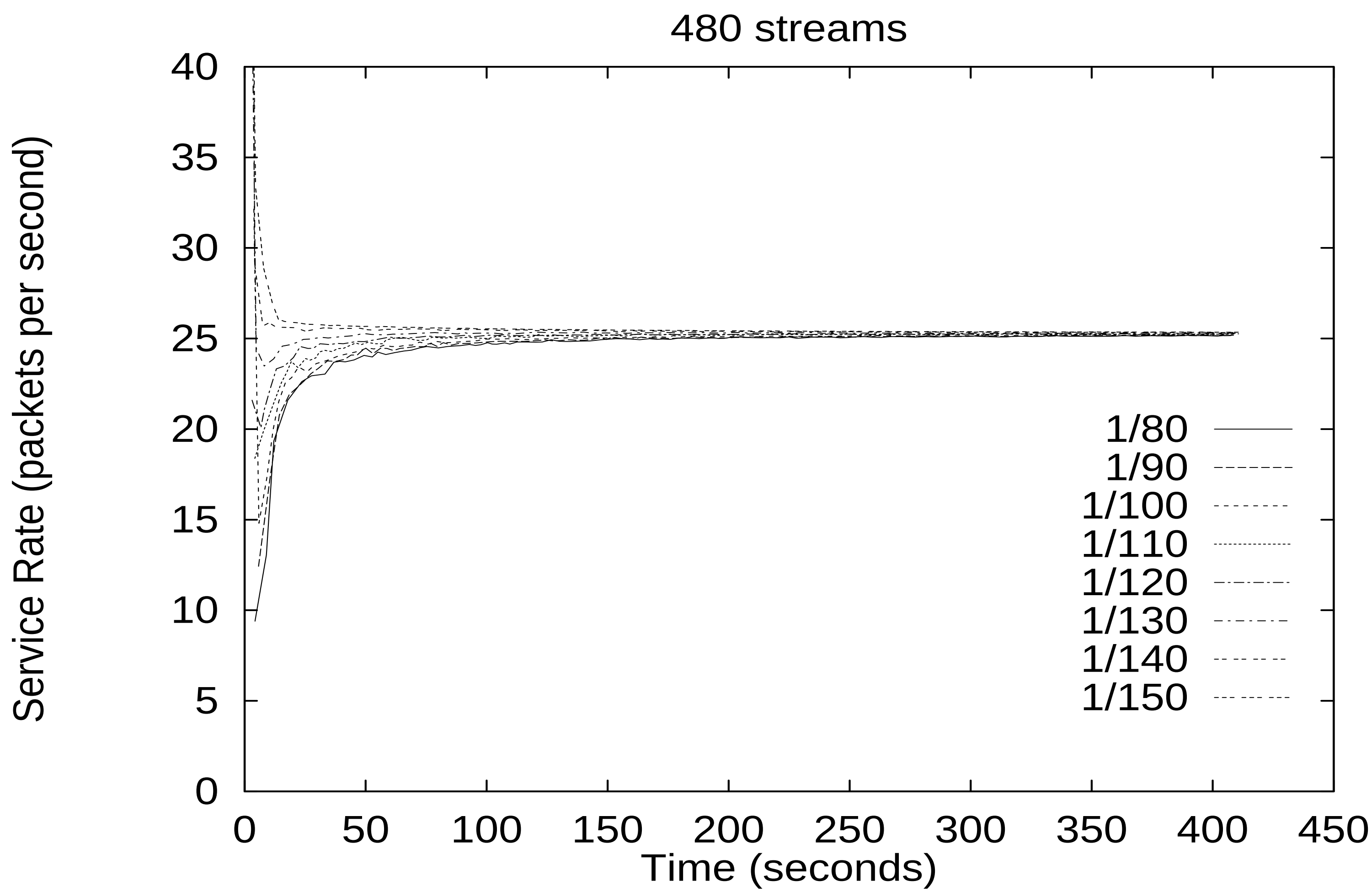
Packets Serviced Per Second



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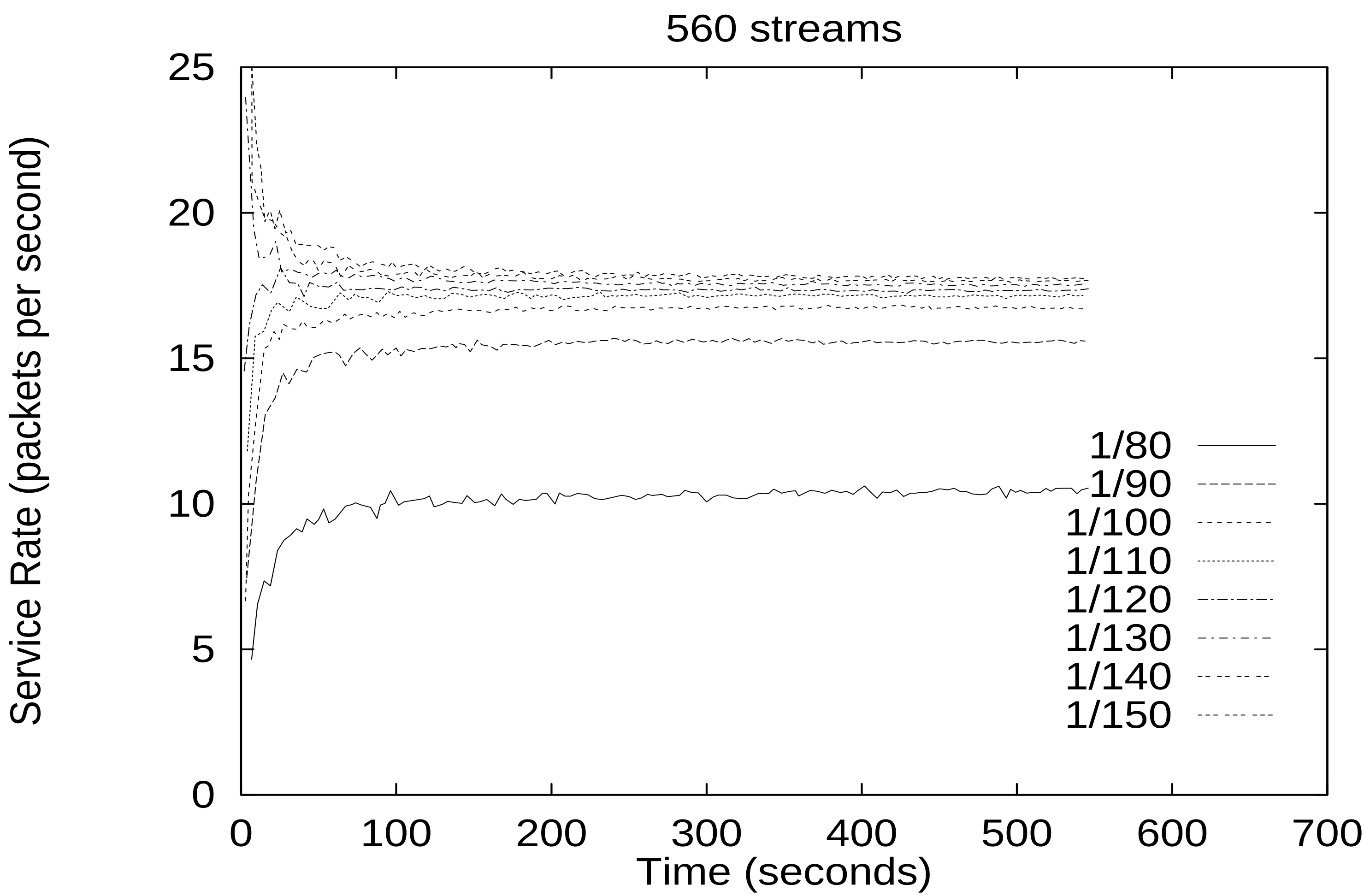

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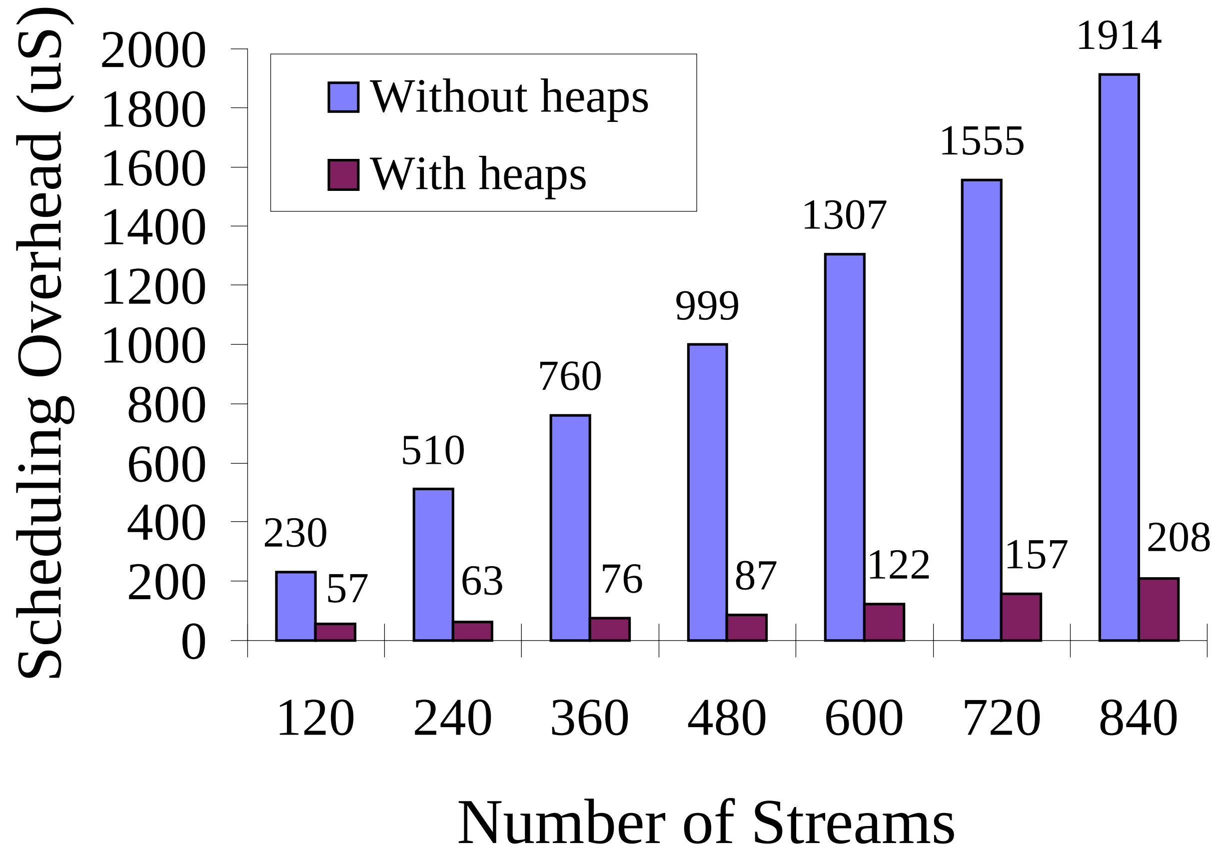
Scheduling Overhead



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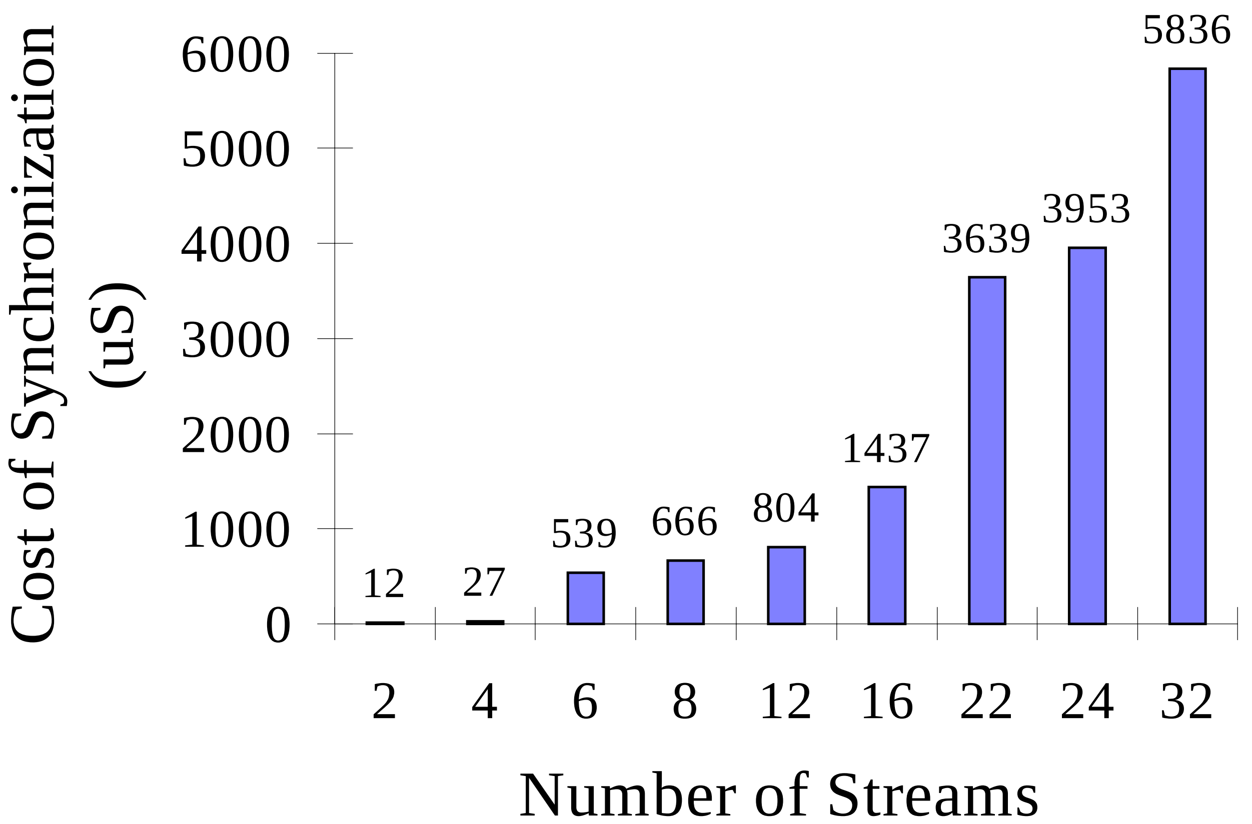
Synchronization Costs



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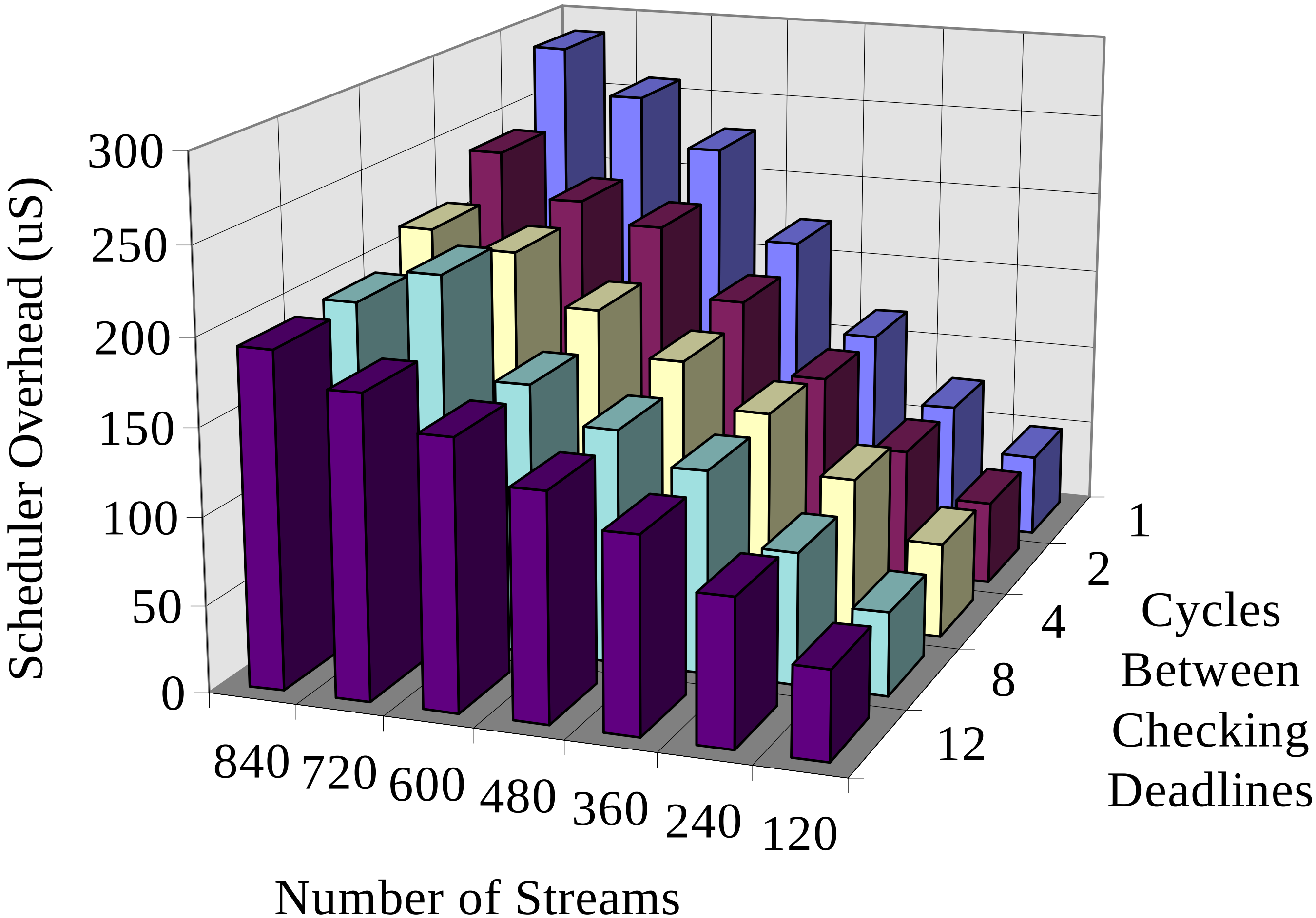
Approximation Overheads (D=200)



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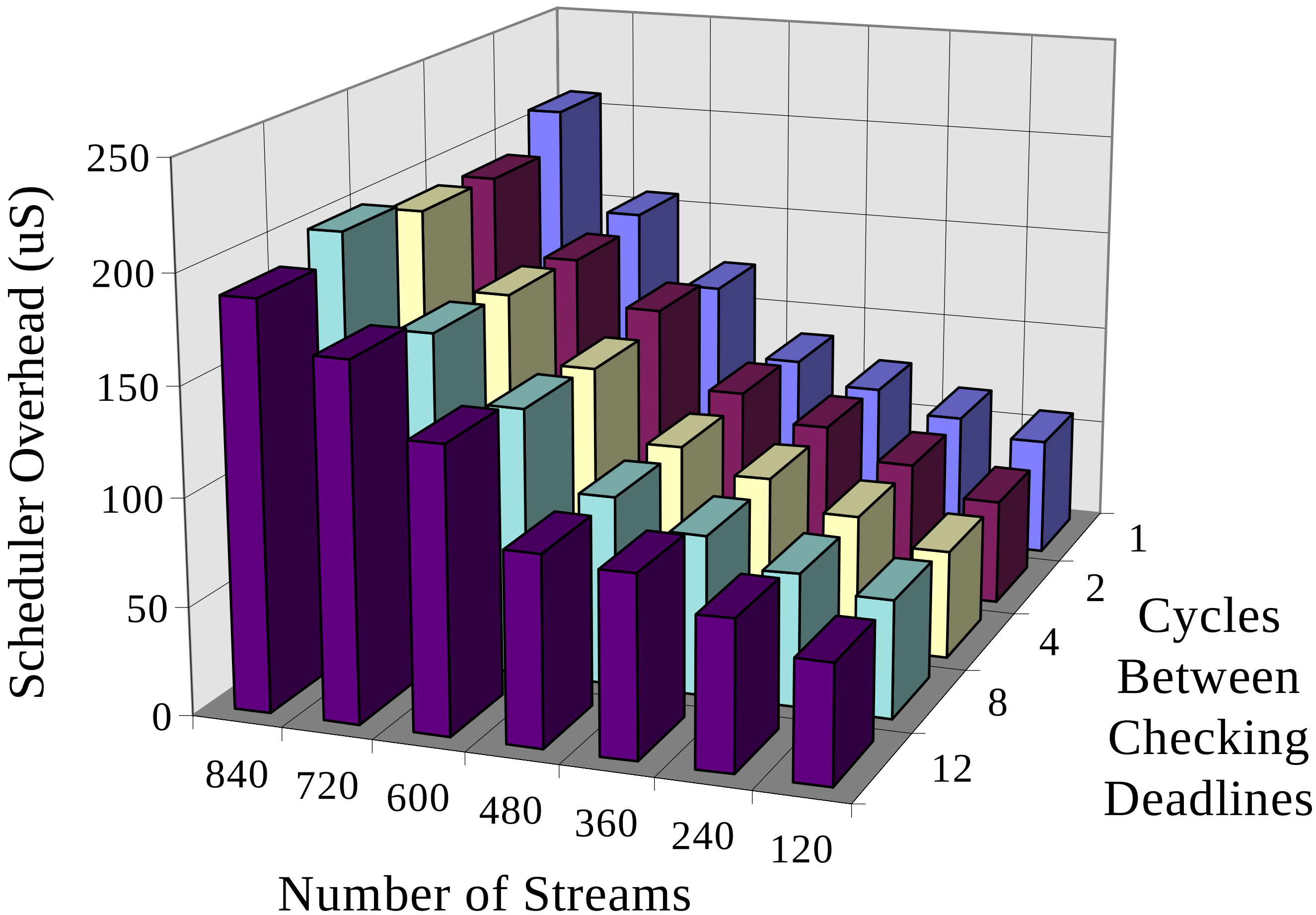

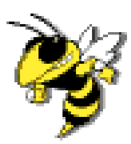

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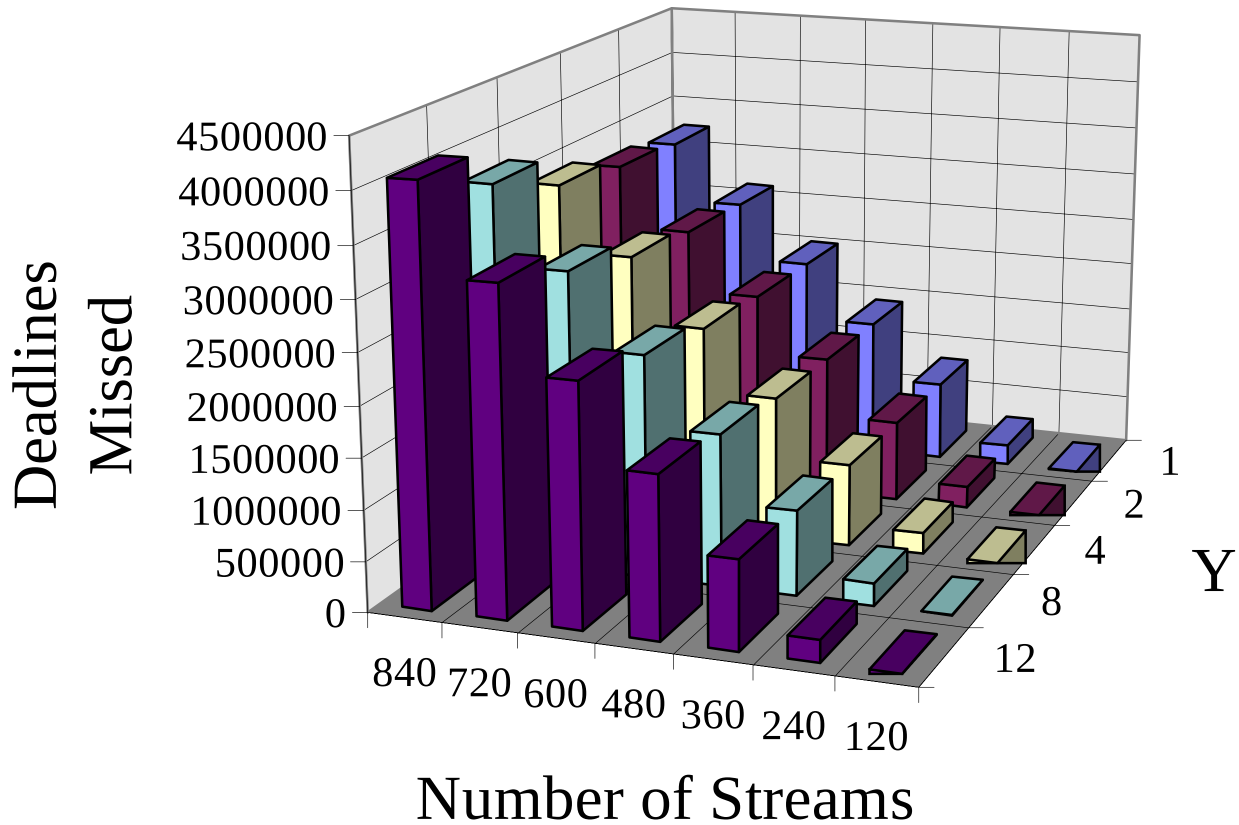
Deadlines Missed (D=200)



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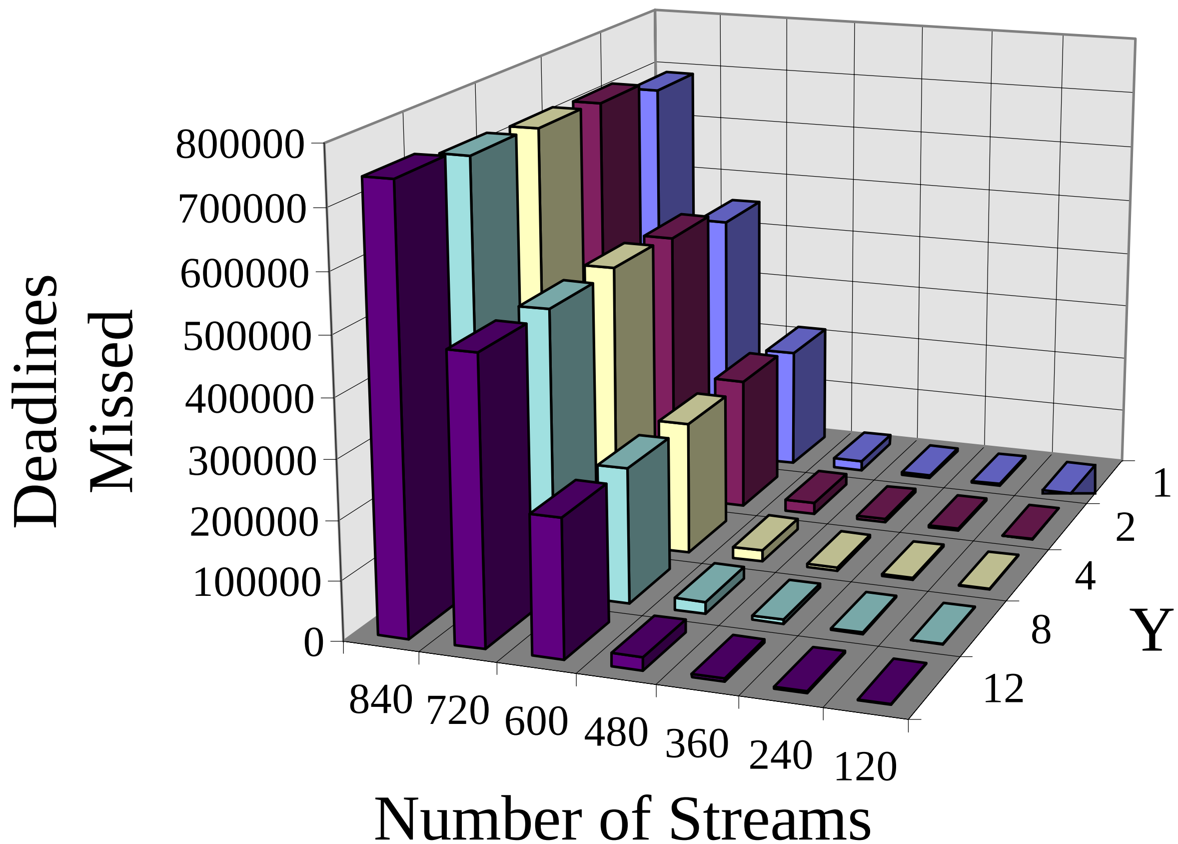
Deadlines Missed (D=500)



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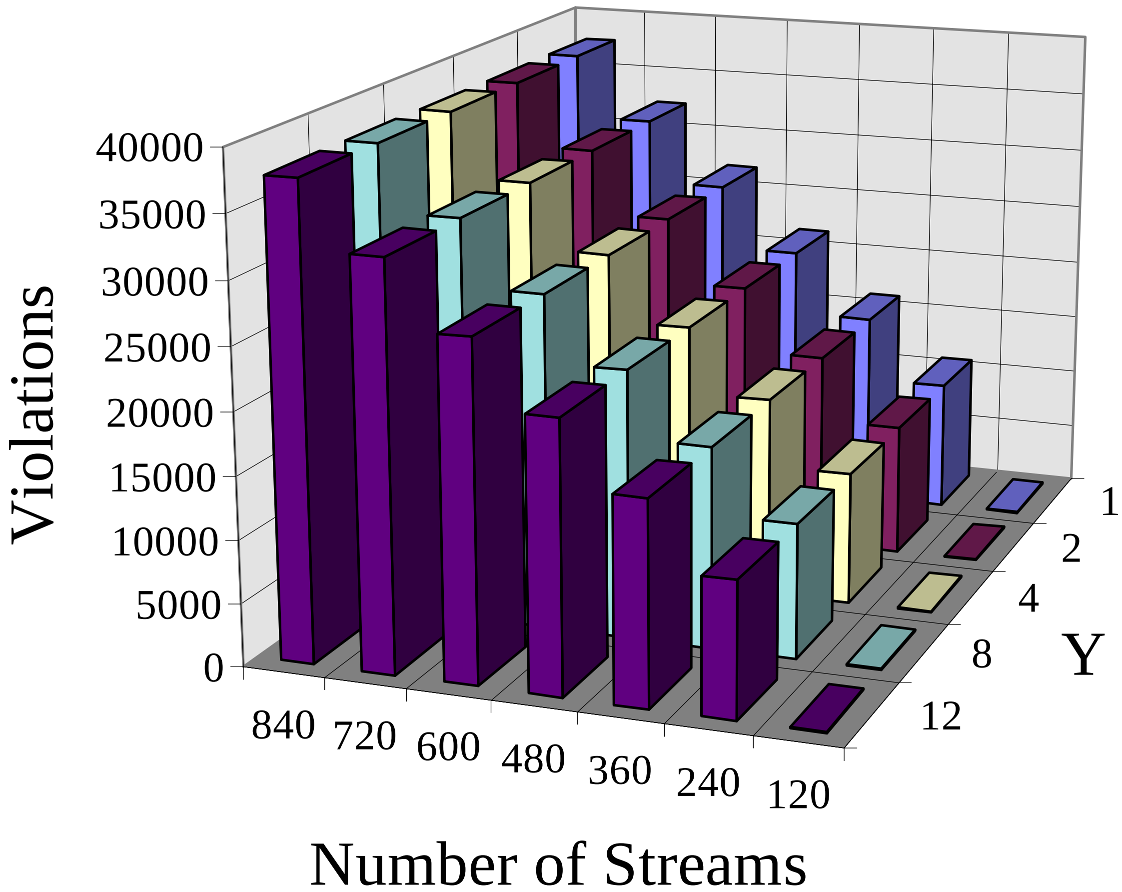
Loss-Tolerance Violations (D=200)



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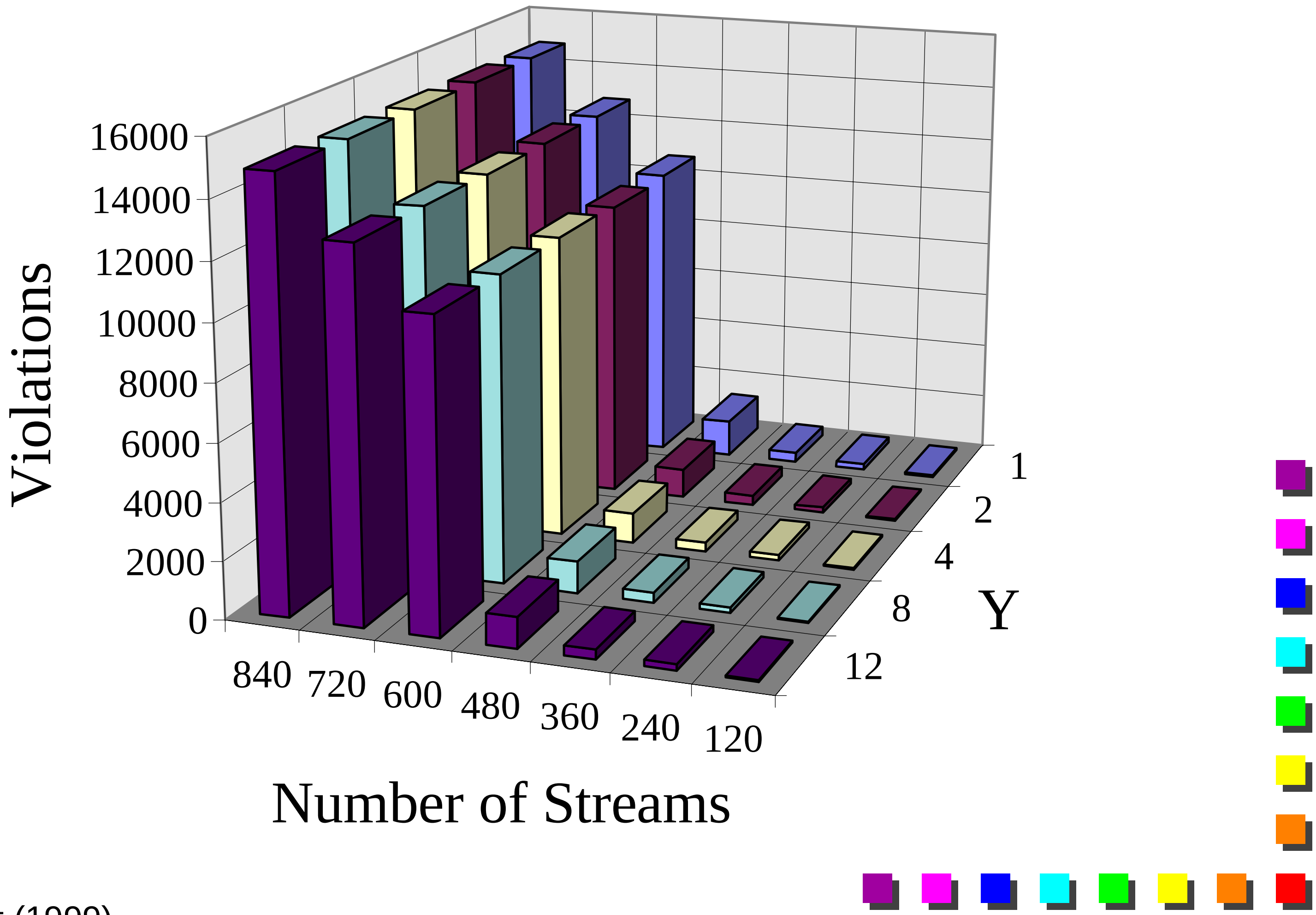
Loss-Tolerance Violations (D=500)



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DWCS Summary

- Aimed at servicing packets with delay and loss-constraints.
- Attempts to service each stream so that at most **x** packets are lost/late for every **y** packets requiring service.
  - DWCS minimizes the number of consecutive late packets over any finite window of packets in a given stream.
- Scheduling overhead can be reduced (and scalability increased) by using appropriate data structures (heaps, circular queues) and approximation methods.

DWCS - Current Work

- DWCS is currently being adapted for use as a CPU scheduler (using Linux), for **hard** real-time threads, so that **(y-x)** out of **y** deadlines can be met.
  - Leads to bounded service delay, and guaranteed service in any finite window of service time.
- Aim is to support **coordinated** thread/packet scheduling.

Scheduling Related Work

- **Fair Scheduling**: WFQ/WF^{2}Q (Shenker, Keshav, Bennett, Zhang etc), SFQ (Goyal et al), EEVDF/Proportional Share (Stoica, Jeffay et al).
- **(m,k) Deadline Scheduling**: Distance-Based Priority (Hamdaoui & Ramanathan), Dual-Priority Scheduling (Bernat & Burns).