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Application Note

Title **Voice Quality Estimation in Wireless & TDM Environments**

- **Series** Understanding VoIP Performance
- **Date** April 2006

Contents

Overview

Voice quality can be affected by a wide variety of problems. In digital cellular and TDM environments, noise, signal level, echo, and frame erasure and common causes of quality degradation. This Application Note describes how **VQmon®** can be used to monitor the performance of TDM-based and digital cellular telecommunications services.

Factors Affecting Voice Quality

The principal factors affecting TDM calls are noise, signal level, echo, codec, and frame-erasure-related distortions:

- Noise can be due to room noise, electrical noise, or interference that impacts the signal before it is digitized and to TDM transmission errors after. Noise levels should ideally be lower than -60dBm0. Sender side noise impacts the speech signal before it is digitized, for example, background noise at the sending end. Receive side (listening side) noise impacts the speech signal after it leaves the network.

- Excessively high signal levels can lead to amplitude clipping and distortion. If signal levels are too low the ratio of signal to noise power becomes low, causing the signal to appear noisier, quantization noise increases, and the signal can be hard to hear.

- Echo, when coupled with delay, can be extremely annoying, and hence echo cancellers are commonly used to reduce the level of echo.

- Low bit-rate codecs can introduce distortion, although many modern cellular codecs do perform extremely well, at least in clean speech conditions.

- Frame erasures in the air/radio interface affect voice quality in mobile calls. They cause temporal clipping.

Speech Quality Estimation

Approaches to Measuring Speech Quality

Speech quality may be measured objectively or subjectively. Subjective measurements are made under laboratory conditions using a panel of listeners to rate the quality of a call; the aggregate user opinion is expressed as a subjective quality score (e.g., MOS). Objective speech quality is measured by analyzing the characteristics of the speech signal or media stream and applying a perceptual model to estimate a subjective quality score.

Subjective testing is expensive and cannot be used for continuously monitoring service quality. Objective testing approaches such as PESQ (P.862) are applicable for active testing or lab testing of equipment; however, for in-service monitoring of carrier networks it is essential to use an efficient non-intrusive approach such as VQmon®.

VQmon® Overview

VQmon® technology is a major building block of the new performance framework; it was the first and is the most widely deployed monitoring function for VoIP performance management today. VQmon's embedded monitoring technology enables network managers to see call quality problems in real-time and identify the root cause of the problem for both active and completed calls.

VQmon® measures key characteristics of the packet voice stream and calculates real-time performance data that network managers can use to detect, characterize and report transient problems. The technology provides detailed information on service quality with less reporting frequency, thus requiring less bandwidth.

VQmon® is a high performance standards-based non-intrusive call quality monitoring and diagnostic agent that can be integrated directly into VoIP CPE, SLA monitoring systems, probes, routers and generally any system that is on the path taken by the voice packets. VQmon® agents are small and highly efficient and can be integrated into existing equipment without requiring additional CPU or memory, scaling from systems that monitor a single call to those that support hundreds of thousands of calls.

VQmon® agents produce call quality metrics, including listening and conversational quality scores. They also provide detailed information on the severity and distribution of packet loss and discards due to jitter and other essential diagnostic data. Most importantly, VQmon® is able to detect transient IP problems and assess their effects on call quality.

VQmon® incorporates a model that estimates the effects of time-varying network impairments and provides a more accurate estimate of user opinion. Several key elements of VQmon® were incorporated into ETSI TS 101 329-5 Annex E. A multi-state Markov Model is used to measure the distribution of lost or discarded packets or frames, and to divide the call into "bursts" and "gaps". Call quality is calculated separately in each state and then combined using a perceptual model.

The VQmon® perceptual quality estimation algorithm incorporates support for key international standards including ITU-T P.564, ITU-T G.107, ITU-T G.1020, ETSI TS 101 329-5 Annex E and IETF RFC 3611. VQmon® incorporates support for time varying IP impairments (typically caused by network congestion) and has been independently shown to provide significantly more accurate and stable metrics than other algorithms such as G.107 (E Model).

Relationship between R and MOS

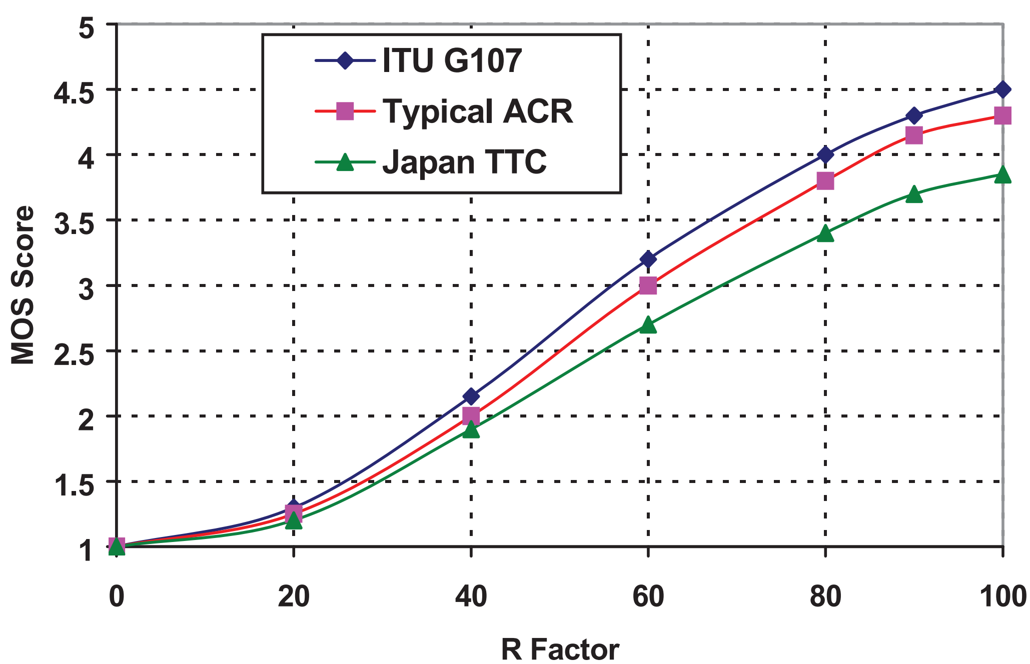
The chart in Figure 1 below shows the relationship between the R factor generated by the E Model and MOS. This shows three curves:

The mapping function provided in ITU G.107 gives a MOS value of 4.4 for an R factor of 93 that corresponds to a typical unimpaired G.711 connection; i.e., the equivalent of a regular telephone connection.

Recent ACR subjective test data suggests that a MOS value of 4.1 would be more appropriate for unimpaired G.711. This would suggest a slightly different mapping, as shown in the above graph for "Typical ACR".

In Japan, the TTC committee developed an R factor to MOS mapping methodology that provides a closer match based on the results of subjective tests conducted in Japan. The TTC scores are traditionally lower than those in the US and Europe due in some part to cultural perceptions of quality and voice transmission.

VQmon® is able to calculate MOS values for all three of these scaling factors.



■ *Figure 1: Chart showing the relationship between R Factor and MOS score*

Acceptable Voice Quality Levels

Table 1 below shows a typical representation of call quality levels for narrowband telecom systems.

Generally, an R Factor of 80 or above represents a good objective. Since R Factors are conversational metrics, the statement that R Factors should be 80 or more implies both a good listening quality and low delay.

A MOS of 4.0 is typically regarded as "toll quality," and a good target level is typically 3.7 or above. MOS values are typically quoted as listening quality scores, i.e., MOS-LQ. The typical manufacturer-quoted MOS values for G.711 and G.729A are 4.1 and for 3.9, respectively, implying that G.729A could not meet the ITU scaled MOS for "Satisfied." This problem is due to the scaling of MOS and not the codecs. Typical ACR scores for codecs should be compared to an ACR scaled range; i.e., "Satisfied" would be range 3.7 to 4.1.

Applications

VQmon® can be integrated into cellular handsets, trunking gateways, voice quality enhancement systems, and other system components in TDM and digital cellular systems. This provides an efficient and cost-effective method for providing real-time performance monitoring of digital services.

Figure 2 on the following page shows how VQmon® can be integrated into key locations—for example, gateways located at the boundary of two services—to measure service quality and identify problems. This helps with both locating/ isolating problems and with ensuring that service level commitments are maintained between interconnect partners.

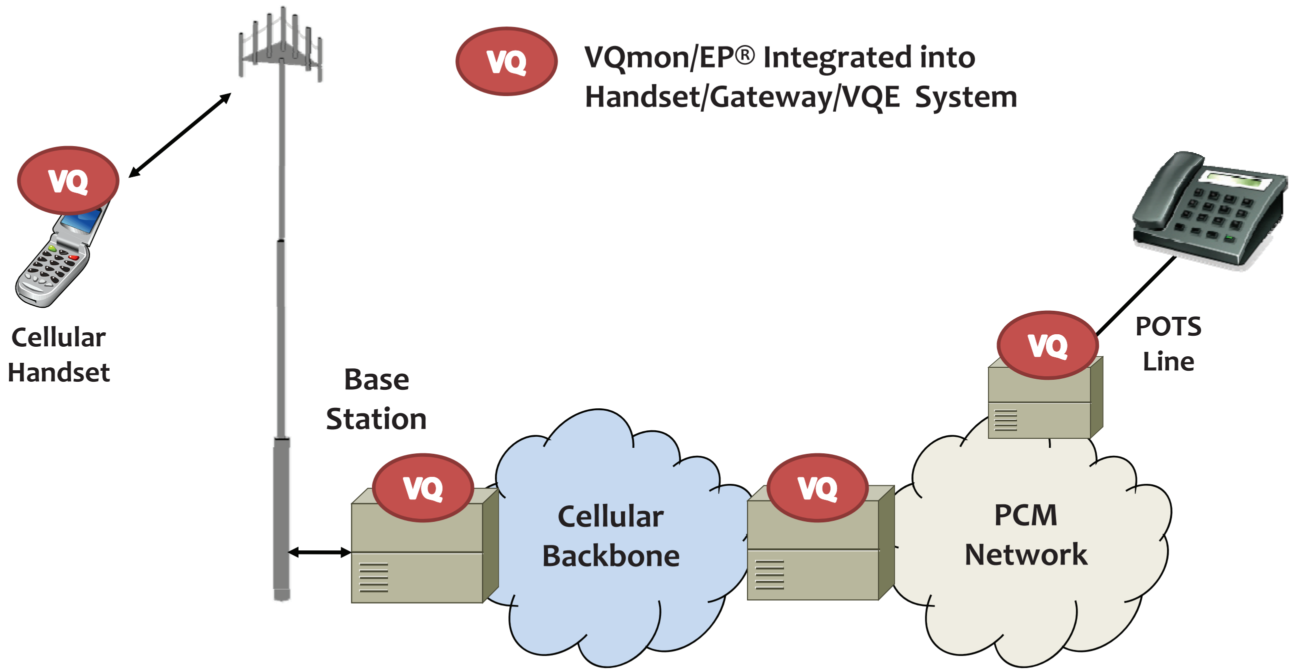
Summary

The quality of digital cellular and TDM calls can be affected by a number of factors such as noise, signal level, echo, codec type, and frame erasures, all of which can introduce distortion. Because degradation can occur anywhere in the call path, service providers need a way to continuously and non-intrusively monitor call quality and system performance at key points throughout the network as well as at the handset.

Telchemy's VQmon® performance analysis technology is designed for integration into cellular handsets, trunking gateways, and other network elements and system components, providing a scalable and cost-effective solution for non-intrusive, end-to-end quality monitoring. Reporting real-time perceptual quality scores, performance metrics, and diagnostic data, VQmon® is the most widely-deployed technology for non-intrusive call quality monitoring and analysis.

■ *Table 1: Call quality levels (R Factor and MOS) for narrowband telecom systems*

User Opinion	R Factor	MOS (ITU Scale)	MOS (ACR Scale)
Maximum Obtainable for G.711	93	4.4	4.1
Very Satisfied	90-100	4.3-5.0	4.1-5.0
Satisfied	80-90	4.0-4.3	3.7-4.1
Some Users Satisfied	70-80	3.6-4.0	3.4-3.7
Many Users Dissatisfied	60-70	3.1-3.6	2.9-3.4
Nearly All Users Dissatisfied	50-60	2.6-3.1	2.4-2.9
Not Recommended	0-50	1.0-2.6	1.0-2.4



■ *Figure 2: VQmon integration into cellular handset and network elements*

Acronyms

- **ACR** Absolute Category Rating (Test)
- **ETSI** European Telecommunications Standardization Institute
- **ETR** ETSI Technical Report
- **IETF** Internet Engineering Task Force
- **ITU** International Telecommunications Union
- **MOS** Mean Opinion Score
- **MOS-CQ** Mean Opinion Score - Conversational Quality
- **MOS-LQ** Mean Opinion Score - Listening Quality
- **PCM** Pulse Code Modulation
- **PESQ** Perceptual Evaluation of Speech Quality
- **POTS** Plain Old Telephone Service
- **R Factor** Transmission Quality Rating
- **TDM** Time Division Multiplexing
- **TTC** Telecommunication Technology Committee (Japan)
- **VoIP** Voice over Internet Protocol
- **VQE** Voice Quality Enhancement

References

[1] ITU-T Recommendation G.107. The E Model, a computational model for transmission planning.

[2] ITU-T Recommendation P.862. Perceptual Estimation of Speech Quality

[3] ITU-T Recommendation P.563. Single Ended Method for Objective Speech Quality Assessment in Narrow-Band Telephony Applications

About Telchemy, Incorporated

Telchemy, Incorporated is the global leader in VoIP and IP Video fault and performance management with its **VQmon**® family of multimedia quality monitoring and analysis software. Telchemy is the world's first company to provide voice quality management technology that considers the effects of time-varying network impairments and the perceptual effects of time-varying call quality. Founded in 1999, the company has products deployed worldwide and markets its technology through leading networking, test and management product companies. For more information, please visit www.telchemy.com.

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