KEYNOTE
The Internet Performance Authority

Keynote® Service Level Rankings™

Keynote Competitive Intelligence Study for VoIP Providers

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VoIP Services Study Overview

Keynote Systems—an independent, trusted authority on internet performance—conducts benchmarking studies for various industries on an ongoing basis, to assess the experiences of end-users with key applications over time. The VoIP Competitive Intelligence study is the first-of-its-kind study that evaluates critical performance factors that affect the consumer's experience with VoIP service, in the New York and San Francisco metro areas. The study is a cost-effective way for VoIP providers and network carriers to assess how end-users perceive their service relative to competitors, and enhance their service quality to capture additional market share and improve customer retention.

Analysts estimate that residential adoption of VoIP service is bound to grow exponentially from 6.5M homes in 2004 to over 26M homes in 2008. The enterprise market forecasts are equally aggressive as well. Even so, VoIP reliability and audio clarity remain important factors that limit the widespread adoption of VoIP in consumer markets. Consumers are still unsure whether VoIP can live up to the dial-tone reliability and crystal-clear communication quality they have come to expect with traditional phone service over the years. The Keynote Competitive Intelligence study provides objective insight into how VoIP providers on average compare to traditional Public Switched Telephone Networks (PSTN). The study ranks the various providers on overall reliability and audio clarity, based on an aggregation of several network and audio fidelity analysis metrics. Furthermore, it analyzes the impact of the underlying network—whether it is a business-class or residential DSL or Cable provider—on the end-user experience.

Leading VoIP providers in the study can utilize the study results to evaluate how they compare to PSTN and utilize the in-depth analysis to narrow the gap and capitalize on residential customers switching over to VoIP. Lagging providers on the study can determine how they compare to leaders in their respective markets and enhance their performance factors to build a competitive edge. Network carriers can leverage the insight provided to tune their networks and proactively demonstrate SLA compliance to their VoIP provider partners. By analyzing the end-user experience with VoIP service, providers and carriers can tune their infrastructure and application components to provide high reliability and clear communication to consumers and add significant revenue streams from this emerging market trend.

Study Participants

Keynote measured and evaluated the performance of the following consumer VoIP Service Providers as part of this competitive intelligence study. These providers all offer VoIP service in both the San Francisco and New York metropolitan areas:

AT&T

lingo
The talk of broadband

Packet8

skype

verizon

VONAGE
THE BROADBAND PHONE COMPANY

Vonage offers VoIP services that use either a hardware phone adapter or a software client that runs on a personal computer with a sound card. Keynote measured both the "hard phone" and the "soft phone" service offerings from Vonage. Skype also implements its SkypeOut VoIP service as a "soft phone." The other service providers all offer their services with hardware phone adapters.

For each of the VoIP providers stated above, Keynote measured and evaluated VoIP call performance over the following network carriers:

Comcast Cable, Time Warner Cable, SBC DSL, and Verizon DSL connection used in this study were all standard residential service offerings. The three Business Class network carriers used in the study, AT&T, Sprint, and UUNet were standard data center or hosting facility service offerings.

Overall Best VoIP Service Providers

Keynote ranked VoIP Service Providers on two aggregated performance indicators: Reliability and Audio Clarity. Reliability includes service availability, the average number of dial attempts and dropped calls. Audio Clarity was computed based on a weighted average of the Average Mean Opinion Score (MOS) and Average Audio Delay including adjustments for percentage of calls below minimum acceptable thresholds and high geographic variability.

The Keynote study found that the following VoIP service providers ranked highest in the Most Reliable and Best Audio Clarity rankings:

Most Reliable VoIP Service Provider

VONAGE
THE BROADBAND PHONE COMPANY

Best Audio Clarity

AT&T

Overall Best Network Carriers

Keynote ranked Network Carriers in two categories: Most Reliable and Best Audio Clarity. Service Availability, Average Number of Dial Attempts, and Dropped Calls Performance Factors all contributed to the Most Reliable ranking. This aggregated ranking illustrates which network carriers are providing the most reliable Internet service for VoIP traffic. The Best Audio Clarity ranking was computed as an aggregate of the performance factors related to audio quality and audio delay. This high-level ranking illustrates which network carriers are providing network performance that results in the highest fidelity audio transmission across the VoIP network.

The Keynote study found that the following network carriers ranked highest in the Most Reliable and Best Audio Clarity rankings:

Most Reliable Network Carrier

TIME WARNER CABLE

Best Audio Clarity (Tie Ranking)

TIME WARNER CABLE

UUNET A WorldCom Company

Key Performance Factors

To obtain the Most Reliable and Best Audio Clarity rankings, Keynote measured, evaluated, and compared the performance of service providers and network carriers in ten Key Performance Factors, which constituted the aggregated Reliability and Audio Clarity indicators. The ten Key Performance Factors are:

- Service Availability
- Average Number of Dial Attempts
- Dropped Calls
- Outage Minutes
- Average Mean Opinion Score or MOS (Listening Quality)
- Percentage of Calls with Acceptable MOS
- MOS Geographic Variability
- Average Audio Delay
- Percentage of Calls with Acceptable Audio Delay
- Audio Delay Geographic Variability

Each Key Performance Factor represents a distinct aspect of VoIP call performance; as illustrated by the selection of results presented below. It is rare for a single VoIP service provider or network carrier to excel in all ten aspects. Keynote's Competitive Intelligence Study Report presents detailed analysis and results for each performance aspect separately.

The full report provides detailed answers to questions like:

- Is VoIP service as reliable as PSTN (Publicly Switched Telephone Network) service?
- On which provider's VoIP service does the call audio sound the best?
- Which VoIP service provider had the fewest dropped calls?
- Which network carriers have the lowest network-level jitter and how did that impact the call quality?
- Are residential consumers using VoIP better off on cable modems or DSL?

The following sections offer highlights of the findings for three of the ten performance factors: Service Availability, Average MOS (Listening Quality), and Average Audio Delay.

Service Availability by VoIP Service Provider

The Service Availability factor represents the percentage of call attempts that are successful. Each call attempt includes up to three dial attempts. An unsuccessful call is one in which no connection to the called number can be established. Unsuccessful calls can be the result of standard phone system errors such as no dial tone, no ringing, ring no answer, or busy signal. VoIP service calls can also fail when service is rejected for insufficient funds in an account.

Of the VoIP Service Providers in the study, Vonage Soft Phone had the highest level of Service Availability, followed by Vonage hardware phone.

Service Availability

Rank	VoIP Service Provider
1	Vonage Soft Phone
2	Vonage

Average MOS by VoIP Service Provider

A Mean Opinion Score (MOS) measures the voice audio quality of a phone call on a scale of 1 to 5. Traditionally, this score was derived from a sample of subjective human opinion scores. Today, an algorithm, ITU Standard P.862, known as PESQ (Perceptual Evaluation of Speech Quality) replaces the human panel and scores call audio by comparing a digital test audio file sent over a phone call with a reference copy of the same digital test audio file to see how much the audio degrades over the phone call. Comparing the two audio files, the PESQ algorithm can determine a MOS score for the call that has a 94.5% correlation with human perception. The Average MOS for a VoIP service provider is an indication of the audio quality each service provider delivers to end-users.

Keynote's research shows that Vonage has the highest Average MOS across all network carriers, followed by AT&T CallVantage.

Average MOS

Rank	VoIP Service Provider
1	Vonage
2	AT&T CallVantage

Average Audio Delay by VoIP Service Provider

The Average Audio Delay performance factor measures the amount of time it takes audio to travel from one end of the phone call to the other. Excessive delay can result in conversational disruption. ITU recommendations for the Publicly Switched Telephone Network encourage audio delays of 150 ms or less. None of the VoIP service providers has achieved this goal.

AT&T CallVantage and Vonage Soft Phone had the lowest Average Audio Delay.

Average Audio Delay

Rank	VoIP Service Provider
1	AT&T CallVantage
2	Vonage Soft Phone

Study Results

The study results are available in two formats:

- An Executive Summary presentation, which reveals general industry trends and highlights the performance of only the best VoIP Service Providers and Network Carriers. The insight gained from this competitive intelligence helps Marketing and Operations executives at VoIP providers and network carriers identify general areas of service improvement that will have the maximum impact on VoIP customer experience.
- A detailed presentation that analyzes each of the ten performance factors in depth. The detailed presentation includes analysis of the data across VoIP Service Providers, Network Carriers, network connection types, and different cities. The presentation also reports on the network-level performance of each Network Carrier. Armed with this intelligence, IT Managers can tune specific aspects of their VoIP service to provide better performance to customers than their competition.
- Monthly updates on the detailed reports to trend performance of VoIP providers and network carriers over time and to understand how their relative position changes based on corrective measures implemented.

Study Methodology

Keynote's VoIP Perspective Agent technology was the basis for the competitive intelligence study. With VoIP Perspective, you can accurately measure the performance and availability of VoIP phone systems. Unlike other product offerings that estimate VoIP performance based on just network level performance metrics, Keynote VoIP Perspective analyzes the received actual call audio for the highest measurement fidelity possible.

- Call audio analysis is based on the ITU Standard P.862, also known as PESQ (Perceptual Evaluation of Speech Quality.)
- Audio performance metrics include MOS (Mean Opinion Score) and values for audio delay, signal levels, noise levels, silence levels, and codec used.
- Network metric analysis includes packet counts, latency, ordering, and jitter information.
- Standard call error codes such as no dial tone, no ringing, ring no answer, busy signals, and operator intervention are captured and recorded.
- Enhanced error tracking for soft phone clients includes client application errors and notification of insufficient funds in prepaid accounts.

The figure below illustrates the overall study methodology:

Overall Methodology

1 Investigation

- What VoIP providers are the largest in two major metropolitan areas: San Francisco and New York?
- What types of network carriers are being used to access these VoIP providers?

2 Deployment

- Accounts are created at VoIP providers using their normal customer sign-in processes
- Calls are defined across all providers and ISP combinations
- Each call uses the same reference audio to ensure consistency in measurement from call to call
- All calls are made to PSTN numbers to ensure comparable measurements
- Measurement configurations are deployed to the Keynote VoIP perspective agents for measurement

3 Data Collection

- Data is collected over a five week period

4 Analysis

- Data sample undergoes statistical analysis
- Providers and carriers are investigated individually
- Perform first level problem diagnosis
- Industry trends are noted

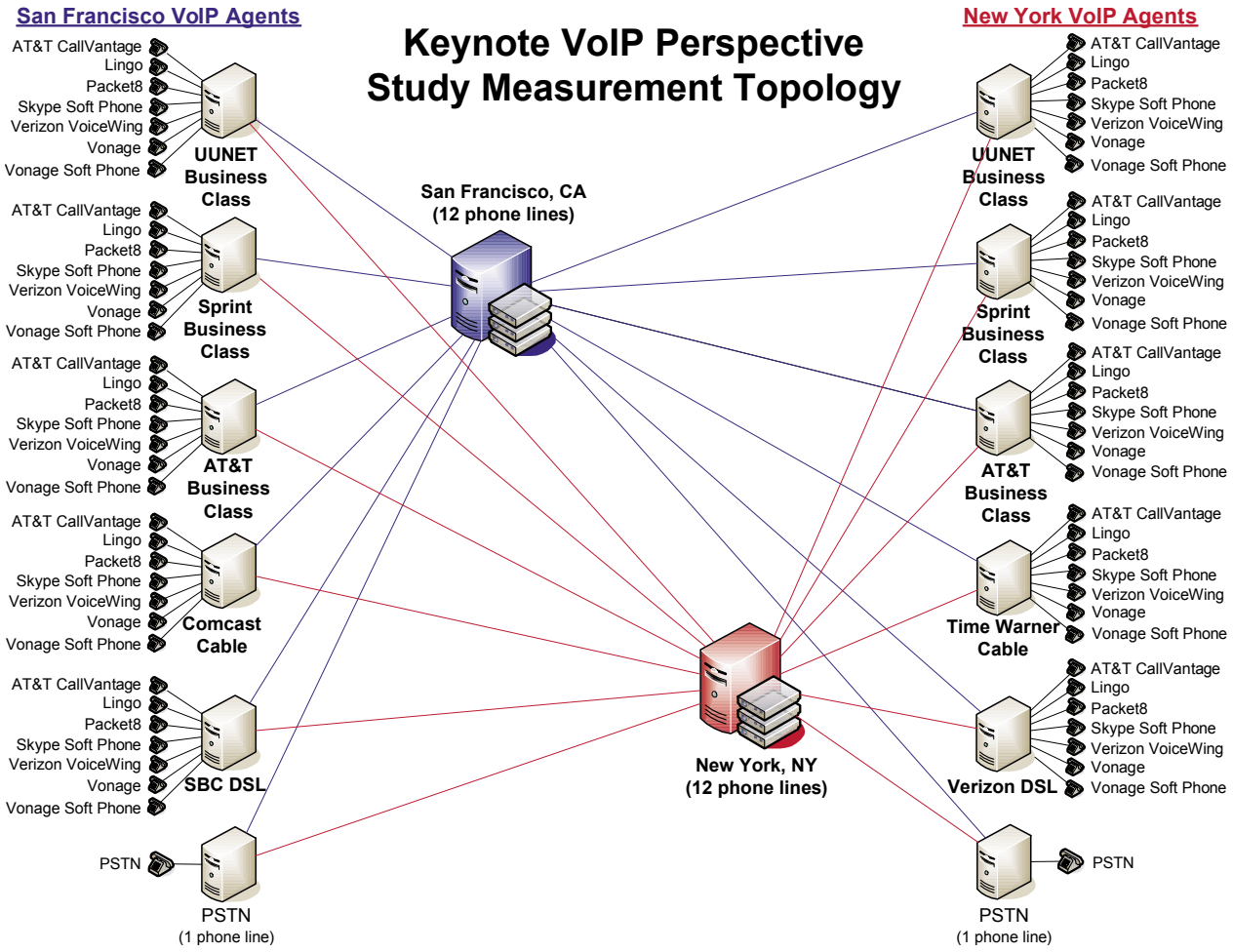
5 Rankings

- Rankings are created and presented
- Best providers named

Measurement Topology and Frequency

For this study, we placed Keynote VoIP Perspective Caller Agents in the New York and San Francisco metropolitan areas. Every thirty minutes, these Agents placed VoIP-to-PSTN calls across all combination of VoIP Service Provider and Network Carrier to PSTN phone numbers in both New York and San Francisco. Data was collected over a five-week period from May 21, 2005 to June 25, 2005, and included over 22,000 calls on each VoIP service provider, and over 22,000 calls on each network carrier.

The diagram below illustrates the network topology of the study. In each city, there is a Keynote Responder with 12 PSTN phone lines dedicated to the study. Each city has six calling Agents, one on each of five network carriers (three Business Class carriers, a residential Cable Modem carrier, and a residential DSL carrier) as well as one Caller Agent connected to a PSTN line. Each Caller Agent is equipped with hardware and software phone adaptors to place VoIP calls on all seven of the VoIP Service Providers in the study.



Call Test Audio File

To ensure a meaningful measurement of any voice communications system, the test audio must be a good representation of human speech. The Keynote VoIP Perspective Competitive Intelligence Study used a 15 second test signal specifically designed for voice audio quality testing. The test file includes the following characteristics:

- Includes male and female voices
- Low noise floor
- Correct speech audio levels
- Utterances of 1 to 3 seconds in duration
- Contains intervals of silence
- Consistent volume

Ranking Methodology

The **Most Reliable** ranking was computed based on the Service Availability, Average Number of Dial Attempts, and Dropped Calls Performance Factors. Each provider earns up to 10 points based on their relative index ranking in each of the three performance factors. These points are summed and then normalized by a factor of 10/3 to produce a final score for each provider out of a possible 100 points.

The **Best Audio Clarity** ranking is computed by the formula:

100 x ((0.7 x MOS Component)
+ (0.3 x Audio Delay Component))

The MOS Component is a computed value between 0 and 1 for each provider that is based on the MOS measured for each call, factoring in acceptability and uniformity. The Delay component is a computed value between 0 and 1 that is based on the Audio Delay values measured for each call, factoring in acceptability and uniformity.

About Keynote Systems

Keynote Systems, The Internet Performance Authority®, is the worldwide leader in e-business performance management services. Over 2,100 corporate IT departments and 19,000 individual subscribers rely on Keynote's growing range of measurement and monitoring, service level and customer experience management services to improve e-business performance by reducing costs, improving customer satisfaction and increasing profitability.

Keynote Service Level Management (SLM) solutions provide enterprises with the tools to align IT and e-business goals. Keynote's SLM solution suites offer comprehensive approach to the problem of managing e-business service levels effectively for IT, application deployment and support personnel and e-business executives. To learn more about Keynote's Competitive Intelligence Study, visit:

http://www.keynote.com/solutions/slm_service_level_rankings.html, or contact us at sales@keynote.com.