Annex F

(informative)

Bursting and bunching considerations

F.1 Topology scenarios

F.1.1 Bridge design models

The sensitivity of bridges to bursting and bunching is highly dependent on the queue management protocols within the bridge. To better understand these effects, a few bridge design models are evaluated, as illustrated in Figure F.1.

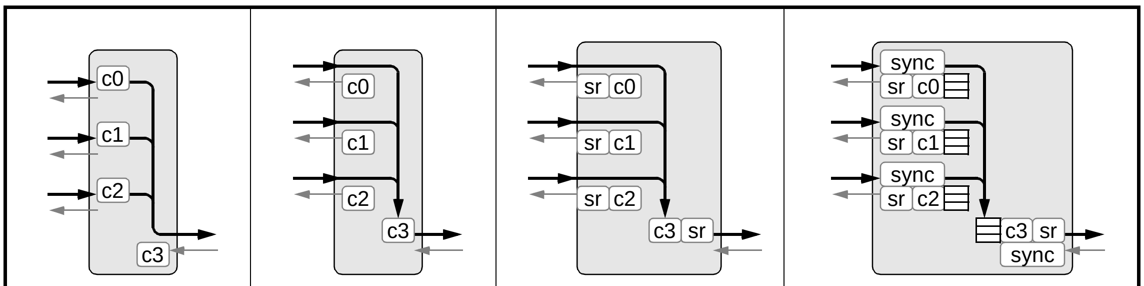


Figure F.1—Bridge design models

The input-queue design (see Figure F.1-a) assumes that frames are queued in receive buffers. The transmitter accepts frames are from the receivers, based on service-class precedence. In the case of a tie (two receivers can provide same-class frames), the lowest numbered receive port has precedence. This model best illustrates nonlinear bunching problems.

The output-queue design (see Figure F.1-b) assumes that received frames are queued in transmit buffers. Within each service class, frames are forwarded in FIFO order. This model best illustrates linear bunching problems (for steady flows), but also exhibits nonlinear bunching (for nonsteady flows).

The throttled-output design (see Figure F.1-c) is an enhanced output-queue model, with an output shaper to limit transmission rates. The purpose of the output shaper is to ensure sufficient nonreserved bandwidth for less time-sensitive control and monitoring purposes. The model illustrates how shapers can worsen the output-queue bridge's bunching behaviors.

The retimed-outputs design (see Figure F.1-d) reduces (and can eliminate) bunching problems by detecting late-arrival frames at the receivers. Several synchronous-cycle buffers are provided at the transmitters, to compensate for transmission delays in the received data.

F.1.2 Three-source hierarchical topology

A hierarchical topology best illustrate potential problems with bunching, as illustrated in Figure F.2. Traffic from talkers {a0,a1,a2} flows into bridge B. Bridge B concentrates traffic received from three talkers, with the cumulative b3 traffic sent to c3. Identical traffic flows are assumed at bridge ports {c0,c1,c3}, although only one of these sources is illustrated. Bridges {C,D,E,F,G,H} behave similarly.

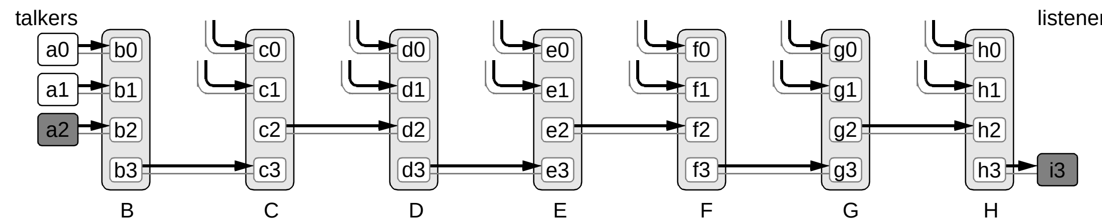


Figure F.2—Three-source topology

F.1.3 Six-source hierarchical topology

Spreading the traffic over multiple sources, as illustrated in Figure F.3, exasperates bursting and bunching problems. Traffic from talkers {a0,a1,a2,a3,a4,a5} flows into ports on bridge B. Bridge B concentrates traffic received from six talkers, with the cumulative b6 traffic sent to c6. Identical traffic flows are assumed at bridge ports {c0,c1,c3,c3,c4,c6}, although only one of these sources is illustrated. Bridges {C,D,E,F,G,H} behave similarly.

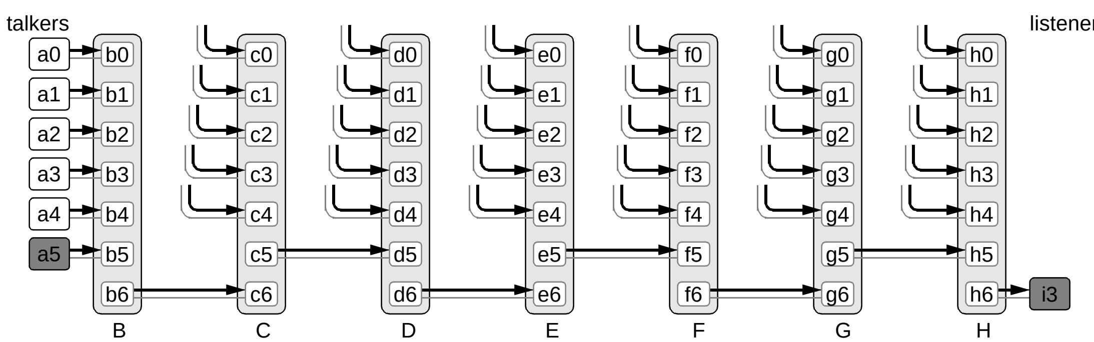


Figure F.3—Six-source topology

F.2 Bursting considerations

F.2.1 Three-source bursting scenario

A troublesome bursting scenario on a 100 Mb/s link can occur when small bandwidth streams coincidentally provide their infrequent 1500 byte frames concurrently, as illustrated in Figure F.4. Even though the cumulative bandwidths are considerably less than the capacity of the 100 Mb/s links, significant delays are incurred when passing through multiple bridges.

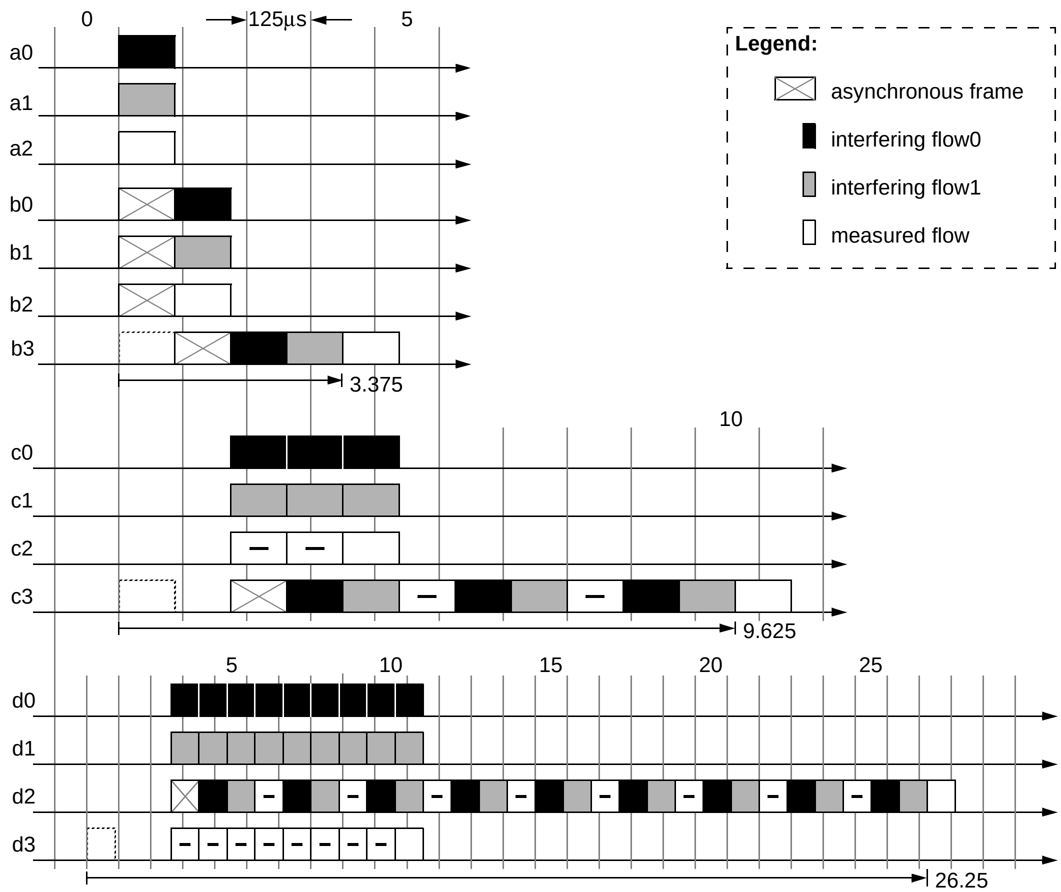


Figure F.4—Three-source bunching timing; input-queue bridges

F.2.1.1 Cumulative bunching latencies

The cumulative worst-case latencies implied by coincidental bursting are listed in Table F.1 and plotted in Figure F.5.

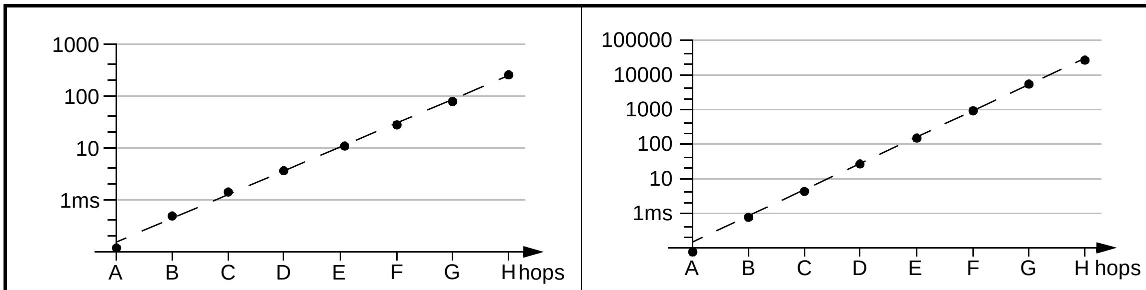
Table F.1—Cumulative bursting latencies

Topology	Units	Measurement point							
		A	B	C	D	E	F	G	H
3-source (see F.2.2.1)	mtu	1	4	11	30	85	248	735	2194
	ms	.120	.480	1.32	3.6	10.2	29.6	88.2	263
6-source (see F.2.2.2)	mtu	1	7	38	219	1300	7781	46662	229943
	ms	.120	.840	4.56	26.3	156	934	5600	27600

The values within this table are computed based on Equation F.1.

$$delay[n] = mtu\times(n + p^n) \tag{F.1}$$

Where:
- *mtu* (maximum transfer unit) is the maximum frame size
- *n* is the number of hops from the source
- *p* is the number of receive ports in each bridge.



a) 3-source coincidental burst latency **b) 6-source coincidental burst latency**

Figure F.5—Cumulative coincidental burst latencies

Conclusion: The classA traffic bandwidths should be enforced over a time interval that is on the order of an MTU size (120µs), so as to avoid excessive delays caused by coincidental back-to-back large-block transmissions.

F.2.2 Bunching scenarios; input-queue bridges

F.2.2.1 Three-source bunching; input-queue bridges

To illustrate the effects of worst case bunching on input-queue bridges, specific flows are illustrated in Figure F.6. Bridge ports {b0,b1,b2} concentrates traffic from three talkers; one third of the cumulative traffic is forwarded through b3. Each stream consumes 25% of the link bandwidth; 25% is available for asynchronous traffic.

For clarity, the traces for input traffic on ports {c0,c1,c3},…,{e0,e1,e3}, only illustrate the passing-through listener traffic; the remainder of the traffic is assumed to be routed elsewhere.

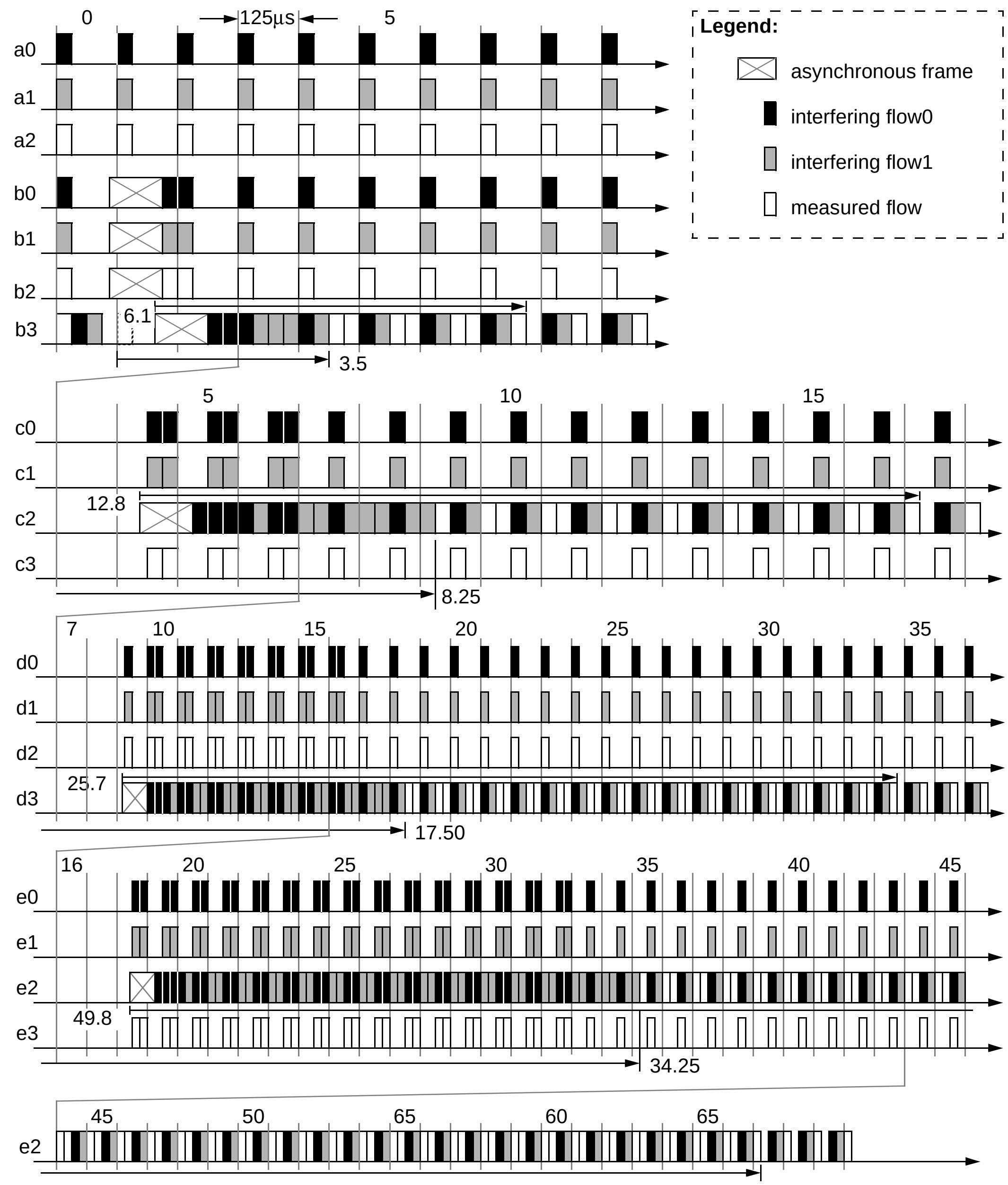


Figure F.6—Three-source bunching; input-queue bridges

F.2.2.2 Six-source bunching; input-queue bridges

To better illustrate the effects of worst case bunching on input-queue bridges, specific flows are illustrated in Figure F.7. Bridge ports {b0,b1,b2,b3,b4,b5} concentrates traffic from three talkers; one sixth of the cumulative traffic is forwarded through b6. Each of six streams consumes 12.5% of the link bandwidth, so that 25% is available for asynchronous traffic.

For clarity, the traces for input traffic on ports {c0,c1,c2,c3,c4,c6} only illustrate passing-through traffic; the remainder of the traffic is routed elsewhere.

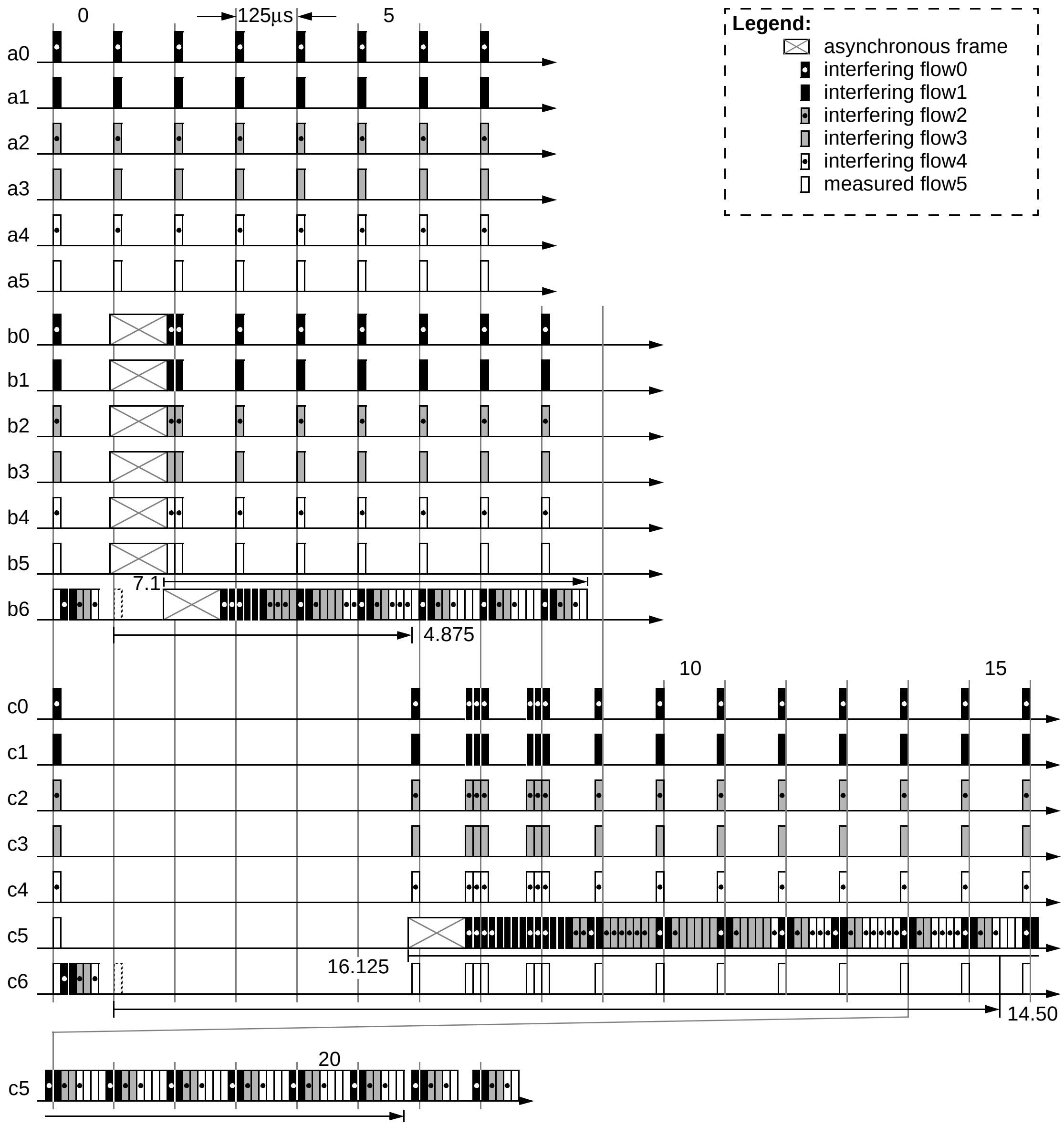


Figure F.7—Six source bunching timing; input-queue bridges

F.2.2.3 Cumulative bunching latencies, input-queue bridge

The cumulative worst-case latencies implied by coincidental bursting are listed in Table F.2 and plotted in Figure F.8.

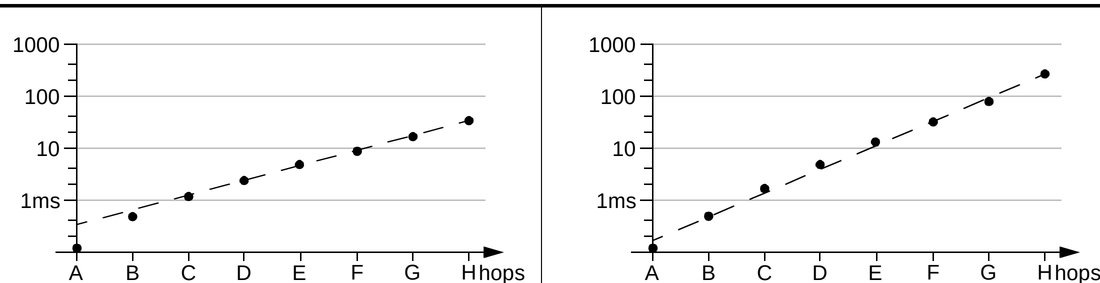
Table F.2—Cumulative bunching latencies; input-queue bridge

Topology	Units	Measurement point							
		A	B	C	D	E	F	G	H
3-source (see F.2.2.1)	cycles	0.125	3.5	8.25	17.5	34.25	(70.75)	(143.2)	(288.2)
	ms	0.01	0.44	1.03	2.19	4.28	8.84	17.9	36.0
6-source (see F.2.2.2)	cycles	0.125	4.875	14.50	(39.33)	(107.2)	(288.2)	(771)	2058
	ms	0.01	0.61	1.81	4.92	13.4	36.0	96.4	257

The first few numbers are generated using graphical techniques, as illustrated in Figure F.2.2.2. The following numbers are estimated, based on Equation F.2.

$$delay[n+1] = (mtu + delay[n])\times(1/(1-0.75\times(p-1)/p)) \qquad (F.2)$$

Where:
- *mtu* (maximum transfer unit) is the maximum frame size
- *rate* is the fraction of the bandwidth reserved for class A traffic, assumed to be 0.75
- *n* is the number of hops from the source
- *p* is the number of receive ports in each bridge.



a) 3-source input-queue bunching latency

b) 6-source input-queue bunching latency

Figure F.8—Cumulative bunching latencies; input-queue bridge

Conclusion: A FIFO based output-queue bridge should be used. Alternatively (if input queuing is used), received frames should be time-stamped to ensure FIFO like forwarding.

F.2.3 Bunching topology scenarios; output-queue bridges

F.2.3.1 Three-source bunching timing; output-queue bridges

To illustrate the effects of worst case bunching, specific flows are illustrated in Figure F.9. Bridge ports {b0,b1,b2} concentrates traffic from three talkers; one third of the cumulative traffic is forwarded through b3. Each stream consumes 25% of the link bandwidth; 25% of the link bandwidth is available for asynchronous traffic.

For clarity, the traces for input traffic on ports {b0,b1,b2},…,{e0,e1,e3} only illustrate the passing-through listener traffic; the remainder of the traffic is assumed to be routed elsewhere.

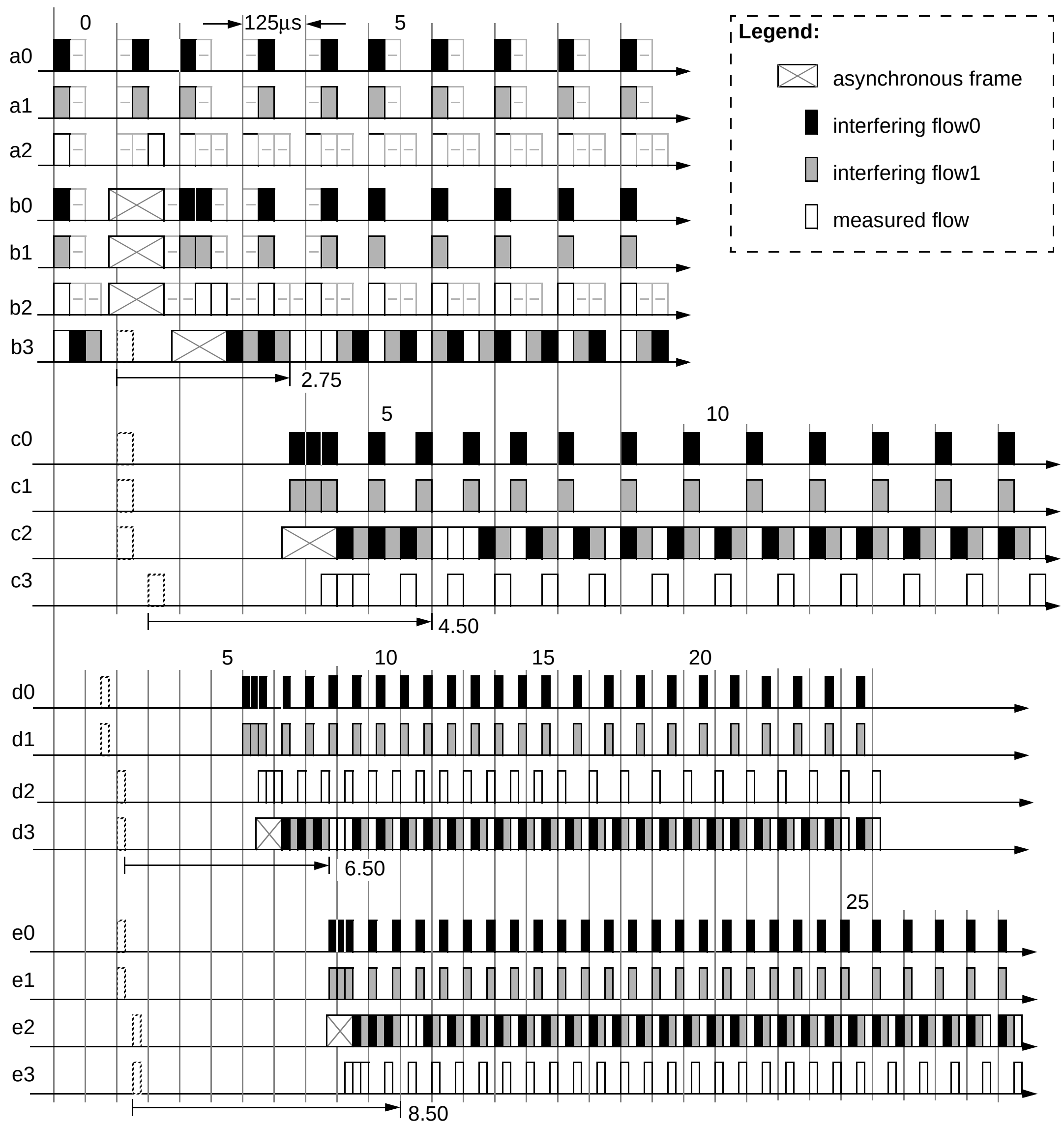


Figure F.9—Three-source bunching; output-queue bridges

F.2.3.2 Six-source bunching; output-queue bridges

To better illustrate the effects of worst case bunching, specific flows are illustrated in Figure F.10. Bridge ports {b0,b1,b2,b3,b4,b5} concentrates traffic from six talkers; one sixth of the cumulative traffic is forwarded through port b6. Each of six streams consumes 12.5% of the link bandwidth; 25% of the link bandwidth is available for asynchronous traffic.

For clarity, the traces for input traffic on ports {c0,c1,c2,c3,c4,c6} and {d0,d1,d2,d3,d4,d5} only illustrate passing-through traffic; the remainder of the traffic is routed elsewhere.

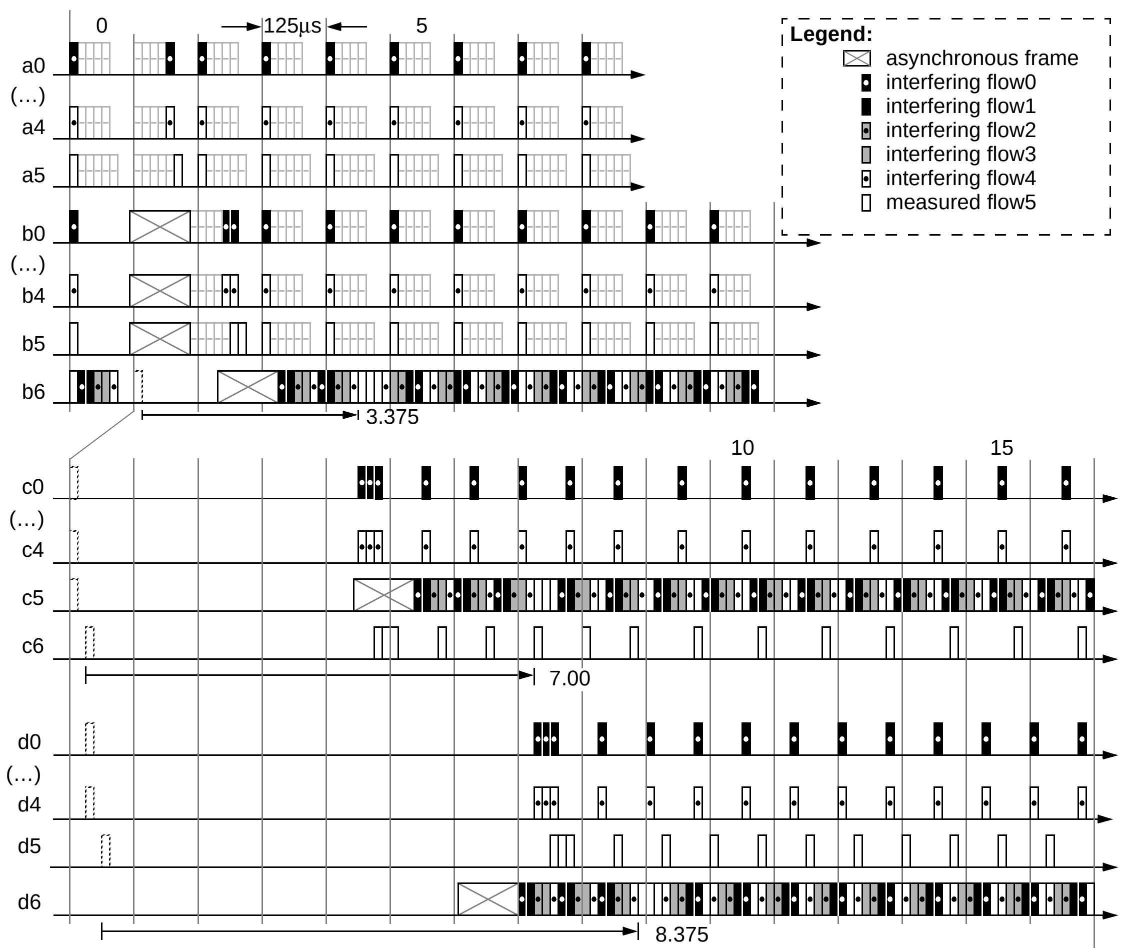


Figure F.10—Six source bunching; output-queue bridges

F.2.3.3 Cumulative bunching latencies; output-queue bridge

The cumulative worst-case latencies implied by coincidental bursting are listed in Table F.3 and plotted in Figure F.11.

Table F.3—Cumulative bunching latencies; output-queue bridge

Topology	Units	Measurement point							
		B	C	D	E	F	G	H	I
3-source (see F.2.2.1)	cycles	.875	2.75	4.5	6.5	8.5	–	–	–
	ms	0.10	0.34	0.56	0.81	1.6	–	–	–
6-source (see F.2.2.2)	cycles	.875	3.375	7.00	8.375	–	–	–	–
	ms	0.10	0.42	.875	1.05	–	–	–	–

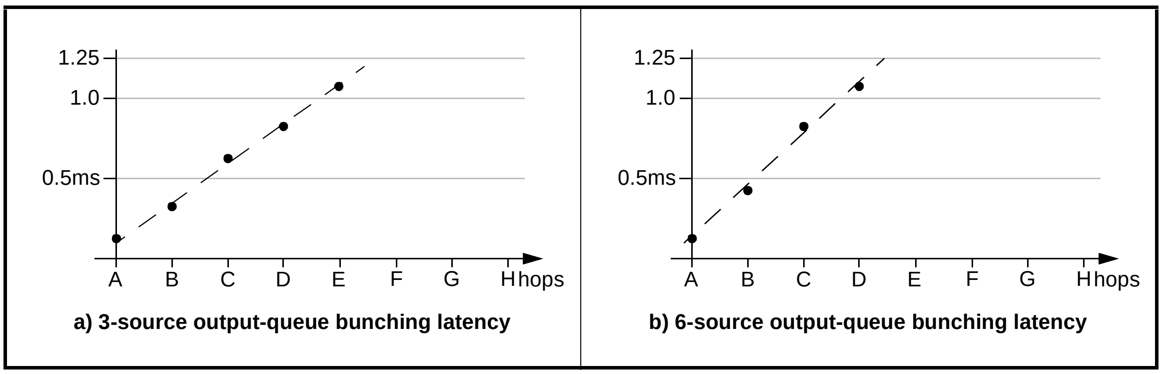


Figure F.11—Cumulative bunching latencies; output-queue bridge

Conclusion: For steady-state classA traffic, acceptably small linear latencies are introduced by output-queue bridges on 75% loaded links. Unfortunately, the nonsteady-state nature of variable-rate traffic makes this conclusion suspect (see F.2.4).

F.2.4 Bunching topology scenarios; variable-rate output-queue bridges

F.2.4.1 Three-source bunching; variable-rate output-queue bridges

To illustrate the effects of worst case bunching, specific flows are illustrated in Figure F.12. Bridge ports {b0,b1,b2} concentrates traffic from three talkers; one third of the cumulative traffic is forwarded through port b3. Each stream consumes 25% of the link bandwidth; 25% of the link bandwidth is available for asynchronous traffic.

For clarity, the traces for input traffic on ports {c0,c1,c3},…,{e0,e1,e3} only illustrate the passing-through listener traffic; the remainder of the traffic is assumed to be routed elsewhere.

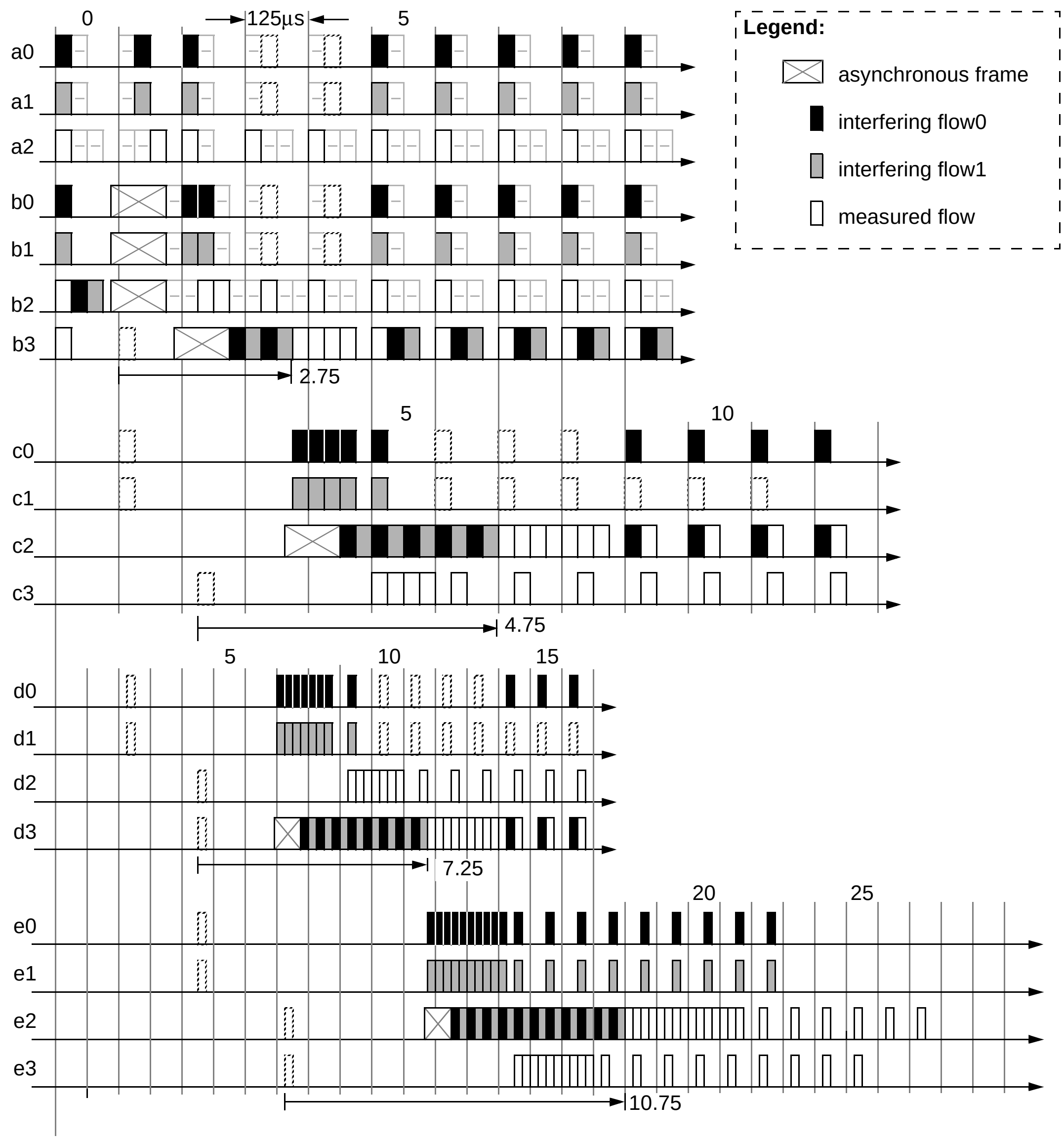


Figure F.12—Three-source bunching; variable-rate output-queue bridges

F.2.4.2 Six-source bunching; variable-rate output-queue bridges

To better illustrate the effects of worst case bunching, specific flows are illustrated in Figure F.13. Bridge ports {b0,b1,b2,b3,b4,b5} concentrates traffic from six talkers; one sixth of the cumulative traffic is forwarded through port b6. Each of six streams consumes 12.5% of the link bandwidth; 25% of the link bandwidth is available for asynchronous traffic.

For clarity, the traces for input traffic on ports {c0,c1,c2,c3,c4,c6}, {d0,d1,d2,d3,d4,d5}, and {e0,e1,e2,e3,e4,e6} only illustrate passing-through traffic; the remainder of the traffic is routed elsewhere.

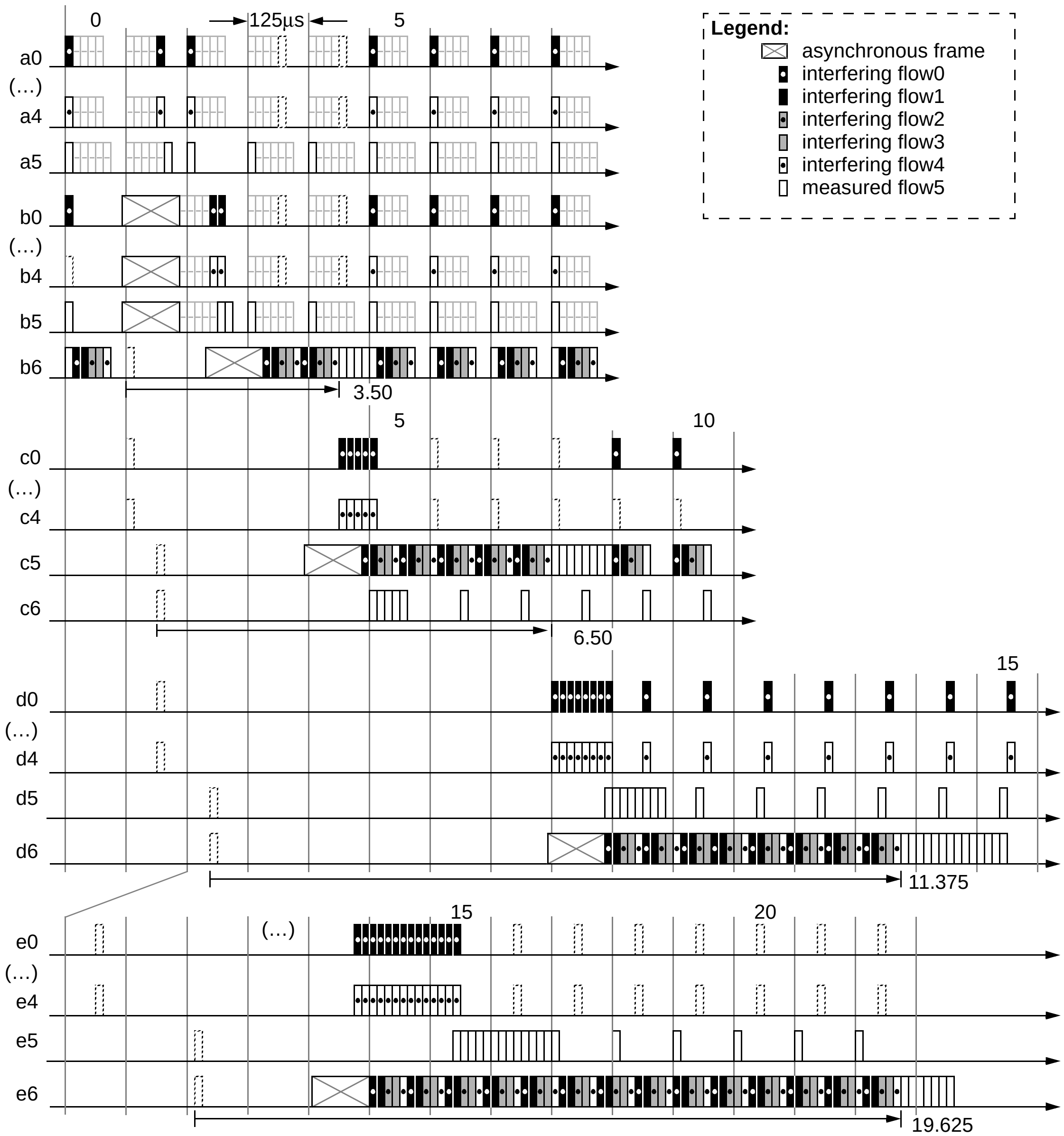


Figure F.13—Six source bunching; variable-rate output-queue bridges

F.2.4.3 Cumulative bunching latencies; variable-rate output-queue bridge

The cumulative worst-case latencies implied by coincidental bursting are listed in Table F.4 and plotted in Figure F.14.

Table F.4—Cumulative bunching latencies; variable-rate output-queue bridge

Topology	Units	Measurement point							
		A	B	C	D	E	F	G	H
3-source (see F.2.2.1)	cycles	0.75	2.75	4.75	7.25	10.75	–	–	–
	ms	0.10	0.34	0.59	0.90	1.34	–	–	–
6-source (see F.2.2.2)	cycles	0.75	3.50	6.50	11.38	19.63	–	–	–
	ms	0.10	0.44	0.81	1.42	2.45	–	–	–

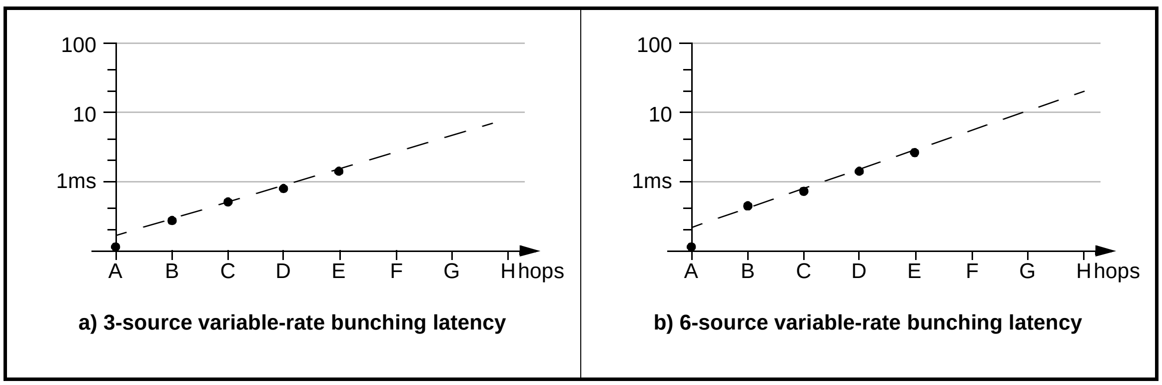


Figure F.14—Cumulative bunching latencies; variable-rate output-queue bridge

Conclusion: For nonsteady-state classA traffic, significant expediential latencies are introduced by output-queue bridges on 75% loaded links. Unfortunately, throttled outputs further exasperates this latency (see F.2.4).

F.2.5 Bunching topology scenarios; throttled-rate output-queue bridges

F.2.5.1 Three-source bunching; throttled-rate output-queue bridges

To illustrate the effects of worst case bunching, specific flows are illustrated in Figure F.15. Bridge ports {b0,b1,b2} concentrates traffic from three talkers; one third of the cumulative traffic is forwarded through port b3. Each stream consumes 25% of the link bandwidth; 25% of the link bandwidth is available for asynchronous traffic.

For clarity, the traces for input traffic on ports {c0,c1,c3}, {d0,d1,d2}, and {e0,e1,e3} only illustrate the passing-through listener traffic; the remainder of the traffic is assumed to be routed elsewhere.

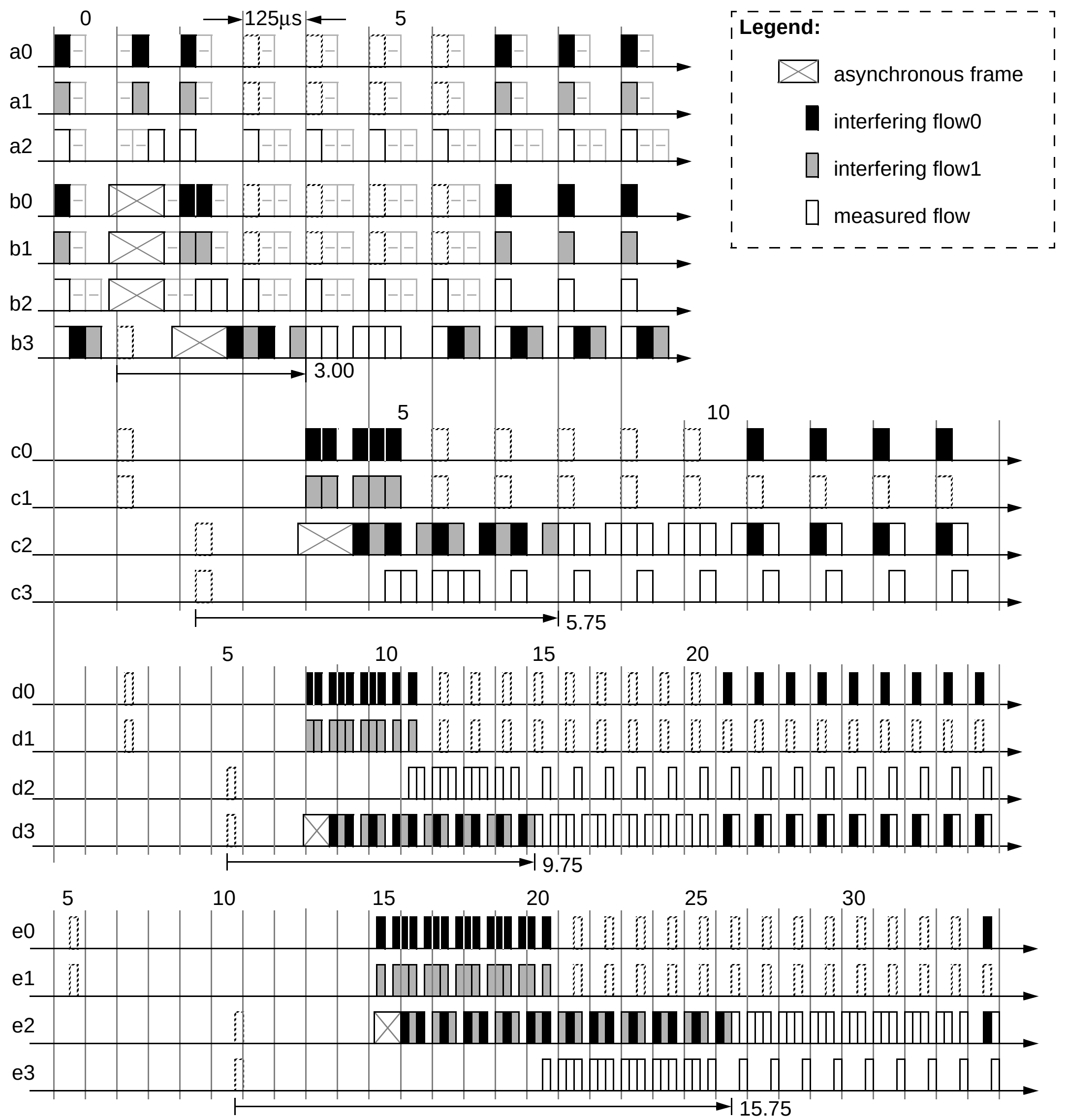


Figure F.15—Three-source bunching; throttled-rate output-queue bridges

F.2.5.2 Six-source bunching; throttled-rate output-queue bridges

To better illustrate the effects of worst case bunching, specific flows are illustrated in Figure F.16. Bridge ports {b0,b1,b2,b3,b4,b5} concentrates traffic from six talkers; one sixth of the cumulative traffic is forwarded through port b6. Each of six streams consumes 12.5% of the link bandwidth; 25% of the link bandwidth is available for asynchronous traffic.

For clarity, the traces for input traffic on ports {c0,c1,c2,c3,c4,c5},…,{e0,e1,e2,e3,e4,e6} only illustrate passing-through traffic; the remainder of the traffic is routed elsewhere.

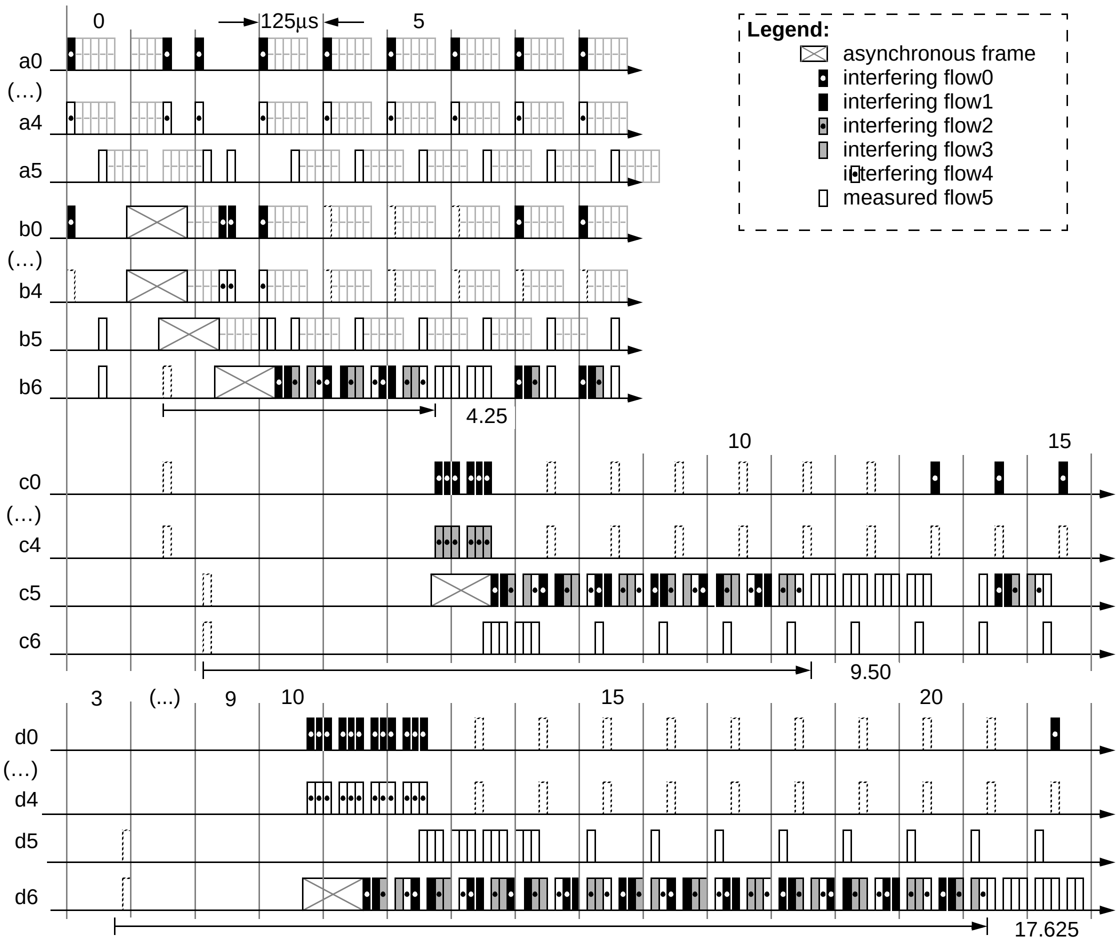


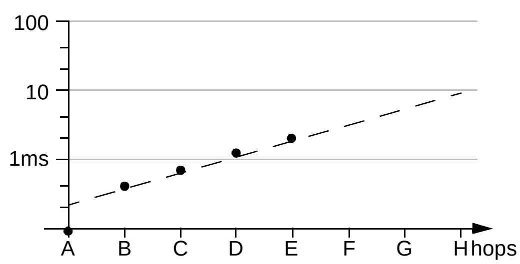
Figure F.16—Six source bunching; throttled-rate output-queue bridges

F.2.5.3 Cumulative bunching latencies; throttled-rate output-queue bridge

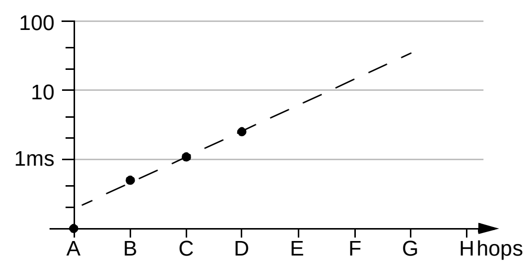
The cumulative worst-case latencies implied by coincidental bursting are listed in Table F.5 and plotted in Figure F.17.

Table F.5—Cumulative bunching latencies; throttled-rate output-queue bridge

Topology	Units	Measurement point							
		A	B	C	D	E	F	G	H
3-source (see F.2.2.1)	cycles	0.75	3.00	5.75	9.75	15.75	–	–	–
	ms	0.09	0.38	0.73	1.21	1.97	–	–	–
6-source (see F.2.2.2)	cycles	0.75	4.25	9.5	17.63	–	–	–	–
	ms	0.09	0.53	1.19	2.20	–	–	–	–



a) 3-source throttled-rate output-queue latency



b) 6-source throttled-rate output-queue latency

Figure F.17—Cumulative bunching latencies; throttled-rate output-queue bridge

Conclusion: On large topologies, the classA traffic latencies can accumulate beyond acceptable limits. Some form of receiver retiming may therefore be desired.

F.2.6 Bunching topology scenarios; classA throttled-rate output-queue bridges

The extent of bunching extent is worst when large classC frames are present. However, bunching can also occur in the absence of large classC frames, as described in the remainder of this subannex.

F.2.6.1 Three-source bunching; classA throttled-rate output-queue bridges

To illustrate the effects of worst case bunching, specific flows are illustrated in Figure F.18 and Figure F.19. Bridge ports {b0,b1,b2} concentrates traffic from three talkers; one third of the cumulative traffic is forwarded through port b3. Each stream consumes 25% of the link bandwidth; 25% of the link bandwidth is available for asynchronous traffic.

For clarity, the traces for input traffic on ports {c0,c1,c3}, {c0,d1,d2}, and {e0,e1,e3} only illustrate the passing-through listener traffic; the remainder of the traffic is assumed to be routed elsewhere.

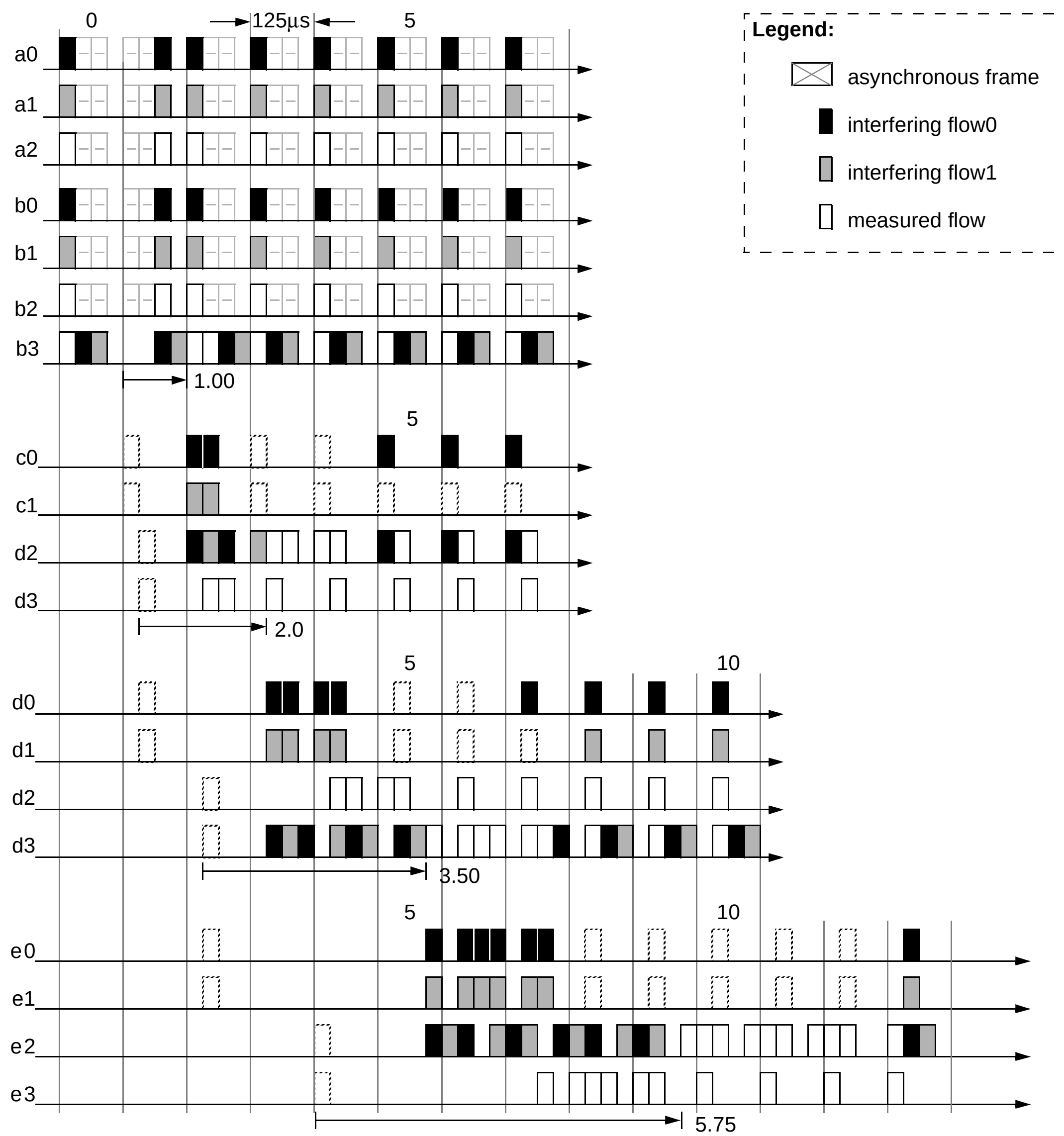


Figure F.18—Three-source bunching; throttled-rate output-queue bridges

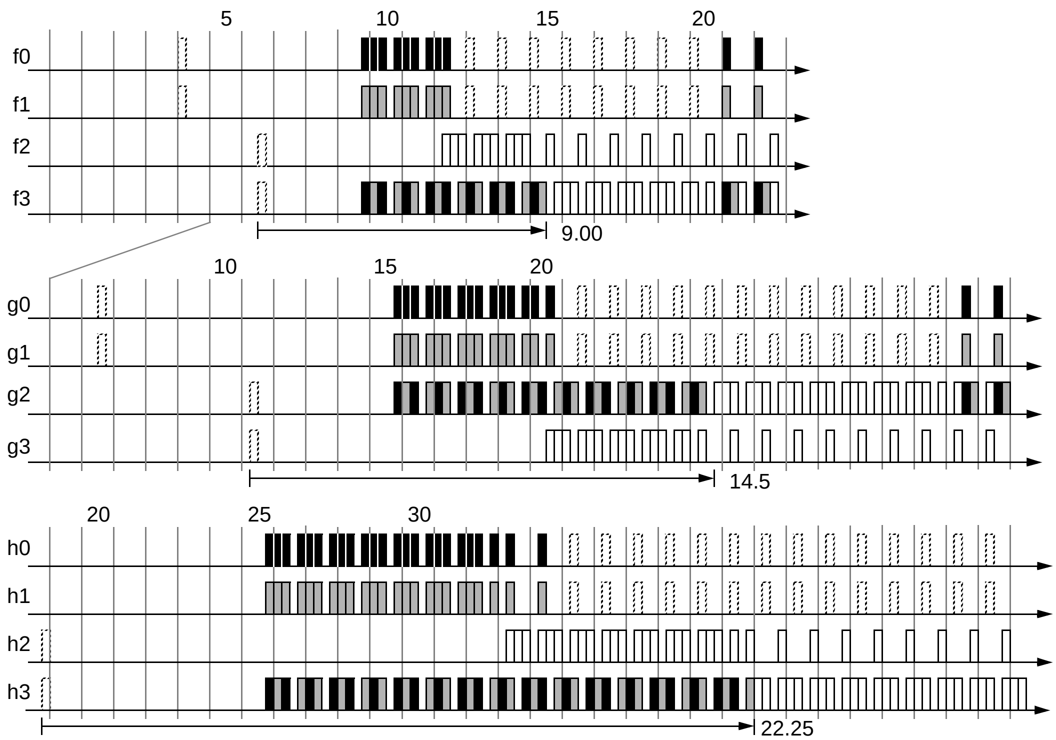


Figure F.19—Three-source bunching; throttled-rate output-queue bridges

F.2.6.2 Six-source bunching; classA throttled-rate output-queue bridges

To better illustrate the effects of worst case bunching, specific flows are illustrated in Figure F.20. Bridge ports {b0,b1,b2,b3,b4,b5} concentrates traffic from six talkers; one sixth of the cumulative traffic is forwarded through port b6. Each of six streams consumes 12.5% of the link bandwidth; 25% of the link bandwidth is available for asynchronous traffic.

For clarity, the traces for input traffic on ports {c0,c1,c2,c3,c4,c5},…,{d0,d1,d2,d3,d4,d6} only illustrate passing-through traffic; the remainder of the traffic is routed elsewhere.

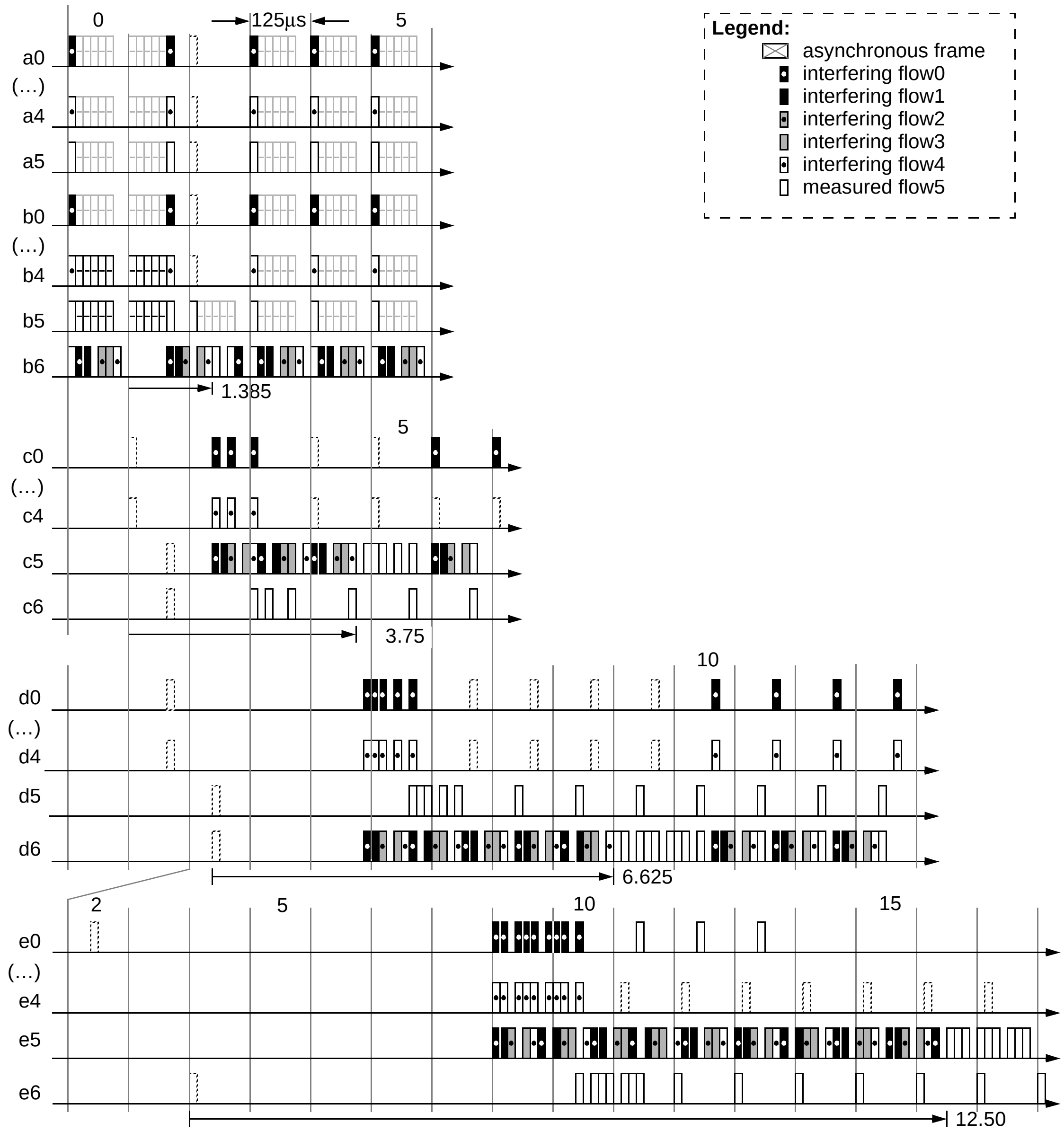


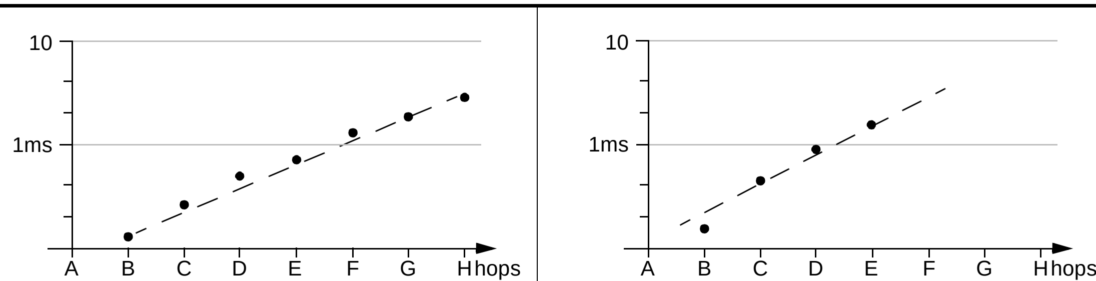
Figure F.20—Six source bunching; classA throttled-rate output-queue bridges

F.2.6.3 Cumulative bunching latencies; classA throttled-rate output-queue bridge

The cumulative worst-case latencies implied by coincidental bursting are listed in Table F.6 and plotted in Figure F.21.

Table F.6—Cumulative bunching latencies; classA throttled-rate output-queue bridge

Topology	Units	Measurement point							
		A	B	C	D	E	F	G	H
3-source (see F.2.2.1)	cycles	–	1.00	2.00	3.5	5.75	9.00	14.5	22.5
	ms	–	0.125	0.25	0.44	0.72	1.13	1.81	2.81
6-source (see F.2.2.2)	cycles	–	1.385	3.75	6.625	12.50	–	–	–
	ms	–	0.17	0.47	0.83	1.56	–	–	–



a) 3-source throttled-rate output-queue latency

b) 6-source throttled-rate output-queue latency

Figure F.21—Cumulative bunching latencies; classA throttled-rate output-queue bridge

Conclusion: On large topologies, the classA traffic latencies can accumulate beyond acceptable limits, even in the absence of conflicting lower-class traffic. Some form of receiver retiming may therefore be desired, even on higher speed links where the size of the MTU (in time) becomes much smaller than an assumed 8 kHz cycle time.