DSL Usage Meter Accuracy Analysis

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Prepared by

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Terminology

The following terms and abbreviations are used throughout the report:

- **Stamper Box** – Linux based mini-computer that ATS has customized for the purposes of usage generation and measurement.
- **Ethernet Port** – An opening on computer network equipment that Ethernet cables plug into. Each Stamper Box contains 4 Ethernet Ports and each Ethernet Port is set up as a Shentel DSL account.
- **Bits** – A measurement of data on a computer. A bit is the smallest unit of measurement.
- **Mbps** – Short for megabits per second, a measure of data transfer speed.
- **Bytes** – A measurement of data on a computer that is equivalent to 8 bits.
- **NTP Server** –Network Time Protocol (NTP) is a protocol used to synchronize the clocks of computers.
- **Protocol Overhead** - Refers to metadata and network routing information sent by an application, which uses a portion of the available bandwidth of a communications protocol. This extra data, making up the protocol headers and application-specific information is referred to as overhead, since it does not contribute to the content of the message.
- **SUMA** – Stamper Usage Measurement Accuracy (SUMA) score is a measure of accuracy when comparing Stamper Box actual readings to those reported for billing purposes.

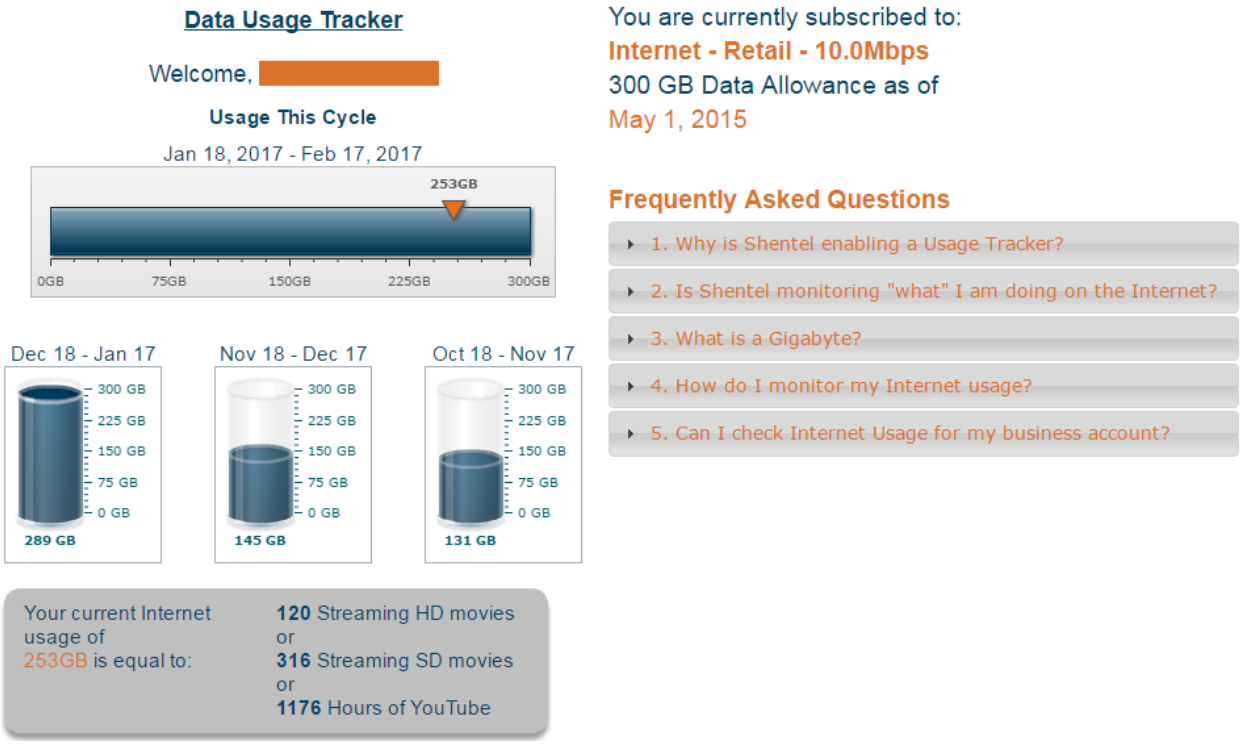
About ATS

Advanced Technologies & Services, Inc. (ATS) is the industry leader for telecommunications and cable network integrity, switch automation, and revenue assurance. ATS offers a wide range of solutions through web based software applications and consulting services. ATS was incorporated in 1995 and is headquartered in Wayne, New Jersey with regional offices in California, Arizona, North Carolina, and Massachusetts. Since its inception in 1995, ATS has worked with dozens of North American telecom and cable companies ranging from the largest Tier 1 companies to leading cable providers, to some of the smaller ILECs and CLECs.

The ATS professional team has over 150+ years of combined experience in the telecommunications and cable industries and has extensive expertise in assisting companies in the areas of billing, switch translations, service assurance, regulatory compliance, and network integrity. ATS is a unique company in the industry in that it offers customers both tailor made software solutions and industry rich, highly experienced consulting services to assist communications companies of all types.

Overview

The Shentel data usage meter is used to measure and report on the amount of data consumed by subscribers over a given billing cycle. With the implementation of data allowances on subscriber plans, the usage meter is ultimately used to drive subscriber billing. The accuracy of the usage meter is critical to ensure billing accuracy as well as customer confidence and loyalty. Below is an example of the usage information available to a subscriber through the Shentel subscriber portal.



Advanced Technologies and Services, Inc. (ATS) performed an independent audit of Shentel's DSL usage meter which is used to drive customer billing. Using Linux based mini-computers dubbed "Stamper Boxes" and proprietary testing algorithms, ATS generated traffic through the Shentel network. Each Ethernet Port on each Stamper Box was assigned a Shentel DSL account with varying speed/billing arrangements. Accounts were evenly distributed between BRAS Routers located in Edinburg and Strasburg. For 1 billing cycle (December 2016), ATS generated and measured traffic to various destinations in the US and across the world. The traffic generated was measured by ATS using 3 different methods in order to ensure accuracy. ATS then compared its own usage measurements to those provided by the Shentel billing system.

ATS' usage meter validation process has been implemented at various other operators and has proven to be invaluable in validating the accuracy of the 'end to end' billing process. Usage meters are typically expected to perform within +/- 1% accuracy over any given month.

Over the 31 day bill cycle used in the analysis, ATS generated nearly 25,000 tests across all 12 test accounts. In total, these tests generated approximately 3.4 Terabytes of data. The following report will explain in full detail how the testing was completed as well as the results.

Stamper Box Implementation

The foundation of the ATS usage meter accuracy analysis involves a scripted procedure to download files that vary in size and location. The variance of the file sizes and complex download patterns ensure comprehensive testing is completed. The test plan was designed using combinatorial mathematics, and started with the notion that each Stamper Box had three Ethernet ports assigned and available for testing. Each Stamper Box also had a fourth port, used only for control purposes, so as to not generate any usage on the test accounts.

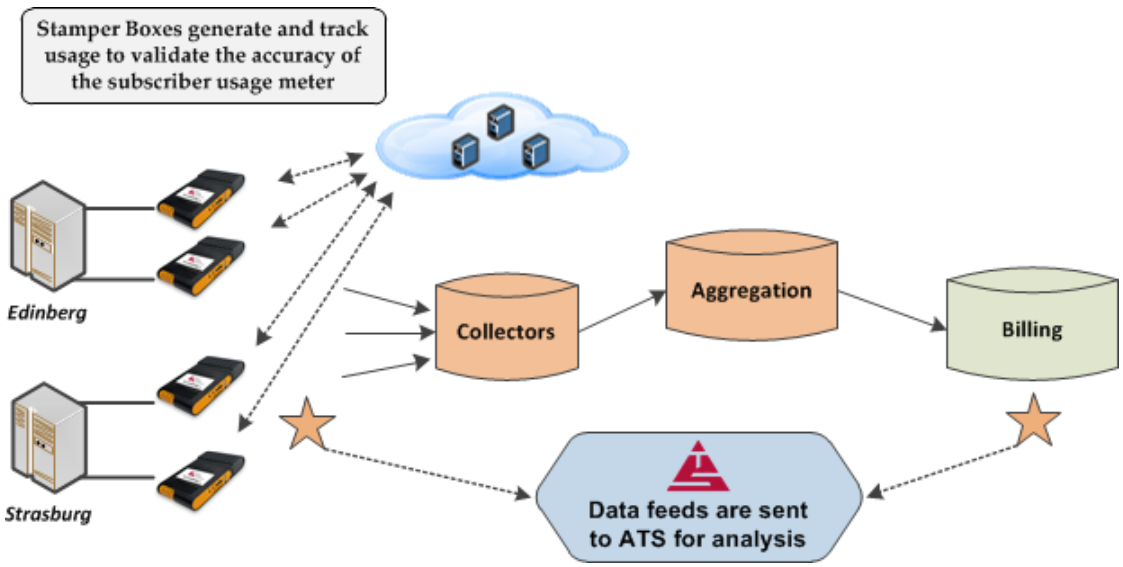
Potential download points included the following locations:

- Virginia
- California (San Francisco)
- California (Los Angeles)
- Colorado
- Ireland
- Japan

The successful repetition of the test scenarios resulted in a plan that would generate the following overall statistics:

- Test Period: 2016-12-01 00:00:0 to 2016-12-31 23:59:59 (ET)
- Number of Accounts: 12
- Number of '15 minute' Test periods: 1,976
- Number of Tests Completed: 24,807

A high level view of the testing process and data flow is below.



Background Traffic

Extreme care was taken to ensure no traffic other than the intended test traffic was sent or received through the Stamper Boxes. In order to account for any small amount of background traffic that occurs such as SNMP polls or health checks, ATS observed a 1 week 'quiet period' where no traffic was generated but monitoring still occurred. All potential sources of miscellaneous traffic such as automatic updates, programs that use the internet, etc. were turned off to ensure no other test traffic was generated on the accounts. The amount of background traffic observed by ATS was very minimal and not enough to impact meter accuracy.

Protocol Overhead

In any download/upload scenario, there is traffic due to protocol overhead that is invisible to the typical user. The amount of overhead will vary by protocol and many other conditions such as packet retransmissions. Take an example of a user downloading a 1 GB file (1024 MB). In addition to the 1GB of actual content downloaded, there is approximately 50 MB of overhead data downloaded as well. The added 50 MB is virtually invisible to the end user, but still contributes to the amount of data transmitted, and therefore is included in the calculation of volume. In the tests ATS performed, there was an average overhead of 5% downloaded and 1% overhead uploaded.

Account Speed & Billing Arrangements

ATS was assigned 12 Shentel DSL accounts with varying speed/billing arrangements. Each billing arrangement was assigned to 2 test accounts. 1 account was designed to remain under the usage allowance while the other was designed to go above the allowance and trigger a usage based billing event. A description of each account billing arrangement is below.

Acct	BRAS	Up Rate	Down Rate	Allowance	Target Amount
1	Edinburg	128 kbps	384 kbps	100 GB	Under Allowance
2	Edinburg	128 kbps	384 kbps	100 GB	Over Allowance
3	Strasburg	512 kbps	768 kbps	100 GB	Under Allowance
4	Strasburg	512 kbps	768 kbps	100 GB	Over Allowance
5	Edinburg	512 kbps	1.536 Mbps	150 GB	Under Allowance
6	Edinburg	512 kbps	1.536 Mbps	150 GB	Over Allowance
7	Strasburg	768 kbps	3.072 Mbps	200 GB	Under Allowance
8	Strasburg	768 kbps	3.072 Mbps	200 GB	Over Allowance
9	Edinburg	768 kbps	5.088 Mbps	250 GB	Under Allowance
10	Edinburg	768 kbps	5.088 Mbps	250 GB	Over Allowance
11	Strasburg	1024 kbps	10.240 Mbps	300 GB	Under Allowance
12	Strasburg	1024 kbps	10.240 Mbps	300 GB	Over Allowance

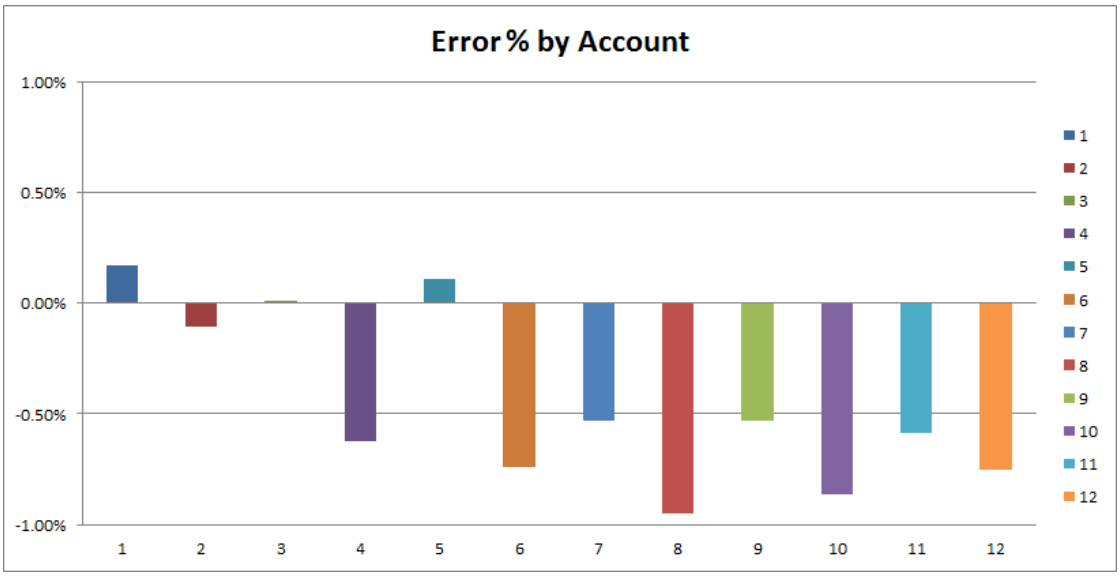
Results

At the conclusion of the billing cycle, ATS collected all data points from the Stamper Boxes and Shentel billing system. The Stamper Box logs were aggregated to the hourly level in order to match the Shentel data points. ATS then compared the Stamper Box and Shentel recordings for each hour on each day of the bill cycle. While the hourly comparison is not expected to perfectly align due to minor differences in collection times, the aggregation of data points over the course of the billing cycle is expected to match +/- 1%.

ATS used the following formula to calculate the usage meter error for the monthly aggregated data.

$$Error = \frac{(Shentel\ Total - ATS\ Total)}{ATS\ Total}$$

The chart below shows the error percentage, by account, for the monthly aggregated ATS and Shentel data totals.



As is evident in the chart, ATS confirms that the Shentel billing system meets the stated goal of performing within +/- 1% for all test accounts in the analysis.

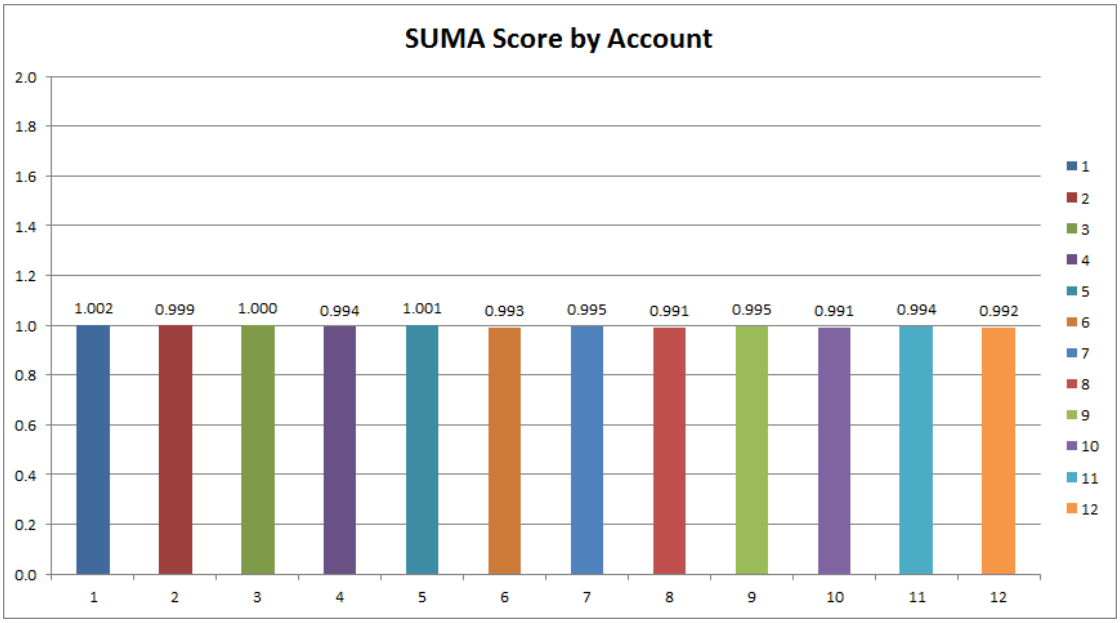
SUMA Scoring

Whenever two independent measures of the same event are taken, as was the case for every Stamper download, we naturally want to know the degree to which they differ. Various statistical tools exist to help us ascertain whether our readings from the two populations of measurements (one 'actual billed' and one 'expected') are equivalent. Let's begin by defining a key concept of our measurement: The Stamper Usage Measurement Accuracy score (SUMA).

The SUMA score is a measure of how high or low one measurement is relative to the other. In this case:

SUMA = Reported Billing MB (Shentel) / Reported Actual MB (ATS)

SUMA scores were calculated at both the hourly and daily aggregation level. Scores at the hourly level fluctuated more widely which was to be expected. However, SUMA scores at the monthly aggregated level were consistently at, or around, 1 as can be seen in the chart below. The SUMA scores for each account further verify the fact that the Shentel usage meter meets the stated goal of being +/- 1%.



Final Conclusions

The ATS Stamper Boxes thoroughly exercised 12 Shentel DSL accounts over the 31 day billing cycle of December 2016. ATS generated nearly 25,000 tests to various points across the United States and international points such as Ireland and Japan. The results of each test were aggregated to the hourly level and compared to the Shentel billing system. The stated goal of the analysis was for the Shentel billing system to be +/- 1% when compared with the ATS Stamper Boxes test usage.

While each test account's results varied slightly, all 12 test accounts' error percentages fell within +/- 1%. Each account was also assigned a SUMA score where the goal is to be within +/- 1% of the ideal SUMA score of 1. Similar to the error percentage results, the SUMA score for each account was well within +/- 1%.

Based on the results of the analysis, ATS certifies that the subscriber usage meter provided by Shentel meets the stated goal of being accurate within +/- 1% of actual usage consumed by the subscriber. Based on the results of ATS' analysis, Shentel subscribers should be confident that their usage meter and resultant billing is accurate.

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