

## Paying for Quality of Service

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Last night I had a totally new telecommunications experience. Now you should know that I never go anywhere without my cell-phone, I take part in multi-participant teleconferences daily, videoconferences weekly, and get hundreds of emails a month. As an amateur radio operator from age 14, I have received Morse code bounced off the moon, viewed slow-scan television, tracked satellites, and felt that special satisfaction of talking with people on islands I had never previously heard of using a transmitter and receiver I built with my own hands. I presently work for a company that manufactures a variety of voice over frame relay, ATM and IP gateways. So what could be dramatically new for me?

The new experience was a totally free long distance phone call.

In case you haven't guessed, I am talking about using one of the new free long distance telephone over the Internet services. I really should qualify the last statement. The call was not really a phone call at all and it was not completely free. It wasn't a phone call in the normal sense since I used a headset and PC instead of a handset and the voice quality was far below that of a cellular phone on a bad day. It wasn't completely free since I still need to pay my flat rate Internet service fee and for the local access to the ISP. But those are technicalities. There was no expensive software to buy, and other than having to endure a rather lengthy sign-up procedure (that I am sure will subject me to even more junk emails than I currently receive) and the gaudy ad banners, I didn't have to part with a dime.

The tenet behind this web site is that we have reached the point where basic phone service can be provided at prices low enough to be covered by advertising revenues. Even if this is not quite true and this Internet site is actually losing money (which seems to be an attractive feature on today's high-tech stock markets), it will be true soon since the underlying price of information transfer is halving every 9 months.

If I no longer need to pay for phone service why was I back using the phone the next morning? I hinted at the answer above - quality. While the quality was definitely good enough for the purpose I had in mind (wishing happy birthday to the aunt of an ex-neighbor), it was definitely insufficient for a technical discussion, and don't even consider using it when talking to an important client.

The moral is clear. We no longer need to pay for *service*, but we *are* willing to pay for *quality of service (QoS)*.

If you aren't yet convinced consider the following historical facts. The first US president to have a telephone in the White House was Rutherford B. Hayes, and his first phone call was with Alexander Graham Bell. It is rumored that the president's first words were 'I can't understand you, could you please speak more slowly?' It is not surprising that with *that* QoS level neither he nor Cleveland nor Harrison used the White House's single telephone line for official business, although the staff did use it to order food. McKinley was willing to compromise somewhat on quality, regarding the using the telephoning as a kind of hobby that 'is bringing us all closer together',

but Roosevelt only used the telephone when there was no alternative. Only during Taft's presidency, after significant improvements in voice quality, did the phone finally become a tool to be trusted. One can only hope that the 'hot-lines', connecting world leaders in times of crisis, are today of sufficient quality.

How can we quantify the connection between quality and price?

The most common measurement of audio *quality* uses a scale from 1 for unintelligible to 5 for perfect quality. The PSTN is supposed to live up to about 4.0, the reduction from five being mainly due to the 4 KHz filtering. For this reason 4.0 is considered *toll quality*, as if you wouldn't pay for anything less. Between 3.5 and 4.0 we speak of *communications quality*; certainly intelligible, but somewhat less 'easy on the ear'. Assuming you are still paying for your calls, you'd probably hang up and dial again if the quality dropped under 3.0.

The most common unit of measurement for the *price* of a phone call has a picture of Lincoln on it.

So the mathematical description of how much QoS is worth can be depicted as a graph with the horizontal axis representing quality from 1 to 5 and the vertical axis portraying price in cents per minute. We already know two points on this graph. Somewhere below quality 3.0 the price drops to zero. At quality 4.0 the vertical coordinate is what you pay for PSTN service. Everything else has to fall in-between on a monotonically increasing curve. At present there is a second, somewhat shifted, curve for cellular service, since people are willing to pay more and accept lower quality audio in exchange for mobility. However, the cellular curve is rapidly approaching the fixed service one.

There are a lot of possible sources of quality degradation. In the traditional PSTN you may hear 'static' on the line, or an annoying echo, or cross-talk from another conversation. However, these impairments are relatively rare; the reliability of the PSTN being remarkably high because those who pay for the service have demanded this quality level. Modern digital packet networks have more problems. The voice quality may be degraded by speech compression, unrecovered bit errors, packet jitter and/or packet loss. However, all of these problems can be ameliorated - for a price.

Let's take speech compression as our first example. Simplistic sampling at 8000 Hz using 16 bit words would require 128 Kbps, but this is halved to 64 Kbps using  $\mu$ -law or A-law encoding with only negligible quality loss. By using ADPCM we obtain a compress the bit stream down to 32 Kbps at the price of increased computational hardware, but with little quality impact. The PSTN stops there. Modern packet networks conserve bandwidth (i.e. costs) by using 8 Kbps and lower, and there is a major international effort afoot to achieve 4 Kbps. These *raison d'etre* of these ever more complex compressions is simple, to reduce bandwidth (i.e. cost) at the expense of controlled reduction in quality (and uncontrolled increase in value of the intellectual property holders).

The other problems are equally explainable in terms of price not paid. Bit error can be corrected by using error correcting codes, but these add overhead that someone has to pay for. Packet loss in frame relay systems occurs when congestion forces an

overloaded network to discard packets that have been marked as dispensable. If users in general would be willing to pay enough, networks wouldn't be overloaded; if the particular user pays for all of the traffic, the packets will all get through. Packet jitter occurs in IP networks when the successive packets take different routes due to congestion or network problems. The reader has probably already guessed that these problems too disappear when enough is paid.

Let's return to our graph of price vs. QoS. The various compressions and types of packet networks contribute a plethora of points on the horizontal quality axis. The importance a user may attribute to the call about to be made furnishes various required qualities of service.

At present the user is not given much choice. He or she will have PSTN service and possibly access to a single alternative network with predefined parameters.

Now consider the following proposed system. You dial in your phone number. If the number is local it will be automatically passed on to the PSTN, but if it is long distance then you will be dropped into an IVR that asks you to rate the call's importance, requiring only one more dial button to be pressed. If the importance is high enough, the PSTN will be used (although this option may possibly be blocked). Calls rated at somewhat lower importance level may be carried over a frame relay network with the best speech compression available. Lower levels yet will go over an IP system with a low bit rate encoder. Very low priority calls may be passed on to a free 'phone over the Internet' service.

How does the user know that he or she really received the desired quality? There are several methods available to objectively rate end-to-end audio quality. One such method called Perceptual Speech Quality Measurement (PSQM for short) has been standardized by the ITU, since it has been found to correlate well with subject opinions of audio quality. Although this standard does not presently handle all of the degradations caused by packet networks, other similar methods have already taken these into account.

In the system we are proposing a PSQM-like mechanism would be run at regular intervals to collect statistics on the true QoS delivered. If it turns out that the user received slightly less quality than requested the billing rate will be reduced accordingly. If the quality was significantly lower, the charge will be waived (after all, no quality is not worth anything). Logs will be saved and retrievable by the customer service department.

The combination of these three elements:

1. enabling the user to specify the desired quality,
2. monitoring to ensure that this quality was indeed delivered, and
3. billing according to the price vs. QoS graph,

will at long last allow users to truly pay for *quality of service*, rather than merely paying for *service*.