

Message Transaction Analysis of JFCOM Simulation Experiment

Application Characterization Environment (ACE)*:
Multi-transaction Report
BlueIMP-163
October 14, 2004

*ACE is an OPNET Technologies, Inc. trademark. This report was generated with the aid of OPNET Technologies' ACE software, which provides visualization and diagnosis of multi-tier application performance.

1. Scenario Summary

As part of a larger research effort funded by the Defense Modeling and Simulation Office (DMSO), George Mason University C3I Center participated in a JFCOM J9 simulation experiment during the period October 13, 2004 to October 15, 2004. The purpose of the participation was to collect and analyze message transaction flow between elements of the simulation experiment in order to better understand the networking requirements of a large simulation experiment. The results of this analysis is to be used for support of the continued research and development of a multicast overlay protocol designed to support real-time distributed simulation in an open network.

The experiment included 211 federates connected via RTI and distributed across a wide area network built over the DREN. The geographic background contained an average of 110,000 entities or objects

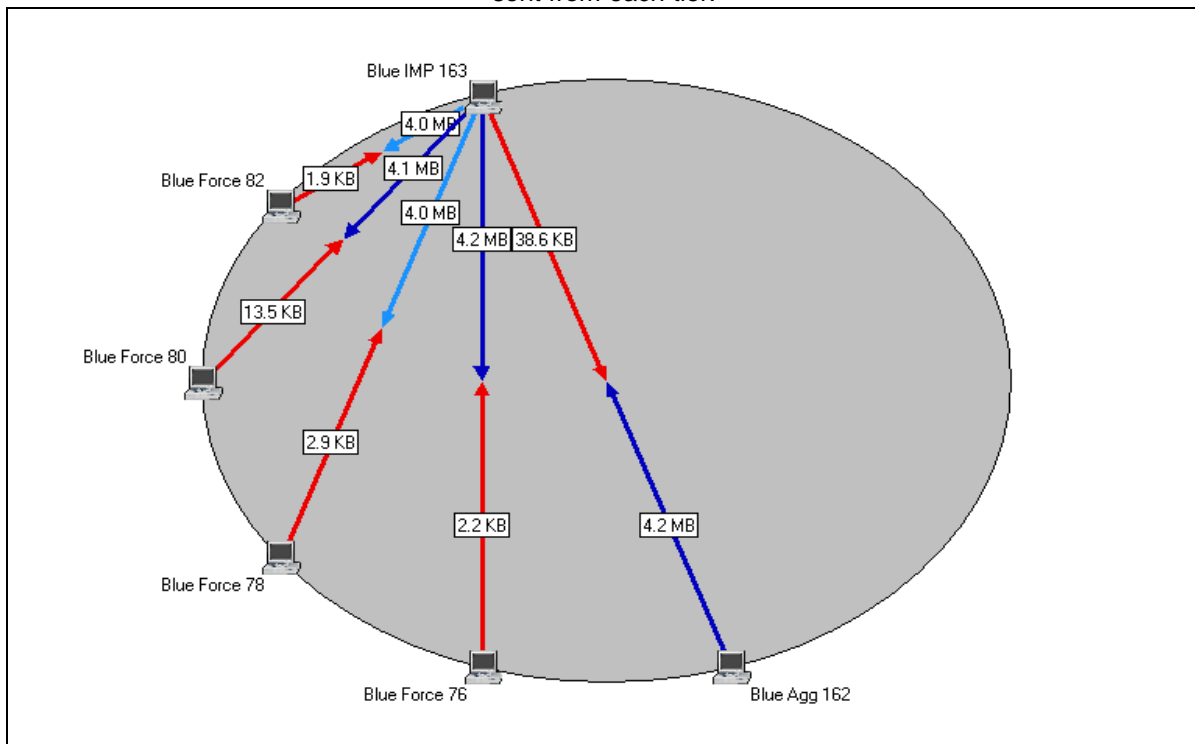
This summary report contains information from 1 trace collected at the Blue IMP-163 on October 14, 2004. The trace indicates the dominant traffic source to be the scenario geographic background generator. A very low traffic was observed being generated at the federate. All message exchange of interest was by TCP services. For trace **jfcom_10_14__163-1**, the total response time was 8.6 seconds. 20.4 MB of application data was transferred.

The general message pattern behavior was representative of an On-Off type traffic source. The interpretation is that when a source is on, there is a high rate of message transfer and when the source is off, there is a low rate of message transfer (Off does not mean there was no traffic). This behavior pattern is consistent with other simulation experiment observations.

2. Transaction Summary for Blue IMP-163

This transaction has 6 tiers: **Blue IMP 163**, **Blue Force 76**, **Blue Force 82**, **Blue Force 80**, **Blue Force 78**, and **Blue Agg 162**. The data capture agent was hosted on Blue IMP163.

The following diagram is a high-level depiction of the transaction and shows the total application bytes sent from each tier.



3. Scenario Diagnosis

3.1 Summary Trace Table

The following table summarizes scenario data analysis.

	Across All Tiers	Blue Force 76	Blue IMP 163	Blue Force 82
Processing	87.5%	0.0%	1.4%	0.0%

	Blue Force 80	Blue Agg 162	Blue Force 78
Processing	0.0%	84.5%	0.0%

	Across All Tier Pairs	Blue Force 76 << Blue IMP 163	Blue Force 82 << Blue IMP 163	Blue Force 80 << Blue IMP 163	Blue Agg 162 << Blue IMP 163	Blue IMP 163 << Blue Force 78
Protocol Overhead	5.7%	5.3%	5.3%	5.4%	6.9%	5.3%
Chattiness	157,611	313,588	296,395	134,008	82,178	189,522
Network Effects of Chattiness	0.002	0.000	0.000	0.001	0.001	0.000
Effect of Latency	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Effect of Bandwidth	3.4%	0.0%	0.0%	0.0%	2.8%	0.0%
Effect of Protocol/Congestion	5.7%	0.2%	0.1%	0.0%	2.5%	0.0%
Connection Resets	0	0	0	0	0	0
Retransmissions	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Out of Sequence Packets	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TCP Windowing (A ® B)	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
TCP Windowing (A – B)	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
TCP Frozen Window	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TCP Nagle's Algorithm	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

3.2 Individual Tier Statistics

Individual Tier Statistics

This table shows statistics for individual tiers.

	Across All Tiers	Blue Force 76	Blue IMP 163	Blue Force 82
Effect of Processing (sec)	7.517952	0.000000	0.117880	0.000000
Effect of Network (sec)	0.901194	Not Applicable	Not Applicable	Not Applicable

	Blue Force 80	Blue Agg 162	Blue Force 78
Effect of Processing (sec)	0.000475	7.263434	0.000000
Effect of Network (sec)	Not Applicable	Not Applicable	Not Applicable

This table shows statistics for individual tier pairs.

	Across All Tier Pairs	Blue Force 76 « Blue IMP 163	Blue Force 82 « Blue IMP 163	Blue Force 80 « Blue IMP 163	Blue Agg 162 « Blue IMP 163	Blue IMP 163 « Blue Force 78
Response Time (sec)	8.590860	8.588108	8.583471	8.583341	8.584395	8.583232
Application Turns	136	14	14	32	54	22
Application Messages	1,645	279	287	289	507	283
Application Data (bytes)	21,435,132	4,390,236	4,149,524	4,288,261	4,437,625	4,169,486
Average Application Message (bytes)	13,030.48	15,735.61	14,458.27	14,838.27	8,752.71	14,733.17
Network Packets	19,432	3,716	3,540	3,691	4,947	3,538
Network Data (bytes)	22,719,684	4,635,524	4,383,196	4,533,779	4,764,159	4,403,026
Average Network Packet (bytes)	1,169.19	1,247.45	1,238.19	1,228.33	963.04	1,244.50
Latency (ms)	Not Applicable	0.00	0.00	0.00	0.00	0.00
Effect of Latency (sec)	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Bandwidth (Kbps)	Not Applicable	100,000.000	100,000.000	100,000.000	100,000.000	100,000.000
Effect of Bandwidth (sec)	0.294071	0.001991	0.000029	0.000801	0.240534	0.000331
Effect of Protocol/Congestion (sec)	0.489754	0.020832	0.007360	0.001500	0.214141	0.000000
Max Application Bytes Per Turn (A ® B)	Not Applicable	1,298	856	2,896	664,017	1,566,367
Max Application Bytes Per Turn (A - B)	Not Applicable	1,962,405	1,911,113	772,447	6,660	1,334
Max Unacknowledged Data (A ® B) (bytes)	Not Applicable	883	441	2,896	32,142	62,264
Max Unacknowledged Data (A - B) (bytes)	Not Applicable	66,608	59,795	57,920	6,660	919
Retransmissions	1	0	0	1	0	0
Out of Sequence Packets	1	0	0	1	0	0
Connection Resets	0	0	0	0	0	0
TCP Frozen Window (sec)	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
TCP Nagle's Algorithm (sec)	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
TCP Triple - Duplicate ACK loss indications	1	0	0	1	0	0

4. Tier Pair Analysis

4.1 Message View Flow Chart

This chart displays the overall flow of application-layer data between tiers focusing on the time interval 6.549 seconds to 6.696 seconds. Notice that the arrival of a message from the highest layer tier, Blue Agg 162, typically spawns a multiple set of messages to the lower tiers. In some cases, there is a significant time lag as to when this occurs. The dominant delay measurement is attributed to this tier processing at the Blue IMP 163.

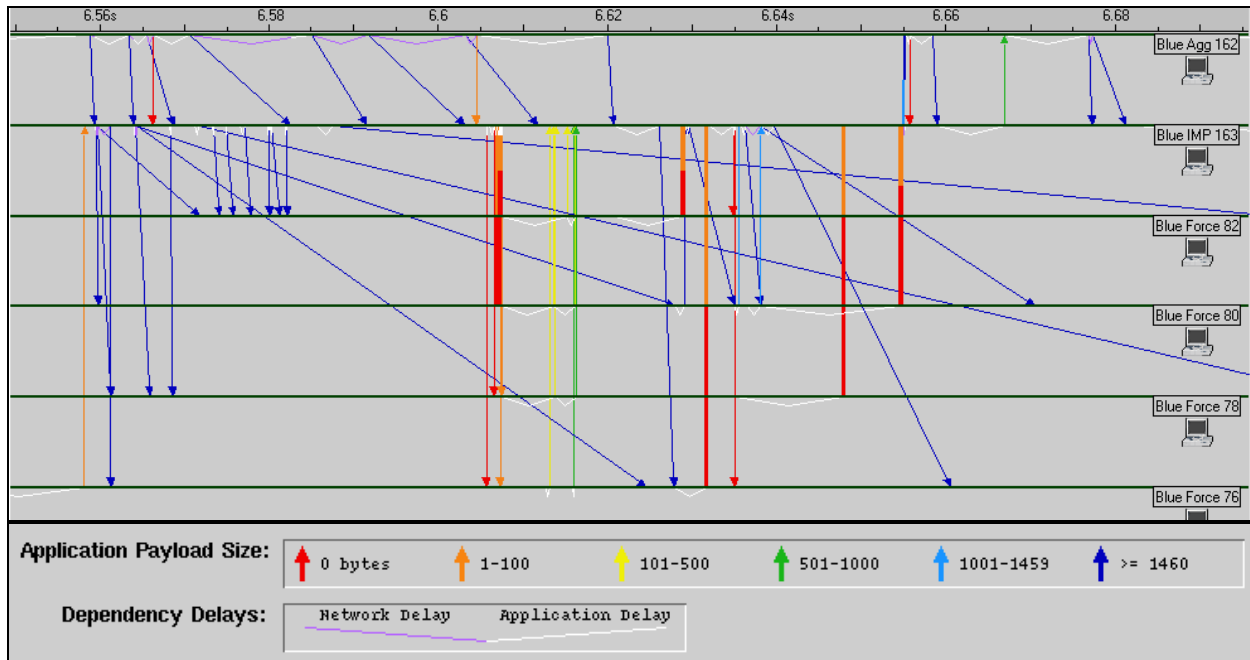


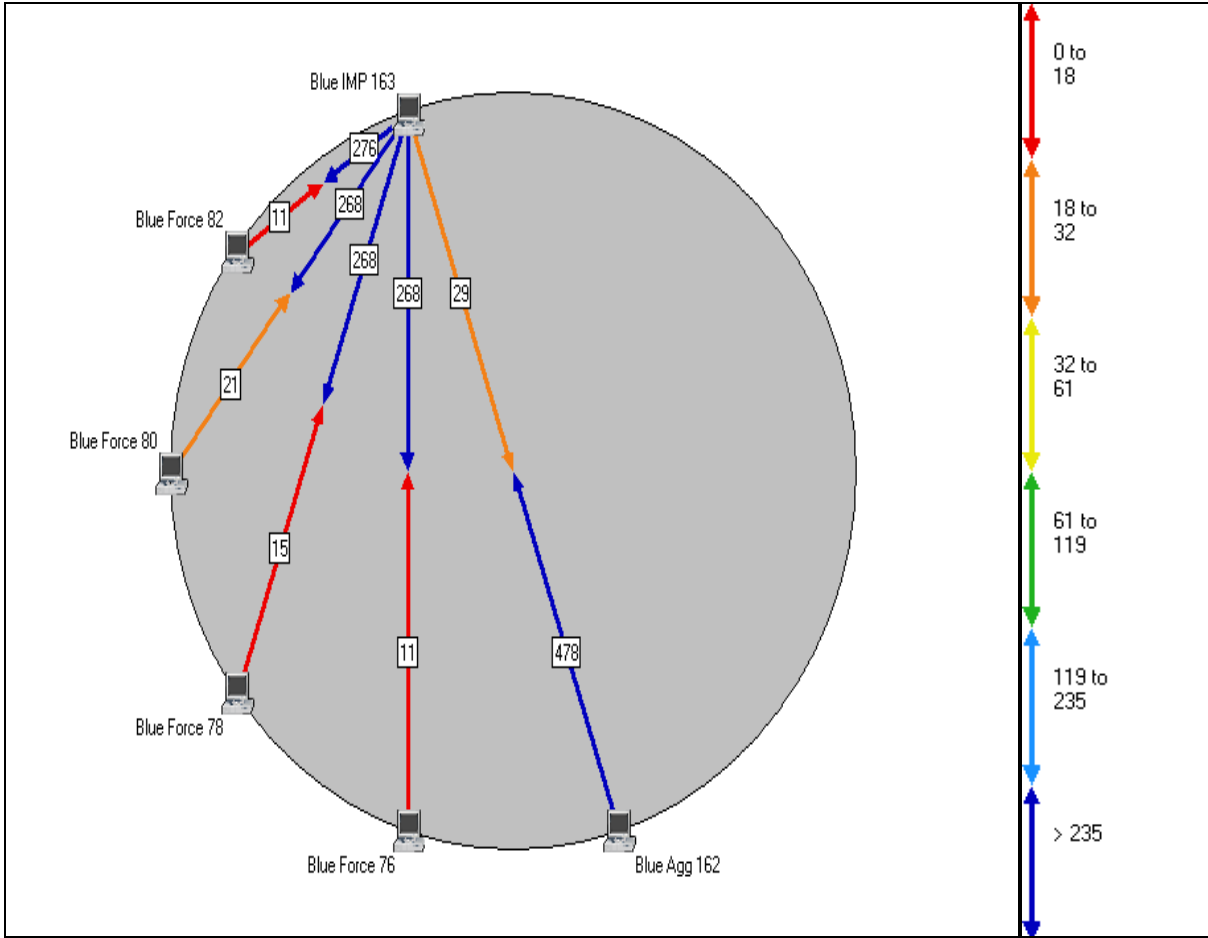
Chart conventions

- Time is marked along the top.
- Each solid horizontal line represents a tier (labeled on the right).
- Each arrow represents a single application message. An application message may be comprised of several network packets. The locations of an arrow's head and tail represent the message departure and arrival time.
- Colors represent the amount of application data contained in each message, as indicated by the **Application Payload Size** legend at the bottom.
- Application message groups represent closely spaced application messages and are shown as bars with multiple bands of color. The height of each color band indicates the proportion of message sizes within each application message group.

"Dependencies" indicate network or application delay. A V-shaped line beneath a tier indicates delay between two messages at that tier. A black line represents application delay and a gray line represents network delay

4.2 Application Messages (Directional)

This diagram displays **Application Messages (Directional** - Total number of application messages (per direction.)) for all included tiers. Arrows connecting each tier pair represent a data exchange and are colored according to the legend on the right.



4.3 Tier View Statistics: Tier Pair Data Exchange Tables

These tables show statistics associated with individual tier pair data exchanges. This is a hierarchical view of the data exchanges between tier pairs. Each indented row below a tier pair represents a connection.

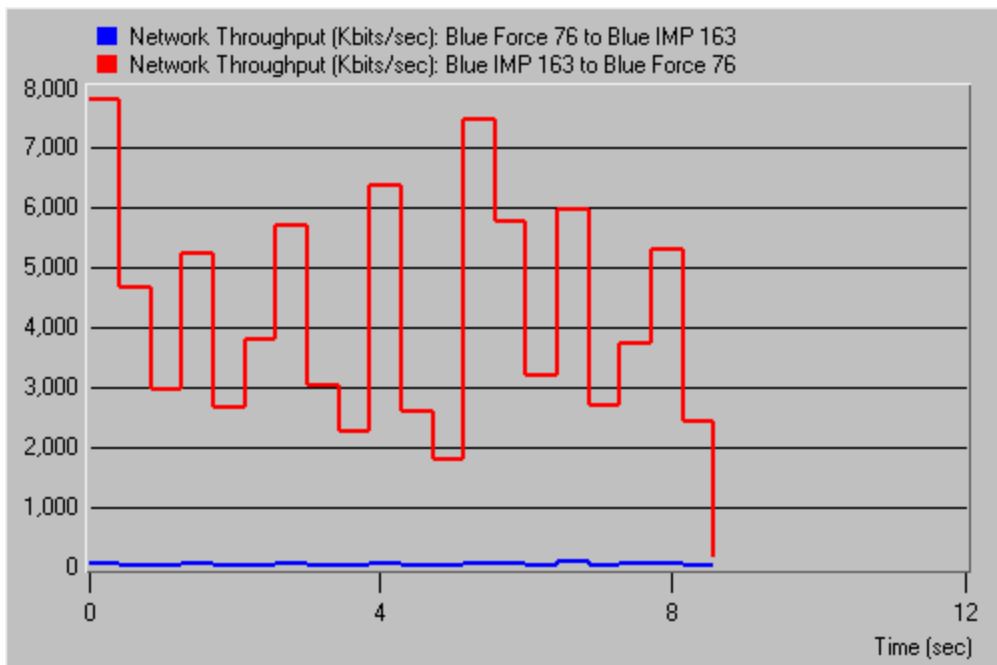
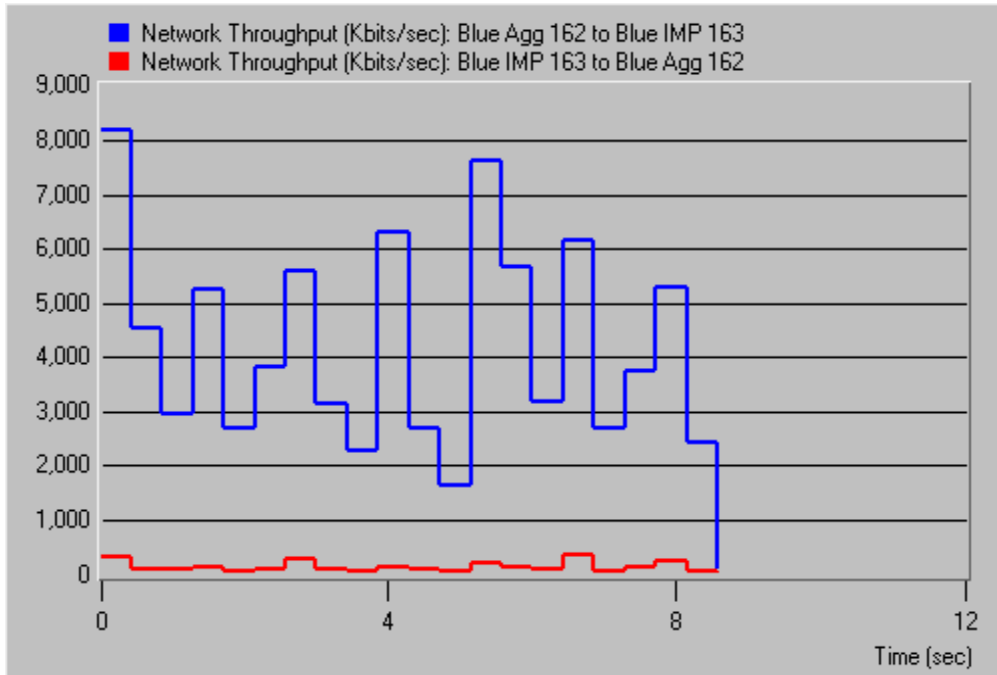
	App Bytes ®	App Bytes ↵	Start Time	End Time	Duration
Blue Force 76 « Blue IMP 163	2217	4388019	0.000000	8.602838	8.602838
TCP: 35895« 2243 Dest port=2243 Src port=35895 ACK=2568551634 SEQ=2755672179 LEN=0 WIN=49051	856	4387380	0.000000	8.602838	8.602838
TCP: 8181« 56066 Dest port=8181 Src port=56066 SYN SEQ=3981560783 LEN=0 WIN=5840	63	566	5.289466	5.298687	0.009221
TCP: 8181« 56070 Dest port=8181 Src port=56070 SYN SEQ=3988634296 LEN=0 WIN=5840	1298	73	6.605705	6.636573	0.030868
Blue Force 82 « Blue IMP 163	1958	4147566	0.005651	8.597035	8.591384
TCP: 37480« 2243 Dest port=2243 Src port=37480 ACK=2568203377 SEQ=2629946013 LEN=0 WIN=48643	1039	4146927	0.005651	8.597035	8.591384
TCP: 8181« 56069 Dest port=8181 Src port=56069 SYN SEQ=3981001212 LEN=0 WIN=5840	63	566	5.290377	5.299465	0.009088
TCP: 8181« 56073 Dest port=8181 Src port=56073 SYN SEQ=3988584248 LEN=0 WIN=5840	856	73	6.607078	6.635512	0.028434
Blue Force 80 « Blue IMP 163	13875	4274386	0.008540	8.597664	8.589124
TCP: 37299« 2243 Dest port=2243 Src port=37299 ACK=2589551191 SEQ=2591156567 LEN=0 WIN=48870	12956	4273747	0.008540	8.597664	8.589124
TCP: 8181« 56068 Dest port=8181 Src port=56068 SYN SEQ=3981298930 LEN=0 WIN=5840	63	566	5.290070	5.300709	0.010639
TCP: 8181« 56072 Dest port=8181 Src port=56072 SYN SEQ=3986098214 LEN=0 WIN=5840	856	73	6.606794	6.655102	0.048308
Blue Agg 162 « Blue IMP 163	4398085	39540	0.011978	8.596384	8.584406
TCP: 2243« 50717 Dest port=50717 Src port=2243 ACK=808745542 SEQ=2540548927 LEN=1448 WIN=49071	4397446	34944	0.011978	8.596384	8.584406
TCP: 55955« 8181 Dest port=8181 Src port=55955 SYN SEQ=3942229743 LEN=0 WIN=5840	566	252	5.287244	5.301871	0.014627
TCP: 55959« 8181 Dest port=8181 Src port=55959 SYN SEQ=3941397384 LEN=0 WIN=5840	73	4344	6.566109	6.655754	0.089645
Blue IMP 163 « Blue Force 78	4166500	2986	0.013526	8.596758	8.583232
TCP: 2243« 37453 Dest port=37453 Src port=2243 ACK=2644185156 SEQ=2549096450 LEN=1448 WIN=14114	4165861	1589	0.013526	8.596758	8.583232
TCP: 56067« 8181 Dest port=8181 Src port=56067 SYN SEQ=3989666007 LEN=0 WIN=5840	566	63	5.289778	5.299443	0.009665
TCP: 56071« 8181 Dest port=8181 Src port=56071 SYN SEQ=3982353356 LEN=0 WIN=5840	73	1334	6.606494	6.648421	0.041927

	Num Turns	App Msgs ®	App Msgs ↵	Source Hostname	Dest Hostname
Blue Force 76 « Blue IMP 163	14	11	268	Blue Force 76	Blue IMP 163
TCP: 35895 « 2243 Dest port=2243 Src port=35895 ACK=2568551634 SEQ=2755672179 LEN=0 WIN=49051	10	5	262	Blue Force 76	Blue IMP 163
TCP: 8181 « 56066 Dest port=8181 Src port=56066 SYN SEQ=3981560783 LEN=0 WIN=5840	2	2	3	Blue IMP 163	Blue Force 76
TCP: 8181 « 56070 Dest port=8181 Src port=56070 SYN SEQ=3988634296 LEN=0 WIN=5840	2	4	3	Blue IMP 163	Blue Force 76
Blue Force 82 « Blue IMP 163	14	11	276	Blue Force 82	Blue IMP 163
TCP: 37480 « 2243 Dest port=2243 Src port=37480 ACK=2568203377 SEQ=2629946013 LEN=0 WIN=48643	10	5	270	Blue Force 82	Blue IMP 163
TCP: 8181 « 56069 Dest port=8181 Src port=56069 SYN SEQ=3981001212 LEN=0 WIN=5840	2	2	3	Blue IMP 163	Blue Force 82
TCP: 8181 « 56073 Dest port=8181 Src port=56073 SYN SEQ=3988584248 LEN=0 WIN=5840	2	4	3	Blue IMP 163	Blue Force 82
Blue Force 80 « Blue IMP 163	32	21	268	Blue Force 80	Blue IMP 163
TCP: 37299 « 2243 Dest port=2243 Src port=37299 ACK=2589551191 SEQ=2591156567 LEN=0 WIN=48870	28	15	262	Blue Force 80	Blue IMP 163
TCP: 8181 « 56068 Dest port=8181 Src port=56068 SYN SEQ=3981298930 LEN=0 WIN=5840	2	2	3	Blue IMP 163	Blue Force 80
TCP: 8181 « 56072 Dest port=8181 Src port=56072 SYN SEQ=3986098214 LEN=0 WIN=5840	2	4	3	Blue IMP 163	Blue Force 80
Blue Agg 162 « Blue IMP 163	54	478	29	Blue Agg 162	Blue IMP 163
TCP: 2243 « 50717 Dest port=50717 Src port=2243 ACK=808745542 SEQ=2540548927 LEN=1448 WIN=49071	50	472	25	Blue Agg 162	Blue IMP 163
TCP: 55955 « 8181 Dest port=8181 Src port=55955 SYN SEQ=3942229743 LEN=0 WIN=5840	2	3	2	Blue Agg 162	Blue IMP 163
TCP: 55959 « 8181 Dest port=8181 Src port=55959 SYN SEQ=3941397384 LEN=0 WIN=5840	2	3	2	Blue Agg 162	Blue IMP 163
Blue IMP 163 « Blue Force 78	22	268	15	Blue IMP 163	Blue Force 78
TCP: 2243 « 37453 Dest port=37453 Src port=2243 ACK=2644185156 SEQ=2549096450 LEN=1448 WIN=14114	18	262	9	Blue IMP 163	Blue Force 78
TCP: 56067 « 8181 Dest port=8181 Src port=56067 SYN SEQ=3989666007 LEN=0 WIN=5840	2	3	2	Blue IMP 163	Blue Force 78
TCP: 56071 « 8181 Dest port=8181 Src port=56071 SYN SEQ=3982353356 LEN=0 WIN=5840	2	3	4	Blue IMP 163	Blue Force 78

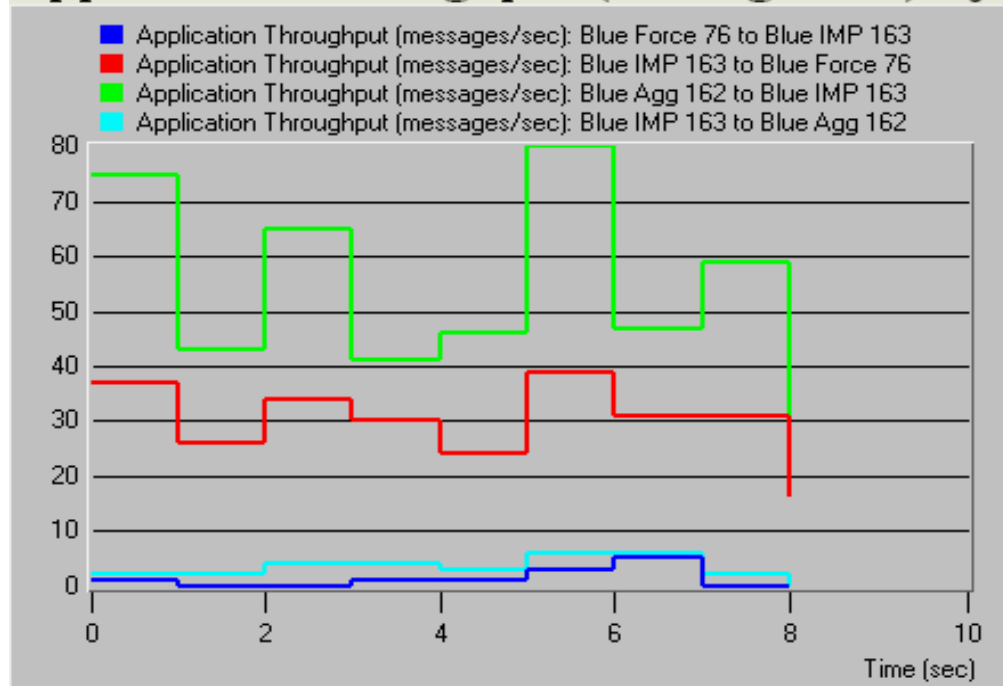
5. Network Throughput

These graphs represent the average amount of network data transmitted from the source to the destination tier. This statistic measures network throughput, including all application data and network protocol overhead. In the interest in maintaining a smaller file for viewing from our web site, only a single tier graph relationship is included here for illustrative purposes as all tiers demonstrated similar patterns. The first graphic indicates the highest observed tier message throughput (Kbits/sec) from the source at Blue AGG 162 to destination of the Blue IMP 163. The second graph indicates the message forwarding response of the Blue IMP to the Blue Force Federate 76. Notice that there is nearly a one-to-one relationship in pattern except that there is slightly fewer messages forwarded. The relationship is easier to observe in the third graphic. This graph presents throughput (messages/sec) simultaneously across both tiers.

The most significant observation is that the traffic pattern is strongly correlated with ON-OFF type traffic pattern where ON means a high message transfer rate and OFF means a low message transfer rate. This pattern helps explain the observed processing delay at the higher tiers where message transfer services must que to accommodate the higher message arrival rate.



Application Throughput (messages/sec) - jfo



6. Summary of Observations

- The dominating source of traffic is the publishing of updates to the background geography used in the experiment. The resulting network traffic loading pattern also indicates a periodic process for publishing updates to this information.
- There were no observed cases of bottleneck or serious protocol congestion. In fact, it was extremely rare for message retransmission or even out of order messages to be observed.
- All application message exchange used TCP. The average message payload size in bytes in the summary analysis is somewhat misleading because the calculation includes ack messages associated with TCP. A closer examination of the application message payload size indicated typical size of 1460 bytes which is assumed to be associated with application MTU setting of 1460 bytes size. Network protocols typically added 54 bytes for a total network packet size of 1514 bytes.
- A typical application information transfer (connection) included 5-8 messages of maximum MTU size.
- Because the message traffic loading is dominated by the background geography source and that this source has a periodic update process, the message load behavior offered to the network reflects an On-Off traffic pattern.