VBR Video Retrieval

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Outline

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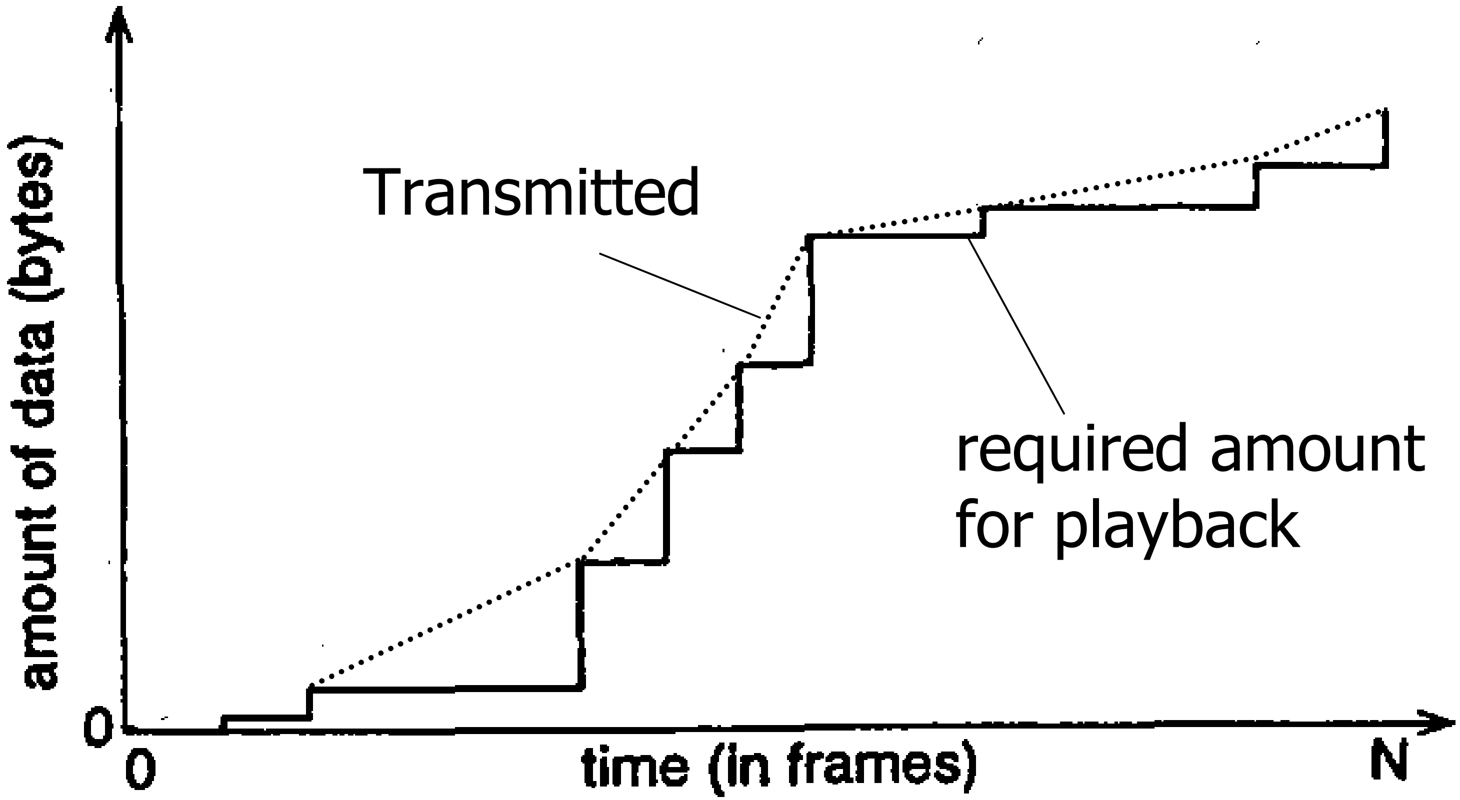
- Single Stream Case
- Multiplexing Streams
- E-EDF Scheduling
- Simulation Results
- Problems

Introduction

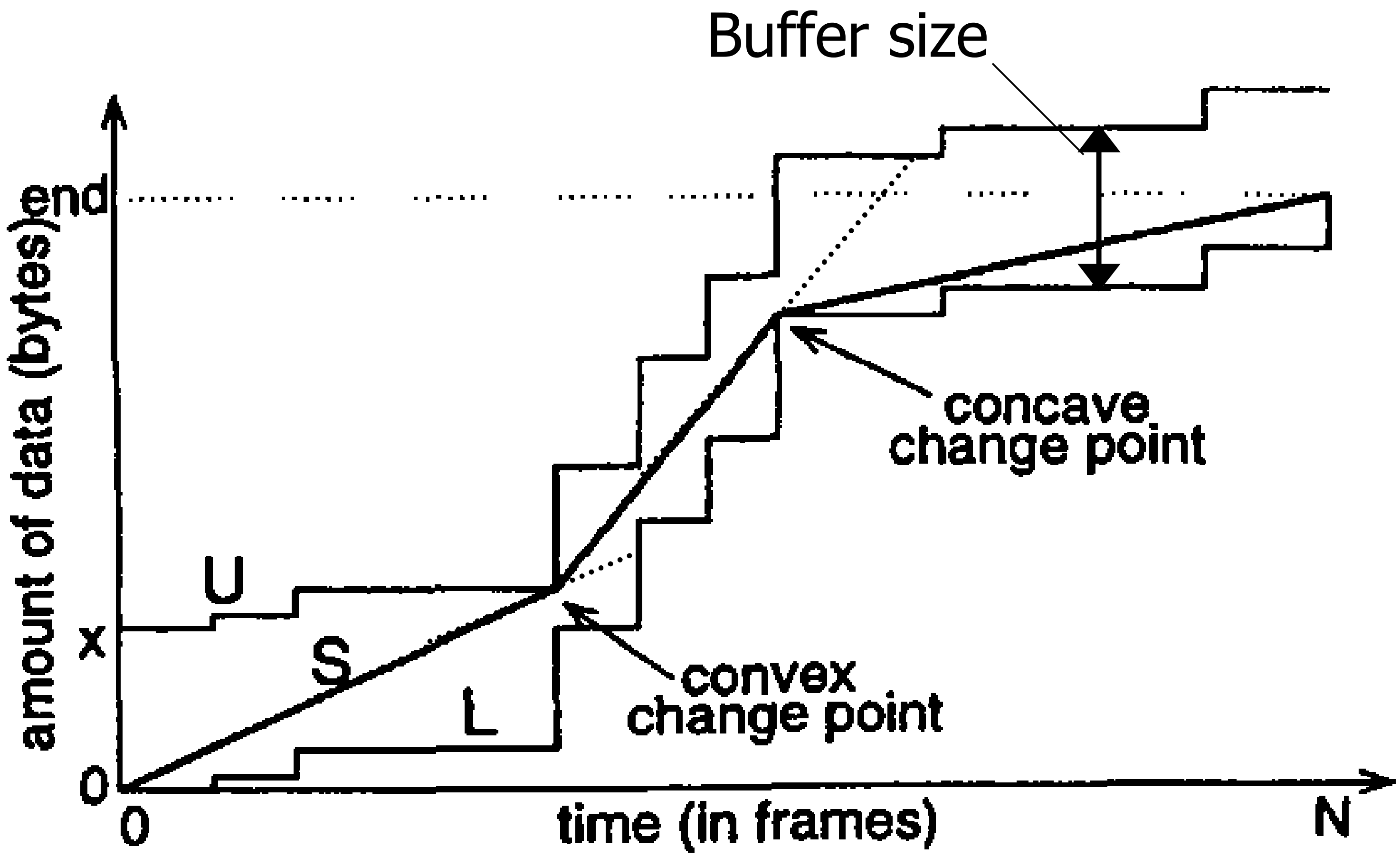
Wei Zhao & Satish K. Tripathi, "*Bandwidth-efficient continuous media streaming through optimal multiplexing*", Joint International Conference on Measurement and Modeling of Computer Systems, 1999

- Maximum bit rate of VBR videos can be several times that of the minimum in the same video clip.
- Without proper buffering and scheduling, the required bit rate would be the maximum bit rate, which is inefficient.

Single Stream Case



Single Stream Case



Single Stream Case

- Peak data rate can be reduced by buffering.
- Max. bit rate = $\max\limits_{0 \le a < b \le N} \frac{L(b) - U(a)}{b - a}$
- Min. bit rate = $\min\limits_{0 \le a < b \le N} \frac{L(b) - L(a)}{b - a}$

Multiplexing Streams

- Consider the multiplexing of K streams, each with feasible regions bounded by (L_i, U_i)
- Feasible region of multiplexed stream is:

$$\left(\sum_{i=1}^{K} L_i, \sum_{i=1}^{K} U_i\right)$$

- If S_i is a valid schedule of stream s_i, then $\sum_{i=1}^{K} S_i$ is a valid schedule of the multiplexed stream $\sum_{i=1}^{K} s_i$

Multiplexing Streams

- Inevitable Bandwidth:

$$\max_{0 \le a < b \le N} \sum_{i=1}^{K} \frac{L_i(b) - U_i(a)}{b - a}$$

E-EDF Scheduling

- Eligible Earliest Deadline First (E-EDF) scheduling scheme is to order tasks in the way that the task which is eligible and has the earliest deadline is handled first.
- Eligible means that the transmission of that video block does not lead to buffer overflow.

E-EDF Scheduling

- Algorithm: at any time, select and transmit the eligible block with the earliest deadline.

- Claim: an E-EDF schedule under the inevitable bandwidth does not lead to data starvation.

E-EDF Scheduling

- Proof: (by contradiction)
  - Suppose starvation occurs at time t(j), and t(i) is the last time before t(j) that either a block with deadline later than t(j) is transmitted, or nothing is transmitted.
  - Call streams with deadlines between t(i) and t(j) "pending streams"
  - Then from the time t(i) to t(j), we should be transmitting the pending streams at the inevitable bandwidth.

E-EDF Scheduling

- Proof: (cont.)
  - At time t(i), all pending streams should have their buffers filled $S_k(t(i)) = U_k(t(i)), k \in pending$
  - Starvation occurs at t(j) which means data transmitted between t(i) and t(j) is smaller than $\sum_{k \in pending} L_k(t(j)) - S_k(t(i))$
  - For every non-pending stream: $L_k(t(j)) - S_k(t(i)) \leq 0, k \notin pending$

E-EDF Scheduling

- Proof: (cont.)
  - Sum up all streams, the data transmitted between t(i) and t(j) is less than:

$$\sum_{k=1}^{K}\left(L_k(t(j)) - S_k(t(i))\right)$$

  - Contradicts to the earlier result that we should be transmitting at the inevitable bandwidth:

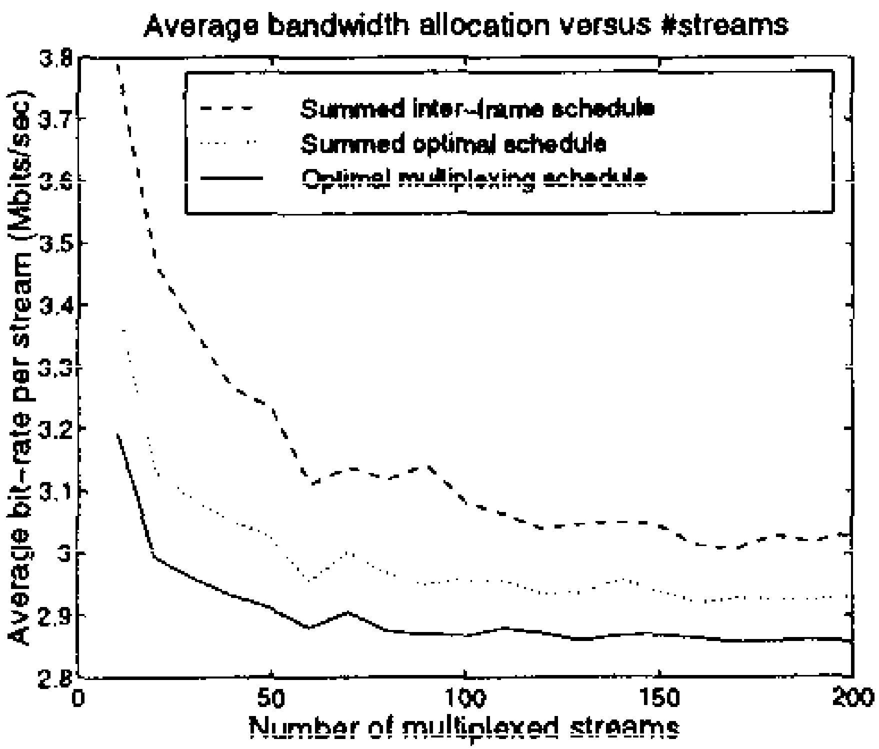
$$\max_{0 \le t(i) < t(j) \le N} \sum_{i=1}^{K} \frac{L_i(t(j)) - U_i(t(i))}{t(j) - t(i)}$$

Simulation Results

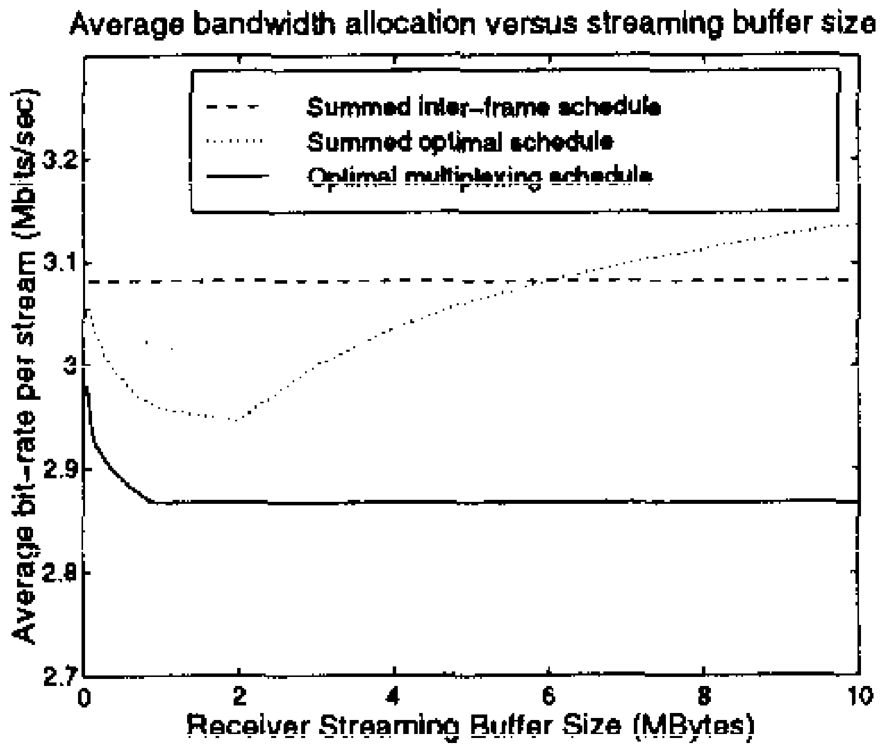
Video Name	Avg. Rate (Mbps)	Frame Sizes (Byte)			
		Avg	Max	Min	S. Dev.
Beauty and Beast	3.04	12661	30367	2701	3580
Big	2.96	12346	23485	1503	2366
Crocodile Dundee	2.59	10773	19439	1263	2336
E.T.	2.17	9022	19961	2333	2574
Home Alone 2	2.73	11383	22009	3583	2480
Honey, I Blew Up the Kid	3.32	13836	23291	3789	3183
Hot Shots 2	3.06	12766	29933	3379	3240
Jurassic Park	2.73	11363	23883	1267	3252
Junior	3.36	14013	25119	1197	3188
Rookie of the Year	2.98	12435	27877	3531	2731
Sister Act	2.86	11902	24907	1457	2608
Sleepless in Seattle	2.28	9477	16617	3207	2459
Speed	2.97	12374	29485	2741	2707
Total Recall	2.88	11978	24769	2741	2692

Video Clips Used

Simulation Results

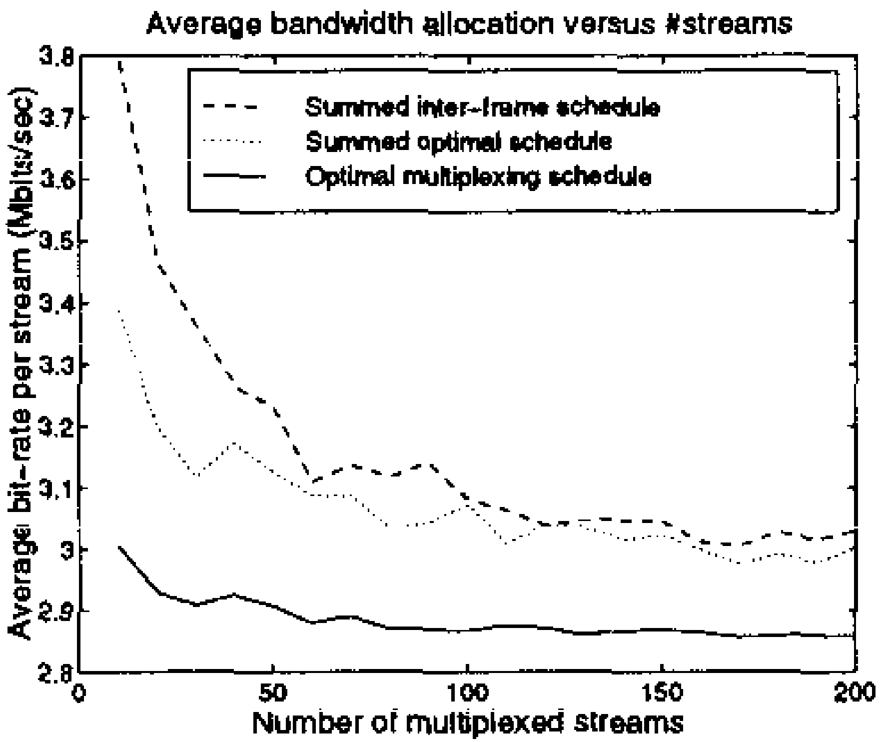


(a) 10-200 streams, 1MB buffer

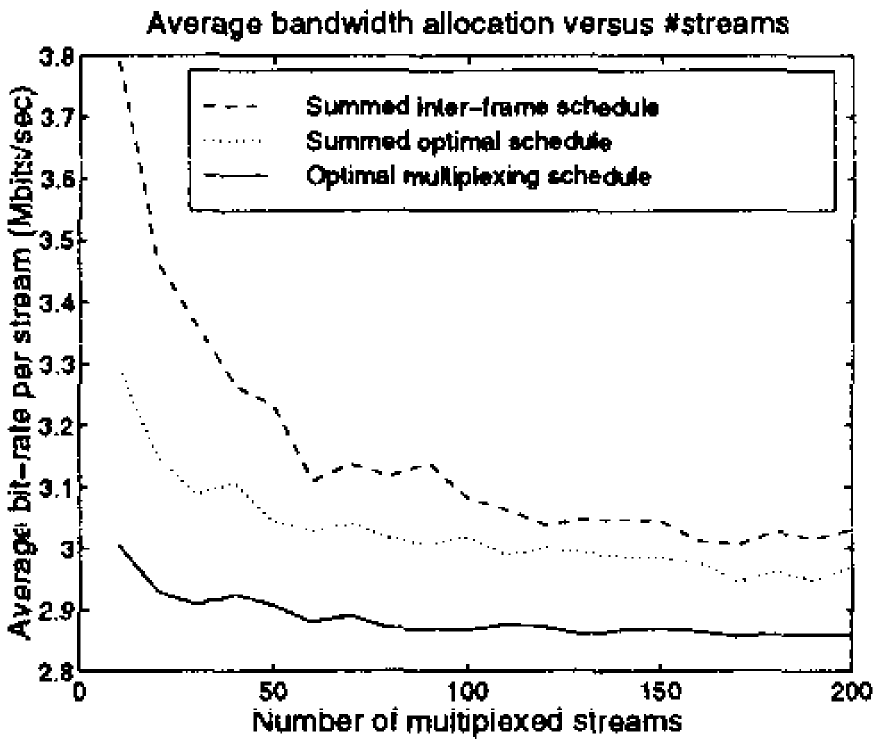


(b) 100 streams, 50KB-10MB buffer

Simulation Results

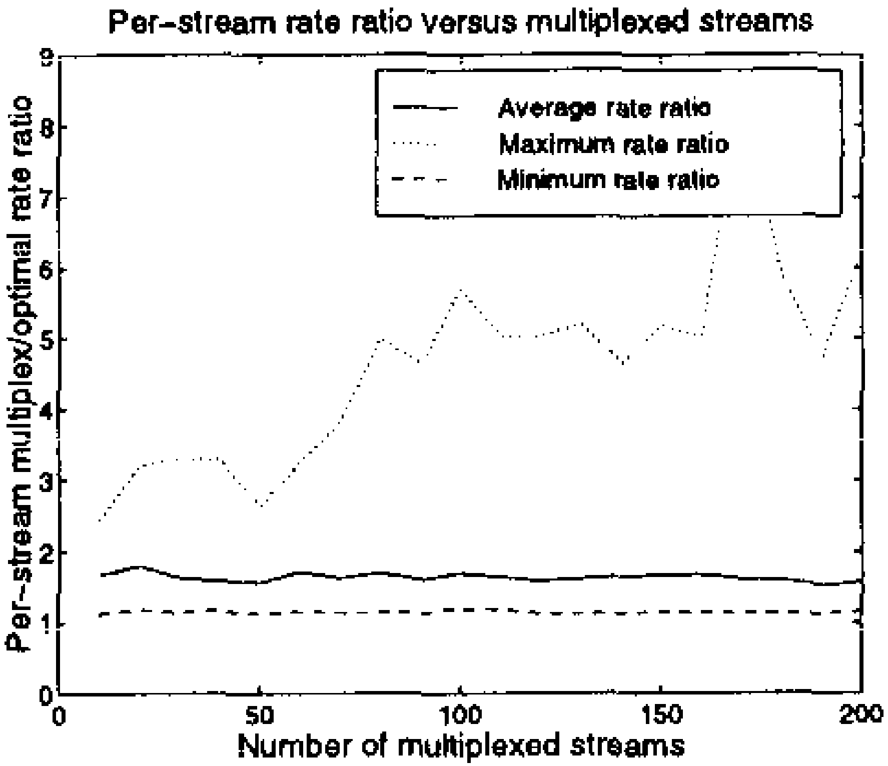


(a) 100KB and 10MB buffer

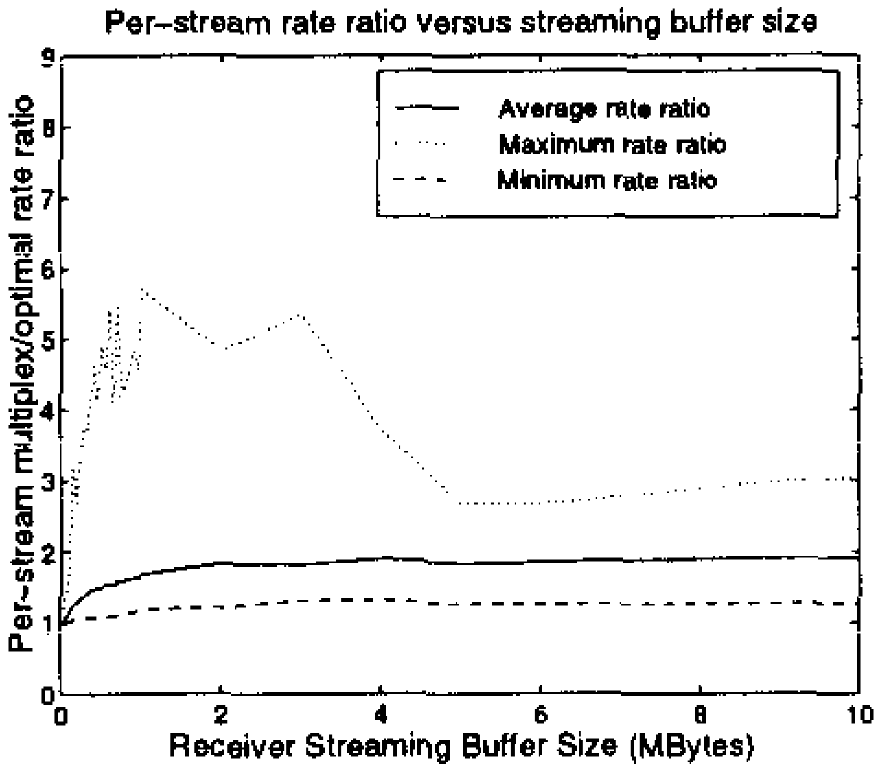


(b) 100KB, 1MB and 10MB buffer

Simulation Results



(a) 10-200 streams, 1MB buffer

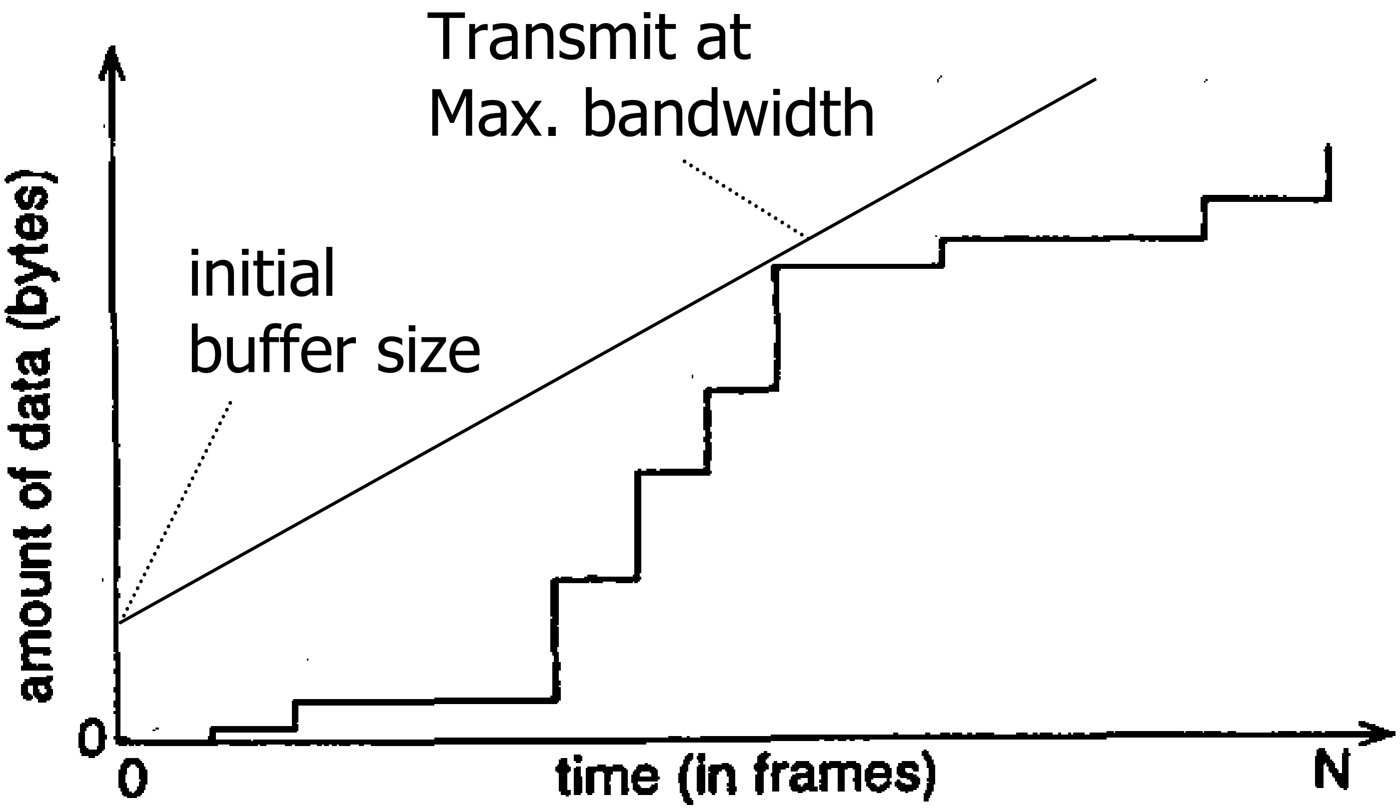


(b) 100 streams, 50KB-10MB buffer

Problems

- The bandwidth limit of an individual stream is not considered.
- Solution: Pre-Play Buffering

Problems



Transmit at
Max. bandwidth
initial
buffer size
amount of data (bytes)
0
0
time (in frames)
N

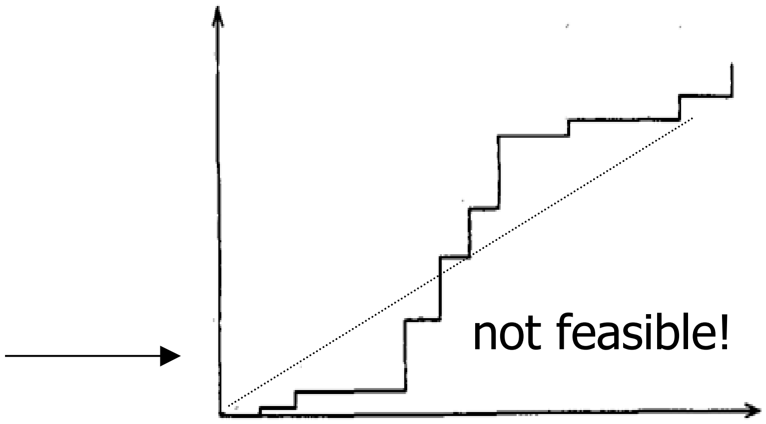
Problems

- Bad worse case bandwidth requirement of multiplexed stream.

- Solution: Schedule to avoid the high bit rate portions of streams to be sent at the same time.

Problems

Stream A	A_i	A_{i+1}	A_{i+2}	...
Stream B	B_i	B_{i+1}	B_{i+2}	...
Stream C	C_i	C_{i+1}	C_{i+2}	...
Sum	S_i	S_{i+1}	S_{i+2}	...



Stream A	A_i	A_{i+1}	A_{i+2}	...
Stream B	B_i	B_{i+1}	B_{i+2}	...
Stream C	C_{i+1}	C_{i+2}	C_{i+3}	...
Sum	S_i	S_{i+1}	S_{i+2}	...