Dynamic Window-Constrained Scheduling for Multimedia Applications

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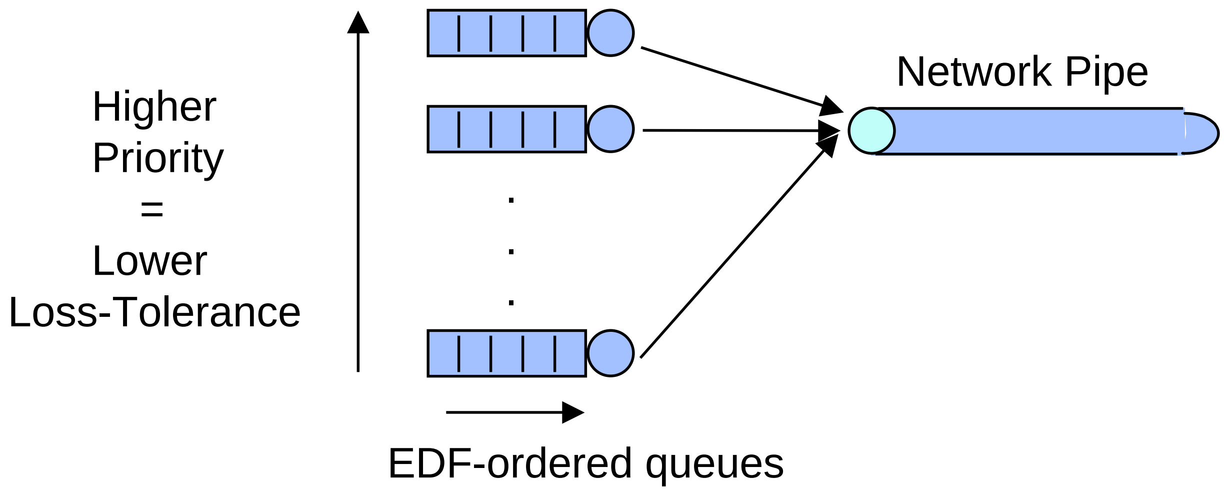
Introduction

- 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.
  - DWCS can be both fair and unfair when necessary - Performs Fair-Queueing, SP and EDF.
  - We demonstrate DWCS using a streaming video application.

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



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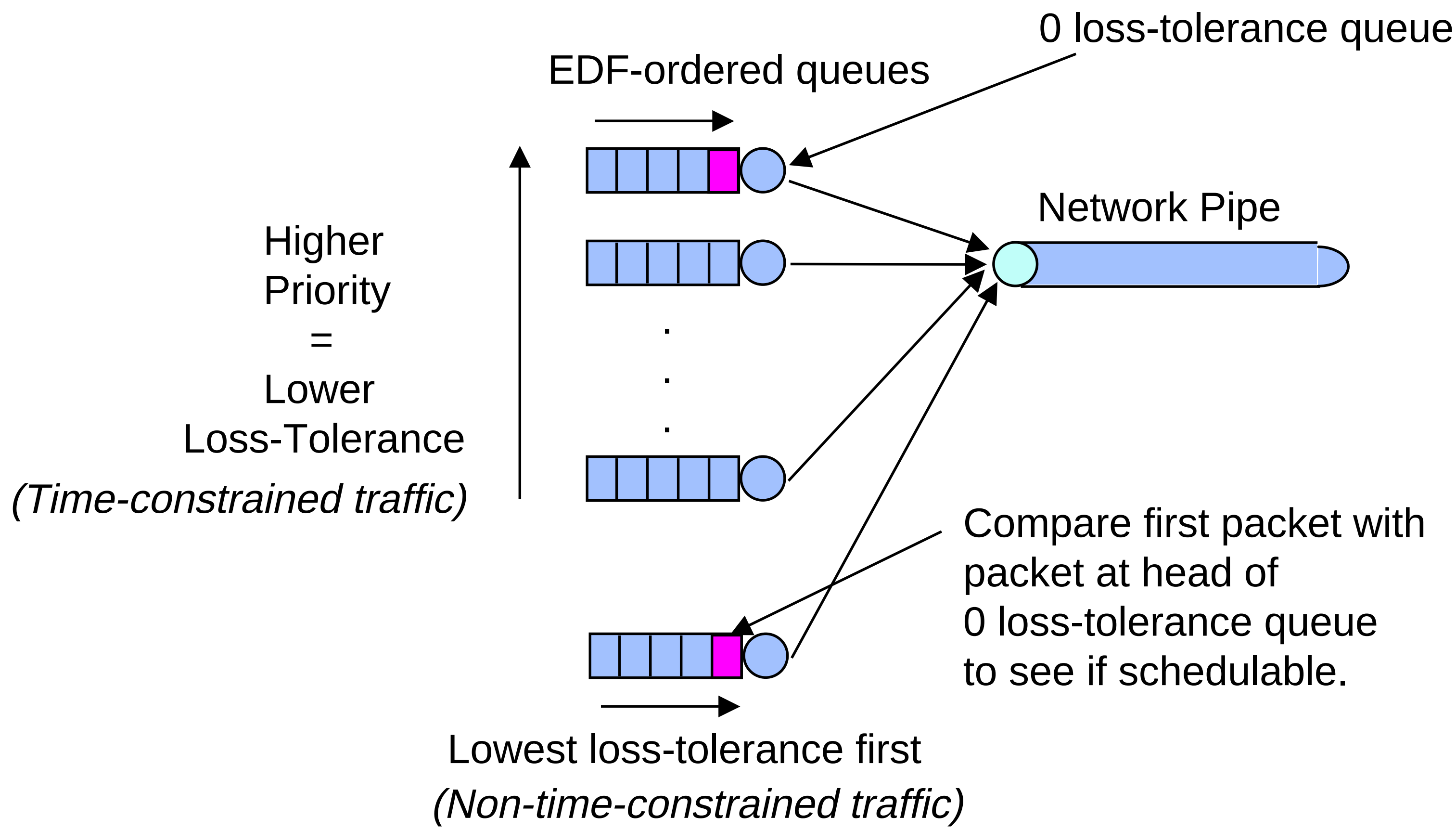
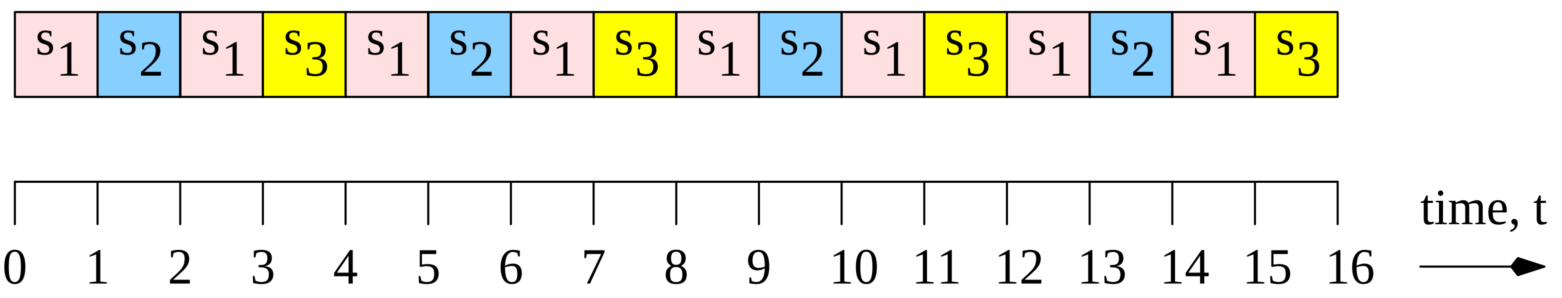
Heterogeneous Scheduling



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

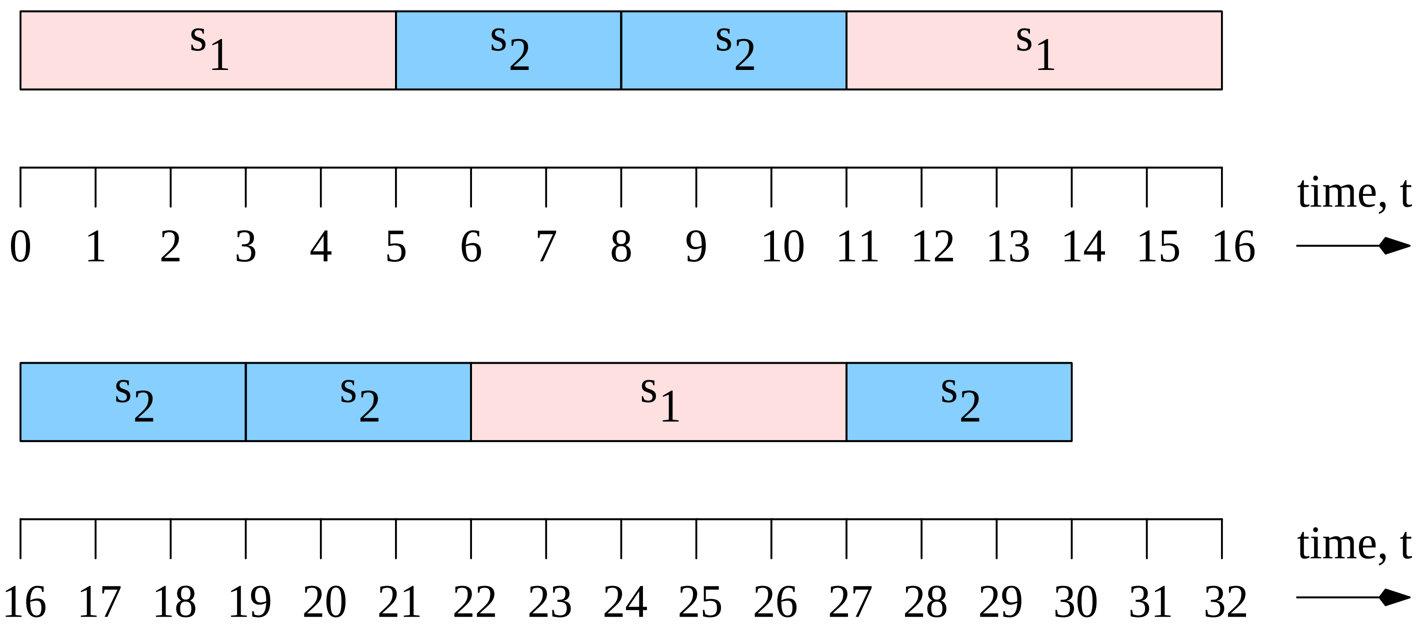


s_1 1/2(0), 1/1(1),1/2(2),1/1(3),1/2(4)...

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 ($\mathbf{y_i}'$ > $\mathbf{x_i}'$) then $\mathbf{y_i}'=\mathbf{y_i}'-1$;
  - if ($\mathbf{x_i}'=\mathbf{y_i}'=0$) then $\mathbf{x_i}'=\mathbf{x_i}$; $\mathbf{y_i}'=\mathbf{y_i}$;
- Where:
  - $\mathbf{x_i}$=Original loss-numerator for stream **i**
  - $\mathbf{y_i}$=Original loss-denominator for stream **i**
  - $\mathbf{x_i}'$=Current loss-numerator for stream **i**
  - $\mathbf{y_i}'$=Current loss-denominator for stream **i**

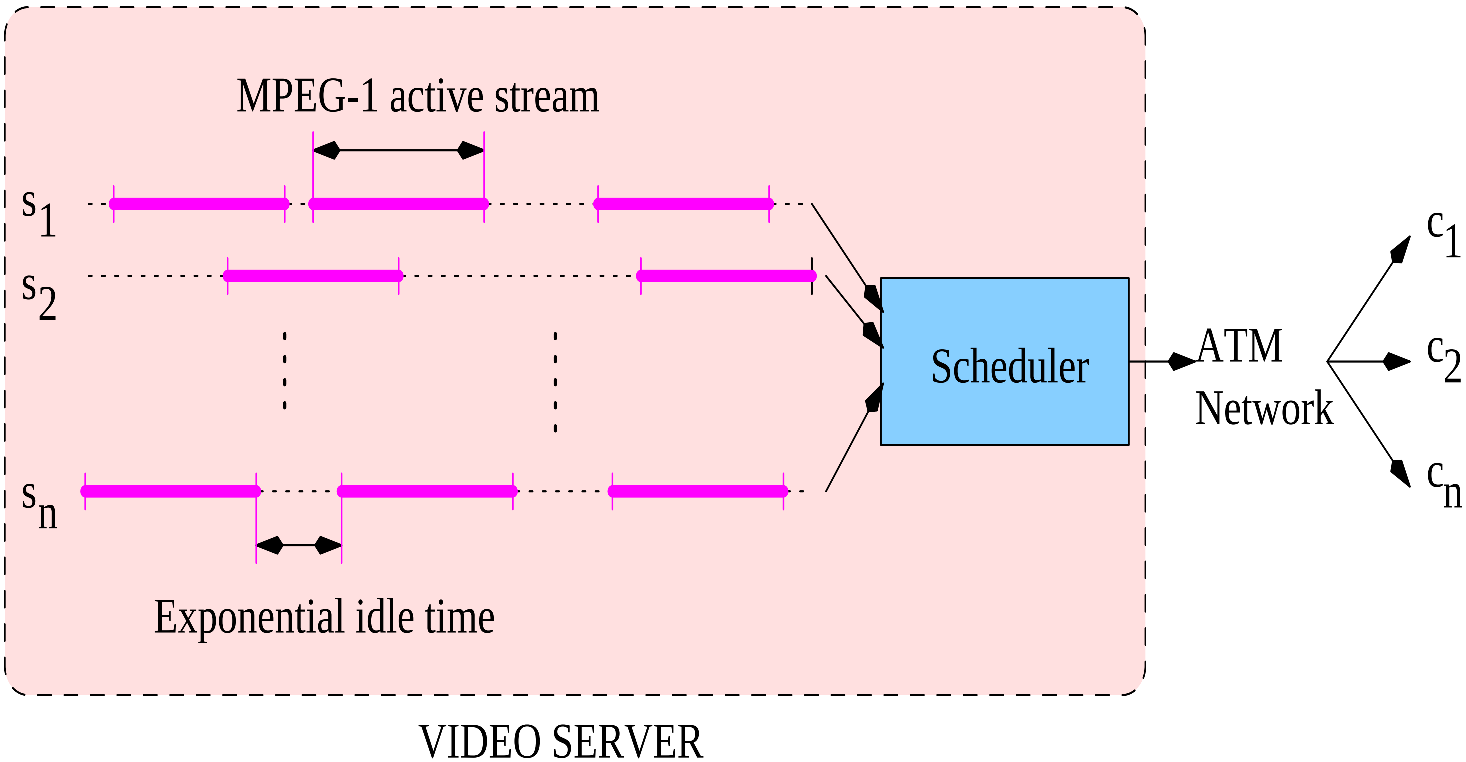
Loss-Tolerance Adjustment (B)

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

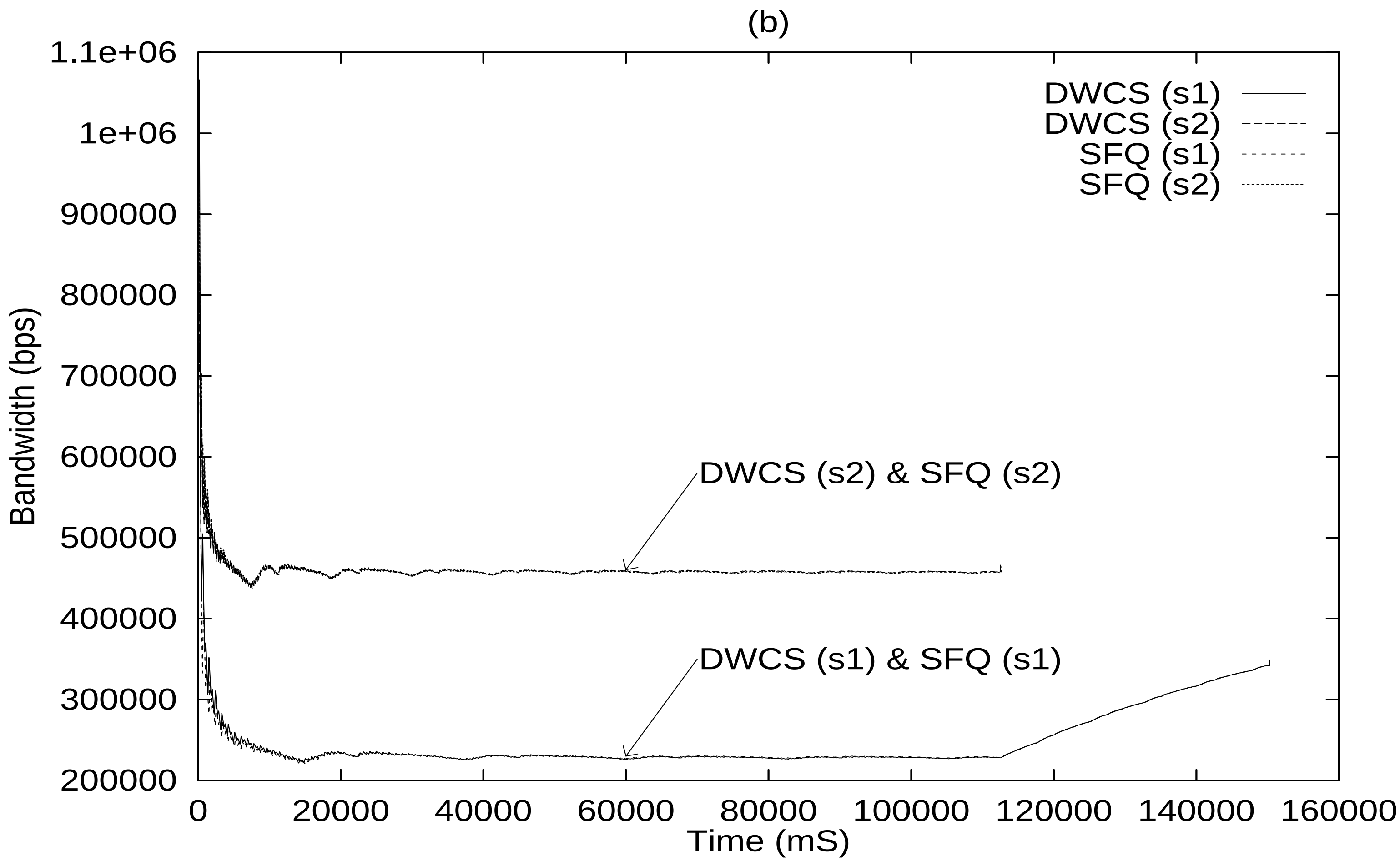
DWCS Algorithm Outline

- 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**)

Video Server



Fair Scheduling: W=1,2
L=2/3,1/3



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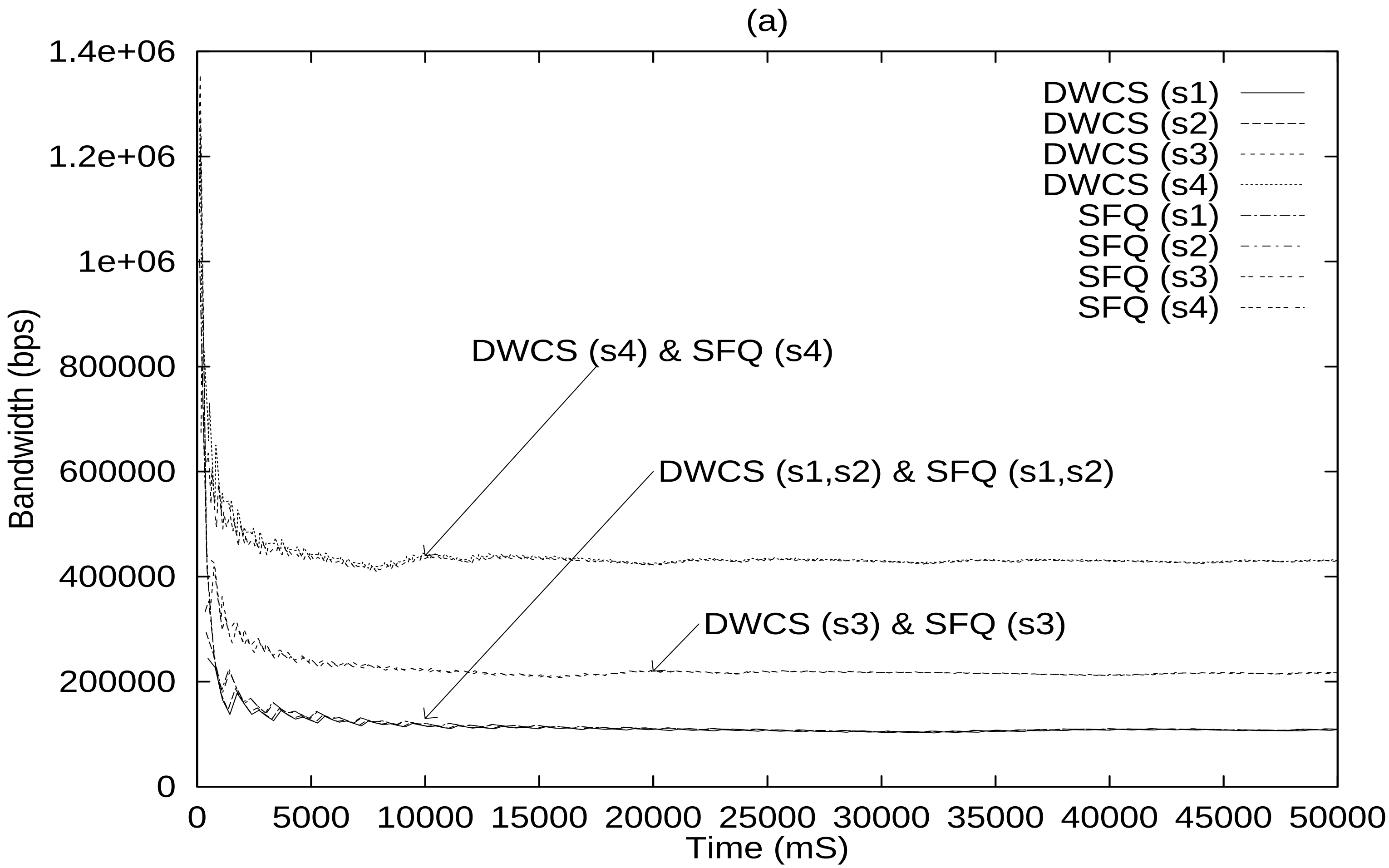
Fair Scheduling: W=1,1,2,4 L=7/8,14/16,6/8,4/8



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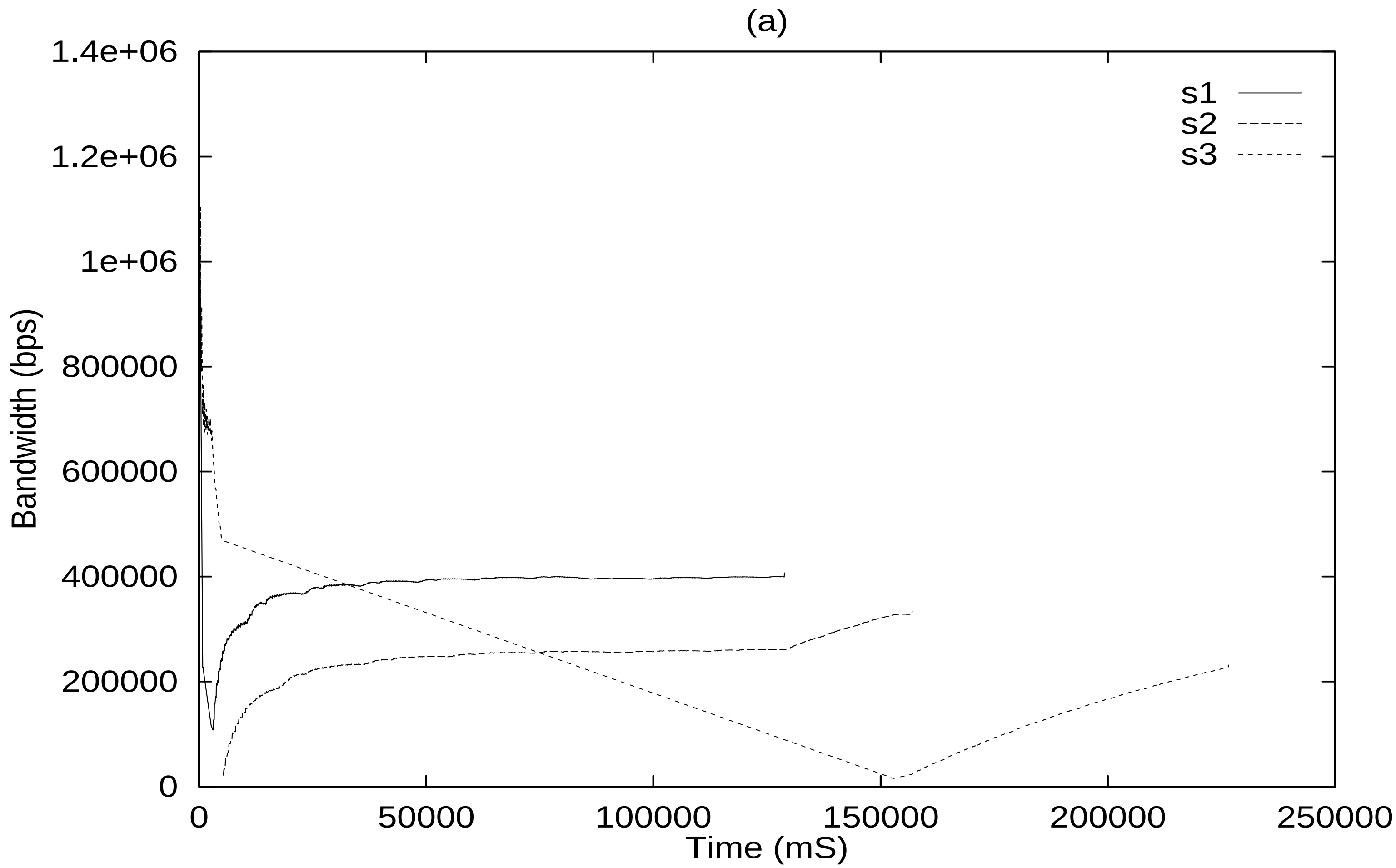
Mixed Traffic: L1=1/3,L2=2/3, L3=0/100,D1=1,D2=1,D3=∞



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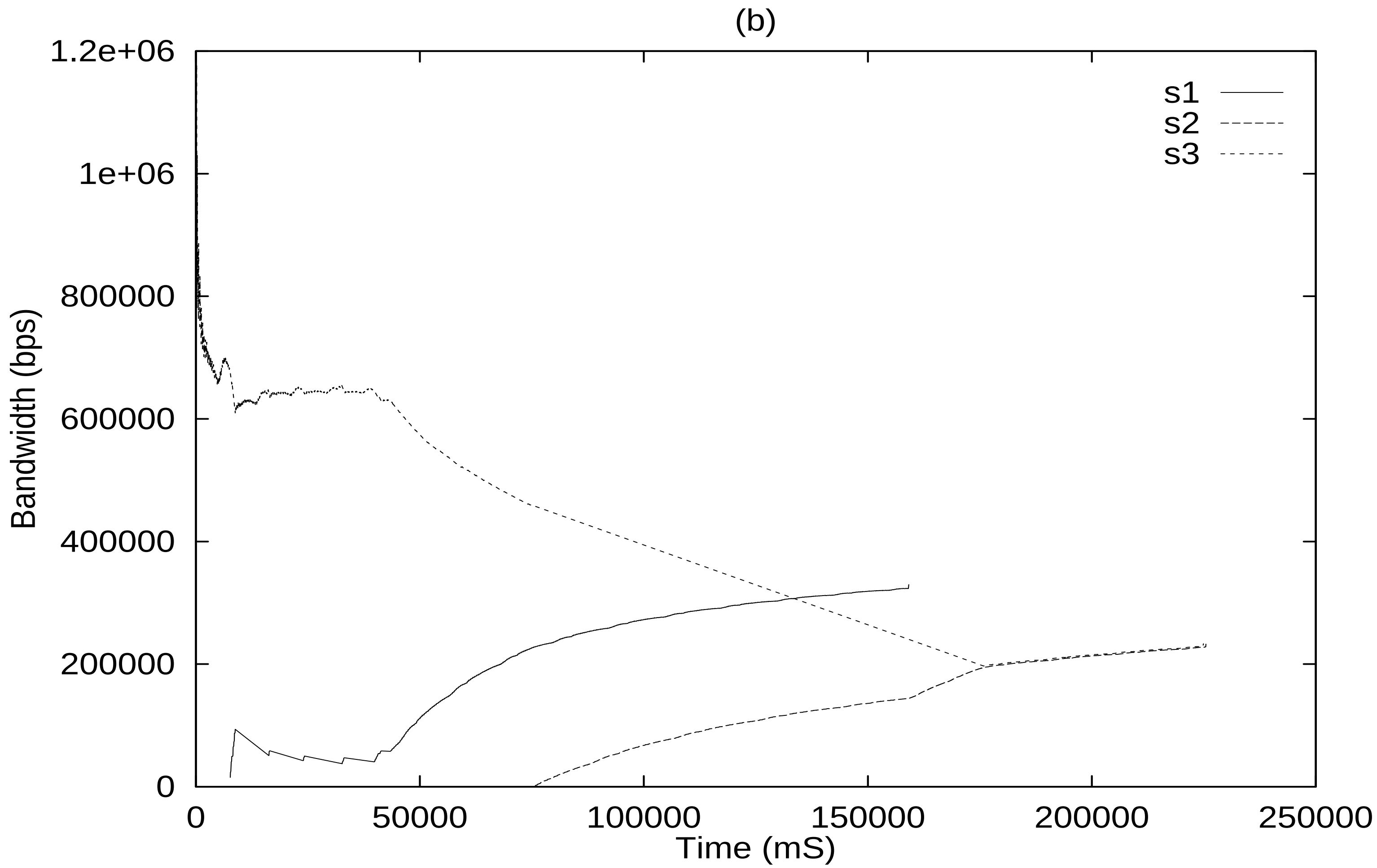
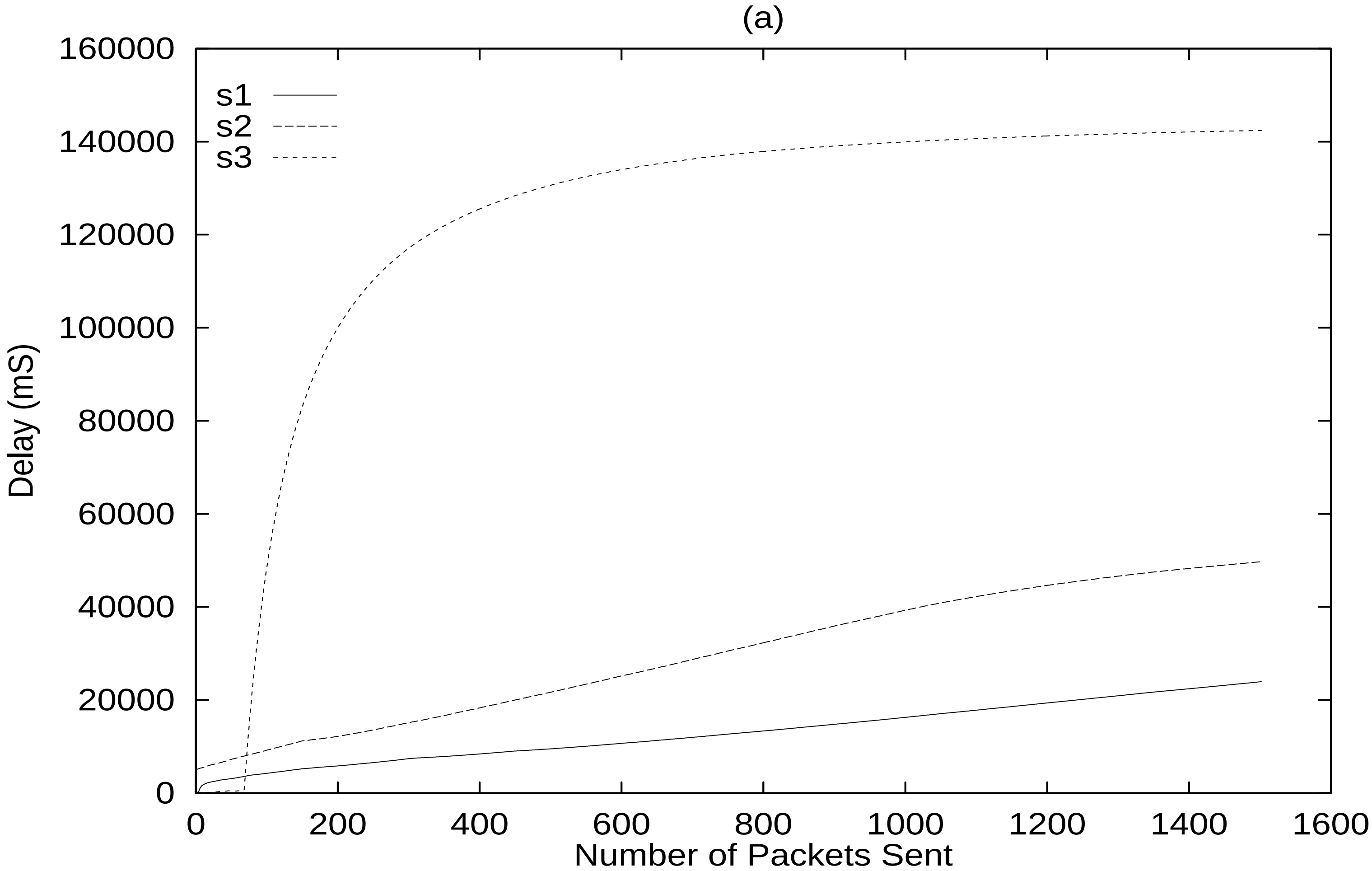
Mixed Traffic: L1=1/3,L2=2/3, L3=0/1500,D1=1,D2=1,D3=∞



Mixed Traffic: L1=1/3,L2=2/3, L3=0/100,D1=1,D2=1,D3=∞



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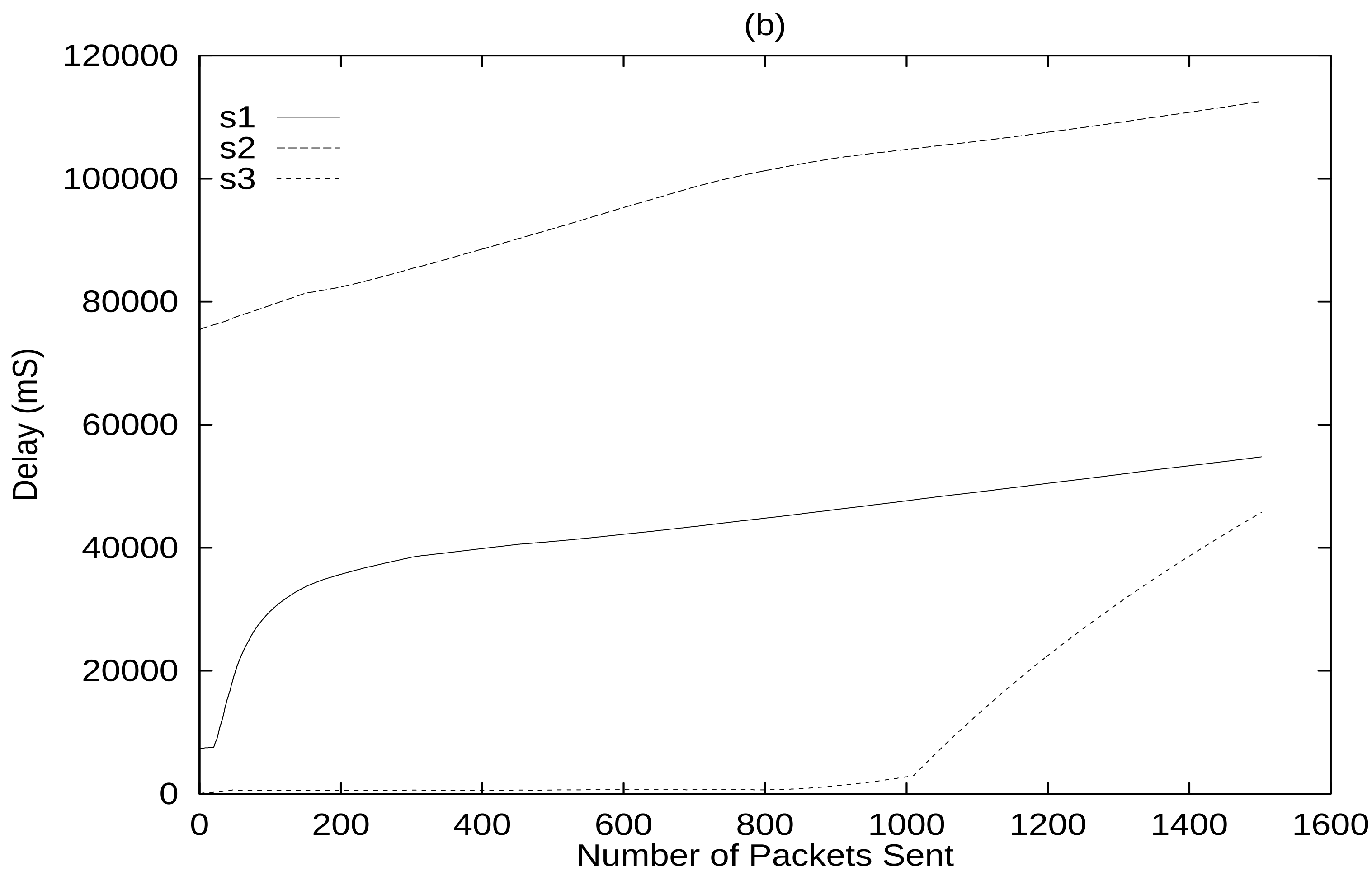
Mixed Traffic: L1=1/3,L2=2/3, L3=0/1500,D1=1,D2=1,D3=∞



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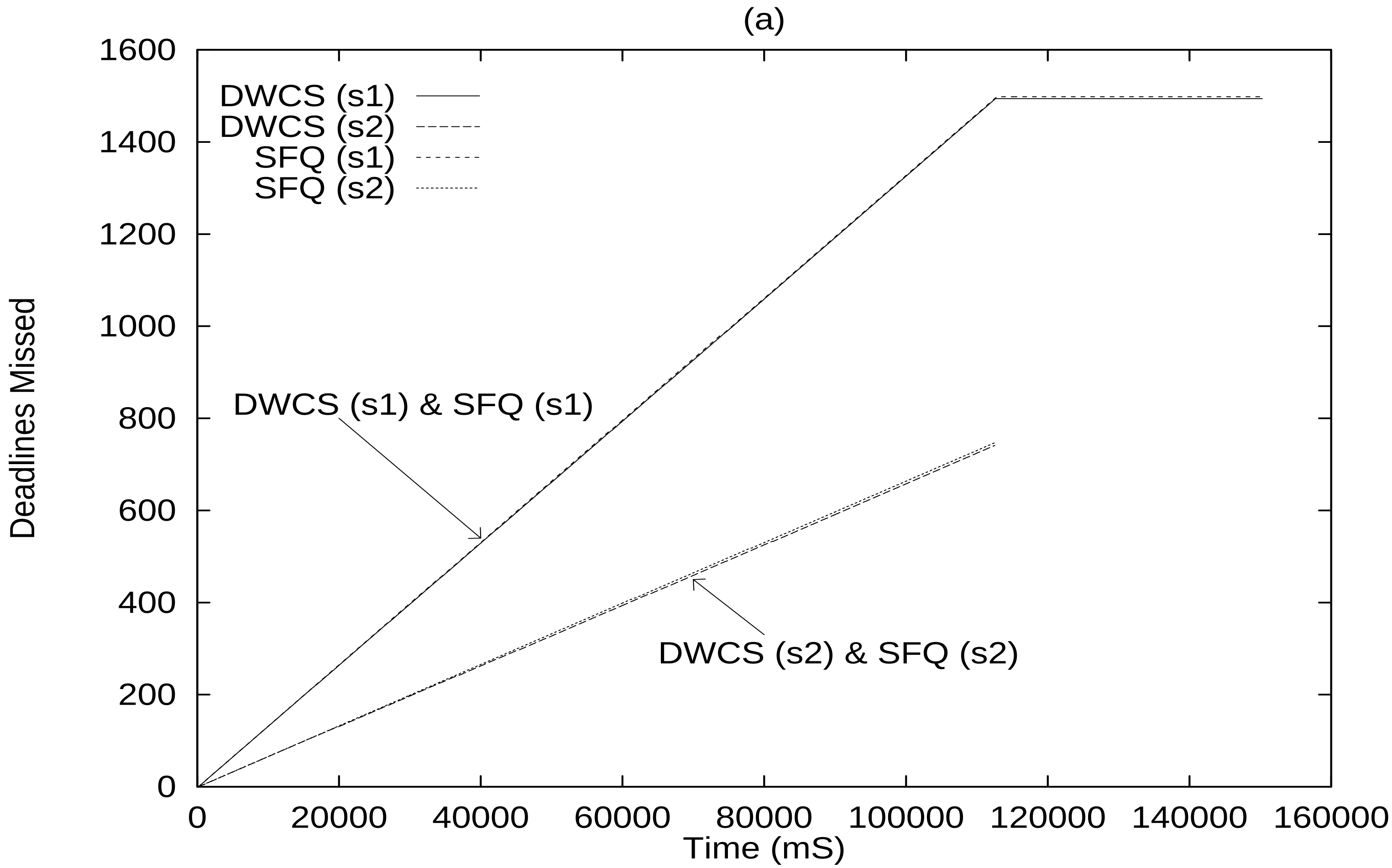
Missed Deadlines: W=1,2 L=2/3,1/3



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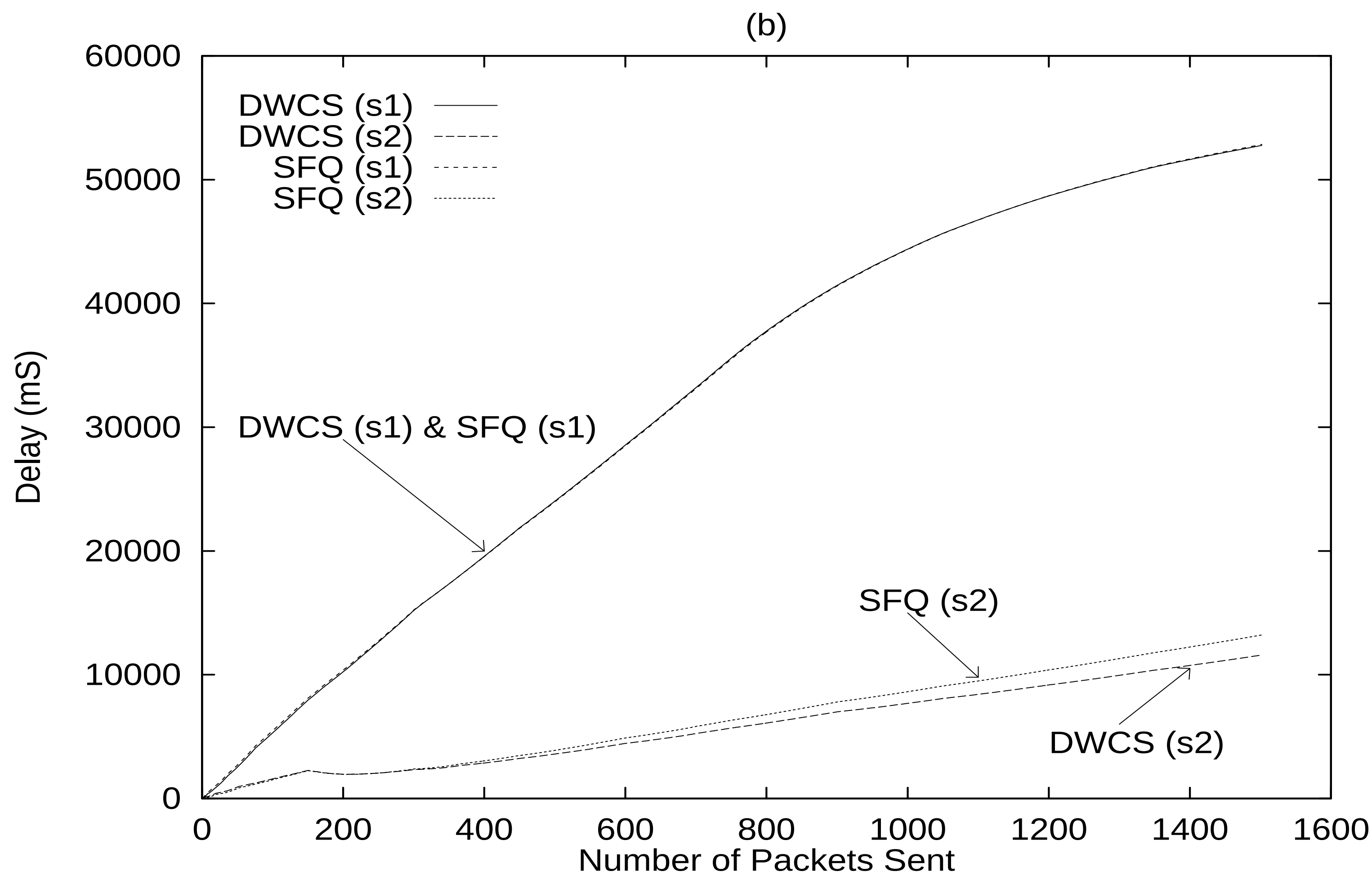
Mean Packet Delay: W=1,2 L=2/3,1/3



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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.
- DWCS can perform fair scheduling, SP, and EDF scheduling. (*It can be unfair when necessary*).

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^2Q (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).