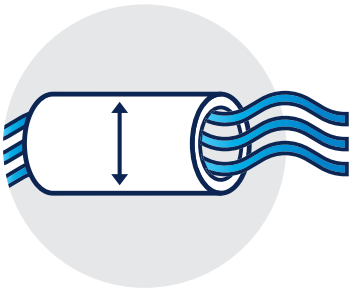
WHITE PAPER

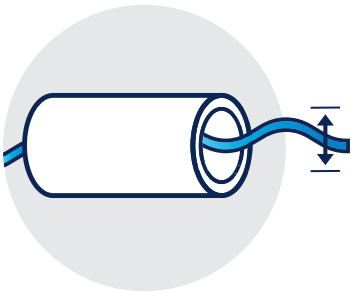
The evasive ‘speed’ of your Internet

Spectrum ENTERPRISE

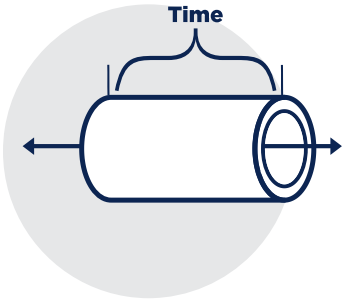
Figure 1



Bandwidth
Bandwidth = Capacity
Bigger pipe = More data/second



Throughput
Throughput = Amount of data flowing through (measured per second)



Speed
How fast data goes through

Why am I not getting the 10 gigs I'm paying for?

Purchasing an intangible product or service naturally puts buyers on high alert to protect their interests. Such can be the case with a nebulous service like Internet connectivity. Unlike buying a car that you can look at, touch, and drive, connectivity is invisible and cannot be physically scrutinized to assess its value.

So, when you buy 10 gigs, for example, what is it you are really buying? In a typical description, you'll hear terms like "bandwidth" and "speed" tossed about interchangeably, and "throughput" may not be discussed at all. What do you really need to know when assessing connectivity?

The right decision can make all the difference when it comes to downloading large files and transmitting time-sensitive data. To meet your business' Internet connectivity needs, you must understand what 10 gigs really means and what affects your Internet connection.

Defining the terms

Bandwidth and speed are not the same. Throughput, yet another term, may actually be the most important concept. All three terms represent slightly different but interrelated concepts, each with its own unit of measurement. The definitions and how the terms relate will help clarify how real-world factors negatively affect connectivity, thus impacting gigabits.

Bandwidth

The easiest way to think of bandwidth is to envision the capacity of a pipe. A small diameter pipe carries less water, while a larger diameter pipe carries more. You measure the capacity of the pipe by the amount of water it can carry over a certain period. For example, 10 gallons of water per second can pass through a pipe. You measure bandwidth in relatively the same way. But, in a network, you are pushing data instead of water, so you measure in bits instead of gallons.

So, the bandwidth of a connection can be 10 gigabits per second - the amount of raw data the "pipe" can handle per second. An important note: Bandwidth measures the capacity of a single pipe, a connection from point A to point B, and not necessarily the capacity of an entire network system.

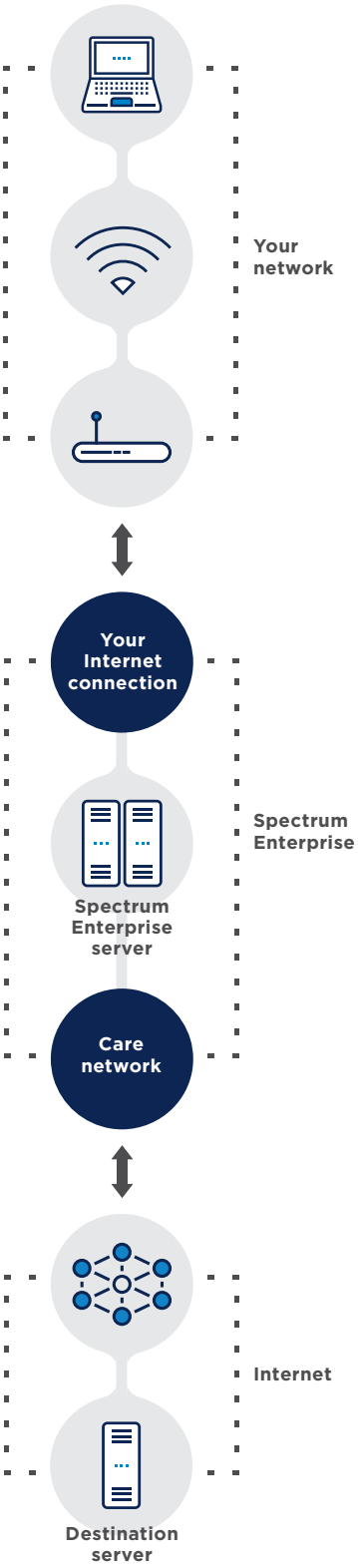
Throughput

If bandwidth is the capacity of the pipe, throughput is the amount of water that actually comes out of the pipe at any particular moment. Also measured in bits per second, throughput measures the actual amount of data flowing through, whether it is a rush of 10 Gbps or a trickle of 5 Mbps. This is a notable distinction from bandwidth because, as we'll address later, even if your pipe is capable of 10 Gbps, what you actually receive is probably less.

Speed

While bandwidth and throughput are meaningful to compare, speed is another key element. Speed is often used synonymously with bandwidth, and that can be confusing. If bandwidth is the capacity of the pipe and throughput is the amount you receive, then speed is how long it takes for a single drop of water to travel from point A to point Z. Measured in milliseconds with a ping test (a method of testing the reaction time of your connectivity), speed tells us the time it takes a single packet of information to traverse across the entire

Figure 2



network system, over all connections, through every server and spanning continuously varying mileage, to its intended location. Since data over a wire travels at a consistent rate, other factors delay the speed of a packet, and that delay is commonly known as latency.

Over the course of repeatedly delivering packets back and forth between two points, latency begins to adversely affect throughput.

What are you actually purchasing?

When you buy 10 gigs from Spectrum Enterprise, what is it you get?

The Internet service is a connection from your office(s) to the Internet. However, it may be easier to understand if we break it down into three components: your internal network, the Spectrum Enterprise network and the Internet.

Your internal network is just that—yours. You control it. You control the type and number of computers that need access to it, the type of connection you have to the router or modem, and whether it is over the company's WiFi or even over a hard-wired Ethernet connection. To some extent, you even control the firewall that data must pass through to get in and out of your company's network.

Then you hand off access to Spectrum Enterprise. We carry your information from the router in your office over the 10 Gbps of bandwidth (capacity) via fiber to our core network, where we route it to one of several peering points where Internet traffic is exchanged.

And once the traffic is exchanged, it is in the Internet—the big, complex system of large pipes and routers that make it possible to exchange data across the world. Your data travels a few miles across town or overseas to reach its location, which may be at the end of another broadband pipe, accessing a server through another firewall, over a 1 Gbps connection.

When you buy 10 gigs from Spectrum Enterprise, we deliver a bandwidth connection of 10 Gbps between your office and our core network. We take pride in our network, which is built to satisfy the rapidly growing demand of enterprises for reliable bandwidth. It may be surprising to learn that the service connection you purchased is throttled at the connection point, while the capacity of the connection to our core network is much larger. To ensure that you are receiving the bandwidth that you expect, we proactively monitor all of our connections so that if anything does go wrong, we know about it and often fix it before you even notice.

However, while we call this service "Internet connectivity", it is only one link in a much larger chain. The bandwidth of this link may be the full 10 Gbps you ordered, but the throughput is determined by the performance of the overall system—your internal network, the Spectrum Enterprise network and the Internet. As with any chain, the weakest link can cause the entire chain to underperform. All these other factors need to be considered before you say you're not getting your gigs.

Why am I not getting 10 Gbps?

Now that you understand you bought an Internet connection with 10 Gbps of bandwidth, and that bandwidth does not mean throughput, it helps to explain all the factors that influence throughput and why it may never equal 10 Gbps.

Throughput measures the performance of an entire system. This system relies on countless factors to transmit data, including the processing speed of the computer you are using, the protocol of the transmission, IP packet overhead and even the miles traveled. Each element must do its part to ensure data is exchanged. Each element relies on the next to be built, designed and operated at peak performance, but we know some routes through the Internet will incur a bottleneck. Factors that cause bottlenecks fall into a few different categories: obstacles, overhead and latency.

Obstacles

When sending or receiving data over the Internet, obstacles or bottlenecks can occur, even before your data travels out of your building:

- **Computers:** A 10 Gbps connection won't do you much good if your computer's processor or Ethernet hardware can't push data that quickly. Or the system will be choked if an entire office building's worth of computers and tablets are on the same connection, each of which is requesting some of the bandwidth.
- **WiFi:** While your Internet connection may be 10 Gbps, is your company's WiFi capable of delivering that kind of bandwidth? How many people access the WiFi, and is it set up properly?
- **Firewall:** Firewalls are a necessity these days. Your firewall inspects each incoming data packet for threats, but this inspection takes time, and may slow down the throughput of the system. Is the firewall capable of a physical 10 Gbps connection?
- **Router:** While your router delivers the Internet to your office, is it physically capable and set up to supply the amount of bandwidth your connection can provide? If your router is older or the settings aren't optimal, your router could be slowing the very traffic it is meant to deliver.

It's also worth considering that the destination server you are trying to access via the Internet may have these same limitations on its side. It may be easy to overlook our internal obstacles as factors in Internet throughput, but they are an essential link in the overall system and should be able to support the bandwidth you've ordered.

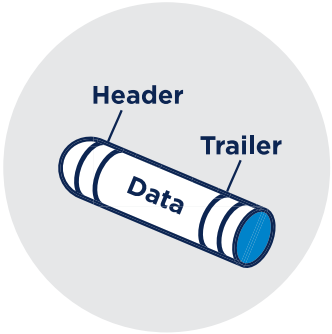
Overhead

When you exchange data over the Internet, meaning anything from emailing to online gaming, how does your data know where to go? How does it get back to you?

If you think about your data like shipping a flat-screen TV from Japan to New York City, you don't just put a flat-screen TV on a cargo ship and expect it to arrive safely. You pack it in Styrofoam to protect it from damage, you put it in a box with directions, you put the box on a pallet with a shipping label so people know where it goes, and you put the pallet in a container for loading onto a cargo ship. Now, you're not just shipping a flat-screen TV; you are shipping the

Figure 3

Packet of data:
Email



Header	**96 bits**

- Sender's IP address
- Receiver's IP address
- Protocol
- Packet number

Payload	**896 bits**

- Data

Trailer	**32 bits**

- Data to show end of packet
- Error correction

TV, the packaging, the address labels, and the container itself. That's overhead, and it is the same with sending data across the Internet.

A packet of data includes overhead that communicates to the network where the packet is going, how it should be assembled, and what to do if other packets don't show up. It is this overhead that makes networking work. So, your "raw" data is packaged up with this overhead and sent out through the Internet. However, since the overhead isn't part of the content, but simply its guide, it is not calculated as a part of throughput. Therefore, your throughput will never equal your bandwidth as your data will always require some overhead.

Overhead depends on the type of protocol, or transmission language you use to send the data. Ethernet, IP and other protocols all have different sizes and types of overhead to ensure transmission across a network.

TCP windowing
To compound matters, as part of these protocols, the origination computer and destination server over the Internet, point A and point Z, respectively, communicate with each other to acknowledge receipt of the packets. This is important because point Z tells point A how much data it can process at any given time so point A knows how much data to send. However, when point Z becomes too busy and does not acknowledge receipt, point A will automatically decrease the amount of data it's sending, or stop all together, until it hears back from point Z. This is called TCP windowing and all of this back and forth between computers counts as overhead.

TCP windowing is an essential part of how data transmits across a network, but unfortunately, it does decrease the throughput of any particular system.

Latency
As mentioned above, latency is the measure of delay to your data's speed. And while latency is measured in milliseconds, the factors that cause latency compound on top of each other and are multiplied by the constant back-and-forth communication of data over a network. When this happens, it begins to strangle your throughput. The most common causes of latency are line rate, physical distance and switching delays.

Line rate
Line rate is the bandwidth or capacity of the entire system. While you might have a 10 Gbps connection working optimally on your end, the server you communicate with may only have a 1 Gbps connection. So no matter how much data you transmit, the server may not consume it as quickly.

Thinking back to our cargo ship carrying flat-screen TVs, even if it is one of the newer models that can carry up to 18,700 containers, when we transfer our cargo to another carrier, its ship might only have the capacity for 10,000 containers, slowing the entire process down.

Physical distance
It is hard to imagine anything going as fast as one-third the speed of light, like data down a cable, for example, being impacted by the distance it travels. But there are a couple of things to consider. First, if the server is halfway around

the globe, the data exchange between your computer and the destination server makes that journey repeatedly until the exchange is complete. Second, depending on the route your traffic takes, it may very well go via satellite, meaning your 1s and 0s are traveling to a height of 22,236 miles above the surface of the earth and back again, and again and again.

Just like our cargo ship, the farther away it is, the longer it takes to deliver.

Switching delays

And finally, as your data takes its trip through the Internet, it can pass through dozens of routers, each of which must read your packet's instructions and put it on the right path to its destination. Each instance through a router doesn't necessarily take too long. However, your data may see the inside of 30 or 40 routers as it traverses these routes back and forth as the two computers communicate, so the delay begins. And that's if the routers aren't busy, which they sometimes are, forcing your data to stand in line waiting to be shown the way.

As our flat-screen TVs are inspected, off-loaded, on-loaded and transferred, or even if the ship is stuck in the harbor waiting for a slip at the dock, our cargo is not just subject to the speed of the ship itself, but the speed of manipulating the cargo to its location.

The bottom line with latency, in normal data transfer where two computers are constantly communicating, is that if communication becomes slower, your data transfer slows, meaning your throughput is negatively affected.

At lower speeds, it's the line rate that dictates actual throughput. However, as your pipe size increases, throughput becomes more sensitive to the issues outlined above.

Why are bandwidth and speed testing difficult to comprehend?

Today's Internet is flooded with free speed test services that claim to tell you how much bandwidth you have at any given time.

These services are really testing the speed to their servers and your throughput on that route. And, hopefully, their servers are close by.

But remember, the data needs to go from your location, through the Spectrum Enterprise network, to an Internet peering point, and over the Internet to that server. Change servers and the route is completely different and has different throughput results. However, none of this specifically measures the performance of the link between your office and the Spectrum Enterprise network or, said differently, the 10 Gbps of bandwidth you purchased.

Identifying and diagnosing real problems

If you're asking yourself, "How do I figure out if there is a problem with my connection and how do I fix it?" there are a few things you can do to help determine if a problem exists and help us diagnose it.

First, a useful exercise is to benchmark your throughput over time using consistent measuring tools and servers to build a trend line. If throughput falls dramatically from the trend, then give us a call at 866.603.3199. We'll be able

to diagnose the problem more quickly if you gather the following information in advance:

- Ensure the elements of your internal network are all functioning correctly and can receive information.
- What are you doing that seems to slow down the network (e.g., transferring files, video, online gaming)?
- What is the trace route that seems to be a problem?
- Have you added more bandwidth-intensive applications to your network (e.g., video, hosted CRM systems)?

Armed with this information, we will help resolve your problem. Our approach is to look at each of the three network sections we've already discussed (internal network, Spectrum Enterprise network and the Internet) and try to zero in on the issue. Once we have identified the issue, we will endeavor to correct it, sometimes even if the problem is outside our control. For example, if the problem is discovered to be somewhere in the Internet, we can work with our peering partners to try to resolve issues affecting your Internet performance.

Summary

Bandwidth. Speed. Throughput. These terms are not interchangeable. They are interrelated concepts in data networking that help measure capacity, the time it takes to get from one point to the next and the actual amount of data you're receiving, respectively.

When you buy an Internet connection from Spectrum Enterprise, you're buying a pipe between your office and the Internet with a set capacity, whether it is 25 Mbps, 10 Gbps, or any increment in between. However, the bandwidth we provide does not tell the whole story; it is the throughput of the entire system that matters. Throughput is affected by obstacles, overhead and latency, meaning the throughput of the system will never equal the bandwidth of your Internet connection.

The good news is that an Internet connection from Spectrum Enterprise is engineered to ensure you receive the capacity you purchase; we proactively monitor your bandwidth to ensure problems are dealt with promptly, and we are your advocates across the Internet whenever one of our peers isn't performing optimally. We provide high-speed, reliable Internet access over our wholly owned and managed core network. And our flexible bandwidth tiers allow you to easily scale from 25 Mbps to 10 Gbps as your business grows.

No matter how many gigs your business needs now and in the future, you'll optimize your Internet connectivity with Spectrum Enterprise.

About Spectrum Enterprise

Spectrum Enterprise, a part of Charter Communications, is a national provider of scalable, fiber-based technology solutions serving many of America's largest businesses and communications service providers. The broad Spectrum Enterprise portfolio includes networking and managed services solutions, including Internet access, Ethernet and Managed Network Services, Voice and TV solutions, Managed Application, Cloud Infrastructure and Managed Hosting Services. Our team of experts works closely with clients to achieve greater business success by providing solutions designed to meet their evolving needs. For more information, visit enterprise.spectrum.com.

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