Our Smart Hubs

How we substantiate our marketing claims

Contents

1. Introduction

Our Smart Hubs provide better wi-fi coverage than routers provided by all other major broadband providers. And we can prove it.

We explain in this report how we tested the hubs to prove our claim that they provide the best 'performance at range' wi-fi coverage.

We used the IEEE802.11T method to make sure our data was reliable and that the results were repeatable.

Before you go any further, you need to know that:

- Although all of the routers we tested were dual band (2.4GHz and 5GHz), our claim focuses on 2.4GHz because this gives the best coverage.

- We tested the routers by connecting devices that our customers typically use. And we used the same devices and locations when we were putting our competitors' routers through their paces too.

- The tests recorded speeds for normal customer activities.

- To make sure we tested the reach of the routers in all directions, regardless of which direction they were pointing in, we used turntables to revolve them.

- We captured hundreds of data points to make sure the results were repeatable and reliable.

2. How we tested wi-fi

2.1. Devices under test

We tested the wi-fi on all of the major ISP's (Internet Service Provider) routers.

The routers we tested

ISP	Router	Wi-fi capabilities
BT	Smart Hub 2	3x3 11n + 4x4 11ac
BT	Smart Hub	3x3 11n + 4x4 11ac
TalkTalk	TalkTalk Wi-Fi Hub	3x3 11n + 4x4 11ac
EE	EE SmartHub	3x3 11n + 4x4 11ac
Virgin Media	Super Hub 3	2x2 11n + 3x3 11ac
Virgin Media	Super Hub 2AC	2x2 11n + 3x3 11ac
SKY	SKY Q	2x2 11n + 3x3 11ac
Plusnet	Plusnet ONE	2x2 11n + 3x3 11ac

2.2. What we measured

To find the best wi-fi 'performance at range' compared to the competitors listed above, we measured the Transmission Control Protocol over IP (TCP/IP) throughput. This is the amount of data transferred successfully from the wi-fi device to the Local Area Network (LAN) interface in a given time period. We measured it in megabits per second (Mbps).

TCP/IP throughput is the most meaningful 'real-world' wi-fi performance measure. It determines your experience when you're using applications. If it's too slow, you'll have problems doing things like browsing online, downloading files, and transferring data around an office environment.

2.3. How we did the tests

We used 'Over-the-Air' (OTA) testing because we believe it's the best, most representative way of testing wi-fi performance:

- It captures how customers experience wi-fi in the home

- It takes the wi-fi antennas into account (patterns, polarisation, isolation, and position).

- The test uses typical customer devices.

- It's a fair and consistent way to compare different Access Point router hardware.

- It reflects how our customers experience wi-fi.

We tested the routers in an interference-free environment (except when controlled levels of interference formed part of the tests, of course).

And, as you'll see from the following test results, we tested devices on both 2.4GHz and 5GHz at a range of distances from the router.

2.4. The test devices we used

We tested two typical devices that customers use at home:

- MacBook Pro with three antennas - typical 3x3 Multiple-Input and Multiple-Output (MIMO) laptop.

- Samsung Galaxy S8 with two antennas - typical 2x2 MIMO smartphone.

Both of these devices are dual-band.

2.5. Where we did the tests

We ran the tests at our wi-fi test house, a remote rural test facility 800m from any other buildings.

It's a large brick house with rooms that exhibit similar signal strength attenuation (as a device moves away from the router) as you'd see in a typical customer premises. The building is clear of radio frequency (RF) interference, and well out of range of any other wi-fi networks.

We test the wi-fi performance at four points in the house to establish how it performs at different distances.

Diagram of the test house – section view
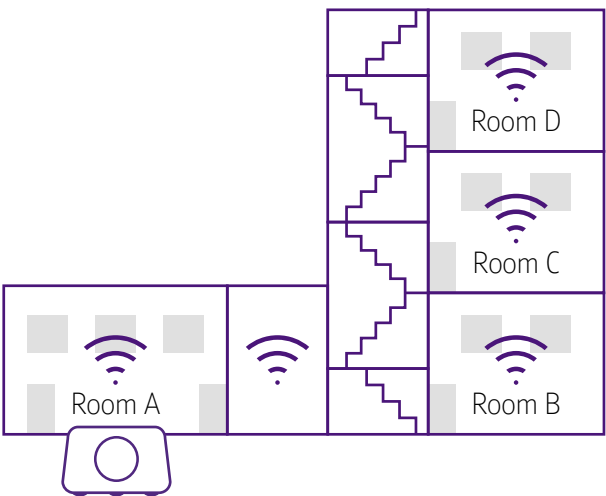
Moving the smartphone and laptop away from the router

Test points in the house

| Test point location	Location of smartphone or laptop
Room A	In the same rooms as the router
Room B	On the same level as the router
Room C	One level up from the router
Room D	Two levels up; edge of coverage for 2.4GHz

2.6. Test set-up

We put each router on a turntable and connected them to our server.

We also placed the test devices (the laptop and smartphone) on a turntable in each of the test rooms as we progressed through each individual test. The test device connected to the router using wi-fi.

During the test, we set the turntables at rotation speeds that made sure each second represented a unique combination of angles for the router and device. For each test, we rotated the turntables and recorded the TCP IP upload and download throughput every second for a total of 480 seconds, repeated three times.

To control the tests and capture data we used an application called iperf.V3.

Diagram of the test set-up
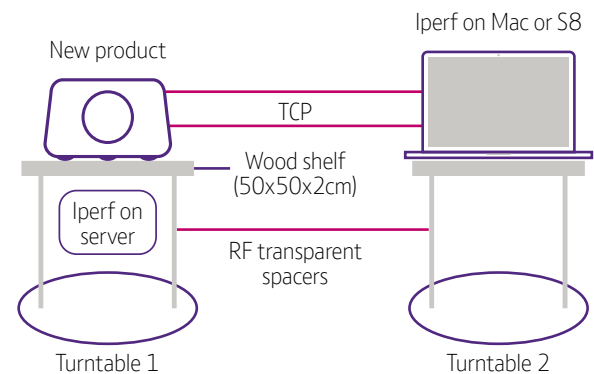
3. Results: Coverage tests

3.1.   Over-the-Air 2.4GHz coverage results

We conducted these tests without interference.

2.4GHz MacBook Pro download test

All speeds are in Mbps.

Router	Room A	Room B	Room C	Room D
BT Smart Hub 2	156	147.2	108.67	6.18
BT Smart Hub	162.50	144.67	91.57	6.95
TalkTalk	157.60	138.20	89.70	1.80
EE Smart Hub	139.17	131.67	71.45	0.82
Virgin Media Super Hub 3	104.83	97.53	55.18	0.27
Virgin Media Super Hub 2AC	111.50	111.17	73.32	1.29
SKY Q	95.96	91.80	21.65	1.13
Plusnet ONE	99.72	97.23	36.23	0.07
Best of other ISPs	157.60	138.20	89.70	1.80
BT Smart Hub as % of best of other ISPs	103%	105%	102%	386%
BT Smart Hub 2 as % of best of other ISPs	99%	107%	121%	343%

At the edge of wi-fi coverage (Room D), the Smart Hub (386%) and Smart Hub 2 (343%) are stronger than the best of the other ISPs. Our performance is significantly better than the other ISPs for the medium range tests, and we're on a par with the best of other ISPs for tests in the same room.

As you'll see later, our performance in the equivalent same-room test for 5GHz is an impressive 749Mbps (Smart Hub 2) and 733.67Mbps (Smart Hub), comfortably beating every other ISP in the comparison.

2.4GHz Samsung S8 download test

All speeds are in Mbps.

Router	Room A	Room B	Room C	Room D
BT Smart Hub 2	146.17	129.4	65.35	5.23
BT Smart Hub	134.50	116.50	46.47	3.51
TalkTalk	112.60	93.28	40.30	3.21
EE Smart Hub	139.17	117.00	46.35	0.00
Virgin Media Super Hub 3	105.83	86.15	27.32	1.73
Virgin Media Super Hub 2AC	110.33	91.98	31.77	0.00
SKY Q	92.90	58.48	14.55	0.11
Plusnet ONE	96.55	68.63	19.57	0.10
Best of other ISPs	139.17	117.00	46.35	3.21
BT Smart Hub as % of best of other ISPs	97%	100%	100%	109%
BT Smart Hub 2 as % of best of other ISPs	105%	111%	141%	163%

The test results with the S8 at 2.4GHz show the BT Smart Hub 2 is the superior device at all distances with BT Smart Hub marginally superior to all other ISPs.

2.4GHz MacBook Pro upload test

All speeds are in Mbps.

Router	Room A	Room B	Room C	Room D
BT Smart Hub 2	156.5	120.67	46.22	2. 70
BT Smart Hub	167.17	122.00	49.35	2.10
TalkTalk	159.2	119.80	47.58	0.88
EE Smart Hub	177.50	96.42	28.33	0.25
Virgin Media Super Hub 3	110.83	45.20	13.95	0.03
Virgin Media Super Hub 2AC	102.80	71.58	23.57	0.30
SKY Q	106.20	62.46	14.18	0.49
Plusnet ONE	95.62	56.77	16.08	0.05
Best of other ISPs	177.50	119.80	47.58	0.88
BT Smart Hub as % of best of other ISPs	94%	102%	104%	239%
BT Smart Hub 2 as % of best of other ISPs	88%	101%	97%	307%

The BT Smart Hubs are significantly better on the furthest distance although EE and TalkTalk perform well on the shorter links.

2.4GHz Samsung S8 upload test

All speeds are in Mbps.

Router	Room A	Room B	Room C	Room D
BT Smart Hub 2	125.33	93.35	33	2.19
BT Smart Hub	132.67	99.07	34.40	3.39
TalkTalk	112.40	106.80	34.97	1.85
EE Smart Hub	147.50	94.83	12.30	0.00
Virgin Media Super Hub 3	108.75	46.27	7.16	0.06
Virgin Media Super Hub 2AC	107.67	74.77	15.60	0.00
SKY Q	105.00	66.35	13.95	0.00
Plusnet ONE	103.60	53.96	9.98	0.03
Best of other ISPs	147.50	106.80	34.97	1.85
BT Smart Hub as % of best of other ISPs	90%	93%	98%	183%
BT Smart Hub 2 as % of best of other ISPs	85%	87%	94%	118%

The BT Smart Hubs are the best performers on the furthest distance, with EE and TalkTalk showing well on the shorter links.

3.2. Over-the-Air 5GHz coverage results

5GHz MacBook Pro download test

All speeds are in Mbps.

Router	Room A	Room B
BT Smart Hub 2	749.67	336
BT Smart Hub	733.67	316.33
TalkTalk	711.67	302.00
EE Smart Hub	593.33	243.33
Virgin Media Super Hub 3	366.33	175.00
Virgin Media Super Hub 2AC	378.67	186.67
SKY Q	484.00	171.67
Plusnet	456.2	207.6
Best of other ISPs	711.67	302.00
BT Smart Hub as % of best of other ISPs	103%	105%
BT Smart Hub 2 as % of best of other ISPs	105%	111%

The BT Smart Hubs are the best performing routers with all 5GHz MacBook Pro download tests.

5GHz Samsung S8 download test

All speeds are in Mbps.

Router	Room A	Room B
BT Smart Hub 2	604.67	288.25
BT Smart Hub	580.00	202.00
TalkTalk	558.00	163.33
EE Smart Hub	574.67	172.33
Virgin Media Super Hub 3	280.67	81.37
Virgin Media Super Hub 2AC	279.33	112.00
SKY Q	453.00	92.21
Plusnet ONE	466.6	125
Best of other ISPs	574.67	172.33
BT Smart Hub as % of best of other ISPs	101%	117%
BT Smart Hub 2 as % of best of other ISPs	105%	167%

The BT Smart Hubs are the best performing routers with all 5GHz Samsung S8 download tests.

5GHz MacBook Pro upload test

All speeds are in Mbps.

Router	Room A	Room B
BT Smart Hub 2	817	220.33
BT Smart Hub	805.67	214.00
TalkTalk	799.67	223.33
EE Smart Hub	679.67	114.00
Virgin Media Super Hub 3	360.33	96.30
Virgin Media Super Hub 2AC	417.00	91.03
SKY Q	372.67	127.22
Plusnet ONE	481.8	102
Best of other ISPs	799.67	223.33
BT Smart Hub as % of best of other ISPs	101%	96%
BT Smart Hub 2 as % of best of other ISPs	102%	99%

The BT Smart Hubs and TalkTalk routers are very close with the 5GHz MacBook Pro upload tests.

5GHz Samsung S8 upload test

All speeds are in Mbps.

Router	Room A	Room B
BT Smart Hub 2	536.33	156.75
BT Smart Hub	580.00	164.00
TalkTalk	556.00	154.33
EE Smart Hub	498.67	83.53
Virgin Media Super Hub 3	294.33	78.27
Virgin Media Super Hub 2AC	304.67	86.87
SKY Q	298.70	122.30
Plusnet ONE	379.8	74.65
Best of other ISPs	556.00	154.33
BT Smart Hub as % of best of other ISPs	104%	106%
BT Smart Hub 2 as % of best of other ISPs	96%	102%

The BT Smart Hubs and TalkTalk routers are very close with the 5GHz Samsung S8 upload tests.

4. Coverage testing with interference

Clean environment tests are all very well but, as the Advertising Standards Authority highlighted (in their review of our previous claim in April 2018), to claim that we have the 'UK's most powerful wi-fi signal' we need to prove that our signal is the best at a distance. And in the real world, that means our wi-fi needs to hold up in the face of high levels of interference.

So we ran the medium and long distance tests again on the 2.4GHz band, using the same Over-the-Air test method.

But for these tests we added all of these types of interference at the same time:

- Neighbouring Wi-fi networks.

- Wi-fi co-channel interference (high usage on the same channel).

- Wi-fi adjacent channel interference (high usage on the adjacent channel).

- Bluetooth (frequency-hopping spread spectrum).

Neighbouring wi-fi networks

We set up seven other wi-fi networks in our test house.

To create a realistic scenario, we kept the networks one or two walls away from the router we were testing.

We set the device under test to Channel 6 and did the same for one other network (Co-Channel-Ch6), creating co-channel interference. Both Channels 1 and 11 had three other networks running on them.

We then put all of the routers under test to see how they coped with in a heavy interference situation.

The neighbouring wi-fi networks

Wi-fi network (SSID)	Channel	Notes
Adjacent-Channel-Ch1	1	Adjacent Channel Interference (ACI) loaded with high activity
BTHub4-HNPW-Ch1	1	
SKY13136-Ch1	1	Sky SR101
Device under test	6	
Co-Channel-Ch6	6	Co-channel interference – loaded with high activity
BTHub6-MWRQ-Ch11	11	
BTHub5-QNPK-Ch11	11	
BTHub3-HJGJ-Ch11	11	

Graph of wi-fi networks

10
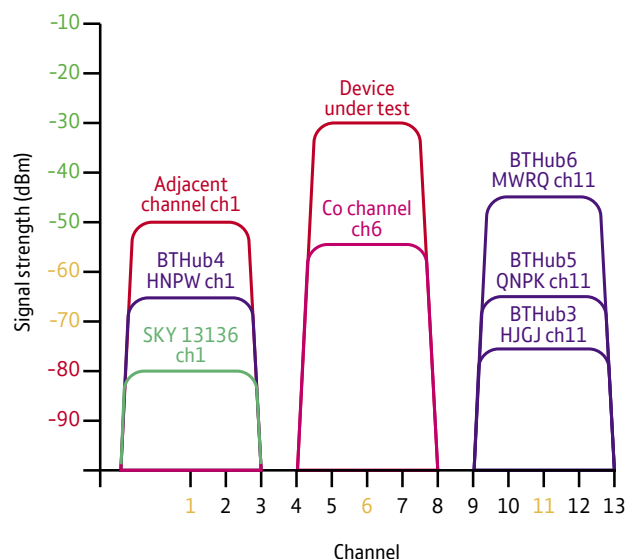
Wi-fi co-channel interference

We created wi-fi co-channel interference by connecting a MacBook Pro to the SSID Co-Channel-Ch6. This created controlled levels of wi-fi traffic on the same channel using iperf3, with TCP download at 35Mbps.

Wi-fi adjacent channel interference

Using a smartphone connected to the SSID Adjacent-Channel-Ch1 we created adjacent channel interference. This created controlled levels of wi-Fi traffic on Channel 1 using iperf3, with TCP upload at 30Mbps.

Bluetooth frequency-hopping spread spectrum

We also used Bluetooth audio streaming at 2.4GHz continuously for the duration of the testing.

Measuring the interference

To accurately measure the interference levels across the 2.4GHz band, we used an AirMagnet SpectrumXT spectrum analyser. This identifies both wi-fi and none- wi-fi interference.

Screen shot of AirMagnet SpectrumXT
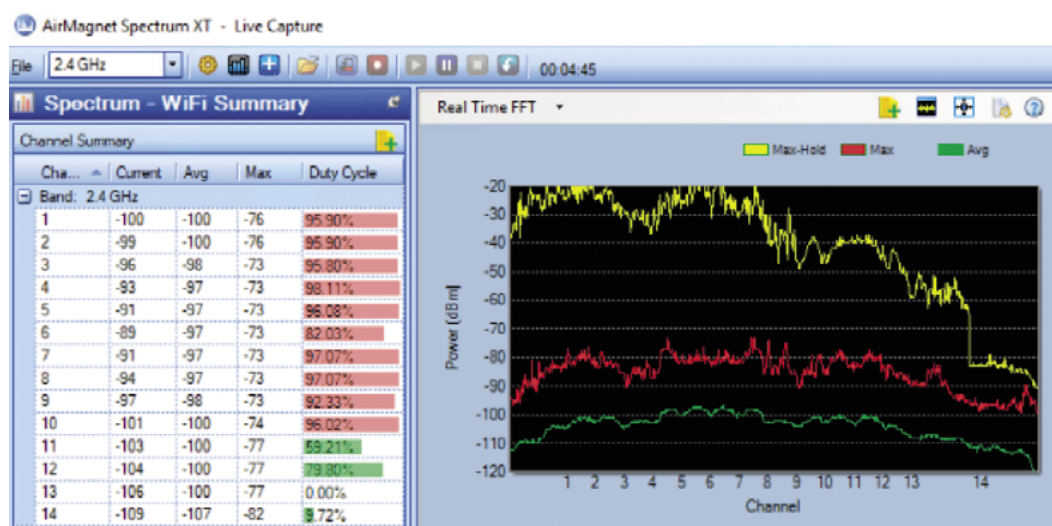
Channels 1, 6 and overlapping channels have a high air time utilisation (duty cycle). The FFT (Fast Fourier Transform) graph shows the interference levels across the band.

MacBook Pro download test with interference

All speeds are in Mbps.

Router	Room C	Room D
BT Smart Hub 2	81.94	3.58
BT Smart Hub	84.21	4.12
TalkTalk	79.74	3.11
EE Smart Hub	56.80	0.00
Virgin Media Super Hub 3	37.74	0.14
Virgin Media Super Hub 2AC	48.42	0.09
SKY Q	15.78	0.02
Plusnet ONE	24.82	0.04
Best of other ISPs	79.74	3.11
BT Smart Hub as % of best of other ISPs	106%	132%
BT Smart Hub 2 as % of best of other ISPs	103%	115%

MacBook Pro upload test with interference

All speeds are in Mbps.

Router	Room C	Room D
BT Smart Hub 2	38.91	1.77
BT Smart Hub	39.58	1.32
TalkTalk	37.13	1.12
EE Smart Hub	19.60	0.00
Virgin Media Super Hub 3	11.01	0.00
Virgin Media Super Hub 2AC	18.21	0.00
SKY Q	11.85	0.00
Plusnet ONE	0.54	0.00
Best of other ISPs	37.13	1.12
BT Smart Hub as % of best of other ISPs	107%	118%
BT Smart Hub 2 as % of best of other ISPs	105%	158%

Samsung S8 download test with interference

All speeds are in Mbps.

Router	Room C	Room D
BT Smart Hub 2	48.10	3.66
BT Smart Hub	41.42	2.63
TalkTalk	33.95	2.39
EE Smart Hub	32.13	0.00
Virgin Media Super Hub 3	2.60	0.00
Virgin Media Super Hub 2AC	14.76	0.00
SKY Q	7.18	0.00
Plusnet ONE	5.22	0.23
Best of other ISPs	33.95	2.39
BT Smart Hub as % of best of other ISPs	112%	110%
BT Smart Hub 2 as % of best of other ISPs	142%	153%

Samsung S8 upload test with interference

All speeds are in Mbps.

Router	Room C	Room D
BT Smart Hub 2	26.86	1.62
BT Smart Hub	28.26	1.91
TalkTalk	20.03	1.06
EE Smart Hub	11.10	0.00
Virgin Media Super Hub 3	3.15	0.00
Virgin Media Super Hub 2AC	3.56	0.04
SKY Q	6.87	0.00
Plusnet ONE	1.73	0.06
Best of other ISPs	20.03	1.06
BT Smart Hub as % of best of other ISPs	141%	180%
BT Smart Hub 2 as % of best of other ISPs	134%	153%

5. Conclusions

We've shown that overall, our Smart Hub and Smart Hub 2 consistently deliver the best performance at range compared to the hubs provided by major broadband providers.

2.4GHz summary results without interference (Smart Hub)

Test	Room A	Room B	Room C	Room D
Download MacBook Pro	103%	105%	102%	386%
Download Samsung S8	97% (EE)	100% (EE)	100%	109%
Upload MacBook Pro	94% (EE)	102%	104%	239%
Upload Samsung S8	90% (EE)	93% (TT)	98% (TT)	183%

TT = TalkTalk Wi-Fi Hub; EE = EE SmartHub

The BT Smart Hub is always better performing at the edge of coverage (Room D) than all other providers. For the short links (Rooms A and B), 5GHz performs better than 2.4GHz.

2.4GHz summary results without interference (Smart Hub 2)

Test	Room A	Room B	Room C	Room D
Download MacBook Pro	99% (TT)	107%	121%	343%
Download Samsung S8	105%	111%	141%	163%
Upload MacBook Pro	88% (EE)	101%	97% (TT)	307%
Upload Samsung S8	85% (EE)	87% (TT)	94% (TT)	118%

TT = TalkTalk Wi-Fi Hub; EE = EE SmartHub

The BT Smart Hub 2 is always the best performing at the edge of coverage (Room D). For the short links (Rooms A and B), 5GHz performs better than 2.4GHz.

The BT Smart Hub 2 is better for most 5GHz tests.

5GHz summary results without interference (Smart Hub)

Test	Room A	Room B
Download MacBook Pro	103%	105%
Download Samsung S8	101%	117%
Upload MacBook Pro	101%	96% (TT)
Upload Samsung S8	104%	106%

For the majority of 5GHz tests, BT Smart Hub outperforms the competitors.

5GHz summary results without interference (Smart Hub 2)

Test	Room A	Room B
Download MacBook Pro	105%	111%
Download Samsung S8	105%	167%
Upload MacBook Pro	102%	99% (TT)
Upload Samsung S8	96% (TT)	102%

For the majority of 5GHz tests, BT Smart Hub 2 outperforms the competitors.

Summary results with interference (Smart Hub)

Test	Room A	Room B
Download MacBook Pro	106%	132%
Download Samsung S8	122%	110%
Upload MacBook Pro	107%	118%
Upload Samsung S8	141%	180%

Summary results with interference (Smart Hub 2)

Test	Room A	Room B
Download MacBook Pro	103%	115%
Download Samsung S8	142%	153%
Upload MacBook Pro	105%	158%
Upload Samsung S8	134%	153%

The BT Smart Hub 2 is always the best performing router on longer (Room C and D) 2.4GHz tests. We didn't test for Rooms A and B.

BT