Satellite and Wireless Network Telemetry Results and Statistics for the US Array Test Bed

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INTRODUCTION

ANZA Network Topology and BBARRAY Telemetry Test Facility

The Broadband Seismic Data Collection Center group currently operates the Anza Seismic Network and Pinon Flat Observatory, located in Southern California (Figure 1), and monitors real-time levels of seismicity in the region. This network serves as a real-time telemetry prototype for US Array, providing valuable insight into network operations.

Seismic data is sent to the Broadband Seismic Data Collection Center via the High Performance Wireless Research and Education Network (HPWREN) and commercial grade Ku/C band satellite links. HPWREN utilizes state-of-the-art 45 Mbps duplex point-to-point radio links as well as typical 802.11b radios. Spacenet utilizes Frequency and Time Division Multiple Access (FTDMA) schemes and VSAT technology to maximize data throughput and efficiency.

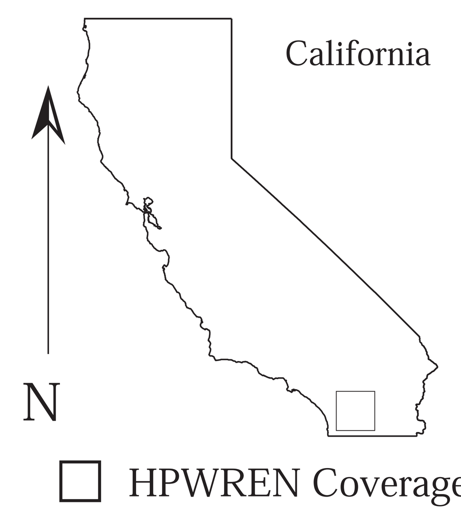


Figure 1: Approximate HPWREN and Anza Seismic Network coverage area in Southern California.

Real-time seismic data (Figure 2) is processed for research and risk analysis. Because of the nature of real-time data, it is easily influenced by a number of network metrics such as: round trip time (RTT), packet loss, link usage and link speed.

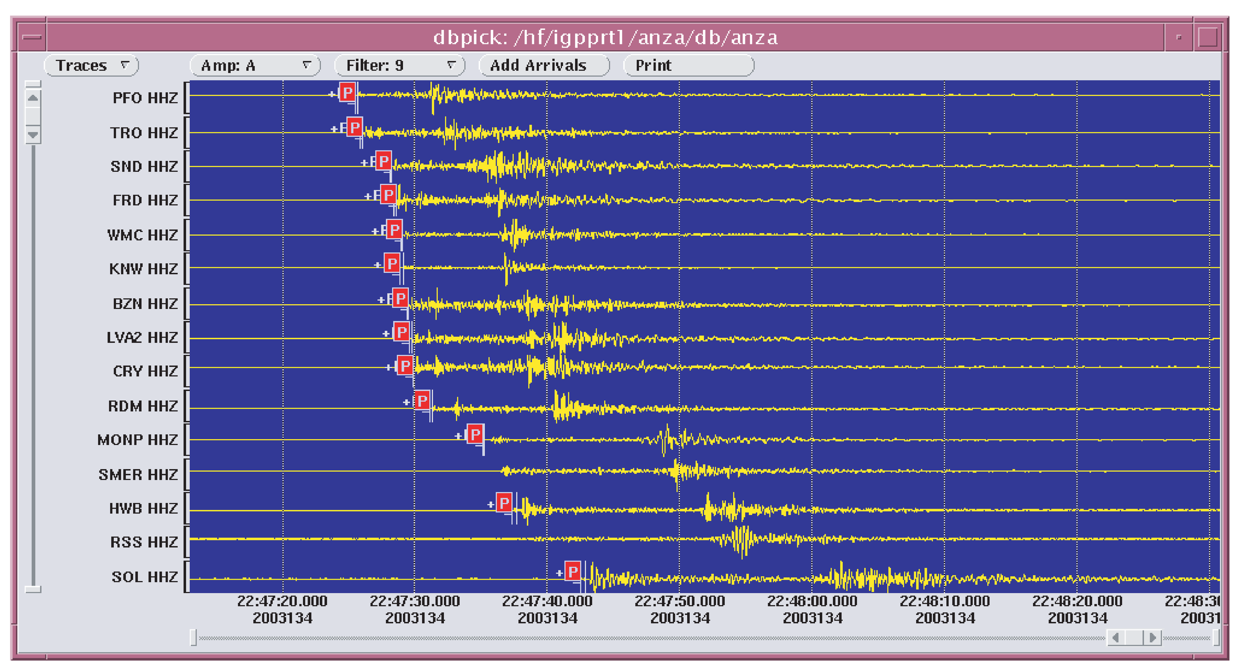


Figure 2: Seismic data which is sent to Broadband Seismic Data Collection Center via the High Performance Wireless Research and Education Network (HPWREN) and satellite can be viewed in real time.

Full understanding of the prototype link, terrain (Figure 3), its inbound and outbound packet ratios and data transfer ratios, as well as the above metrics is vital in terms of understanding throughput performance, storage requirements and network infrastructure for future projects such as US Array.

Satellite Telemetry Links

Satellite telemetered links are a useful means for real-time data connections when 802.11b radio and network infrastructure is economically infeasible or difficult to install. Satellites provide real-time standardized ubiquitous connectivity across the entire country at the expensive of increased cost, increased power consumption and lower data throughput.

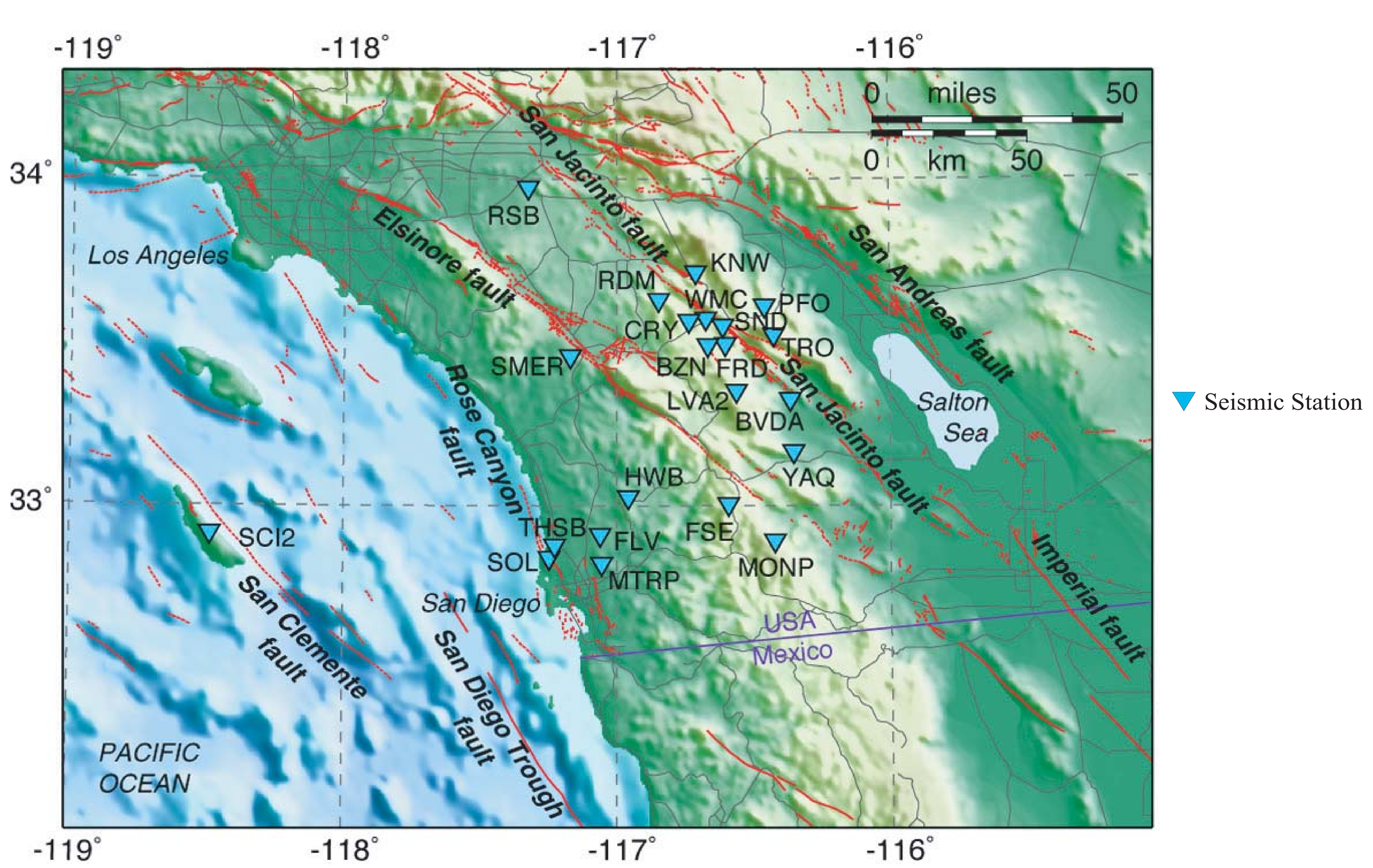
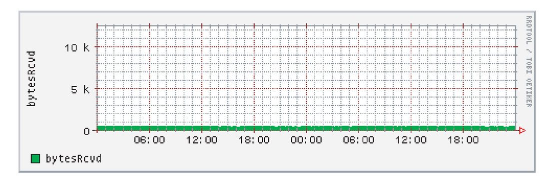


Figure 3: Network topology of the Anza Seismic Network located in Southern California. Stations used in this study are as follows: TRO, STS2 (located at PFO), SOL, FLV and FLV2 (located at FLV).

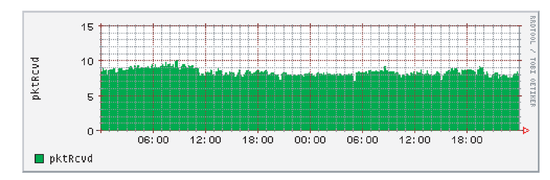
LINK ANALYSIS AND PERFORMANCE STUDIES

1 Station Toro:

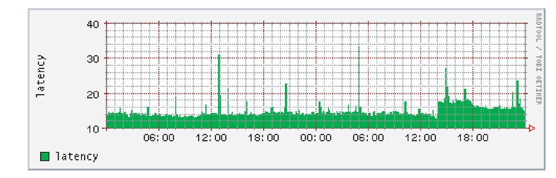
Connects to the Seismic Data Collection Center via a long hop 45 Mbps HPWREN backbone link. Data transmissions are orb to orb style. Total power consumption is about 170 watts.



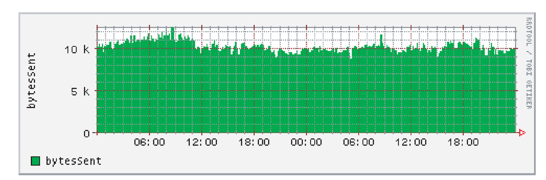
Bytes received by Toro for a typical 48 hour period. Approximately 80.8 megabytes.



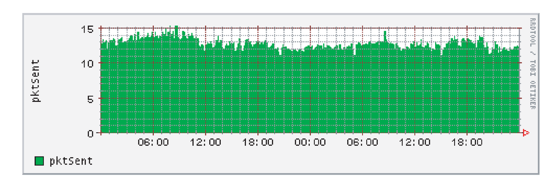
Packets received by Toro for a typical 48 hour period. Approximately 1,445,000 packets.



Network latency for AZ_Toro. Average latency is about 14.9 seconds.



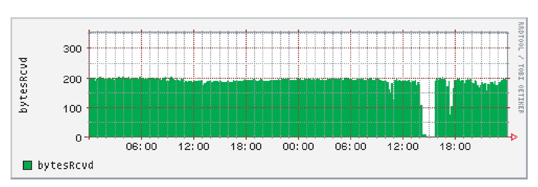
Bytes sent from Toro for a typical 48 hour period. Approximately 1,765 megabytes.



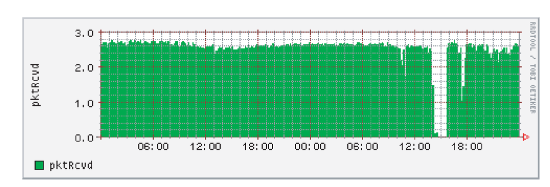
Packets sent from Toro for a typical 48 hour period. Approximately 2,208,000 packets.

2 Station STS2:

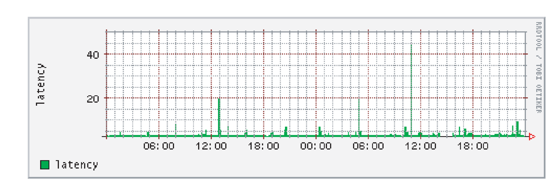
Connects to the Seismic Data Collection center via Spacenet satellite link. Data logger type is Q330. Data Logger traffic is UDP. 40 and 1 sps. This illustrates an ideal US Array connection. Total power consumption is about 33 watts.



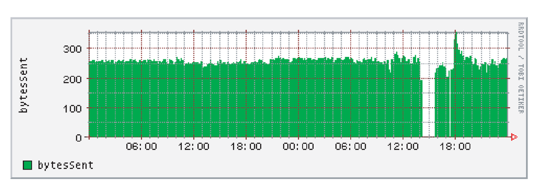
Bytes received by STS2 for a typical 48 hour period. Approximately 32.5 megabytes.



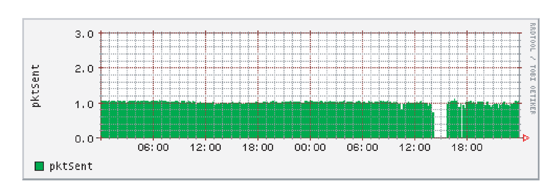
Packets received by STS2 for a typical 24 hour period. Approximately 443,000 packets sent.



Network latency for AZ_STS2. Average latency is about 3.4 seconds.



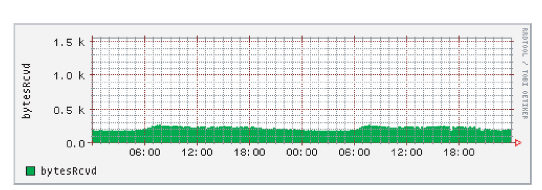
Bytes sent from STS2 for a typical 48 hour period. Approximately 44.3 megabytes.



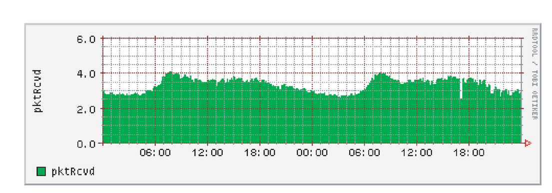
Packets sent from STS2 for a typical 48 hour period. Approximately 174,000 packets sent.

3 Station SOL:

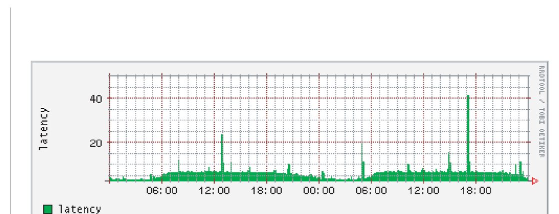
Connects to the Seismic Data Collection Center via a short hop 45 Mbps HPWREN backbone link. Data logger type is Q4120. Data logger traffic is TCP. Data are collected at 100, 40 and 1 sps on the STS2 and 100 sps on the Episensor. Total power consumption is about 166 watts.



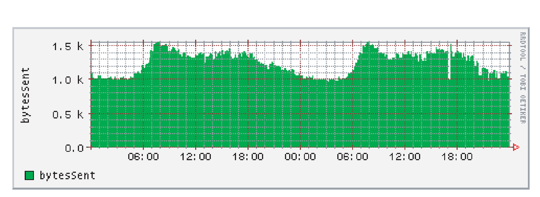
Bytes received by station SOL for a typical 48 hour period. Approximately 36.2 megabytes.



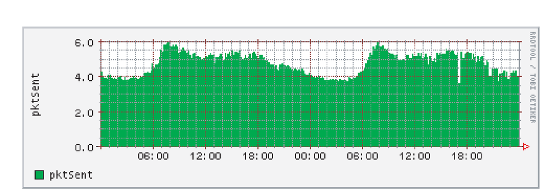
Packets received by station SOL for a typical 48 hour period. Approximately 572,000 packets sent.



Network latency for AZ_SOL. Average latency is about 3.4 seconds.



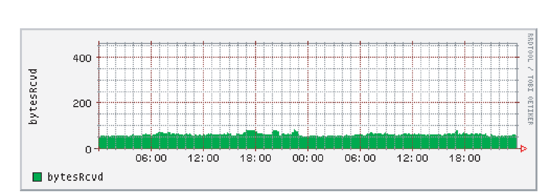
Bytes sent from station SOL for a typical 48 hour period. Approximately 214.8 megabytes.



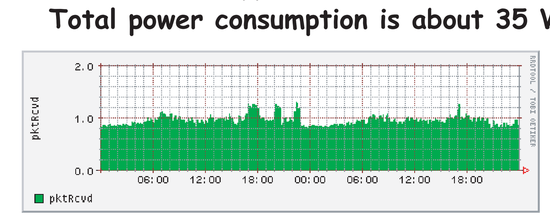
Packets sent from station SOL for a typical 48 hour period. Approximately 821,000 packets sent.

4 Station FLV:

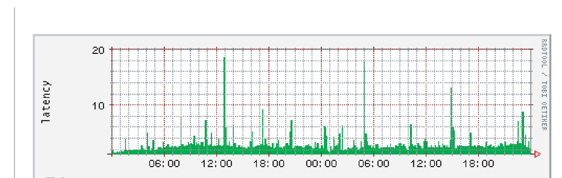
Connects to the Seismic Data Collection Center via a medium hop 802.11b HPWREN link. Data logger type is Q4120. Data logger traffic is TCP. Seismometer type is STS2. Data are collected at 100, 40 and 1 sps. Total power consumption is about 35 Watts.



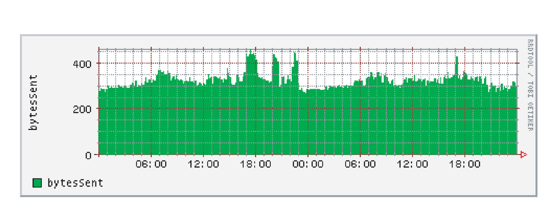
Bytes received by FLV for a typical 48 hour period. Approximately 10.3 megabytes.



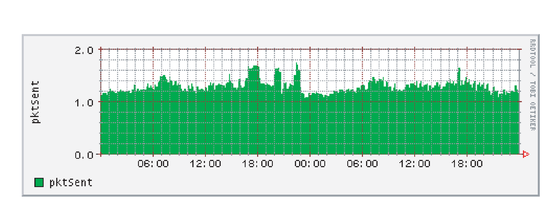
Packets received from FLV for a typical 48 hour period. Approximately 165,000 packets.



Network latency for AZ_FLV. Average latency is about 2.9 seconds.



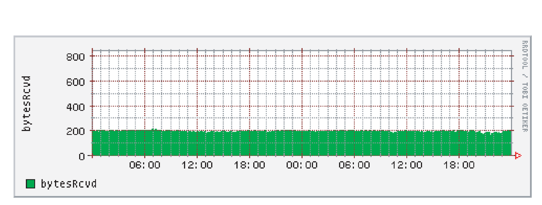
Bytes sent from FLV for a typical 48 hour period. Approximately 55.7 megabytes.



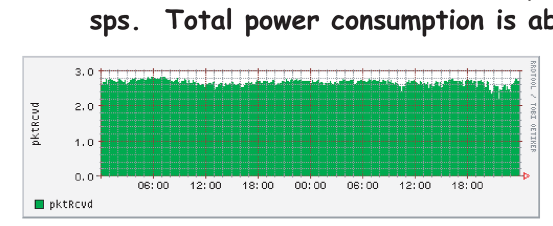
Packets sent from FLV for a typical 48 hour period. Approximately 223,000 packets.

5 Station FLV2:

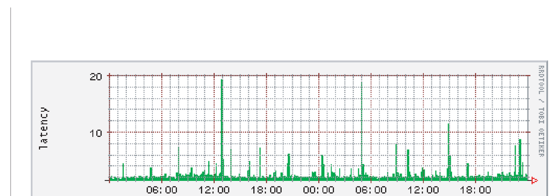
Connects to the Seismic Data Collection Center via a medium hop 802.11b HPWREN link. Data logger type is Q330. Data logger traffic is UDP. Seismometer is Episensor. Data are collected at 100 sps. Total power consumption is about 9.5 Watts.



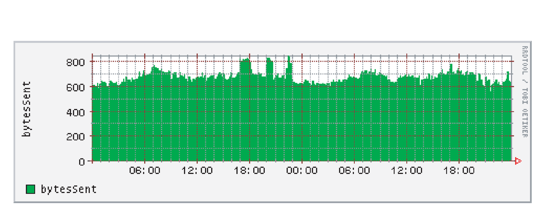
Bytes received by FLV2 for a typical 48 hour period. Approximately 33.7 megabytes.



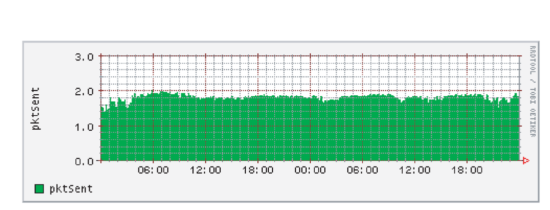
Packets received by FLV2 for a typical 48 hour period. Approximately 460,000 packets.



Network latency for AZ_FLV2. Average latency is about 2.7 seconds.



Bytes sent from FLV2 for a typical 48 hour period. Approximately 117 megabytes.



Packets sent from FLV2 for a typical 48 hour period. Approximately 312,000 packets.

FINDINGS AND RESULTS

A number of data transmission plots (stations: SOL, FLV and FLV2) show significant decreases in the amount of data transfer during the hours of 2300 through 0500 local. The cause for this data decrease is a direct result of data compression schemes and the lower occurrence of human created noise sources, such as vehicle traffic.

We can see an example of station failure for station STS2 at approximately 16:00 on the second day of data collection. One may suspect that the satellite was dropped for a few hours. However, this seems unlikely as we do not see a higher data transmission rate after the connection was reestablished. In a normal telemetry link failure, after the link is reestablished it is common to see increased traffic until all buffered data is pushed to the collection center; conversely we see a normal traffic flow. Most likely this station lost power for the hours in which the data hole exists.

Depending on the connection, data transfer ratios and packet transfer ratios vary significantly. Q330s (FLV2 and STS2) which use UDP transmission protocols have a proprietary correction algorithm thereby increasing the relative number of packets they receive from the Broadband Seismic Data Collection Center (i.e., acknowledgement packets) in comparison to the number of packets they send to the Broadband Seismic Data Collection Center. These can be compared to their TCP/IP station counterparts which send more packets to the Broadband Seismic Data Collection Center than they receive. (Table 1)

Station Toro runs an orb to orb connection between the Broadband Seismic Data Collection Center and itself. Stations Toro, is a hub station, which means it collects seismic data from approximately 17 seismic stations in the field, and sends the aggregate data to the collection center. This accounts for the large amount of data transferred from Toro to the Broadband Seismic Data Collection Center in the above table. Station Toro exhibits promising results. The byte ratio of 21.9 to 1 is advantageous for minimizing IP bandwidth. The low bandwidth upload pipe (from the Broadband Seismic Data Collection Center to Toro) and high bandwidth download pipe is ideal for satellite communication or any point to multipoint telemetry system. (Table 1)

Station Name	Station Type	Packets Sent From:	Packets Received By:	Bytes Sent From:	Bytes Received By:	Packet Ratio (sent: received)	Byte Ratio (sent: received)
TORO	TCP/IP (orb2orb)	2,207,585	1,444,986	1,765,535,398	80,792,946	1.5 : 1	21.9 : 1
STS2	UDP (q3302orb)	174,012	443,199	44,339,936	32,473,916	1 : 2.6	1.4 : 1
SOL	TCP/IP (qt2orb)	820,877	572,114	214,757,007	36,246,623	1.4 : 1	5.9 : 1
FLV	TCP/IP (qt2orb)	223,143	164,779	55,722,203	10,343,390	1.4 : 1	5.4 : 1
FLV2	UDP (q3302orb)	311,829	460,287	117,017,648	33,690,576	1 : 1.5	3.5 : 1

Table 1: Number of packets and bytes sent from station STA to the Broadband Seismic Data Collection Center and the number of packets and bytes received by STA from the Broadband Seismic Data Collection Center. Packet and byte ratios are also shown.

TCP/IP data transfers (Toro, SOL, FLV) vary significantly depending on the instrumentation and connection algorithms (i.e. orb2orb, q3302orb, qt2orb, etc) used. The amount of data sent to the Broadband Seismic Data Collection Center is highly dependent upon data logger (Q330 vs Q4120) and seismometer types (Episensor vs STS2). Sampling rates and individual station configurations also influence packet and byte transfer statistics.

FUTURE WORK

In order to improve our findings:

- Better network analysis tools need to be sought and used. Although ntop did provide some useful data, inrovements are still needed.
- A detailed cost analysis study needs to be preformed. Telemetry costs and bandwidth need to be optimized.
- To fully understand datalogger behavior it would help to collocate similar seismometers, have equal sampling rate (100 sps) and connect to both data logger types (Q330 and Q4120.) This would effectively eliminate station effects and allow a detailed study of the network differences between the Q330 and Q4120.
- Further data logger investigation would be useful. Investigation into the Reftek 130 and Guralp data loggers may provide useful insight.

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