The Gigabit Experience

Technical white paper

Introduction

The move to gigabit speeds creates opportunities and challenges.

Gigabit speeds provide customers with a greatly enhanced broadband experience. It allows multiple applications and devices to get the bandwidth they desire, when they want to use it. The high burst capability allows much faster downloads. It also lets video stream rapidly, and seamlessly fast forward.

However, there are many factors that affect customers' ability to experience these speeds. Thus, a key challenge with gigabit services is closing the gap between customers' expectations (driven by the gigabit headline) and their ability to experience these speeds.

"Why am I only seeing 722 Mbps on speedtest.net?"

"Why can't I download a 1.8 Gigabyte movie in 16 seconds?"

We cannot expect the majority of customers to understand the limitations and characteristics of their broadband speed without assistance. The onus is on us to manage these expectations by creating the right conversations up front and support this with consistent behaviour, messaging, education, information and tools.

About this document

The aim of this paper is to support service providers in defining and managing customer expectations around gigabit speeds. It describes the characteristics of the service and environment that affects customer experience. It also provides suggestions on how customer expectations can be managed.

This paper is partly based on Ofcom's Broadband Speeds voluntary codes of practice.

Chorus endeavours to make this document as comprehensive and technically accurate as possible. However it may need to be updated from time to time to include clarifications, errata or additional content. Feedback on the content, technical accuracy or clarity is welcome and should be forwarded through your account manager.

This document should be read in conjunction with the *NGA Technical User Guide* and the *Chorus Congestion Free Networks* technical white papers, both available on the Chorus Website.

Background

Gigabit speeds are deliberately aspirational. There are no applications today that require a gigabit and perhaps the only time a customer will come close to observing this speed today, is if they run a speed test.

Despite this, gigabit speeds still provide real benefits, even with the constraints described within this document. The number of internet-enabled devices within the household is growing exponentially and Gigabit speeds allow multiple users/devices within a household, to get simultaneous ultrafast broadband.

Furthermore, gigabit speeds are not necessarily about speeding up today's applications. It also creates windows to new applications and content.

Shared nature of networks

Chorus provides a shared network, where multiple customers and service providers are supported by common infrastructure. Due to the highly stochastic behaviour of internet services, the bandwidth demanded by each customer varies significantly over time - even during peak periods.

By sharing common resources, each individual service is able to benefit from other users' unused resources. This results in a customer experience far in excess of the average resources allocated per customer.

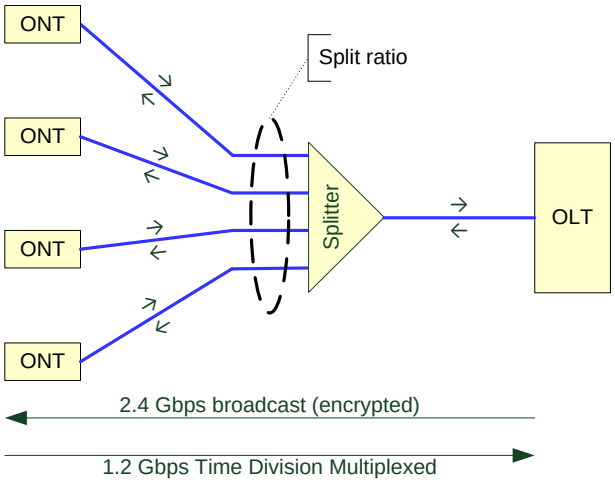
However, the downside to this mechanism is that resources are rarely reserved for individual services. Thus customer experience cannot be absolutely guaranteed. Other factors, such as latency or error correction protocols, can limit throughput - even when the network is lightly loaded.

Chorus actively monitors the utilisation of this shared network and proactively augments capacity, to ensure it is congestion free. For more information on what a congestion free network looks like, please see the *Chorus Congestion Free Networks* technical white paper, available on the Chorus website.

GPON contention

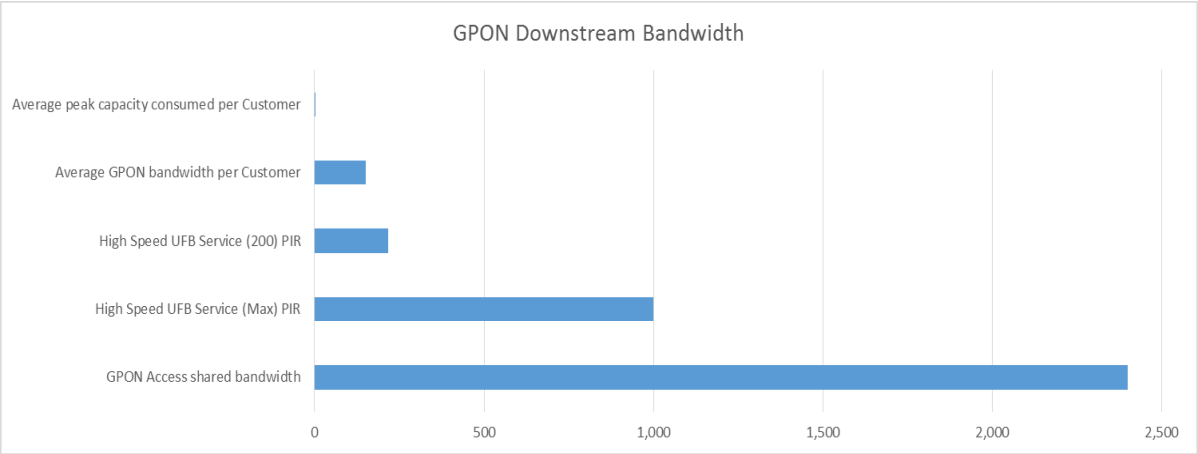
The least-shared part of the NGA network is the GPON access itself. A small number of users share a single Gigabit Passive Optical Network, which supports 2.4 Gbps downstream and 1.2 Gbps upstream.

Chorus' current maximum split ratio is 16:1, although some of the early NGA deployments were at 32:1



Gigabit offers allow broadband customers to get a higher speed than their equal share, by giving them access to any unused bandwidth from other customers on the shared GPON network. The implication is that these broadband customers always have at least 100 Mbps downstream and 50 Mbps upstream available. Bandwidth above this though, depends on the behaviour of other users in the same shared GPON Access at any given time.

In practice, the stochastic nature of bandwidth demand means that customers will generally not be constrained - even for higher speed offers. If we look at Gigatown, for example, we can see that the average capacity consumed by a Gigatown customer is much less than their peak capacity as shown below:



This graph demonstrates the key benefits of contention. An individual broadband customer can experience speeds much higher than the average bandwidth available. It would be very rare for any gigabit customer to not get the bandwidth they are asking for within the Chorus network.

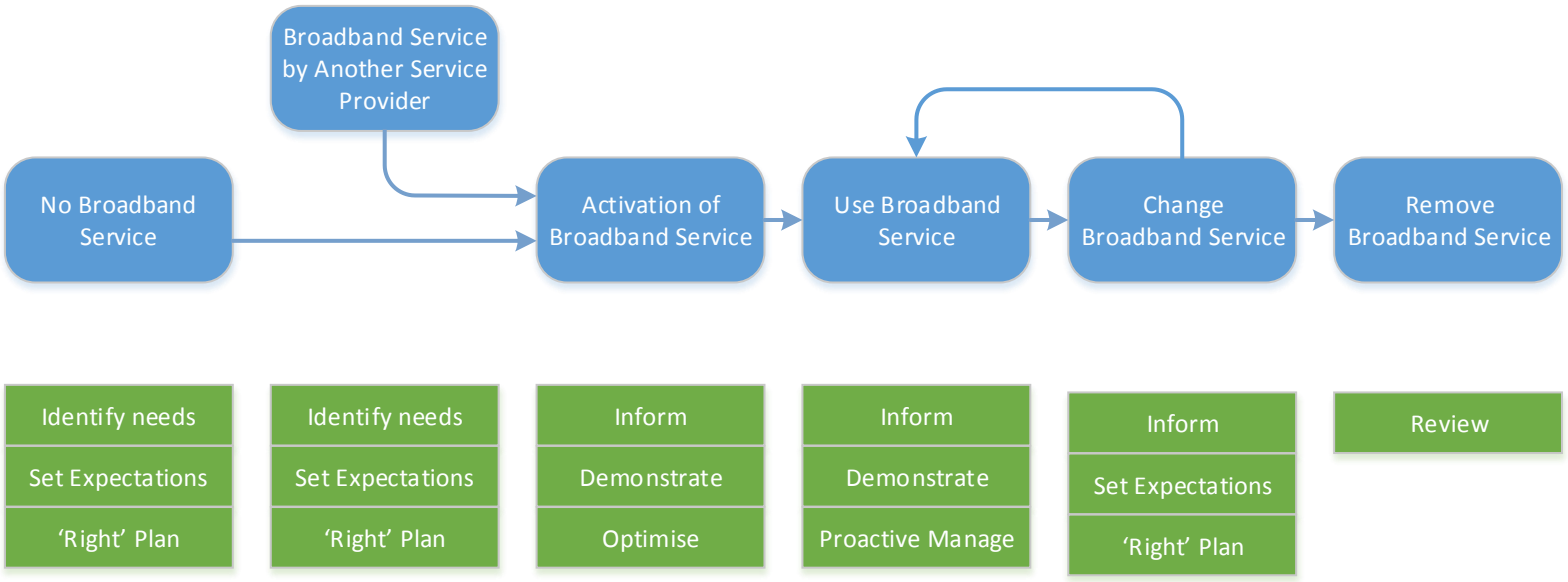
GPON vs P2P

GPON gigabit services are all about redistributing unused, shared Low traffic class bandwidth from one customer to another and are therefore more suitable for elastic applications that can take advantage of variable bandwidths, particularly multi-threaded TCP internet applications. They are less suitable for inelastic applications that expect a fixed bandwidth, which may work better using High traffic class, or moving to Point to Point services.

Given the shared nature of GPON access, customers that expect to use greater than 100 Mbps of sustained bandwidth should also consider using Point to Point services.

Setting and managing customer expectations

Setting and managing customer expectations is not something that is done once. It needs to be continued throughout a customer relationship i.e. from an initial prospect to when a customer leaves.



The following table looks at how customer experience might be managed at different stages of their lifecycle.

Lifecycle stage		**Managing customer experience**		**Why experience needs to be managed**
No broadband service	The customer does not currently have broadband i.e. : Has never had broadband; Had broadband in the past but has removed it; Had broadband by another technology; or Is moving into a new address. The aim is to provide the market proposition that best fits their needs and setting the right expectations.	Identify needs	Determining what the customer wants to use the broadband for.	If these needs are not met then the customer will be disappointed and may churn.
		Set expectations	Identify what kind of speed and performance the customer is likely to receive and what that means in terms of experience.	Setting a correct experience will avoid customers being disappointed or feeling they were misled.
		'Right' plan	The plan needs to be matched to their needs and expectations.	For example, a gamer put on an offer optimised for email may be disappointed by their experience.

Lifecycle stage		Managing customer experience		Why experience needs to be managed
Broadband service by another service provider	This is a customer who has an existing broadband service and thus will naturally compare their new solution to their old one. They will have a preset expectation based on their current solution and may be moving for a number of reasons. However setting the right expectations and meeting them is key to avoiding disappointment and churn.	Identify needs	The key difference here is the customer already has a broadband solution that is either at the wrong price point, or does not meet their current needs.	The customer may have a bad experience, which is why they are changing. Or they might have a good experience on an existing provider and don't want it to degrade when changing service provider.
		Set expectations	Given the customer has an existing experience, setting expectations has to deal with pre-set bias.	Over promising or negative surprises may result in customers being disappointed or feeling they were misled.
		'Right' plan	The customer is moving for a reason and the plan they move to, needs to match that reason.	If the new plan does not meet the customer expectation then this will result in customers being disappointed or feeling they were misled.
Activation of broadband service	This is about first impressions and ensuring the customer is fully informed about how to get the most out of their service.	Inform	Providing information that explain what experience the customer should be getting and why.	This is about closing the gaps between expectation and actual experience.
		Demonstrate	Demonstrate, in a meaningful way, what their experience is. May be as simple as a speed meter, but also how to see line speed, different applications, etc.	Show that you are delivering what you promised, and setting this experience up front.
		Optimise	Provide information on how the customer can get the best experience.	A lot of small tweaks can improve customer experience and helping them will engage them better.

Lifecycle stage		Managing customer experience		Why experience needs to be managed
Use broadband service	This is the experience the customer gets as they use the service and particularly handling any mismatch between expectations and experience. These mismatches may result in fault calls or disappointed customers and churn.	Inform	Same as activation, although likely to be reactive.	Used to reinforce messages, particularly with complaints.
		Demonstrate	Demonstrate that you are delivering what you promised.	Supporting conversations with customers and ensuring they are informed and engaged with the experience.
		Proactive manage	Identifying if their behaviour matches what they asked for and potentially recommending changes to offer or options.	Customers may not understand or articulate what their needs are, or that their needs changed. Being proactive may avoid customers being disappointed if their needs change but their offer does not.
Change broadband service	Customers may want to change service/offers for a number of reasons and it may even be desirable to recommend changes if their behaviour is inconsistent with the offer they are consuming.	Inform	This needs to support the change in experience for the offer	Showing the customer is getting the outcome they are after
		Set expectations	The customer should understand any change in experience and why it is occurring.	Avoid disappointment in experience following the change.
		'Right' plan	The customer is changing for a reason and the plan they move to needs to match that reason.	The plan should match their preferred behaviour to give the best experience.
Remove broadband	When customers leave it may be important to understand their experience both to make it easier for the customer to return, but also to apply any learnings to existing customers, even if the reasons for leaving are not related to performance.	Review	Look at behaviour over the customer life, including speed complaints and whether they were on the correct market proposition for their behaviour.	Understanding why people have left may identify at-risk customers or suggest changes to current customer experience policies.

Setting expectations up front

When creating an offer in the market, consideration should be made towards the target market and what applications and content they may want to access. The requirements of a business service may be very different from a family service. A gamer may want very different behaviour from their service than a remote worker. Individuals may be both a gamer and a video streamer, and households may contain a wide range of people trying to use the internet at the same time.

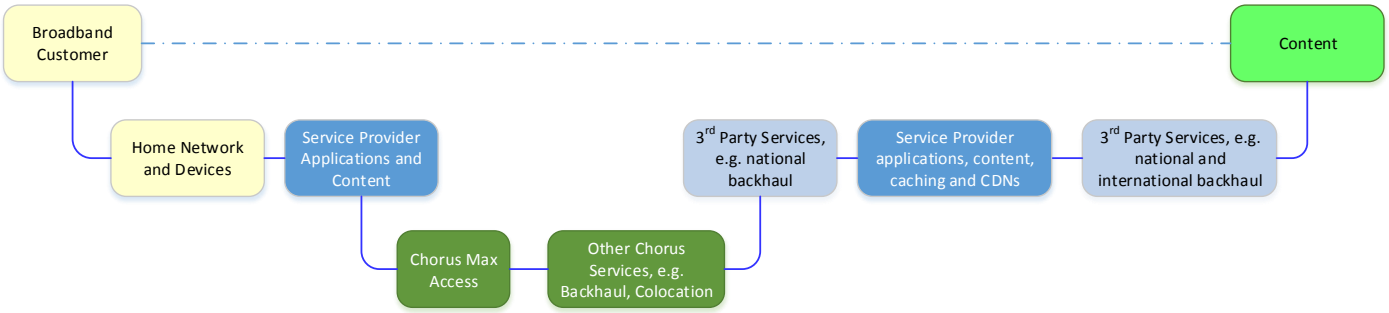
Describing the offer to customers should include clear information about what customer experience they can reasonably expect, before they consume it. This will not only reduce subsequent support costs but will provide a better overall customer experience and may prevent them being disappointed or frustrated later.

A key to providing an optimum experience is channelling customers to the right service for their needs, and encouraging them to change their service as their needs change. This may not matter for all customers but it is important to identify when this is required and to provide the tools and information to facilitate such channelling.

One of the advantages of the gigabit offers is that, apart from very niche activities like running speed meters, access speed is less of a constraint on individual applications. Thus the offer is suitable for a wide range of activities and scenarios, provided customers do not have an unrealistic expectation on what their applications can achieve.

Optimising the experience

The broadband customer experience depends on the path between them and the content they are accessing.



There are several ways customer experience can be optimised:

- Moving content closer to the broadband customer, particularly caching, content delivery networks (CDNs) and the speed meter. Ideally the most commonly accessed content would be as close as possible to the handover point between Chorus and a service provider's network.
- Optimising the caching, CDN and speed meter platforms to ensure they support the expected load. If there are loading constraints, such as the number of simultaneous requests, then it may be worthwhile highlighting these to broadband customers.
- Implementing capacity management analysis to predict future congestion, and augment the network before it happens. As an example, see the *Chorus Congestion Free Networks* technical white paper, available on the Chorus website.
- Providing advice and support to allow Customers to optimise their home environment.

Managing speed queries

Given the shared nature of broadband services, an individual experiencing performance below their initial expectations is not necessarily a fault. Responses to such queries need to consistent, and might include:

- Discussions around the applications being used and where the content is sourced;
- Have consistent rules for determining if a service is below the expected threshold, and what actions can be taken.
- Providing diagnostic tools/information to determine if such speeds are from factors within the customer's control. For example, customers using Wi-Fi to connect to a RGW (modem or router) are unlikely to get the optimum NGA experience. Under these circumstances please advise the customer of how they can reduce such problems.
- You should provide the ability to monitor the problem through to resolution, and provide reasonable remedial actions to address the problem.

Where possible the processes for resolving these issues should be made visible to customers in advance to sets reasonable expectations on how complaints will be managed.

Educating the customer

Educating the customer is not just about setting the right experience, but also providing them with the information and tools for them to understand what they are experiencing and whether it is simply a characteristic of the service, or a fault.

There are a wide range of customers out there, with varying levels of technical knowledge or experience. Consequently there will be extremes in their levels of broadband understanding. Thus educational tools or information may need to be tailored for different customers or applications. Examples include:

- Providing tools that measure relevant performance in a meaningful way. Speed meters, for example, provide useful measures of throughput but often give variable results based on routing paths, distance and time of day. Both the benefits and limitations of such tools should be clear.
- Descriptions of how individual applications or content are expected to perform. You should provide guides on what is reasonable. Customers can then be directed to this information on a case by case basis.
- It should be noted that for many applications, speed is not the only factor driving customer experience. For example, while speed may assist sending and receiving large emails, the frequency of spam and viruses might be a larger source of customer dissatisfaction.
- Information needs to cater for technically illiterate as well as technically literate people. It should provide clear information on what factors influence their individual experience. It needs to be clear about what threshold, if any, would be considered unacceptable performance. The customer then has clear guidelines on what to do if they are unhappy about their experience.

- Include information on policies related to; fair usage, traffic management, traffic shaping, usage caps, content caching and other relevant details impacting customers' experience. Traffic management and shaping information could include; the types of applications / services / protocols affected, and specific information on peak traffic periods.

Training and support material

Customer representatives should provide consistent messaging and should be supported through training and materials around the expected customer experience.

This messaging should to be reinforced with online based material, perhaps including videos that not only explain the typical customers' experience but supports them in optimising their experience.

Testing higher speed services

We recommend you measure end-to-end service performance as part of defining your customer experience. Chorus provides a number of test facilities to support this activity, and is happy to work with your technical specialists to support such testing if required

	Environment	Description	Types of Testing	Notes
1	Non Production Environment (NPE)	The Chorus NPE is located in Wellington and provides a full lab environment and test facilities	Formal testing including technical interface and compatibility testing.	This is an expensive environment that requires Service Providers to have equipment in Chorus Laboratory.
2	Innovation Lab 99 Khyber Pass	Auckland-based environment with access to CCIL and production.	Provides CCIL testing for Service Providers outside Auckland. Also supports Installation testing. Formal testing.	Service Providers need to have equipment in Chorus Laboratory. Provides a managed lab facility for Service Providers
3	Chorus Co-Innovation Laboratory (CCIL)	Isolated production network in Auckland and Wellington that provides test capabilities to Service Provider laboratories	Allows informal and formal testing of new offers and features within the Service Provider's premises.	Intended as the primary onboarding and co-innovation facility.
4	CCIL Test	Production-based test circuits for (limited) testing	Allows limited informal and formal testing of new offers and features within the Service Provider's premises.	A secondary onboarding and co-innovation environment. Useful for testing how an offer performs in production.

The following are some key observations/learnings from previous customer experience testing:

- The Chorus Gigabit offers are configured using the Accelerate feature, which by default has Egress Colour Marking enabled. Some older CPE have been known to have throughput issues when this feature is enabled. For more information, see the *NGA Technical User Guide*.
- Some routers and Residential Gateways (RGWs) may not be optimised for higher speed offers. This has been particularly noticeable upstream, with a few lower-cost RGWs showing some frame loss at higher speeds. Even a small amount of frame loss can impact customer experience.
- Some testing reported higher-than-expected frame loss downstream that was traced back to the way the test equipment was configured.
- Lab environments do not always match production. In particular, Service Providers may use a range of network configuration, backhaul solutions, RGWs or software versions and it may not be practical to reflect every possible combination in a laboratory environment.
- The CCIL Test production facility was introduced to complement laboratory testing for this reason. However CCIL Test does not support sustained throughput testing as such testing may affect other (live) Customers on the Chorus network.

Customer experience drivers

This section looks at the factors that could prevent users from seeing their maximum bandwidth. Note that broadband customers only require a fraction of their peak bandwidth most of the time, and thus may rarely notice these constraints.

IN THE HOME

Drivers inside the home present unique challenges as they can have a significant impact on customer experience but are largely outside the control of the Service Provider or Chorus. Identifying problems can be tricky and customers may not have the knowledge or experience to fix problems if they are identified.

The following are some of the more common causes of customer experience issues within the home:

WiFi

WiFi allows electronic devices to connect to the internet without a direct physical connection. This provides greater flexibility but usually has a peak speed that's much lower than a gigabit. Performance may be further degraded by a number of other issues, as are described in section 0 below.

OLDER DEVICES OR SOFTWARE

The age of devices or the software version used, may affect broadband customers' experience.

Older software may have less sophisticated flow control mechanisms or use default settings not optimised for NGA speeds.

Older hardware may not support gigabit speeds, and could slow down other equipment that does support it.

Adjusting or replacing these devices could be complex and difficult to explain to customers, or be expensive.

HOME NETWORKS AND HOUSE WIRING

Configuration of home networks are variable. Customers may use a variety of dedicated CAT-5 LANs, Powerline or wireless networks.

Home networks may also include older 100 Mbps switches or be wired inefficiently.

Many houses are not optimised for high speed data transfer. Poor wiring may prevent customers from getting the full benefits of their NGA service.

For example, Powerline can be susceptible to AC interference from washing machines and hair dryers.

APPLICATIONS

Applications may be constrained by how much bandwidth they consume. They are often intended to operate in a wide range of internet environments and may be designed to work with the lowest denominator and thus may not be able to take advantage of high speed services.

Other applications may have the ability to improve throughput when bandwidth is available. For example, they may use multi-threaded rather than single-threaded TCP sessions to minimise the impact of latency or distance.

The unique challenges of WiFi

WiFi presents a number of unique challenges in optimising speeds and thus requires its own section.

Effective wireless speeds are usually much less than a gigabit access and will thus act as a limit to the maximum speed a customer could observe on a WiFi-enabled device.

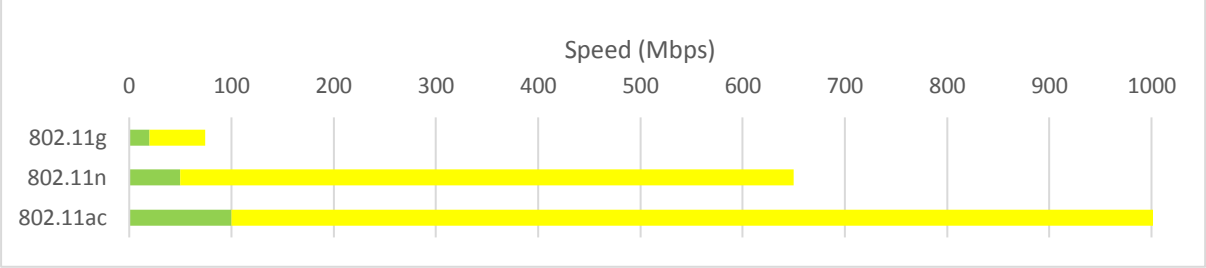
WiFi devices use variations of the 802.11 Ethernet standards. These standards are frequently updated as technology improves, providing greater speeds. Some of the more common standards available today are:

- 802.1n, allowing speeds of 500-600Mbps;
- 802.1ac, allowing speeds of 1 Gbps or more.

However, wireless speeds can vary significantly based on a number of factors, including the configuration of the WiFi Access Points, the premises' environmental conditions and the number of devices trying to use WiFi. WiFi is half-duplex, meaning that only one direction can be transmitting at a time.

Modern implementations use a variety of technologies to get around these limits.

The following graph shows typical versus theoretical speeds of different WiFi technologies.



OPTICAL WIFI ACCESS POINT CONFIGURATION

Most customers will take the WiFi router out of the box and (apart from passwords) expect it to just work. Therefore WiFi routers should be preset for optimal plug and play performance, as much as possible.

Customers may choose to use third party WiFi Access Points. These could have multiple options that can be selected by the customer and may not be optimally configured out of the box. Assure scripts and troubleshooting guides should take into account these scenarios.

POSITIONING OF WIFI SOURCES

The location of the WiFi source is critical to providing the best experience. It should be positioned close to where the customer uses WiFi the most. For example:

- If they use WiFi equally throughout the house, then position it at the centre of the house.
- If they are more likely to use WiFi in a media or common room, then the WiFi source might be better installed in that room (noting this might reduce the WiFi signal strength elsewhere).
- Care must be taken to avoid blocking the Wi-Fi signal:
- Avoid placing it in a cupboard or putting it behind something that may weaken the signal, like a TV or aquarium;
- Avoid placing it on the floor or close to the ground; and
- Ensuring there is a clear path between the WiFi device and the WiFi source;

WIFI COVERAGE WITHIN THE HOME

WiFi strength throughout a house will vary based on distance, interference or any material between the device and the WiFi router. For example:

- Wood and plaster have a low potential of limiting the WiFi signal;
- Water, bricks, marble or some cordless phones have a medium potential of limiting the WiFi signal;
- Concrete, microwave ovens and particularly metal have a high potential of limiting the WiFi signal.

If WiFi coverage is an issue, then WiFi extenders may improve coverage.

USE WIRED WHEN POSSIBLE

WiFi connections are not as fast as wired connections. If speed is more important than mobility, it may be preferable to connect the device using a wired Ethernet connection.

AGE OF DEVICES

While new devices are likely to be built to the latest 802.11 standards, older devices may slow the WiFi experience.

To avoid such constraints, customers should consider upgrading older devices to the latest standard and constraining the WiFi source to the latest standards.

RUNNING MULTIPLE WIRELESS NETWORKS

Running multiple wireless networks may result in interference, confusing devices or reducing speeds. This includes non-WiFi networks, such as cordless phones, baby monitors or interference from microwave ovens.

Where possible, networks should be set to separate channels or even turned off, when not in use.

WiFi sources may use multiple channels (e.g. 2.4GHz and 5GHz) to support multiple devices. The 5GHz channel is faster, although with a more limited range. If range is not an issue then turning off the 2.4GHz channel will ensure devices only connect via the fastest channel.

In the access

There are a number of factors in the NGA access that may limit the customer experience:

UNI SPEED

With 100 and 200Mbps offers, Chorus 'overclocks' the offer bandwidth to allow Layer 3+ Speed Meters to show the headline speed. However, this is not possible with 'Max' offers as the UNI limits throughput to 1000 Mbps at layer 1. The maximum speed test possible under ideal conditions is probably 960 Mbps.

There have also been scenarios where the RGW Ethernet port was limited to 100Mbps. This is less likely now, but may still need to be considered.

UPSTREAM SPEED

Upstream speed is limited to 500Mbps at layer 2. This would limit observable throughput to ~ 480 Mbps when measured at Layer 3+, e.g. on an OOKLA speed meter.

FRAME LOSS WITHIN A CONGESTION FREE NETWORK

A congestion-free network does not guarantee zero frame loss.

Chorus uses Weighted Random Early Detection (WRED) to ensure smooth TCP performance, as network buffer occupancy increases, by selectively discarding frames. Even under a light load, there is a finite chance that a sudden burst of frames will trigger this effect.

The impact of frame loss on typical internet (TCP/IP) traffic is the potential retransmission of lost frames, which ultimately slows the potential maximum observed throughput. The impact of this will vary. Many applications and content servers use a variety of techniques to mitigate this effect including; multiple (parallel) TCP sessions, modern TCP rate control algorithms, window scaling and support for selective acknowledgements.

CPE

Testing has shown that some Residential Gateways may struggle with higher speed connections, particularly upstream. This is due to limitations in the way some Residential Gateway sends traffic upstream, combined with the GPON upstream characteristics (TDM, dynamic bandwidth allocation and ONT upstream buffer size).

RUNNING MULTIPLE SERVICES

The ONT has two ATA ports and four 100/1000Base-T UNIs. It is possible to run multiple services on the ONT, on the same or different UNIs.

The maximum switching capacity of the ONT is 1 Gbps. This could be exceeded when running multiple services simultaneously, such as using multicast while several people are downloading a file, and this may limit an individual service to below its peak rate.

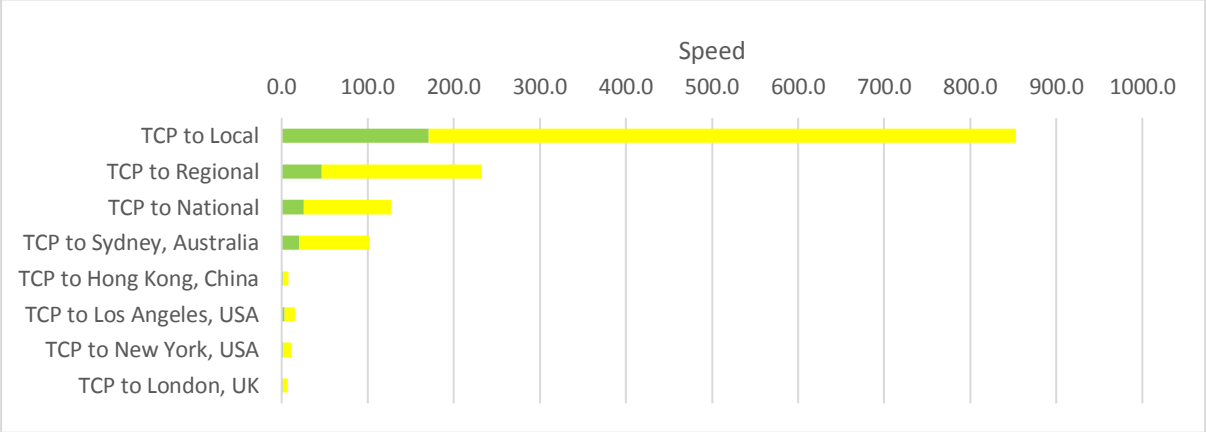
The tyranny of distance

Most internet applications use TCP to provide reliable, ordered and error-checked delivery of traffic from source to destination. Flow control protocols prevent data being sent too fast, by slowing down the transmission of data when congestion is detected.

This flow control requires acknowledgement of data received, known as the TCP Window, which is typically 64kB but can be smaller. If no acknowledgement is received before the window is depleted then the sender stops sending the traffic.

This is problematic for 1 Gbps connections because 64kB can be sent in ~ 60µs. However, the source needs to wait for an acknowledgement before sending more data. The time taken to send the acknowledgement is a direct function of latency and thus distance.

The following graph shows this effect on single (green) and four (yellow) threaded TCP applications:



The following techniques can be used to mitigate this effect:

- Multi-threaded TCP applications
- Using multiple TCP sessions effectively multiplies the throughput based on the number of TCP sessions. For example, a standard speed-test (OOKLA) uses four TCP threads.
- Most modern applications support multiple threads, but at Gbps speeds this can still be an issue over any distance.
- Window Scaling
- Window scaling exponentially increases the window size from 64kB. This can provide significant gains, provided both ends of the session support it. However such sessions are more susceptible to frame loss.
- Content Caching or Content Delivery Networks

Caching content reduces the distance and not only improves throughput but will reduce congestion of remote links, particularly during busy periods.

In the service provider

Key elements within the service provider domain that can improve broadband customers' experience includes:

- Content caching or content delivery networks

- Caching content reduces the distance. It not only improves throughput but reduces congestion of remote links, particularly during busy periods.
- Domain name server
- The Domain name server is critical for broadband customers to access content. Many web pages contain embedded content, sourced from remote locations. A slow or congested DNS can create a delay prior to content downloading. This can reduce a broadband customer's experience.

Appendix: NGA Assure throughput business rules

Chorus Assure will accept performance/throughput faults where service is impacted and the following criteria are met:

Testing proving the fault into the Chorus Network must be provided. This includes, but is not limited to:

- Verifying correct data plan is ordered and provisioned on your Network (QoS)
- Verifying there is no contention or incorrect configuration within your Network
- Isolating customer network to a single device connected directly to the RGW by Ethernet cable (CAT6)
- IPERF tests (both TCP and UDP) or alternatively a combination of FTP stress test (large file size required) and 'smokeping' test.
- Pathpings/MTR to local and international nodes
- Verify customer CPE performance (CPU utilisation etc.) WAN/LAN negotiation speeds and NAT translation capability of the CPE is not limiting circuit performance

When creating a fault report the following information will be required:

- Speed received during testing
- Expectations of circuit performance
- Evidence provided by email of testing conducted with all relevant details, logs and/or screenshots sent to Chorus Assure
- Information about QoS configuration within your Network where this differs from Plan speed ordered.