

OPNET Technologies, Inc.

A Simulation Study of QoS
for TCP Over LEO Satellite
Networks *with* Differentiated
Services



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Overview

- Broadband Satellite Network
- QoS Framework
- Buffer Management Classification
- Simulation Configuration
- Simulation Results: Two vs. Three Colors
- Conclusions

Broadband Satellite Networks: Ka Band

- Convergence of technical, regulatory, and business factors
- Adaptive power control and adaptive coding techniques for improved performance mitigating propagation impacts
- Advanced technology developments, e.g., low noise transistors high power transistors, high efficiency space Traveling Wave Tubes (TWTAs), Space qualified ASICs
- Improved Satellite bus designs with efficient solar arrays, higher efficiency electric propulsion
- Orbital congestion in C- and Ku-Band initiated interest in Ka-Band
- Advanced network protocols, switching and routing algorithm developments enable global interoperability

Broadband Satellite Networks (Partial List)⁽¹⁾

Astrolink	AIL	GEO	ATM-based	MF-TDMA
Spaceway	Hughes	GEO	ATM-based	MF-TDMA
N-Star	Japan	GEO	ATM based	TMDA
EuroSkyWay	Alenia Aerospazio	GEO & MEO	Packet Switching	MFTDMA
Teledesic	Teledesic Corp.	LEO	Fast Packet SW	MF-TDMA
Celestri	Motorola	EO	ATM-based	FDM/TDMA
SkyBridge*	Alcatel	LEO	No	CDMA

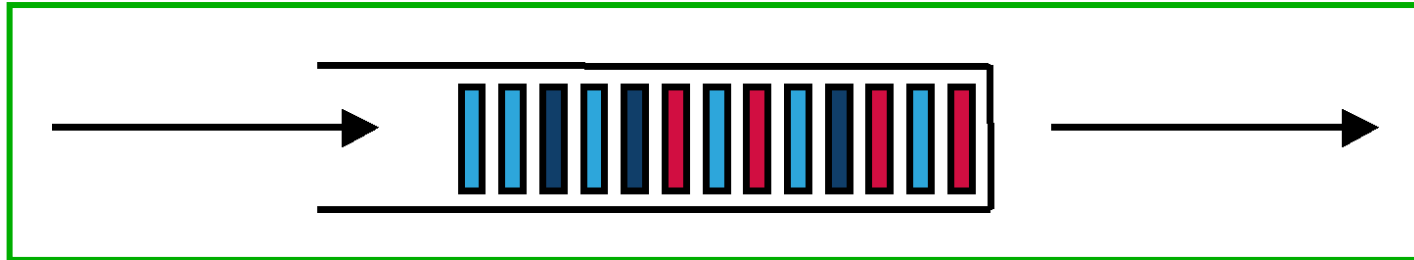
* Ku-band

⁽¹⁾ Subject to design changes

Determine the effect of number of drop precedences on performance of assured forwarding

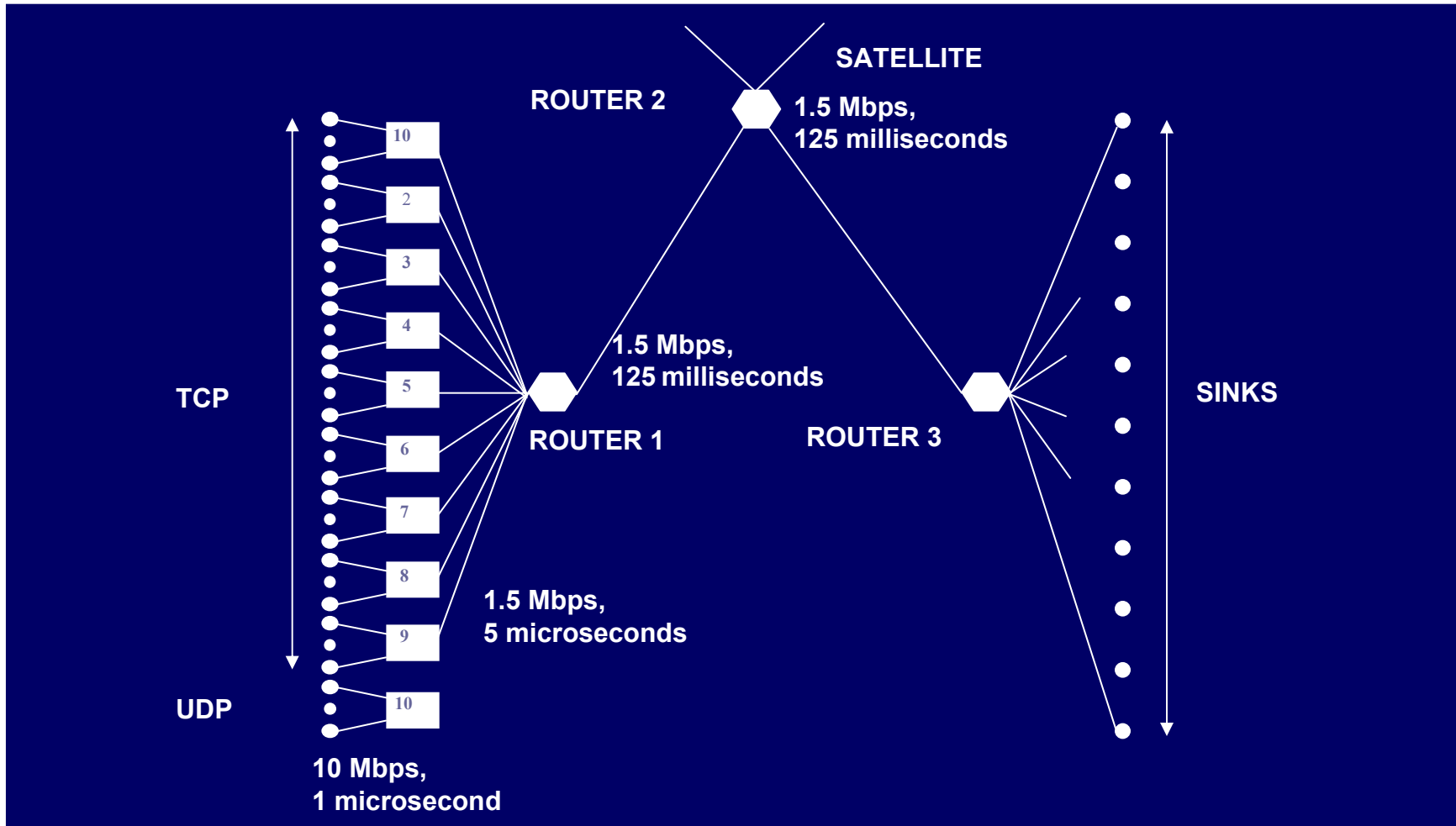
- Bandwidth Management
 - Number of colors: One, Two or Three
 - Percentage of Reserved Traffic: Low, high, over subscribed
- Buffer Management
 - Tail Drop
 - Random Early Drop
- Traffic Types
 - Congestion Sensitivity: TCP vs. UDP
 - Excess TCP vs. Excess UDP

Buffer Management Classification



- Accounting (queued packets):
- Per-color, per-VC, per-flow, or Global
- Multiple or Single
- Threshold: Single or Multiple
- Four Types:
 - Single Accounting, Single threshold (SAST)
 - Single Accounting, Multiple threshold (SAMT)
 - Multiple Accounting, Single threshold (MAST)
 - Multiple Accounting, Multiple threshold (MAMT)

Simulation Configuration



Simulation Configuration Parameters

Simulation Time	100 seconds	Link between Router 1 and Router 2:	
TCP Window	64 packets	Link Bandwidth	1.5 Mbps
TCP/UDP Packet Size	576 bytes	One way Delay	125 milliseconds
UDP Rate	1.28 Mbps		From Router 1 To Router 1
Maximum queue size (for all queues)	60 packets	Drop Policy	RED_n DropTail
		Link between Router 2 and Router 3:	
Link between UDP/TCPs and Customers:		Link Bandwidth	1.5 Mbps
Link Bandwidth	10 Mbps	One way Delay	125 milliseconds
One way Delay	1 microsecond	Drop Policy	DropTail
Drop Policy	DropTail	Link between Router 3 and Sinks:	
Link between Customers & Router 1:		Link Bandwidth	1.5 Mbps
Link Bandwidth	1.5 Mbps	One way Delay	5 microseconds
One way Delay	5 microseconds	Drop Policy	DropTail
Drop Policy	DropTail		



Two Color Simulation Parameters

Simulation ID	Green Rate [kbps]	Max Drop Probability {Green, Red}	Drop Thresholds {Green, Red}	Green Bucket (in Packets)
1-144	12.8	{0.1, 0.1}	{40/60, 0/10}	1
201-344	25.6	{0.1, 0.5}	{40/60, 0/20}	16
401-544	38.4	{0.5, 0.5}	{40/60, 0/5}	2
601-744	76.8	{0.5, 1}	{40/60, 20/40}	32
801-944	102.4	{1, 1}		4
1001-1144	128			8
1201-1344	153.6			
1401-1544	179.2			



Three Color Simulation Parameters

Simulation ID	Green Rate	Max Drop Drop Probability	Max Drop Drop Probability	Yellow Rate	Bucket Size (in packets)	
	[kbps]	{Green, Yellow, Red}	{Green, Yellow, Red}	[kbps]	Green	Yellow
1-720	12.8	{0.1, 0.5, 1}	{40/60, 20/40, 0/10}	128	16	1
1001-1720	25.6	{0.1, 1, 1}	{40/60, 20/40, 0/20}	12.8	1	16
2001-2720	38.4	{0.5, 0.5, 1}			2	2
3001-3720	76.8	{0.5, 1, 1}			32	32
		{1, 1, 1}			4	4
					8	8

Main Factors Influencing Fairness Results in Three Color Simulations

Factor/Interaction	Allocation of Variation (in % age)			
	2 Colors		3 Colors	
	TCP	UDP	TCP	UDP
Green Rate	1.60%	15.65%	2.21%	20.40%
Green Bucket Size	97.51%	69.13%	95.24%	62.45%
Green Rate -				
Green Bucket Size	0.59%	13.45%	1.96%	17.11%

Main Factors Influencing Fairness Results in Three Color Simulations

Factor/Interaction	Allocation of Variation (in % age)
Yellow Rate	41.36
Yellow Bucket Size	28.95
Interaction between Yellow Rate and Yellow Bucket Size	26.49

Fairness Index

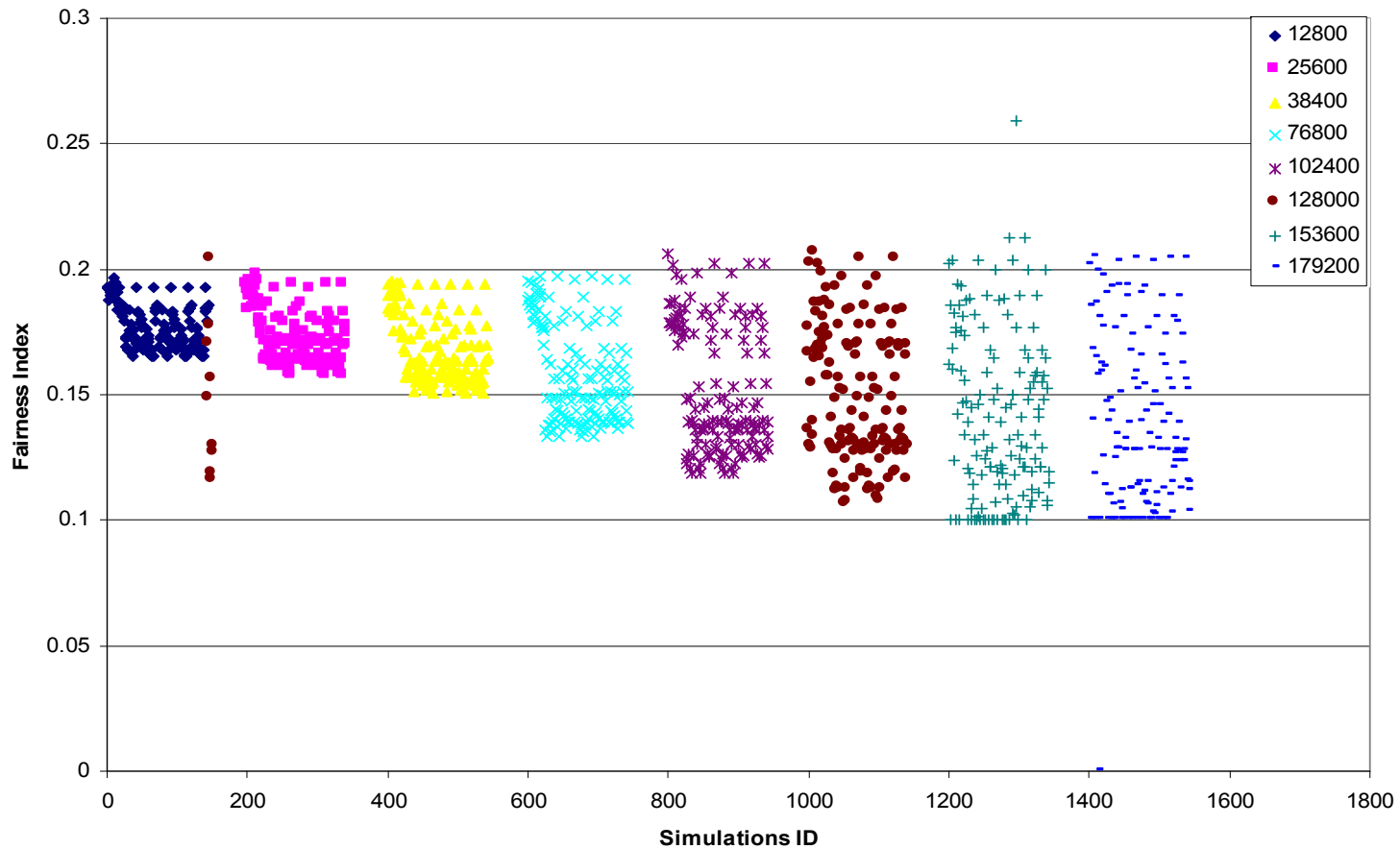
- Fairness in allocation of excess bandwidth among n customers sharing a link:

$$\text{Fairness Index} = \frac{(\sum x_i)^2}{n \times \sum (x_i^2)}$$

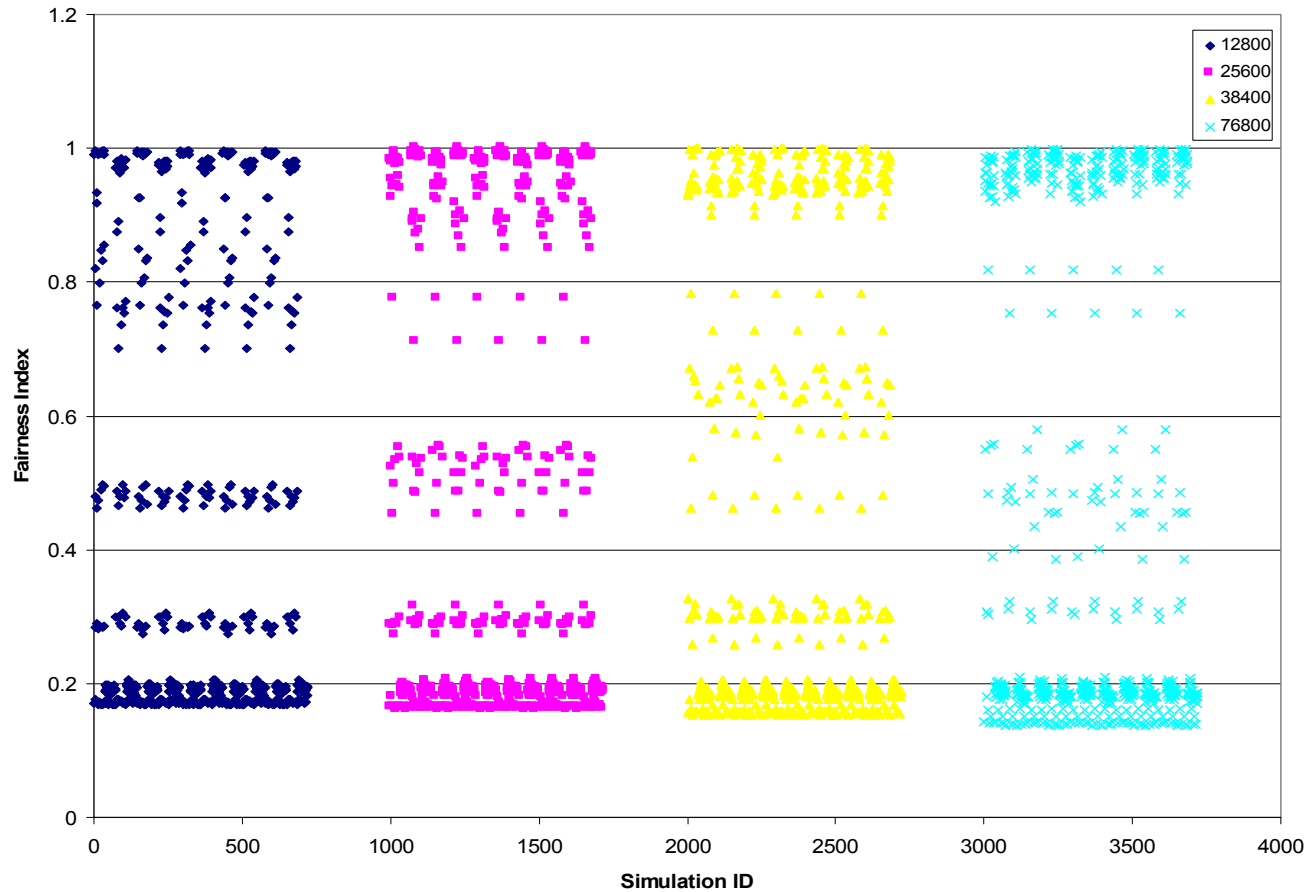
Where x_i is the excess throughput of the i th customer. Excess throughput of a customer is determined by the number of yellow and red packets received at the traffic destination(s).

Simulation Results: Fairness Achieved in 2-Color Simulations with Different Reserved Rates

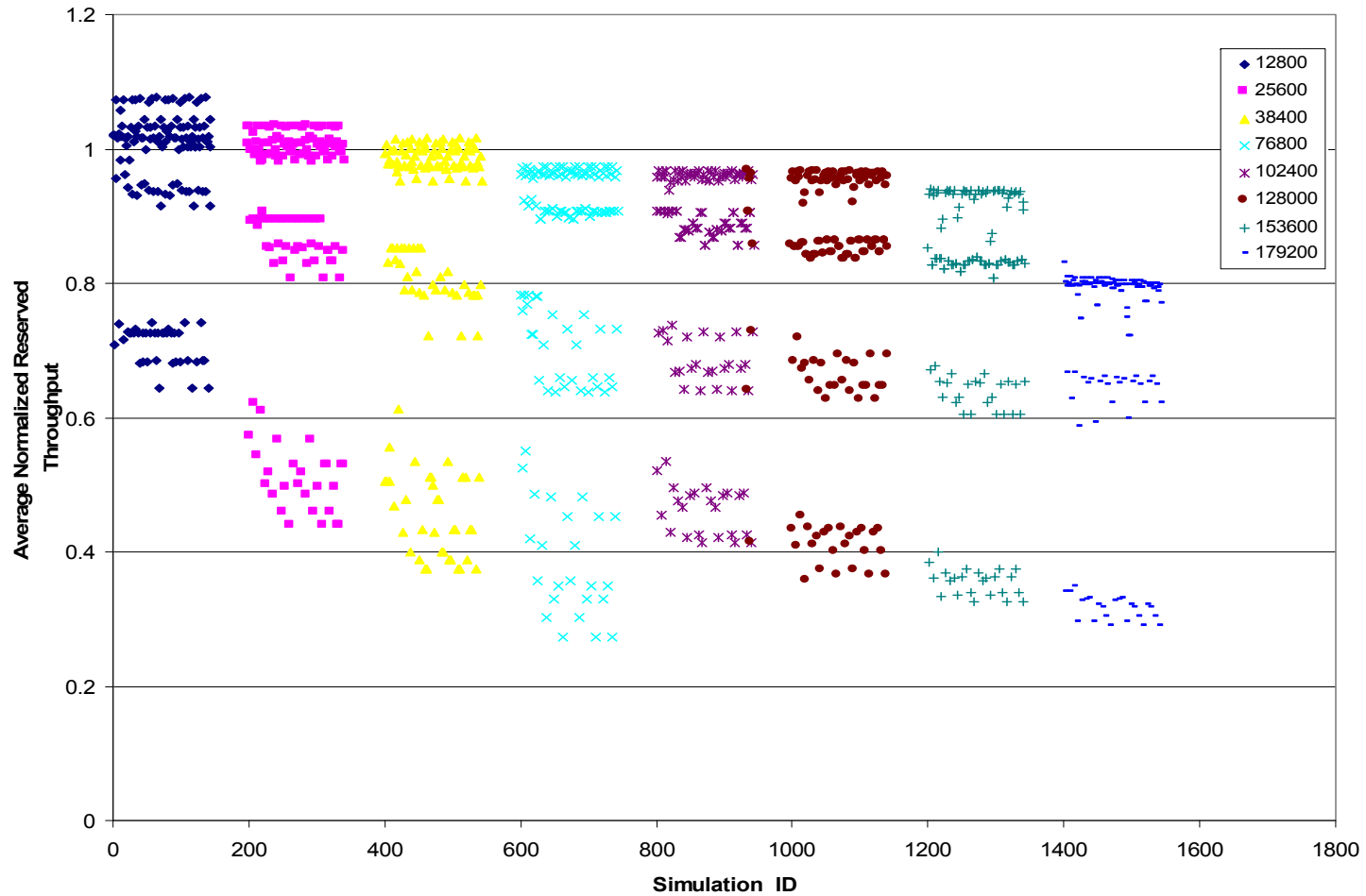
Fairness in Two Colors Simulations: LEO



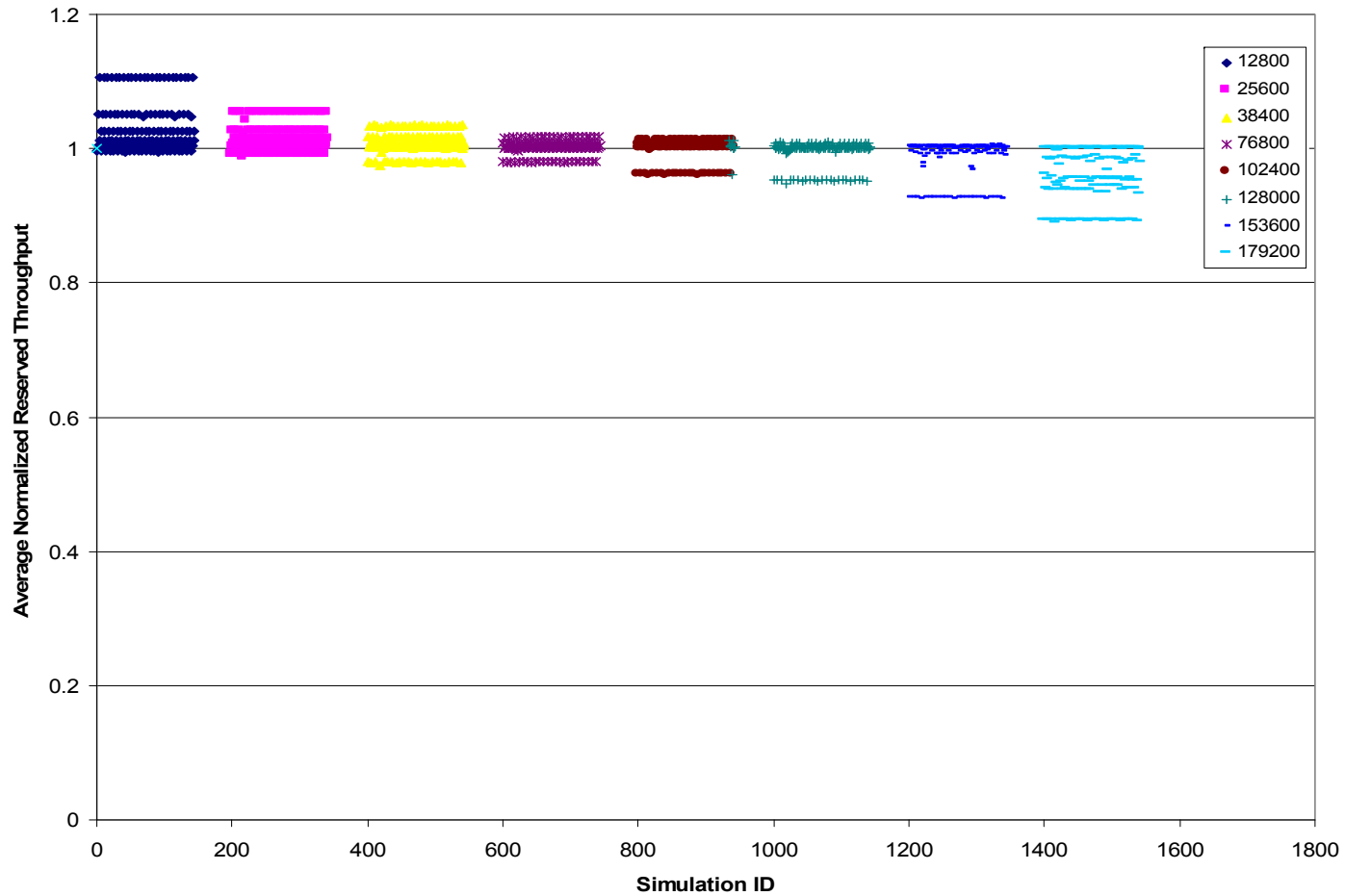
Simulation Results: Fairness Achieved in 3-Color Simulations with Different Reserved Rates



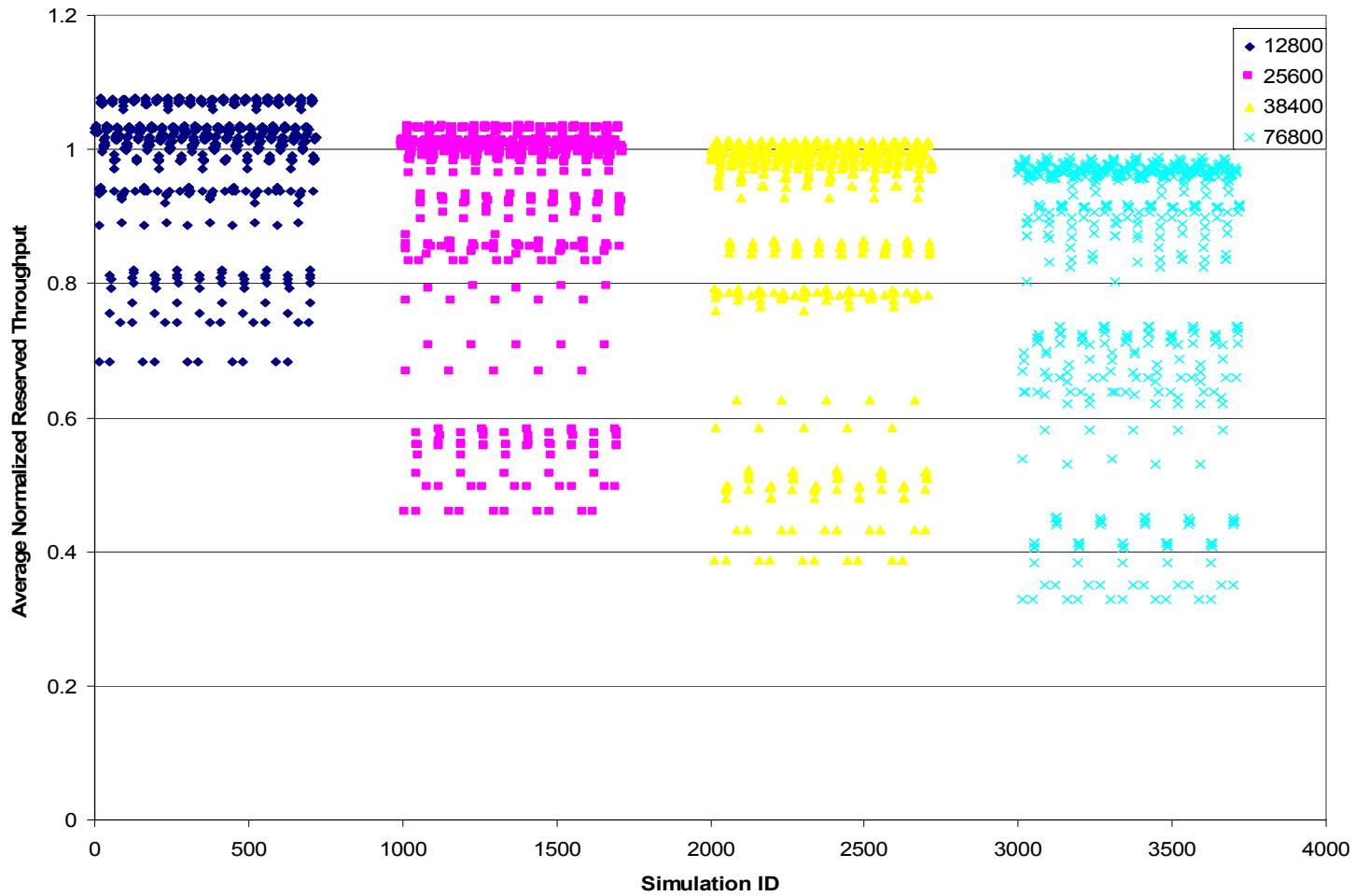
Reserved Rate Utilization by TCP Customers in 2-Color Simulations



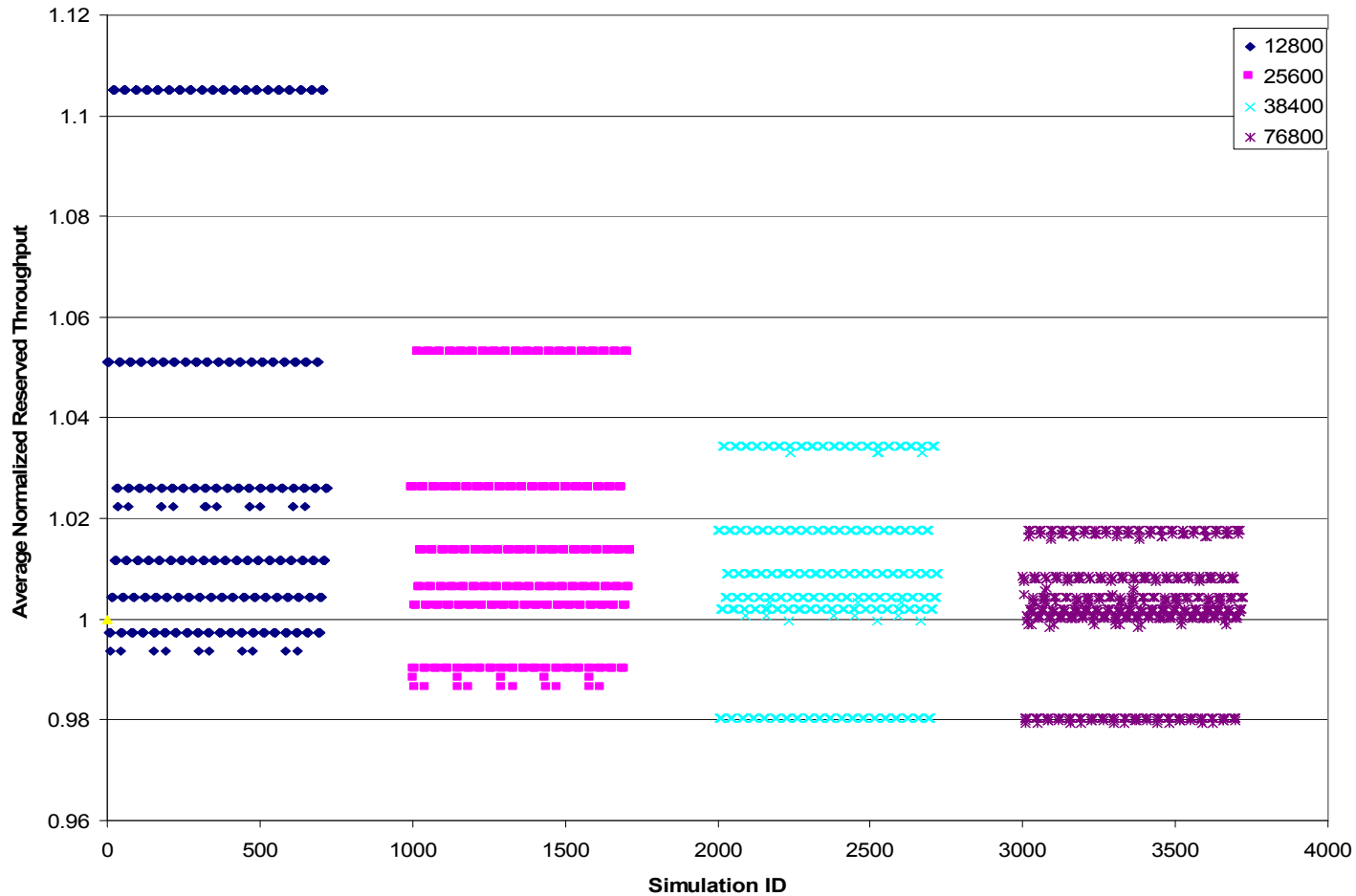
Reserved Rate Utilization by UDP Customers in 2-Color Simulations



Reserved Rate Utilization by TCP Customers in 3-Color Simulations



Reserved Rate Utilization by UDP Customers in 3-Color Simulations



Conclusions

- Key Performance Parameter is the level of green (reserved) traffic
- If reserved traffic level is high or if there is overbooking, 2 and 3 drop precedence give the same throughput and fairness
- If the reserved traffic is low, 3 colors give better fairness than 2 colors
- Classified have to distinguish between TCP and UDP packets in order to meaningfully utilize 3 drop precedence
 - Reserved TCP/UDP => **Green**
 - Exempted => **Yellow**
 - Excess UDP => **Red**
- Red parameters and implementations have significant impact on the performance