More Bandwidth Doesn't Matter (much)

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When choosing an Internet connection, it is intuitive to focus on network bandwidth - "*Speeds up to 5Mbps!*" Bandwidth is important, but it isn't the only factor in performance. And given the way that HTTP uses short, bursty connections, it turns out that the round-trip-times dominate performance more than bandwidth does.

Of course, bandwidth speeds are very important for video, music, and other large content downloads. These types of content, unlike web pages, are able to utilize the network because they are large, whereas web pages are comprised of many short connections. This report is only concerned with the effect of bandwidth and RTT on the loading of web pages.

Two Factors in Web-page Downloads: Bandwidth and Round-Trip Time

If we make an analogy between plumbing and the Internet, we can consider the **bandwidth** of the Internet to be like the diameter of the water pipe. A larger pipe carries a larger volume of water, and hence you can deliver more water between two points.

At the same time, no matter how big your pipe is, if the pipe is empty, and you want to get water from one point to the other, it takes time for water to travel through the pipe. In Internet parlance, the time it takes for water to travel from one end of the pipe to the other and back again is called the **round trip time**, or RTT.

While it is easy to install a bigger pipe between two points to add more bandwidth, minimizing the round trip time is difficult because physics gets in our way. If your server is located in London, for example, and you are in San Francisco, the time it takes to send a message is gated at least by the speed of light (even light would take ~30ms to travel that distance, or 60ms for a full round-trip). On the internet today, round trip times of 150ms to 250ms is common. And no matter how big your pipe is, the RTT will take this long.

Test #1: Vary the Bandwidth

The first test we ran was to see the effect on web-page download times when you change the bandwidth of the network. In this test, we've chosen fixed values for packet loss (0%) and round-trip-time (60ms) so that we can isolate the variable under test, bandwidth. In this test we're downloading a simulation of 25 of the web's

most popular web pages.

Here are the raw results, using HTTP to download the web page:

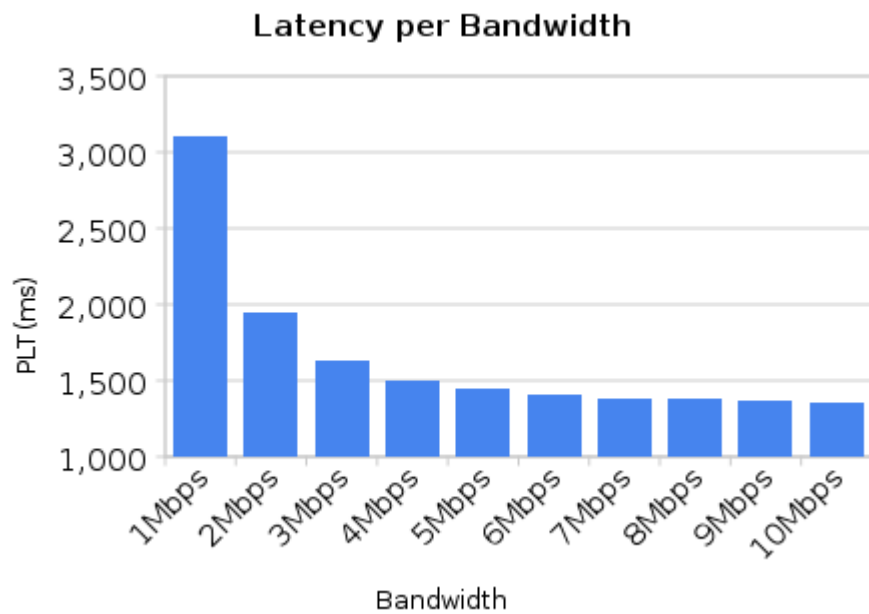| Bandwidth	Page Load Time via HTTP
1Mbps	3106
2Mbps	1950
3Mbps	1632
4Mpbs	1496
5Mbps	1443
6Mbps	1406
7Mbps	1388
8Mbps	1379
9Mbps	1368
10Mbps	1360

Figure 1: This graph shows the decrease in latency (page load time) as the bandwidth goes up. As you can see, there are diminishing returns as the bandwidth gets higher.   According to the Akamai Internet Report Q2'09, the average bandwidth in the US is only 3.9Mbps.

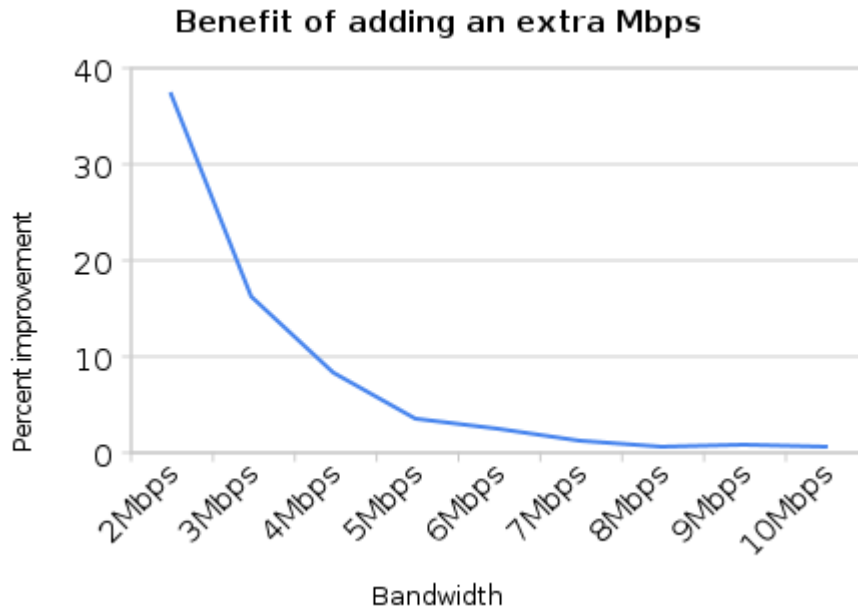**Benefit of adding an extra Mbps**

Figure 2: Here we see the incremental percentage decrease in latency as we add more bandwidth. An increase from 5Mbps to 10Mbps amounts to a 5% improvement in Page Load Times.
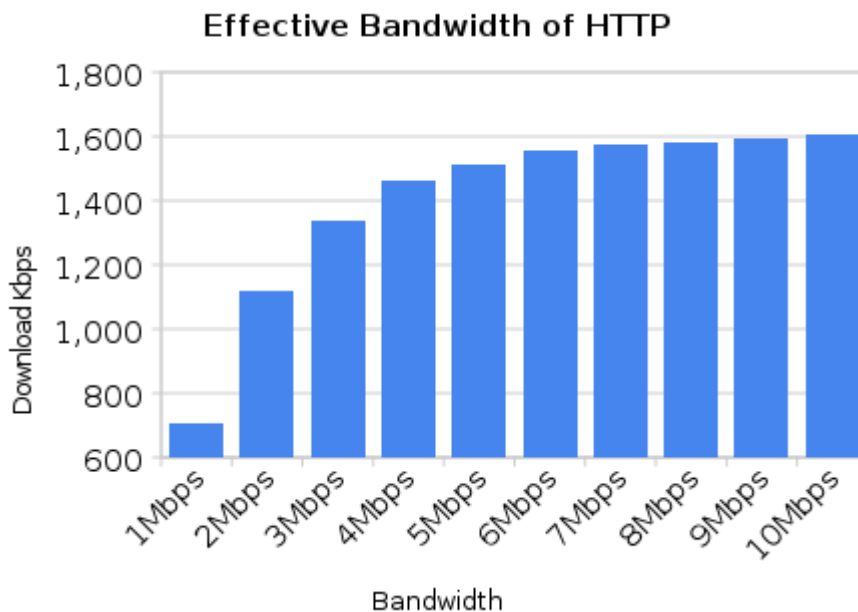

Effective Bandwidth of HTTP

Figure 3: This graph shows the effective bandwidth of the web page download as the raw bandwidth is increased. At 1Mbps, web pages can be downloaded at ~69% of the total bandwidth capacity. At 10Mbps, however, web pages can only be downloaded at ~16% of the total capacity; and we're tapering off.

Test #2: Vary the RTT

For this test, we fix the bandwidth at 5Mbps, and vary the RTT from 0ms to 240ms.
Keep in mind that the worldwide average RTT to Google is over 100ms today. In
the US, RTTs are lower, but 60-70ms is still common.

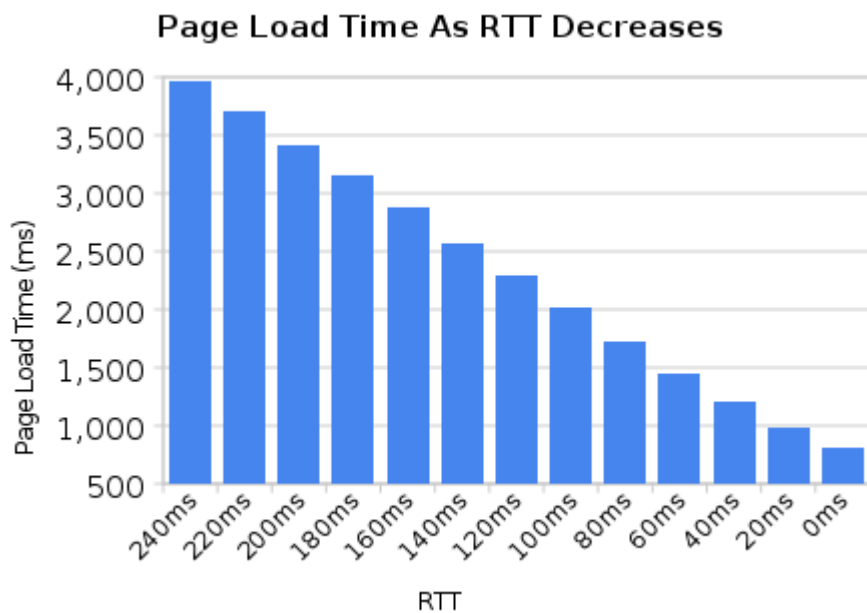| RTT	Page Load Time via HTTP
240ms	3964
220ms	3707
200ms	3418
180ms	3151
160ms	2874
140ms	2572
120ms	2291
100ms	2017
80ms	1732
60ms	1450
40ms	1201
20ms	981
0ms	814

Figure 4: In this graph, we see the obvious effect that Page Load Time decreases
as the RTT decreases. Continued reductions in RTT always helps, even when RTT
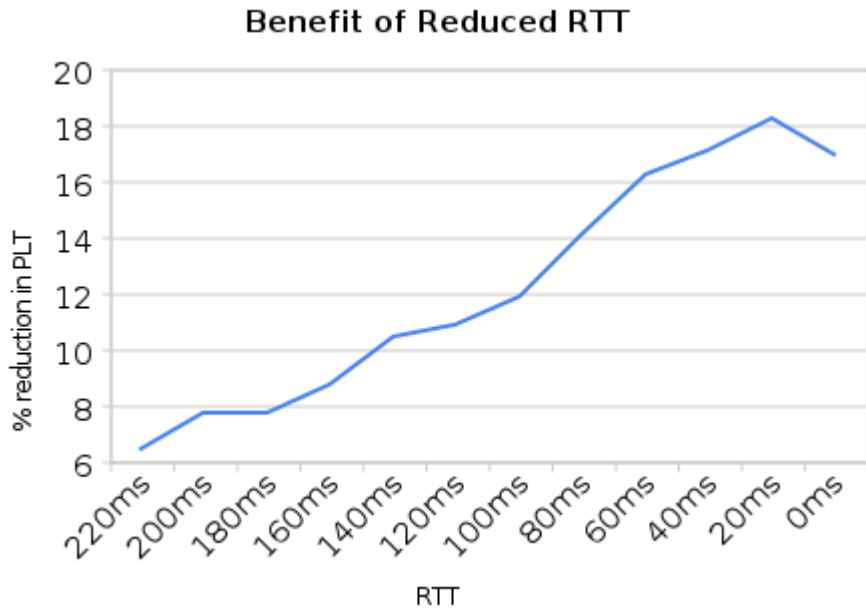is low.

Benefit of Reduced RTT

Figure 5: This graph shows the % reduction in PLT for each 20 milliseconds of reduced RTT. Unlike improvements to bandwidth (figure 2), where benefits diminish, reducing the RTT always helps the overall PLT. In these tests, with bandwidth fixed at 5Mbps, each 20ms yielded 7-15% reduction in PLT.
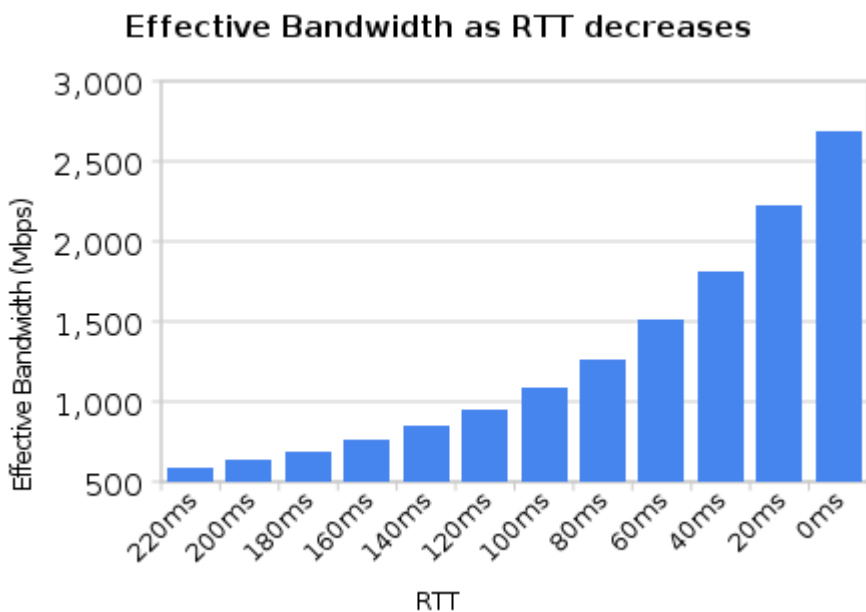
Effective Bandwidth as RTT decreases

Figure 6: This chart shows the increased overall effective bandwidth as RTT is reduced. With high RTT, bandwidth of a page load was as low as 550Kbps, which is a little more than 10% of the 5Mbps theoretical throughput. With low RTT, web page downloads still only achieve ~54% of the total bandwidth available. This is due to other factors of how web pages are loaded.

Conclusions

As you can see from the data above, if users double their bandwidth without reducing their RTT significantly, the effect on Web Browsing will be a minimal improvement. However, decreasing RTT, regardless of current bandwidth always helps make web browsing faster. To speed up the Internet at large, we should look for more ways to bring down RTT. What if we could reduce cross-atlantic RTTs from 150ms to 100ms? This would have a larger effect on the speed of the internet than increasing a user's bandwidth from 3.9Mbps to 10Mbps or even 1Gbps.

Another approach to reducing page load times would be to reduce the number of round trips required per page load. Today, web pages require a certain amount of back and forth between the client and server. The number of round trips is largely due to the handshakes to start communicating between client and server (e.g. DNS, TCP, HTTP), and also round trips induced by the communication protocols (e.g. TCP slow start). If we can improve protocols to transfer this data with fewer round trips, we should also be able to improve page load times. This is one of the goals of [SPDY](#).

This study focused on a few fixed network settings. For the varied-bandwidth test, we fixed the RTT at 60ms. We should do similar tests with lower and higher RTTs to verify that the patterns are common. Further, in the fixed bandwidth test, we only tested 5Mbps. Again, we should test with lower and higher bandwidth settings to verify these trends.

Finally, it should be noted that this study focuses solely on fresh connections to a site. Continued browsing through a site, so long as it can reuse existing connections, may experience better utilization of the link.