Analysis of Proposed Arbitration Enhancements

Enhancements Considered

- Ack Accelerated Arbitration
  - » Bill Duckwall's proposal
- Fly-By Arbitration
  - » Bill Duckwall's proposal
- Transaction Fairness
  - » As discussed at working group meetings
- Fairness Optimization
  - » new proposal
- Some combinations of the above proposals

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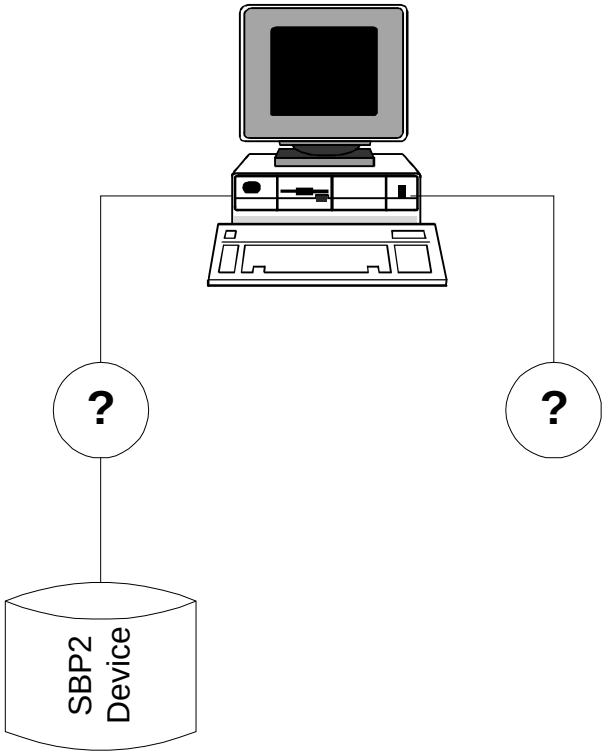
Fairness Optimization

- When enabled by the bus manager, nodes can arbitrate more than once per fairness interval
- Each node has a register specifying the number of accesses per interval
- register value of zero means unlimited access, no fairness
- register resets to one, so by default each node behaves as 1394-1995
- backward compatible with 1394-1995

Example Uses of Fairness Optimization

- Protocol Specific
  - » Devices get number of access which make sense according to the protocol they use
    - – SBP2 disk could get 4 accesses
- Topology Specific
  - » In a topology with just a PC and a disk, fairness could be turned off
- Speed Specific
  - » All devices could be allowed 8 accesses
    - – Helps networks of high speed devices reduce number of arb reset gaps
    - – Depending on gap count, Arb reset gap consumes 1344 to 33088 bit periods on S1600 bus
- Software Optimized
  - » Software can optimize depending on speed, topology, and protocol
    - – Each device gets different number of accesses

System modeled



- Topology Parameters
  - 3 hops
  - gap count 6
  - 2 hops from SBP2 device to root
  - cable_delay .022725 uS
- Asynchronous Traffic Only
- Timing Parameters
  - phy_delay 0.144 uS
  - base_rate 98.304 Mbps
  - arb_speed_signal_start 0
  - speed_signal_length 0.11 uS
  - data_prefix_time 0.08138 uS
  - data_end_time 0.244141 uS
  - ack_response_time 0.17 uS
  - arb_request_delay 0.144 uS
  - grant_delay 0.144 uS

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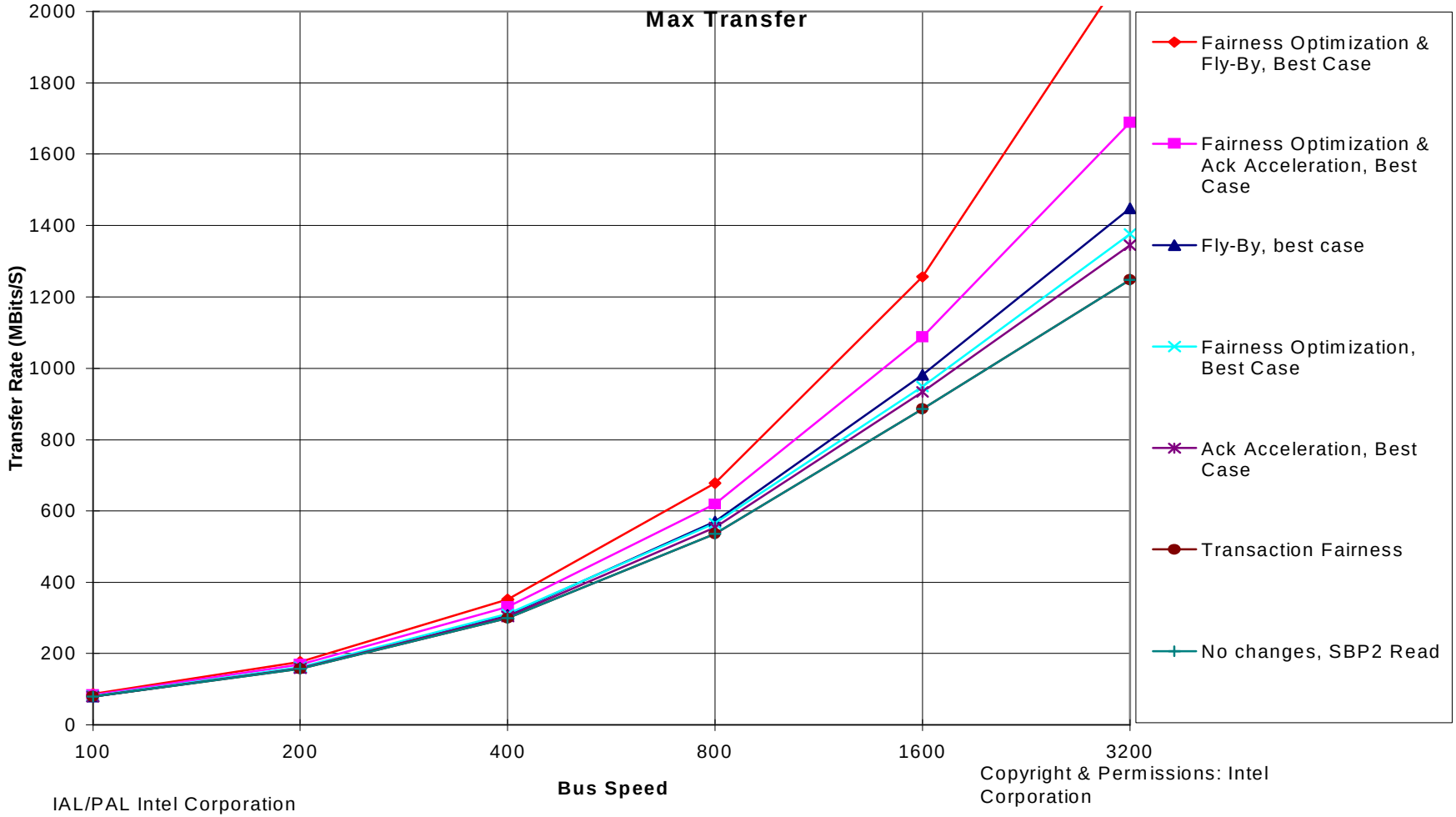
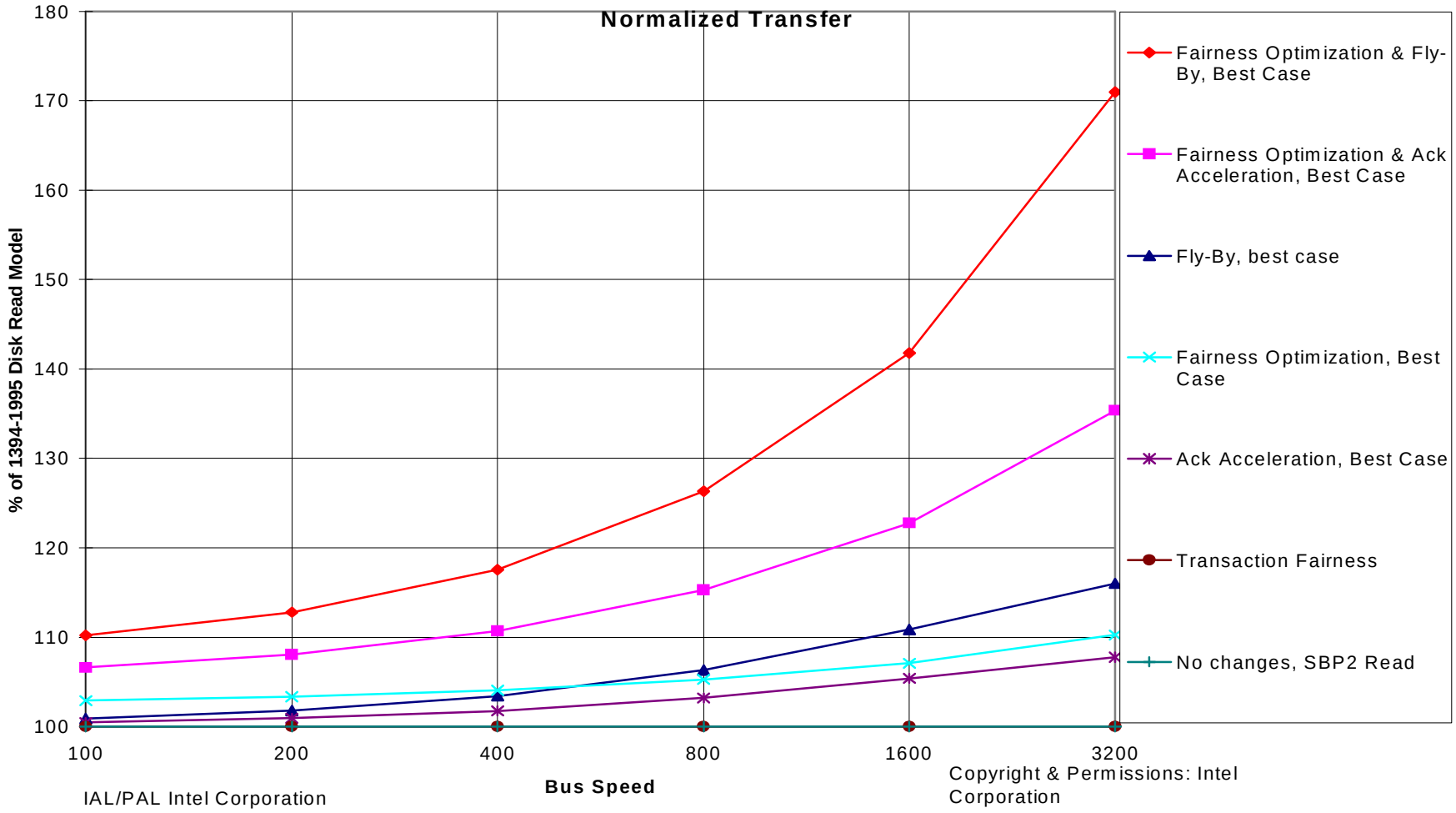
8K Buffer Transfers, SBP2 Read Transactions Include SG and ORB Ptr



8K Buffer Transfers, SBP2 Read Transactions Include SG and ORB Ptr

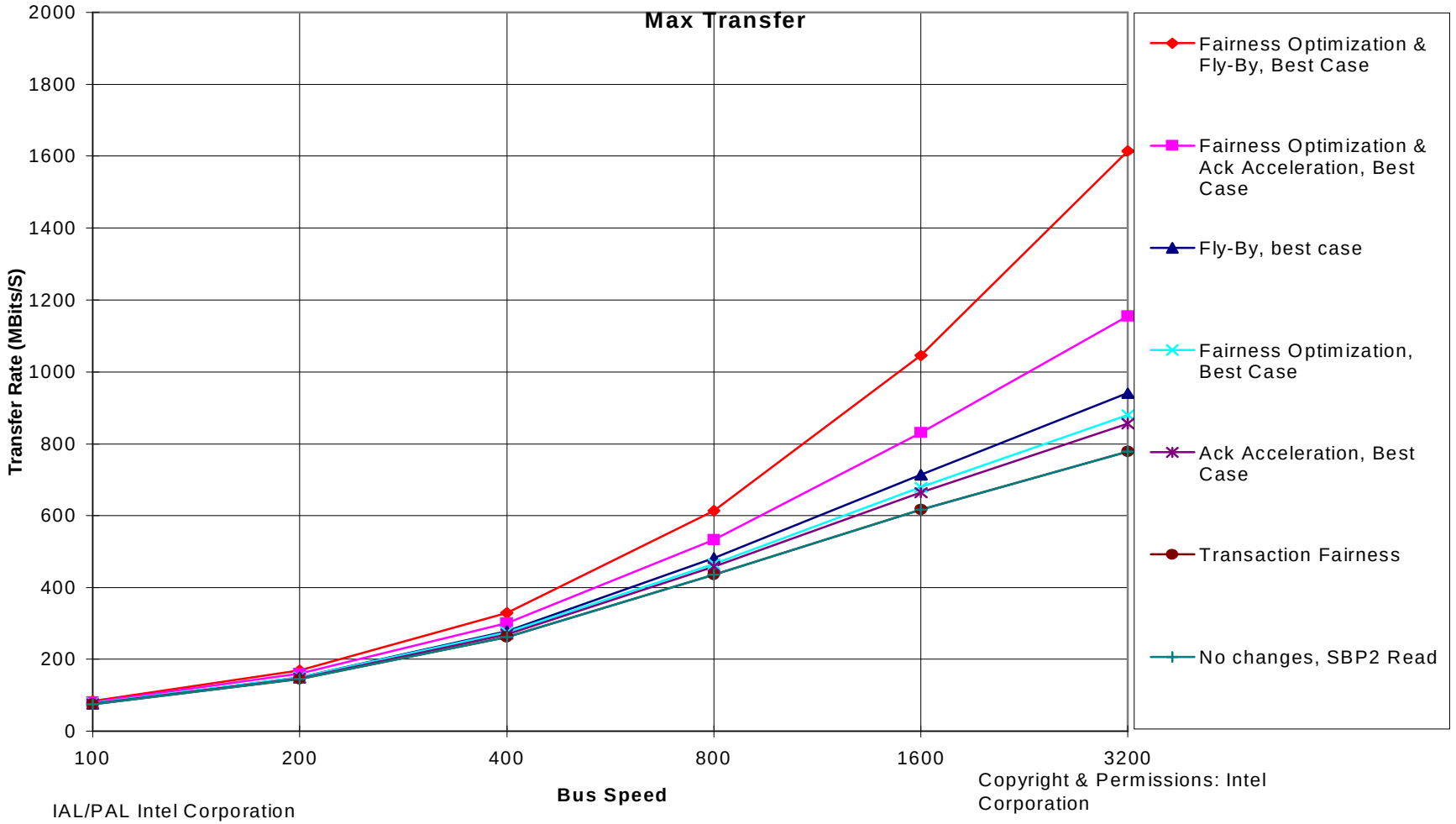


Call to Action

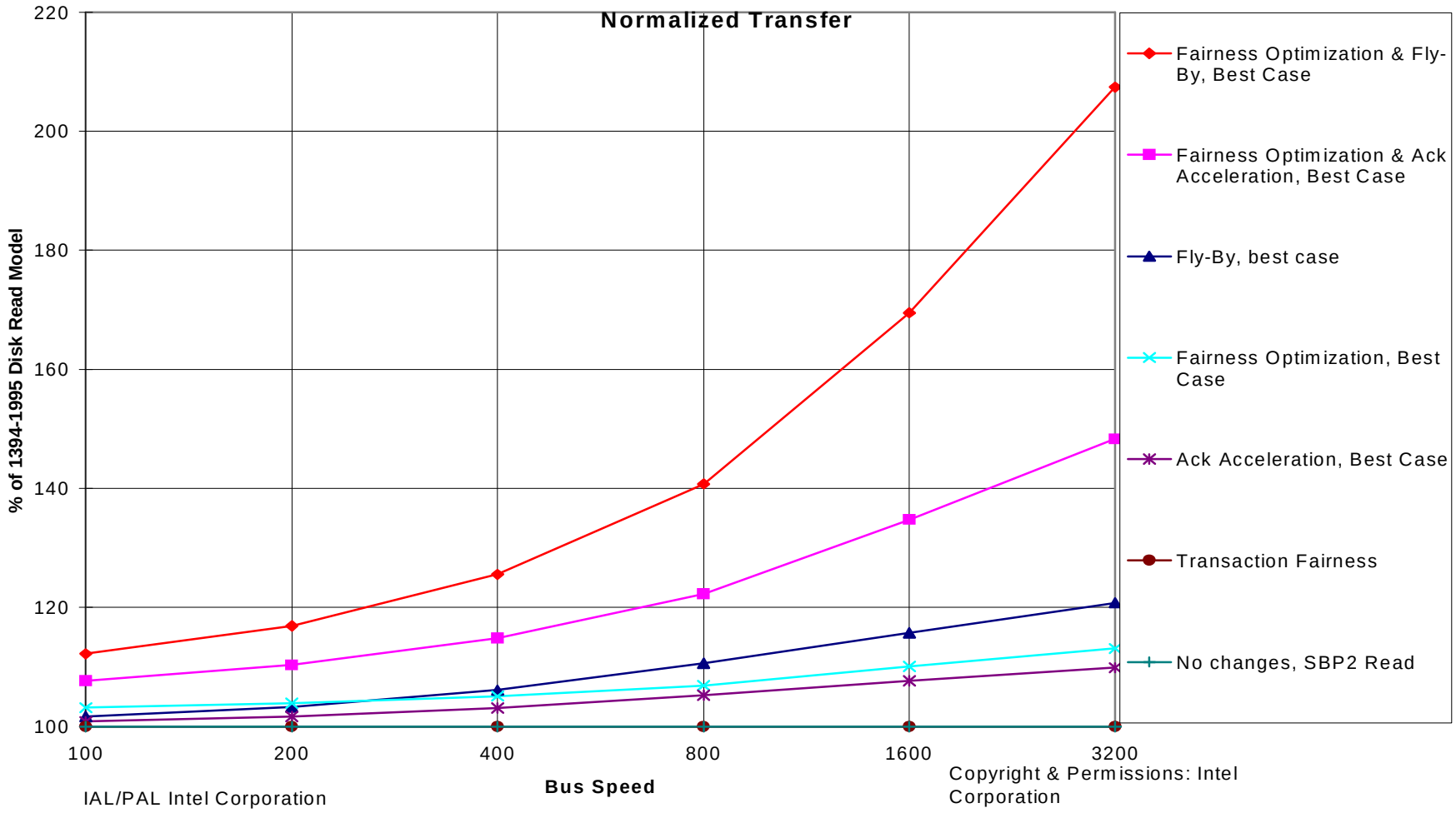
- Technical Issues?
- Does the register go in the Link, Phy, or both?
  - » If in the Phy, the link can make fair requests but doesn't know how many more can go in the fairness interval
  - » If in the Link, the link can make immediate requests until it reaches its limit
- Required or Optional Feature?

Backup

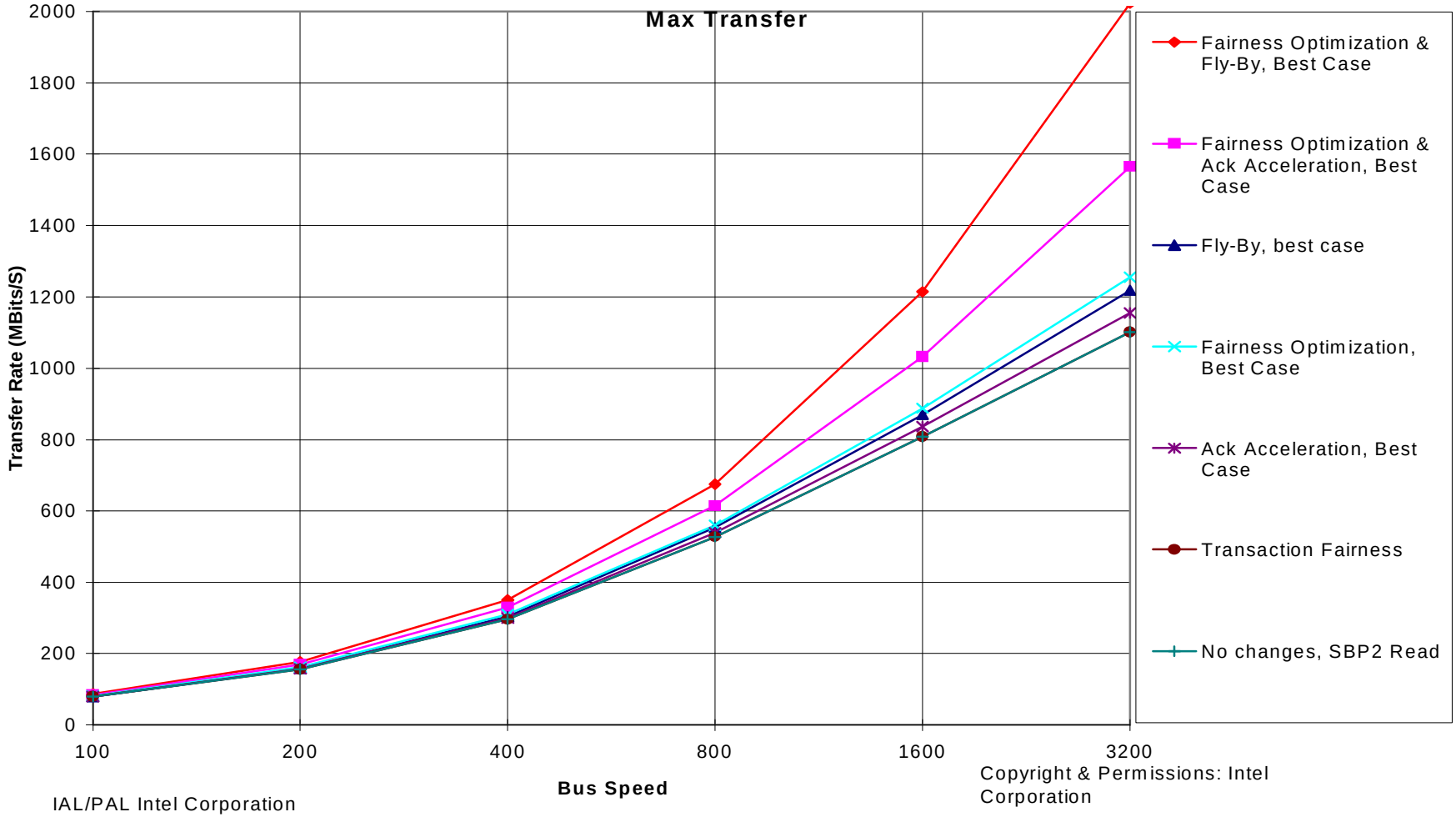
4K Buffer Transfers, SBP2 Read Transactions Include SG and ORB Ptr



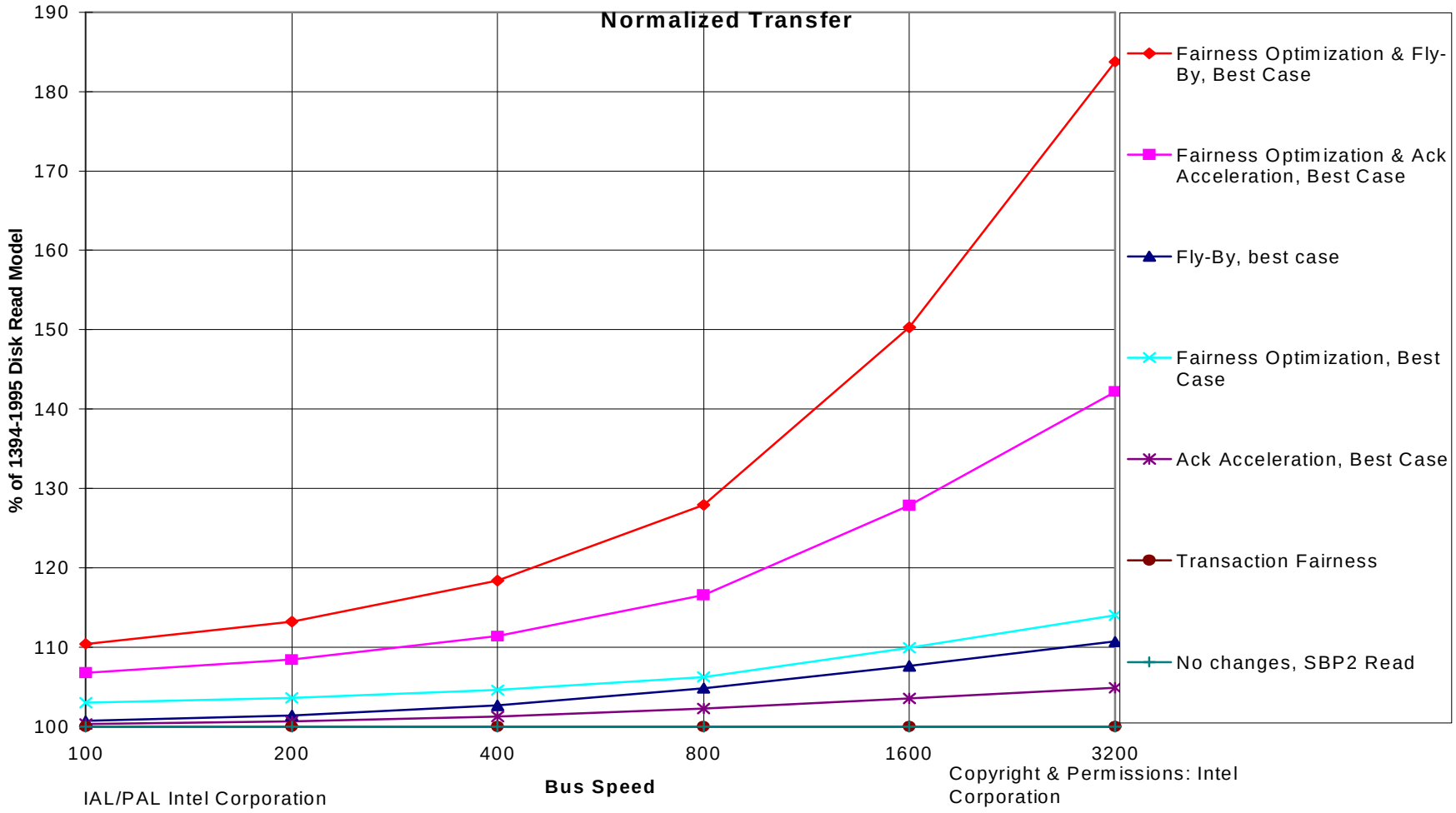
4K Buffer Transfers, SBP2 Read Transactions Include SG and ORB Ptr



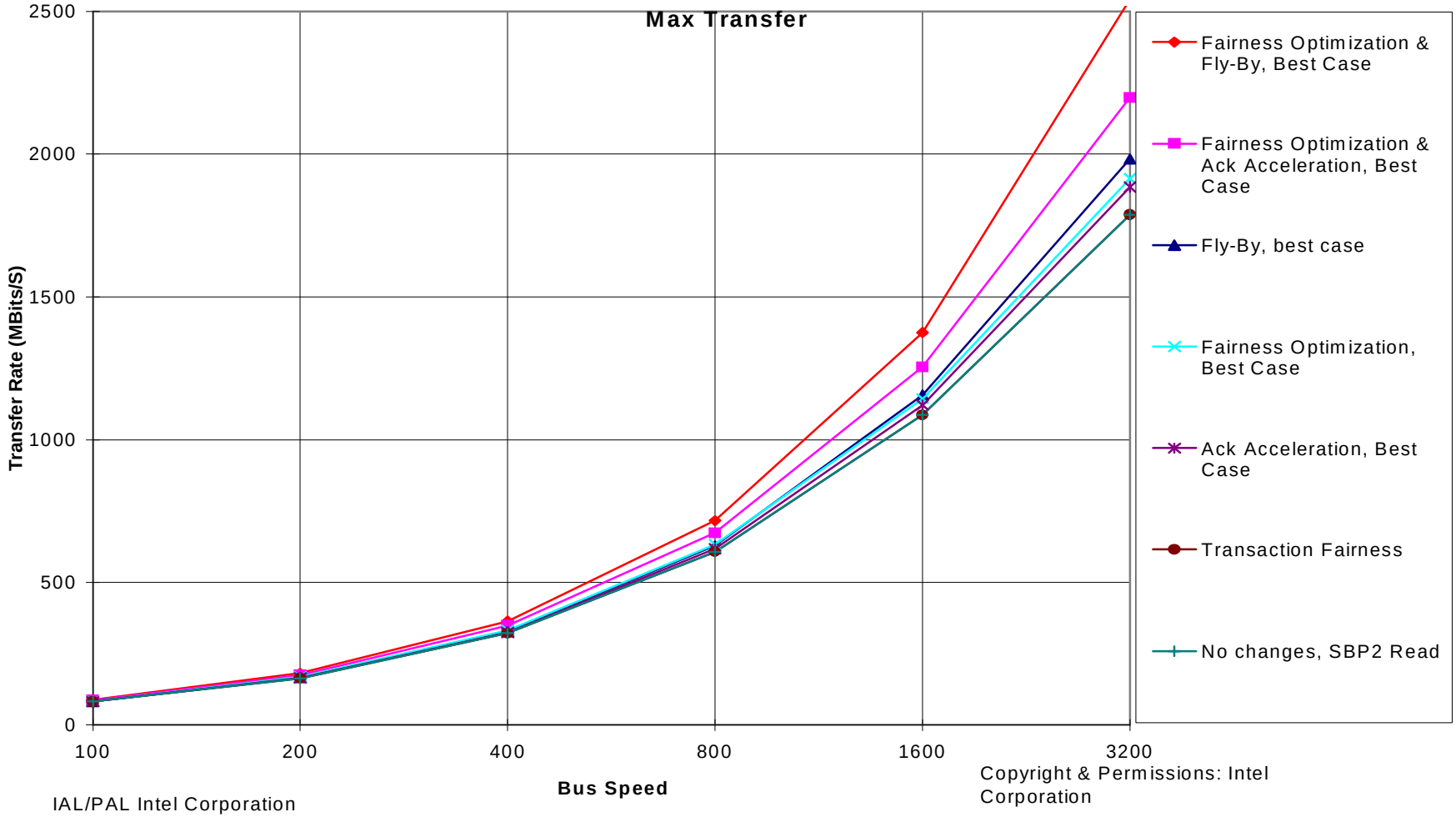
4K Buffer Transfers, SBP2 Read Transactions Include ORB Ptr 1 / 10 of the time and NO SG



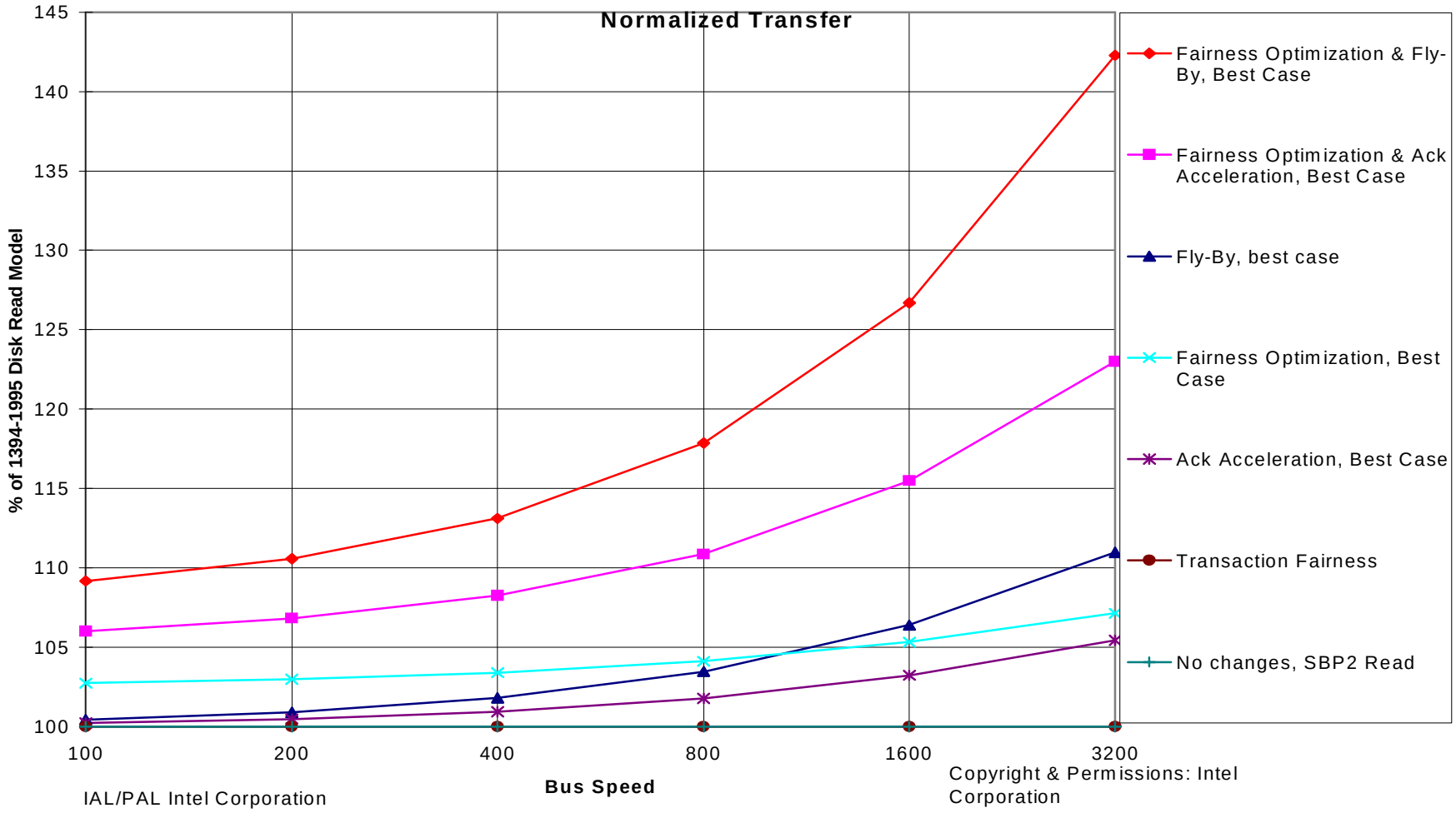
4K Buffer Transfers, SBP2 Read Transactions Include ORB Ptr 1 / 10 of the time and NO SG



16K Buffer Transfers, SBP2 Read Transactions Include SG and ORB Ptr



16K Buffer Transfers, SBP2 Read Transactions Include SG and ORB Ptr



SBP2 Read

Model 7 No changes, SBP2 Read

#	AR Gap	SA Gap	Request	Grant	Data Prefix	Data Bits	Data End	Propagatio	Ack Gap	Data Prefix	Ack	Data End	Propagatio	Totals	Comments
1.00		1.26	0.58	0.33	0.19	2.28	0.24	0.19	0.31	0.19	0.08	0.24	0.19	6.10	PC sends ORB ptr
1.00	2.48		0.58	0.33	0.19	1.63	0.24	0.19	0.31	0.19	0.08	0.24	0.19	6.67	Device requests ORB
1.00		1.26	0.58	0.33	0.19	4.56	0.24	0.19	0.31	0.19	0.08	0.24	0.19	8.38	PC sends ORB
1.00	2.48		0.58	0.33	0.19	1.63	0.24	0.19	0.31	0.19	0.08	0.24	0.19	6.67	Device request SG
1.00		1.26	0.58	0.33	0.19	4.56	0.24	0.19	0.31	0.19	0.08	0.24	0.19	8.38	PC sends SG
16.00	2.48		0.58	0.33	0.19	43.62	0.24	0.19	0.31	0.19	0.08	0.24	0.19	778.53	Device sends Data
1.00	2.48		0.58	0.33	0.19	3.26	0.24	0.19	0.31	0.19	0.08	0.24	0.19	8.29	Device sends Status
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
Totals	47.16	3.78	12.71	7.34	4.21	715.82	5.37	4.17	6.91	4.21	1.79	5.37	4.17	823.00	

- 1394-1995, no enhancements

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Transaction Fairness

Model 6 Transaction Fairness

#	AR Gap	SA Gap	Request	Grant	Data Prefix	Data Bits	Data End	Propagatio	Ack Gap	Data Prefix	Ack	Data End	Propagatio	Totals	Comments
1.00		1.26	0.58	0.33	0.19	2.28	0.24	0.19	0.31	0.19	0.08	0.24	0.19	6.10	PC sends ORB ptr
1.00	2.48		0.58	0.33	0.19	1.63	0.24	0.19	0.31	0.19	0.08	0.24	0.19	6.67	Device requests ORB
1.00		1.26	0.58	0.33	0.19	4.56	0.24	0.19	0.31	0.19	0.08	0.24	0.19	8.38	PC sends ORB
1.00	2.48		0.58	0.33	0.19	1.63	0.24	0.19	0.31	0.19	0.08	0.24	0.19	6.67	Device request SG
1.00		1.26	0.58	0.33	0.19	4.56	0.24	0.19	0.31	0.19	0.08	0.24	0.19	8.38	PC sends SG
16.00	2.48		0.58	0.33	0.19	43.62	0.24	0.19	0.31	0.19	0.08	0.24	0.19	778.53	Device sends Data
1.00	2.48		0.58	0.33	0.19	3.26	0.24	0.19	0.31	0.19	0.08	0.24	0.19	8.29	Device sends Status
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
Totals	47.16	3.78	12.71	7.34	4.21	715.82	5.37	4.17	6.91	4.21	1.79	5.37	4.17	823.00	

- Responses do not follow fairness rule
- No change in this example
  - » would be significant if many devices were making requests to PC
  - » This example is already best case

Ack Accelerated Arbitration

Model 5 Ack Acceleration, Best Case

#	AR Gap	SA Gap	Request	Grant	Data Prefix	Data Bits	Data End	Propagatio	Ack Gap	Data Prefix	Ack	Data End	Propagatio	Totals	Comments
1.00			0.58	0.33	0.19	2.28	0.24	0.19	0.31	0.19	0.08	0.24	0.19	4.84	PC sends ORB ptr
1.00	2.48		0.58	0.33	0.19	1.63	0.24	0.19	0.31	0.19	0.08	0.24	0.19	6.67	Device requests ORB
1.00			0.58	0.33	0.19	4.56	0.24	0.19	0.31	0.19	0.08	0.24	0.19	7.11	PC sends ORB
1.00	2.48		0.58	0.33	0.19	1.63	0.24	0.19	0.31	0.19	0.08	0.24	0.19	6.67	Device request SG
1.00			0.58	0.33	0.19	4.56	0.24	0.19	0.31	0.19	0.08	0.24	0.19	7.11	PC sends SG
16.00	2.48		0.58	0.33	0.19	43.62	0.24	0.19	0.31	0.19	0.08	0.24	0.19	778.53	Device sends Data
1.00	2.48		0.58	0.33	0.19	3.26	0.24	0.19	0.31	0.19	0.08	0.24	0.19	8.29	Device sends Status
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
Totals	47.16	0.00	12.71	7.34	4.21	715.82	5.37	4.17	6.91	4.21	1.79	5.37	4.17	819.22	

- Nodes start arbitration immediately after ack
  - » May be an unrelated ack
- Subaction Gap can be skipped

Fairness Optimization

Model 4 Fairness Optimization, Best Case

#	AR Gap	SA Gap	Request	Grant	Data Prefix	Data Bits	Data End	Propagatio	Ack Gap	Data Prefix	Ack	Data End	Propagatio	Totals	Comments
1.00		1.26	0.58	0.33	0.19	2.28	0.24	0.19	0.31	0.19	0.08	0.24	0.19	6.10	PC sends ORB ptr
1.00		1.26	0.58	0.33	0.19	1.63	0.24	0.19	0.31	0.19	0.08	0.24	0.19	5.45	Device requests ORB
1.00		1.26	0.58	0.33	0.19	4.56	0.24	0.19	0.31	0.19	0.08	0.24	0.19	8.38	PC sends ORB
1.00		1.26	0.58	0.33	0.19	1.63	0.24	0.19	0.31	0.19	0.08	0.24	0.19	5.45	Device request SG
1.00		1.26	0.58	0.33	0.19	4.56	0.24	0.19	0.31	0.19	0.08	0.24	0.19	8.38	PC sends SG
16.00		1.26	0.58	0.33	0.19	43.62	0.24	0.19	0.31	0.19	0.08	0.24	0.19	759.00	Device sends Data
1.00		1.26	0.58	0.33	0.19	3.26	0.24	0.19	0.31	0.19	0.08	0.24	0.19	7.07	Device sends Status
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
Totals	0.00	27.75	12.71	7.34	4.21	715.82	5.37	4.17	6.91	4.21	1.79	5.37	4.17	799.81	

- Allows multiple arbitrations per fairness interval
- Best case eliminates all arb reset gaps
  - » Actual percentage of arb reset gaps eliminated depends on topology and software
  - » Probably not hard to eliminate most arb reset gaps

Fly-By Arbitration

Model 3	Fly-By, best case													
#	AR Gap	SA Gap	Request	Grant	Data Prefix	Data Bits	Data End	Propagatio	Ack Gap	Data Prefix	Ack	Data End	Propagatio	Totals	Comments
1.00					0.19	2.28	0.24	0.19	0.31	0.19	0.08	0.24	0.19	3.92	PC sends ORB ptr
1.00	2.48		0.58	0.33	0.19	1.63	0.24	0.19	0.31	0.19	0.08		0.19	6.42	Device requests ORB
1.00					0.19	4.56	0.24	0.19	0.31	0.19	0.08	0.24	0.19	6.20	PC sends ORB
1.00	2.48		0.58	0.33	0.19	1.63	0.24	0.19	0.31	0.19	0.08		0.19	6.42	Device request SG
1.00					0.19	4.56	0.24	0.19	0.31	0.19	0.08	0.24	0.19	6.20	PC sends SG
16.00	2.48		0.58	0.33	0.19	43.62	0.24	0.19	0.31	0.19	0.08	0.24	0.19	778.53	Device sends Data
1.00	2.48		0.58	0.33	0.19	3.26	0.24	0.19	0.31	0.19	0.08		0.19	8.05	Device sends Status
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
Totals	47.16	0.00	10.97	6.34	4.21	715.82	5.37	4.17	6.91	4.21	1.79	4.64	4.17	815.75	

- Nodes concatenate to Acks from child ports
  - » Software can optimize by performing transactions with lowest nodes in topology first each fairness interval
- Best case eliminates subaction gaps and arbitration

Fairness Optimization & Ack Accelerated Arbitration

Model 2 Fairness Optimization & Ack Acceleration, Best Case

#	AR Gap	SA Gap	Request	Grant	Data Prefix	Data Bits	Data End	Propagatio	Ack Gap	Data Prefix	Ack	Data End	Propagatio	Totals	Comments
1.00			0.58	0.33	0.19	2.28	0.24	0.19	0.31	0.19	0.08	0.24	0.19	4.84	PC sends ORB ptr
1.00			0.58	0.33	0.19	1.63	0.24	0.19	0.31	0.19	0.08	0.24	0.19	4.18	Device requests ORB
1.00			0.58	0.33	0.19	4.56	0.24	0.19	0.31	0.19	0.08	0.24	0.19	7.11	PC sends ORB
1.00			0.58	0.33	0.19	1.63	0.24	0.19	0.31	0.19	0.08	0.24	0.19	4.18	Device request SG
1.00			0.58	0.33	0.19	4.56	0.24	0.19	0.31	0.19	0.08	0.24	0.19	7.11	PC sends SG
16.00			0.58	0.33	0.19	43.62	0.24	0.19	0.31	0.19	0.08	0.24	0.19	738.82	Device sends Data
1.00			0.58	0.33	0.19	3.26	0.24	0.19	0.31	0.19	0.08	0.24	0.19	5.81	Device sends Status
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
Totals	0.00	0.00	12.71	7.34	4.21	715.82	5.37	4.17	6.91	4.21	1.79	5.37	4.17	772.06	

- Fairness Optimization turns Arb Reset gaps to Subaction gaps
- Ack Acceleration eliminates Subaction gaps
- Best case eliminates all gaps

Fairness Optimization & Fly-By Arbitration

Model 1 Fairness Optimization & Fly-By, Best Case

#	AR Gap	SA Gap	Request	Grant	Data Prefix	Data Bits	Data End	Propagatio	Ack Gap	Data Prefix	Ack	Data End	Propagatio	Totals	Comments
1.00					0.19	2.28	0.24	0.19	0.31	0.19	0.08		0.19	3.68	PC sends ORB ptr
1.00					0.19	1.63	0.24	0.19	0.31	0.19	0.08		0.19	3.03	Device requests ORB
1.00					0.19	4.56	0.24	0.19	0.31	0.19	0.08		0.19	5.96	PC sends ORB
1.00					0.19	1.63	0.24	0.19	0.31	0.19	0.08		0.19	3.03	Device request SG
1.00					0.19	4.56	0.24	0.19	0.31	0.19	0.08		0.19	5.96	PC sends SG
16.00					0.19	43.62	0.24	0.19	0.31	0.19	0.08		0.19	720.34	Device sends Data
1.00					0.19	3.26	0.24	0.19	0.31	0.19	0.08		0.19	4.66	Device sends Status
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
														0.00	
Totals	0.00	0.00	0.00	0.00	4.21	715.82	5.37	4.17	6.91	4.21	1.79	0.00	4.17	746.65	

- Fairness Optimization turns Arb Reset gaps to Subaction gaps
- Fly-By Arbitration eliminates Subaction Gaps and Arbitration
- Best Case eliminates all gaps and arbitration

Timing Formulas

- ack_gap = PHY_DELAY + ack_response_time
- subaction_gap = (28 + gap_count * 16) / BASE_RATE
- arbreset_gap = (52 + gap_count * 32) / BASE_RATE
- arb_delay = gap_count * 4 / BASE_RATE
- arb_request_time = arb_delay + (HOPS_TO_ROOT-1) * (PHY_DELAY+ cable_delay) + cable_delay + arb_request_delay
- grant_time = (HOPS_TO_ROOT-1) * (PHY_DELAY+ cable_delay) + cable_delay + grant_delay
- propagation_time = (HOPS_TO_TARGET-1) * (cable_delay + PHY_DELAY) + cable_delay
- data_prefix_length = arb_speed_signal_start + speed_signal_length + data_prefix_time
- ack_length = 8/current_phy_speed