

Jamulus Workshop

3rd September

Dr Patrick Early

Players connect to the nearest (lowest latency) server.

Or a private server, is set up in the vicinity of the players to handle all of the signal processing.

Mandatory requirements for participants, to reduce overall latency to a tolerable level for all the musicians in the rehearsal

Jamulus software downloaded and installed.

Ethernet connection direct to your computer

A good internet connection

A set of regular headphones.

A quality instrument microphone

An audio interface

1. Download Jamulus Software



The Jamulus software enables musicians to perform real-time jam sessions over the internet. There is one server running the Jamulus server software which collects the audio data from each Jamulus client, mixes the audio data and sends the mix back to each client.

Jamulus is **Open Source software (GPL, GNU General Public License)** and runs under **Windows (ASIO)**, **MacOS (Core Audio)** and **Linux (Jack)**. It is based on the **Qt framework** and uses the **OPUS** audio codec.

The required minimum internet connection speed is 200 kbps for the up- and downstream. The ping time (i.e. round trip delay) from your computer to the server should not exceed 40 ms average.

[Download Jamulus!](#)



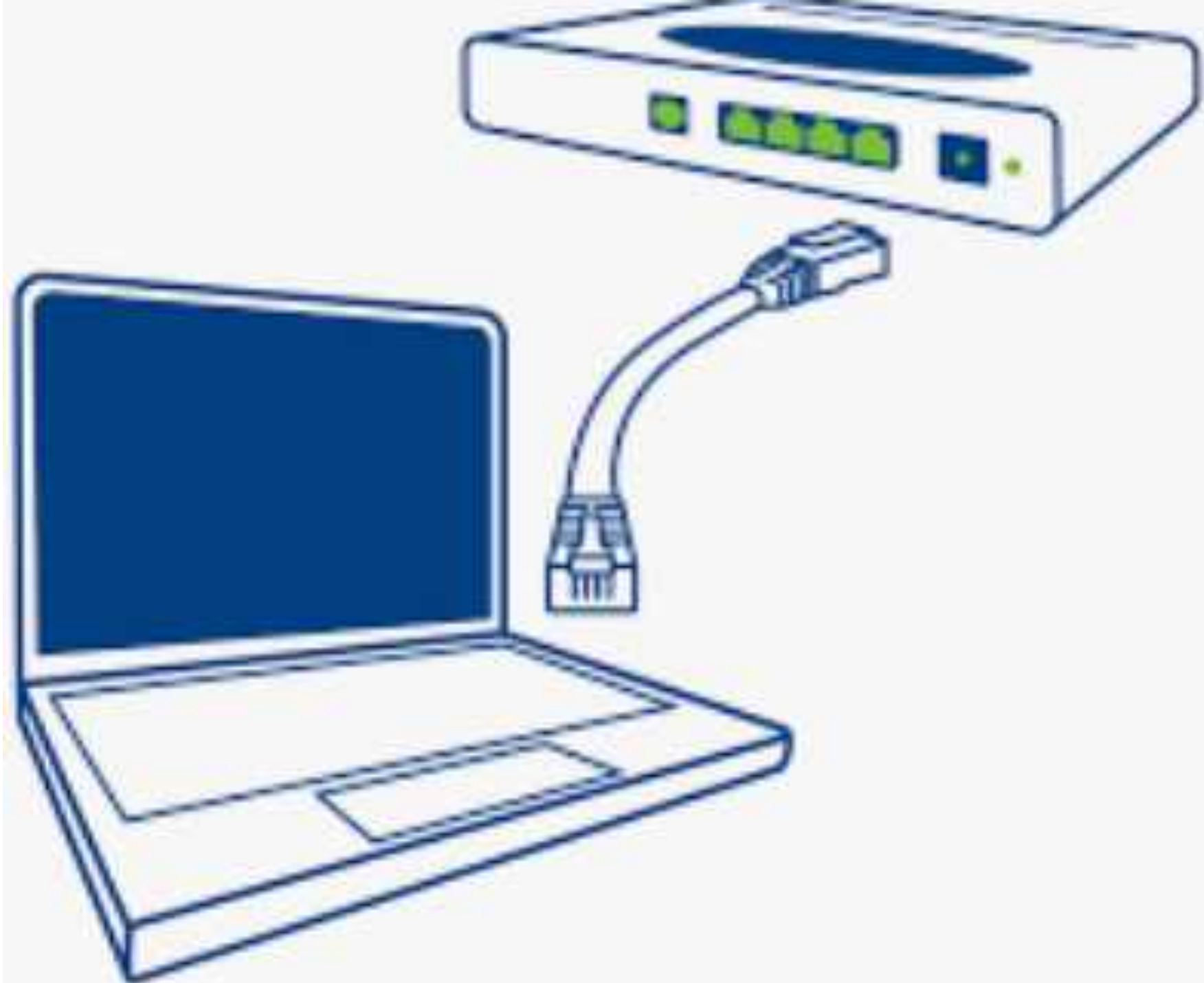
Support

- The Jamulus documentation can be found at the [Github Wiki](#).
- Discussion forums can be found [here](#).
- The Jamulus project is [hosted at Sourceforge.net](#).
- The source code is [hosted at Github](#).

2. Ethernet connection direct to your computer

Wi Fi is unsatisfactory





Use a dongle if there is no Ethernet connection on your computer



3. Secure a good internet connection

What needs to be good about the internet connection?



Internet Speed Test + Deals From Internet Providers in Your Area



Download 37.59 Mbps	Upload 15.55 Mbps	Ping 20 ms
---	---------------------------------------	--------------------------------

Server | EU - London, GB

IP | 95.45.165.188

Provider | Eircom

[My Results](#)

[Share Results](#)

Check Your Bandwidth

Your IP: 95.45.165.188 - Eircom Limited, IE (750 km)

Download

44.09
Mbit/s

Upload

7.26
Mbit/s

Ping

26.00
ms

Jitter

4.25
ms

A relatively *small* speed requirement is specified by Sourceforge

The required minimum internet connection speed is 200 kbps for the up- and downstream. The ping time (i.e. round trip delay) from your computer to the server should not exceed 40 ms average.

[Download Jamulus!](#)



Given the low speed requirement 200kbps for Jamulus, a more accurate way of measuring the quality of your internet connection

is to assess if, from your computer, there are points to and from the server, where delay *variation* is taking place - jitter

Packets of data which carry the audio information get interrupted by this *variation*. This affects the smooth flow of sound on that player's line and manifests as an intermittent crackling in everyone's headphones

Traceroute helps to identify the existence of these blocks by indicating variation in round trip times for 'pings' in ms

Spotlight Search Network Utility

Network Utility

Info

Netstat

Ping

Lookup

Traceroute

Whois

Finger

Port Scan

Enter the network address to ping.

(ex. 10.0.2.1 or www.example.com)

Send an unlimited number of pings

Send only pings

Ping

Ping has started...

PING 52.215.51.128 (52.215.51.128): 56 data bytes

```
64 bytes from 52.215.51.128: icmp_seq=0 ttl=47 time=6.676 ms
64 bytes from 52.215.51.128: icmp_seq=1 ttl=47 time=6.608 ms
64 bytes from 52.215.51.128: icmp_seq=2 ttl=47 time=6.715 ms
64 bytes from 52.215.51.128: icmp_seq=3 ttl=47 time=6.473 ms
64 bytes from 52.215.51.128: icmp_seq=4 ttl=47 time=6.713 ms
64 bytes from 52.215.51.128: icmp_seq=5 ttl=47 time=6.731 ms
64 bytes from 52.215.51.128: icmp_seq=6 ttl=47 time=6.535 ms
64 bytes from 52.215.51.128: icmp_seq=7 ttl=47 time=6.800 ms
64 bytes from 52.215.51.128: icmp_seq=8 ttl=47 time=6.639 ms
64 bytes from 52.215.51.128: icmp_seq=9 ttl=47 time=6.785 ms
```

--- 52.215.51.128 ping statistics ---

10 packets transmitted, 10 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 6.473/6.667/6.800/0.100 ms

Info

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(ex. 10.0.2.1 or www.example.com)

Send an unlimited number of pings

Send only pings

Ping

Ping has started...

```
PING 52.215.51.128 (52.215.51.128): 56 data bytes
64 bytes from 52.215.51.128: icmp_seq=0 ttl=47 time=6.784 ms
64 bytes from 52.215.51.128: icmp_seq=1 ttl=47 time=6.740 ms
64 bytes from 52.215.51.128: icmp_seq=2 ttl=47 time=6.462 ms
64 bytes from 52.215.51.128: icmp_seq=3 ttl=47 time=6.840 ms
64 bytes from 52.215.51.128: icmp_seq=4 ttl=47 time=6.888 ms
64 bytes from 52.215.51.128: icmp_seq=5 ttl=47 time=6.831 ms
64 bytes from 52.215.51.128: icmp_seq=6 ttl=47 time=6.596 ms
64 bytes from 52.215.51.128: icmp_seq=7 ttl=47 time=7.016 ms
64 bytes from 52.215.51.128: icmp_seq=8 ttl=47 time=6.796 ms
64 bytes from 52.215.51.128: icmp_seq=9 ttl=47 time=6.673 ms
64 bytes from 52.215.51.128: icmp_seq=10 ttl=47 time=6.948 ms
64 bytes from 52.215.51.128: icmp_seq=11 ttl=47 time=6.592 ms
64 bytes from 52.215.51.128: icmp_seq=12 ttl=47 time=6.590 ms
64 bytes from 52.215.51.128: icmp_seq=13 ttl=47 time=6.639 ms
64 bytes from 52.215.51.128: icmp_seq=14 ttl=47 time=6.829 ms
64 bytes from 52.215.51.128: icmp_seq=15 ttl=47 time=6.871 ms
64 bytes from 52.215.51.128: icmp_seq=16 ttl=47 time=6.702 ms
64 bytes from 52.215.51.128: icmp_seq=17 ttl=47 time=6.796 ms
64 bytes from 52.215.51.128: icmp_seq=18 ttl=47 time=6.963 ms
64 bytes from 52.215.51.128: icmp_seq=19 ttl=47 time=6.711 ms
64 bytes from 52.215.51.128: icmp_seq=20 ttl=47 time=6.740 ms
64 bytes from 52.215.51.128: icmp_seq=21 ttl=47 time=6.936 ms
64 bytes from 52.215.51.128: icmp_seq=22 ttl=47 time=6.772 ms
64 bytes from 52.215.51.128: icmp_seq=23 ttl=47 time=6.511 ms
64 bytes from 52.215.51.128: icmp_seq=24 ttl=47 time=7.067 ms
64 bytes from 52.215.51.128: icmp_seq=25 ttl=47 time=6.591 ms
64 bytes from 52.215.51.128: icmp_seq=26 ttl=47 time=6.490 ms
```

[Info](#)[Netstat](#)[Ping](#)[Lookup](#)[Traceroute](#)[Whois](#)[Finger](#)[Port Scan](#)

Enter the network address to trace an internet route to.

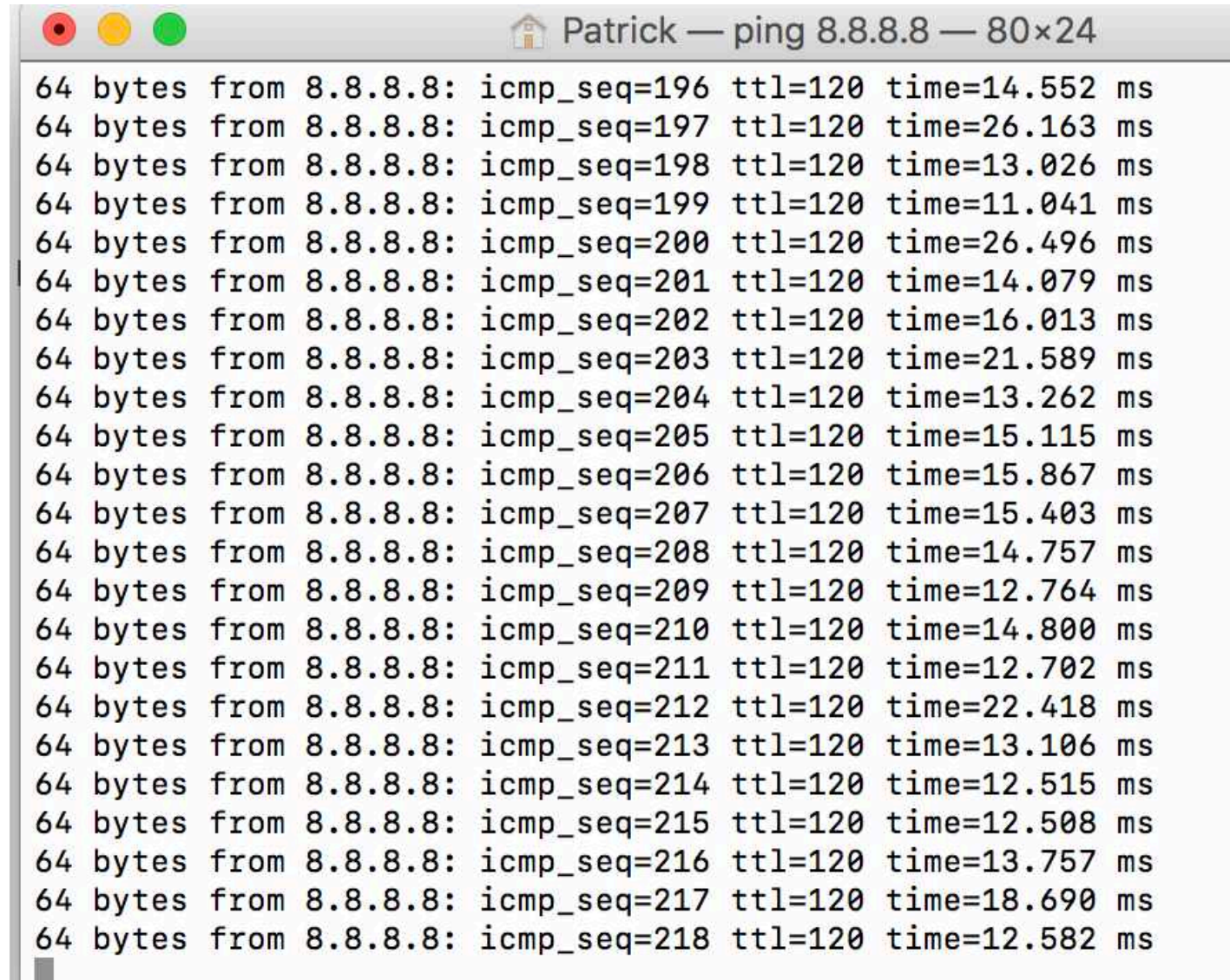
(ex. 10.0.2.1 or www.example.com)

[Trace](#)

Traceroute has started...

```
traceroute to 52.215.51.128 (52.215.51.128), 64 hops max, 72 byte packets
 1 192.168.1.254 (192.168.1.254)  0.877 ms  0.614 ms  0.436 ms
 2 95-45-164-1-dynamic.agg2.crl.cld-dbn.eircom.net (95.45.164.1)  5.514 ms  6.753
ms  8.895 ms
 3 eth-trunk106.hdist1.cld.core.eircom.net (83.174.184.174)  10.033 ms  5.985 ms
5.720 ms
 4 eth-trunk102.hcore1.bdt.core.eircom.net (83.174.185.28)  10.693 ms  6.908 ms
6.300 ms
 5 lag-50-br1-6cr-hcore1-bdt.br1.6cr.border.eircom.net (86.43.12.219)  5.931 ms
5.914 ms  5.768 ms
 6 99.82.177.98 (99.82.177.98)  5.542 ms  5.992 ms  6.322 ms
 7 52.93.100.237 (52.93.100.237)  7.052 ms  8.092 ms  6.419 ms
 8 150.222.195.1 (150.222.195.1)  5.674 ms  6.247 ms  7.116 ms
 9 * * *
10 * * *
11 * * *
12 * * *
13 * * *
14 * * *
15 * * *
16 * * *
17 * * *
18 * * *
19 ec2-52-215-51-128.eu-west-1.compute.amazonaws.com (52.215.51.128)  6.616 ms
6.395 ms  6.168 ms
```

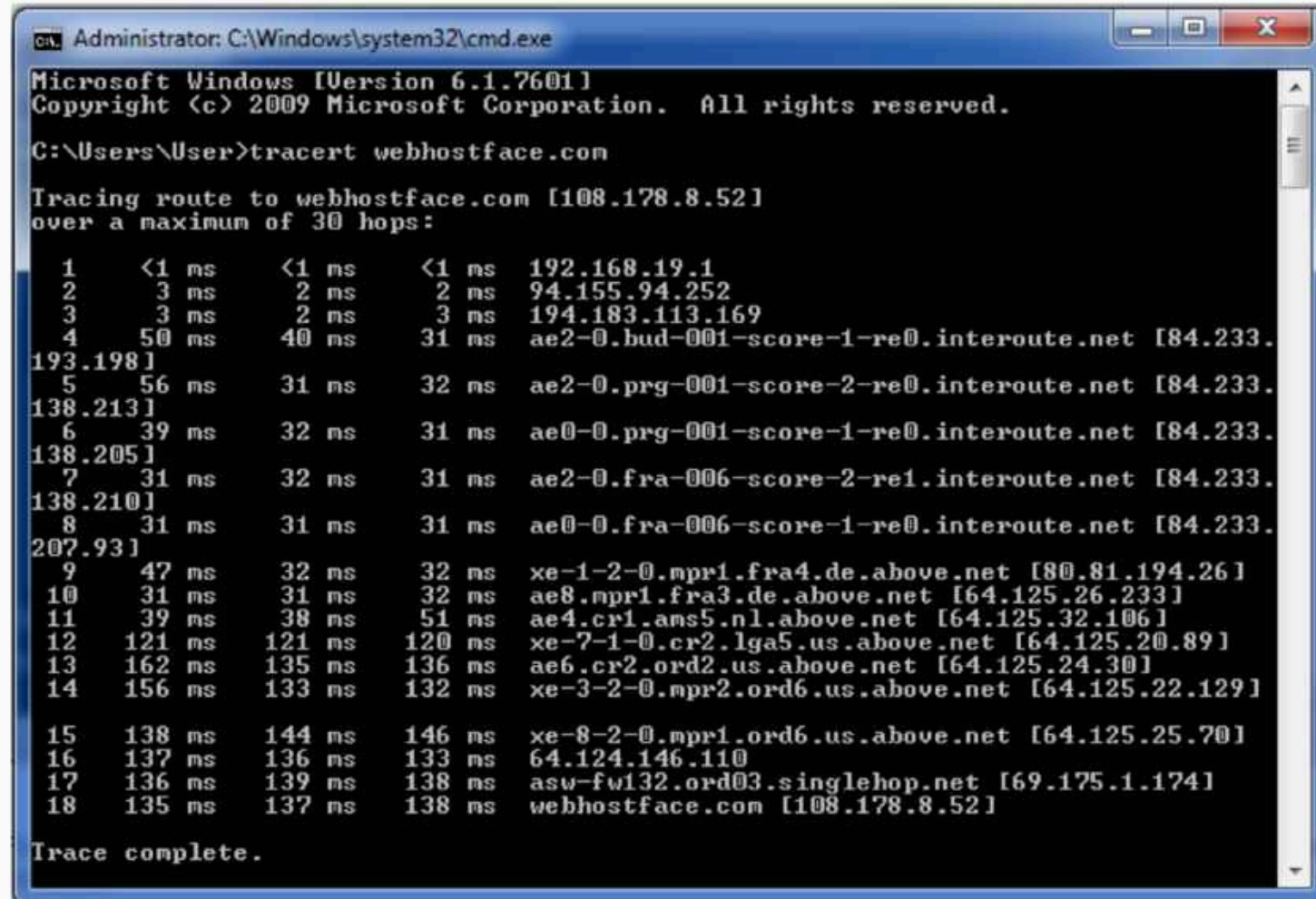
Wider ping time variation indicates a less satisfactory internet service and is the main cause of the audio flow being compromised



```
Patrick — ping 8.8.8.8 — 80x24
64 bytes from 8.8.8.8: icmp_seq=196 ttl=120 time=14.552 ms
64 bytes from 8.8.8.8: icmp_seq=197 ttl=120 time=26.163 ms
64 bytes from 8.8.8.8: icmp_seq=198 ttl=120 time=13.026 ms
64 bytes from 8.8.8.8: icmp_seq=199 ttl=120 time=11.041 ms
64 bytes from 8.8.8.8: icmp_seq=200 ttl=120 time=26.496 ms
64 bytes from 8.8.8.8: icmp_seq=201 ttl=120 time=14.079 ms
64 bytes from 8.8.8.8: icmp_seq=202 ttl=120 time=16.013 ms
64 bytes from 8.8.8.8: icmp_seq=203 ttl=120 time=21.589 ms
64 bytes from 8.8.8.8: icmp_seq=204 ttl=120 time=13.262 ms
64 bytes from 8.8.8.8: icmp_seq=205 ttl=120 time=15.115 ms
64 bytes from 8.8.8.8: icmp_seq=206 ttl=120 time=15.867 ms
64 bytes from 8.8.8.8: icmp_seq=207 ttl=120 time=15.403 ms
64 bytes from 8.8.8.8: icmp_seq=208 ttl=120 time=14.757 ms
64 bytes from 8.8.8.8: icmp_seq=209 ttl=120 time=12.764 ms
64 bytes from 8.8.8.8: icmp_seq=210 ttl=120 time=14.800 ms
64 bytes from 8.8.8.8: icmp_seq=211 ttl=120 time=12.702 ms
64 bytes from 8.8.8.8: icmp_seq=212 ttl=120 time=22.418 ms
64 bytes from 8.8.8.8: icmp_seq=213 ttl=120 time=13.106 ms
64 bytes from 8.8.8.8: icmp_seq=214 ttl=120 time=12.515 ms
64 bytes from 8.8.8.8: icmp_seq=215 ttl=120 time=12.508 ms
64 bytes from 8.8.8.8: icmp_seq=216 ttl=120 time=13.757 ms
64 bytes from 8.8.8.8: icmp_seq=217 ttl=120 time=18.690 ms
64 bytes from 8.8.8.8: icmp_seq=218 ttl=120 time=12.582 ms
```

Traceroute command in Windows

- In Windows, select **Start -> Programs -> Accessories -> Command Prompt** or write **cmd** in the **Search programs and files** field of your **Start** menu and select **cmd.exe**.
- Enter the word *tracert*, followed by a space, and then the domain name (i.e. *webhostface.com*)



```
Administrator: C:\Windows\system32\cmd.exe
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation. All rights reserved.

C:\Users\User>tracert webhostface.com

Tracing route to webhostface.com [108.178.8.52]
over a maximum of 30 hops:

  0  <1 ms    <1 ms    <1 ms    192.168.19.1
  1  3 ms     2 ms     2 ms     94.155.94.252
  2  3 ms     2 ms     3 ms     194.183.113.169
  3  50 ms    40 ms    31 ms    ae2-0.bud-001-score-1-re0.interroute.net [84.233.193.198]
  4  56 ms    31 ms    32 ms    ae2-0.prg-001-score-2-re0.interroute.net [84.233.138.213]
  5  39 ms    32 ms    31 ms    ae0-0.prg-001-score-1-re0.interroute.net [84.233.138.205]
  6  31 ms    32 ms    31 ms    ae2-0.fra-006-score-2-re1.interroute.net [84.233.138.210]
  7  31 ms    31 ms    31 ms    ae0-0.fra-006-score-1-re0.interroute.net [84.233.207.93]
  8  47 ms    32 ms    32 ms    xe-1-2-0.mpr1.fra4.de.above.net [80.81.194.26]
  9  31 ms    31 ms    32 ms    ae8.mpr1.fra3.de.above.net [64.125.26.233]
 10  39 ms    38 ms    51 ms    ae4.cr1.ams5.nl.above.net [64.125.32.106]
 11 121 ms   121 ms   120 ms   xe-7-1-0.cr2.lga5.us.above.net [64.125.20.89]
 12 162 ms   135 ms   136 ms   ae6.cr2.ord2.us.above.net [64.125.24.30]
 13 156 ms   133 ms   132 ms   xe-3-2-0.mpr2.ord6.us.above.net [64.125.22.129]
 14
 15 138 ms   144 ms   146 ms   xe-8-2-0.mpr1.ord6.us.above.net [64.125.25.70]
 16 137 ms   136 ms   133 ms   64.124.146.110
 17 136 ms   139 ms   138 ms   asw-fw132.ord03.singlehop.net [69.175.1.174]
 18 135 ms   137 ms   138 ms   webhostface.com [108.178.8.52]

Trace complete.
```

4. A set of *regular* headphones.

Blue tooth and wi-fi will increase the overall delay
Use headphones with a cable and single stereo jack

5. A quality instrument microphone

You have to tailor your investment to your circumstances



the t.bone Ovid
System CC 100

€49.00

Thomann IE

By BiddingLab



DPA d:vote Core
4099 Violin

€525.00

Thomann IE
Free delivery

By BiddingLab



Audio-Technica
Pro35 CW

€138.00

Thomann IE

By BiddingLab



Superlux PRA-
383D XLR

€59.00

Thomann IE

By BiddingLab



AKG C 411 PP

€122.00

Thomann IE

By BiddingLab



Audio-Technica
ATR4697

€35.00

Thomann IE

By BiddingLab



Shure WB98
H/C

€198.00

Thomann IE

By BiddingLab



Tie Studio
TCX200
Microphone fo...

€59.00

Gear4music.ie

By Productca...



the t.bone Ovid System CC 100

★★★★★ 1083 ratings



the t.bone Ovid System Violin Clip

★★★★☆ 295 ratings



€20.30

Including VAT; Excluding €15 shipping

Dispatch expected by **Thu, 03. September**

Available immediately

1

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[Add to wish list](#)

sales rank in this product group 10
at thomann.de 4762

item number 270436

sales unit 1 piece

available since April 2012

Total Rating ★★★★☆

quality ★★★★☆

Share This Product



6. An audio interface

Behringer U-Phoria UMC22

★★★★★ 685 ratings 🔥 158 Watching



€41

Including VAT; Excluding €15 shipping
Dispatch expected by **Thu, 03. September**

Available immediately

1 **Add to Basket**

[Add to wish list](#)

sales rank in this product group at thomann.de 4 257

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Total Rating ★★★★★
handling ★★★★★
features ★★★★★



Zoom Thunderbolt TAC-2R Audio Interface

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Extreme speed for extraordinary sound. TAC-2R Thunderbolt™ Audio Converter

The compact, rugged TAC-2R audio interface uses the latest Thunderbolt™ technology for blazingly fast speed, near zero latency and the ultimate in high-quality audio, up to 24-bit/192kHz. With its easy-to-use design and advanced converters, the TAC-2R is perfect for studio and field recording of mics and instruments, onstage playback, and pristine audio streaming. It can even serve as an ultra-stable MIDI interface.

Onstage

Take your performance to the next level. Use the TAC-2R onstage to get the best sound quality from your laptop. With its Thunderbolt speed, high quality converters, and rugged chassis, you can trust the TAC-2R to deliver superior audio night after night.



Internet Quality in relation to Sound Quality

Jitter is the variation in time between data packets from your computer arriving at their destination, caused by network congestion, or route changes.

measured is in ms

A **jitter buffer** is a temporary storage **buffer** used to capture incoming data packets. It is used to ensure the continuity of audio streams by smoothing out packet arrival times during periods of network congestion.

‘Crackling’ is due to lost packets. What we've done in choir to reduce this is to switch the auto-buffer off and manually increase it a bit from the auto-set setting.

O'Reilly (2020)

Latency vs. Audio

Reduce the jitter buffer size (latency) until dropouts become unacceptable, then increase the buffer size a little to account for network timing variation. Amsden (2020)

Musicianship

Treat the online rehearsal with the same level of preparation

Follow all 6 points for getting it to work *without* leaving anything out

Conduct a sound test well in advance of the rehearsal

Set all of the players balances for your listening – have a sound check

Cultivate the ability to maintain meter without a metronome

Train yourself to play slightly ahead of the tiny 30ms delay rather than with it

Work with the music score in sections initially to get a sense of which voice is leading or carrying the meter at any given time

Then try playing the entire work together from your part

Walk Through the Settings

The screenshot shows a 'Settings' window with three main sections: Soundcard, Jitter Buffer, and Misc. The Soundcard section has a dropdown menu for 'Device' set to 'System Default In/Out Device' and a checkbox for 'Enable Small Network Buffers' which is unchecked. Below it, a 'Buffer Delay' section has three radio buttons: '2.67 ms (64)', '5.33 ms (128, preferred)' (which is selected), and '10.67 ms (256)'. The Jitter Buffer section has a checked 'Auto' checkbox and two vertical sliders for 'Local Size: 4' and 'Server Size: 9'. The Misc section contains several settings: 'Audio Channels' (Mono), 'Audio Quality' (Normal), 'New Client Level' (100%), 'Fancy Skin' (unchecked), 'Display Channel Levels' (checked), 'Central Server Address' (Default), and a 'Central Server' text field. At the bottom, a status bar shows 'Audio Stream Rate' (366 kbps), 'Ping Time' (7 ms), and 'Overall Delay' (43 ms) with a green indicator light.

Soundcard

Device
System Default In/Out Device

Enable Small Network Buffers

Buffer Delay

- 2.67 ms (64)
- 5.33 ms (128, preferred)
- 10.67 ms (256)

Jitter Buffer

Auto

Local Server
Size: 4 Size: 9

Misc

Audio Channels Mono

Audio Quality Normal

New Client Level 100 %

Fancy Skin Display Channel Levels

Central Server Address: Default

Central Server

Audio Stream Rate 366 kbps

Ping Time 7 ms

Overall Delay 43 ms

Checklist

Everyone joining the rehearsal must adhere to 6 basic criteria and test their settings beforehand, otherwise it doesn't work for all of the players

- 1. Jamulus software downloaded and installed.**
- 2. Ethernet connection plugged directly to your computer**
- 3. A good internet connection - (>500kb upload/download speed) (<40ms ping average round trip) don't confuse it with jitter issues**
- 4. A set of regular headphones with cable.**
- 5. A quality instrument microphone ideally attached to the instrument**
- 6. An audio interface**

Things to observe when running the test

Switch off other applications on your computer

Connect to a public server with lowest ms latency at the top of your connect options

Run the test beforehand by listening to and tweaking your own return sound.

Large variations in ping time, predicts a poor quality sound experience more so than your internet speed

Look for exclusive use of internet during rehearsal to avoid demands on data flow and processing power

Power saving options on the computer should be disabled

Keep your overall delay to less than 50 ms

Obtain private server address from session organisers for rehearsal

Fine Tuning in **Settings Window**

Write Name and instrument into your profile ----Top left – View - My Profile

Set Device to interface that you are using for both in/out in dropdown menu

Set Preferred buffer delay to 5.33ms

Tweak jitter buffer settings to obtain best sound quality vs. latency

Set Audio Channels to Mono in/Stereo-out

Set Audio Quality to High

Click ON Display Channel Levels

Set new client level in settings to 0 to minimise latecomer distractions

Set Central Server Address to Default

Observe Ping time for large jumps (this will indicate a ruffled or crackly sound that might need to be addressed see traceroute)

Keep overall delay to below 50ms

Questions and Discussion

Windows

Audio Stream Input/Output (**ASIO**) is a computer sound card driver protocol for digital audio providing a low-latency and high fidelity interface between a software application and a computer's sound card - needed to get Jamulus to work on Windows

ASIOFORALL

<https://www.sweetwater.com/sweetcare/articles/installing-and-using-asio4all-for-windows/>

FT+N)

How to change internal microphone volume in Windows 10

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjFudSi1_fpAhUHSxUIHTrgBYAQwqsBMAB6BAgKEAQ&url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DmmunTzfs5gY&usg=AOvVaw1dJUDEAIJ9dpWhAQII6jdS

How to setup a Jamulus Server

What is the server for?

This is the service that will allow you and your musician friends to participate in your own Jamulus session.

Where does the server run?

It runs on an Amazon machine , so you don't' have to be concerned with its maintenance. It can be running all the time so you or anyone from your group can setup a session at any time. I am suggesting the Amazon service simply because it is inexpensive and there is a an excellent guide available on Facebook for you to follow.

How do I set it up?

Here is the link for the guide:

<https://www.facebook.com/notes/jamulus-online-musicianssingers-jamming/howto-idiots-guide-to-installing-jamulus-server-on-amazon-aws-lightsail-ubuntu-i/507719749802976/>

Note that each step must be followed exactly as is in the guide. The guide has screenshots at each

Jamulus Choral Festival

<https://youtu.be/m811fZiPyaQ?t=572>