Central London Mobile Network Quality of User Experience

Prepared by

AWTG

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Advance Wireless Technology Group

Origins

- ✓ Started in 2006, AWTG has been providing high end value added services to the telecommunications industry for over 10 years
- ✓ Established by a collective of leading telecommunications professionals and academics with the aim of delivering high value added, full turnkey services to the industry.

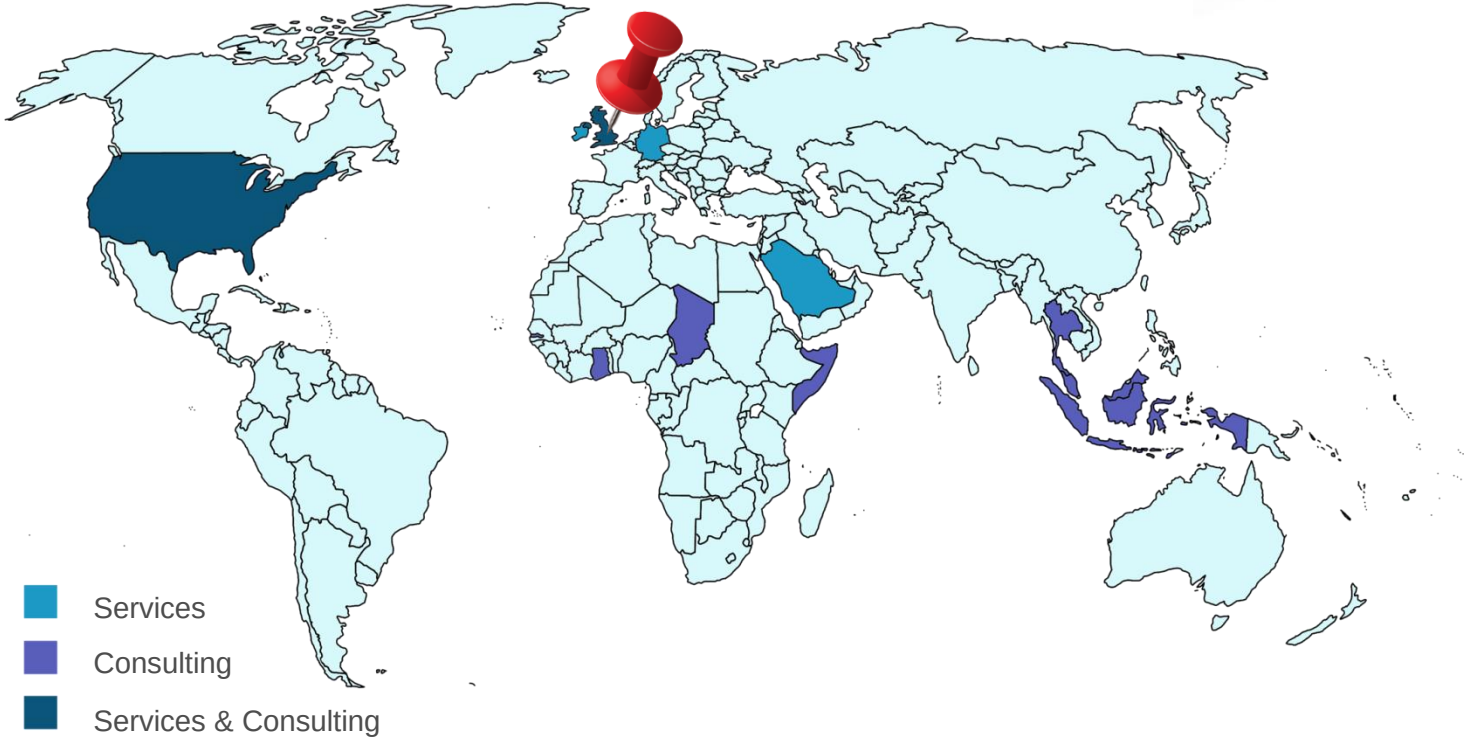
Mission and Strategy

- ✓ Delivery of cost-effective telecommunications solutions and services across global markets.
- ✓ To be the best-in-class supplier of telecommunications services to operators, vendors, government bodies and regulatory authorities.
- ✓ Drive service delivery benefits through innovation, best practices and cutting-edge technology integration

AWTG
Advanced Wireless Technology Group

Accredited to ISO 9001

Our areas of operation and our customers



AWTG offers services to Network Operators, Service Providers, Manufacturers & Government bodies

AWTG Service Proposition

	Cellular Networks – MNOs and Equipment Vendors	Small Cell Networks	Government Bodies and Regulators	Local Councils and Private Enterprises	Advisory Services
Service Positioning	Cost-effective value-driven partner in delivering network services leveraging partnerships and expertise	A leader in developing small cell solutions	An independent services and advisory partner	Vendor agnostic technology expert to help deliver the solutions to meet your needs	Independent technology expert to help deliver the solutions to meet your needs
Activities	• Planning and deployment of cellular sites • Network optimization • Network maintenance and field services • Core and transmission networks	• Design and deployment of Small Cell networks • Network operations and maintenance • Equipment benchmarking	• Network benchmarking • Service performance • user experience benchmarking	• Service creation, design and delivery • Public access wireless networks • Management platforms and service management	• Thought leadership – IOT/ M2M etc. • Technology strategy advisory • Business plan creation • Programme management
Clients	STC, Alcatel-Lucent, nsn, Vodafone, du	Alcatel-Lucent, Cisco, O2, Vodafone, NHS	Ofcom, TRA Telecommunications Regulatory Authority, Commission for Communications Regulation	City of Westminster, The Royal Borough of Kingston upon Thames, Barnsley Metropolitan Borough Council	King's College founded 1969, du, Vodafone, University of Surrey

Deployment Case Study- UoS

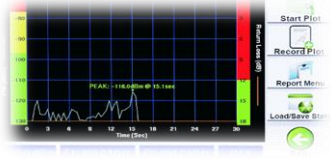
- ✓ AWTG provided the FULL TURNKEY deployment to develop the first-of-its-kind 5G/IoT test bed with the University of Surrey in the UK
  - ✓ **Design**
  - ✓ **Civil works**
  - ✓ **Fibre ring**
  - ✓ **Acceptance**

- ✓ The test bed is designed to help develop and define the new 5G standards that will be required for the provision of future innovative services such as Machine to Machine (M2M), Internet of Things (IoT), Small cells and on how future heterogeneous cell networks operate in an urban environment.

Network Testing, Benchmarking & Maintenance Services

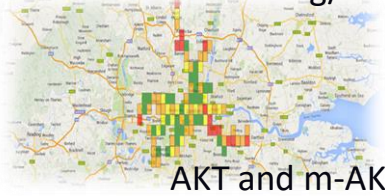
AWTG provide a number of operations and maintenance solutions to enable our clients to maintain advanced networks profitably and efficiently.

- ✓ **Services**
  - Service benchmarking and testing
  - PIM and interference testing
  - Network auditing
- ✓ **Experience**
  - ComReg Bi-Annual Benchmarking 2015-2017
  - Gamma UK country wide benchmark
  - Optimization and Field Services
  - PIM, CW Testing for deployment for STC
  - QoE and QoS testing



PIM/ Interference Testing

Drive Testing/ Walk Testing



AKT and m-AKT solutions

Methodology

Test Location

The walk test was performed in the heart of central London covering the perimeter and roads between the following four subway stations:

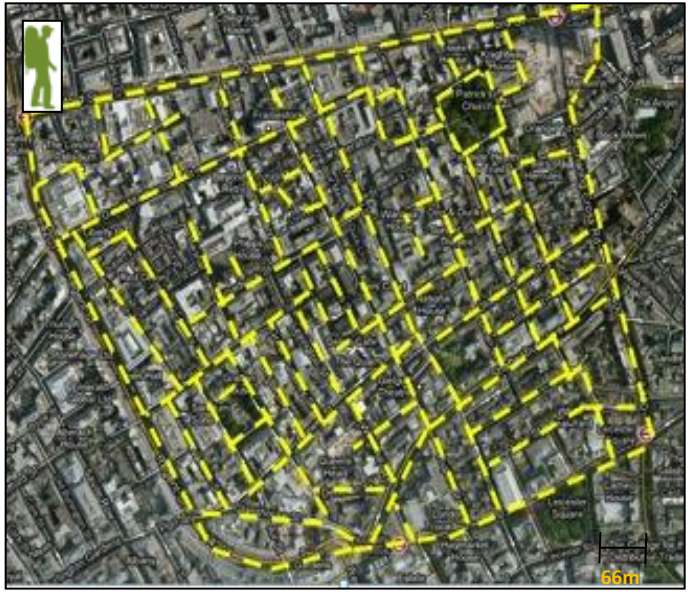
- Oxford Circus
- Tottenham Court Road
- Leicester Square
- Piccadilly

The selected area has high footfall with a clutter of high-rise buildings.

Network operators need to ensure that this type of terrain does not affect the quality of service they provide

Test Route

10-12km (approximately) of pedestrian outdoor walk testing to collect RF coverage samples as well as voice and data performance samples of each operator.



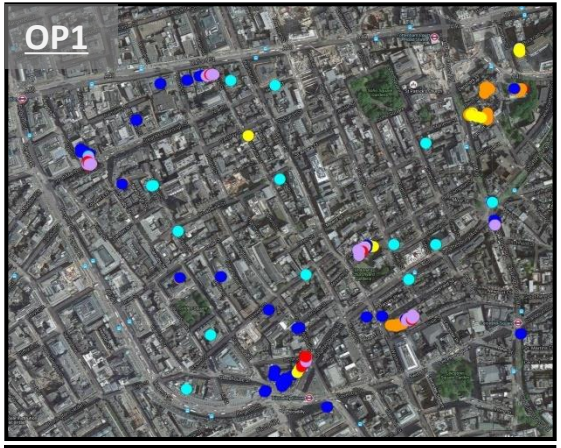
Test Script

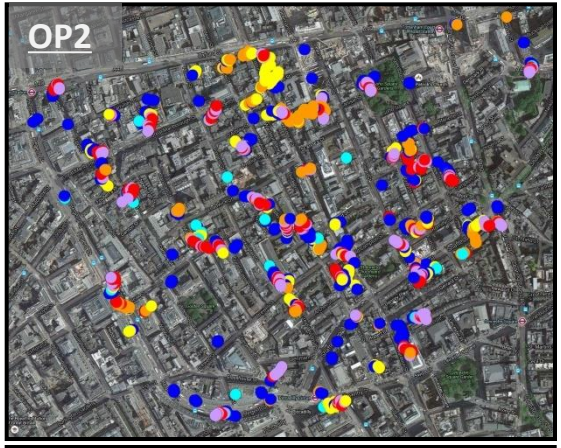
The combined voice and data test script below was used to conduct the walk test.

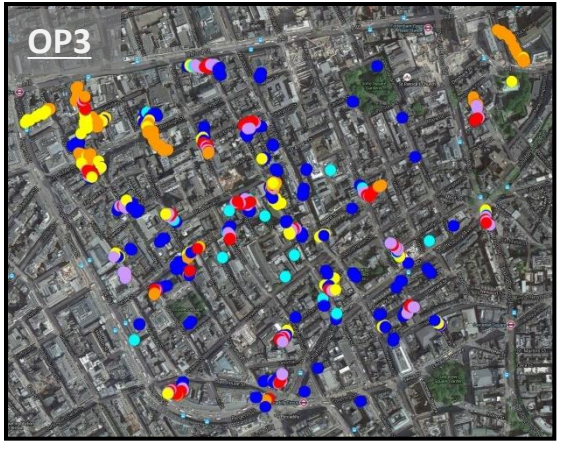
TEST	TIME (sec)
Short call	40
Long call	120
Script synchronisation	
Ping: bbc.co.uk	5
Web Browsing: bbc.co.uk	10
Ping: msn.com	5
Web Browsing: msn.com	10
Script synchronisation	
FTP DL 5MB	10
FTP UL 1MB	10
Script synchronisation	
Ping: yahoo.com	5
Web Browsing: yahoo.com	10
Ping: google.com	5
Web Browsing: google.com	10
FTP DL 5MB	10
FTP UL 1 MB	10
Script synchronisation	
YouTube streaming	60
Wait	10

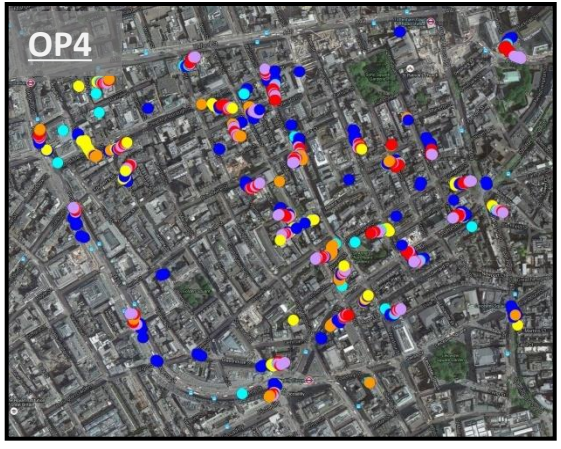
Quality of User Experience(1 of 7)

FTP Download Throughput







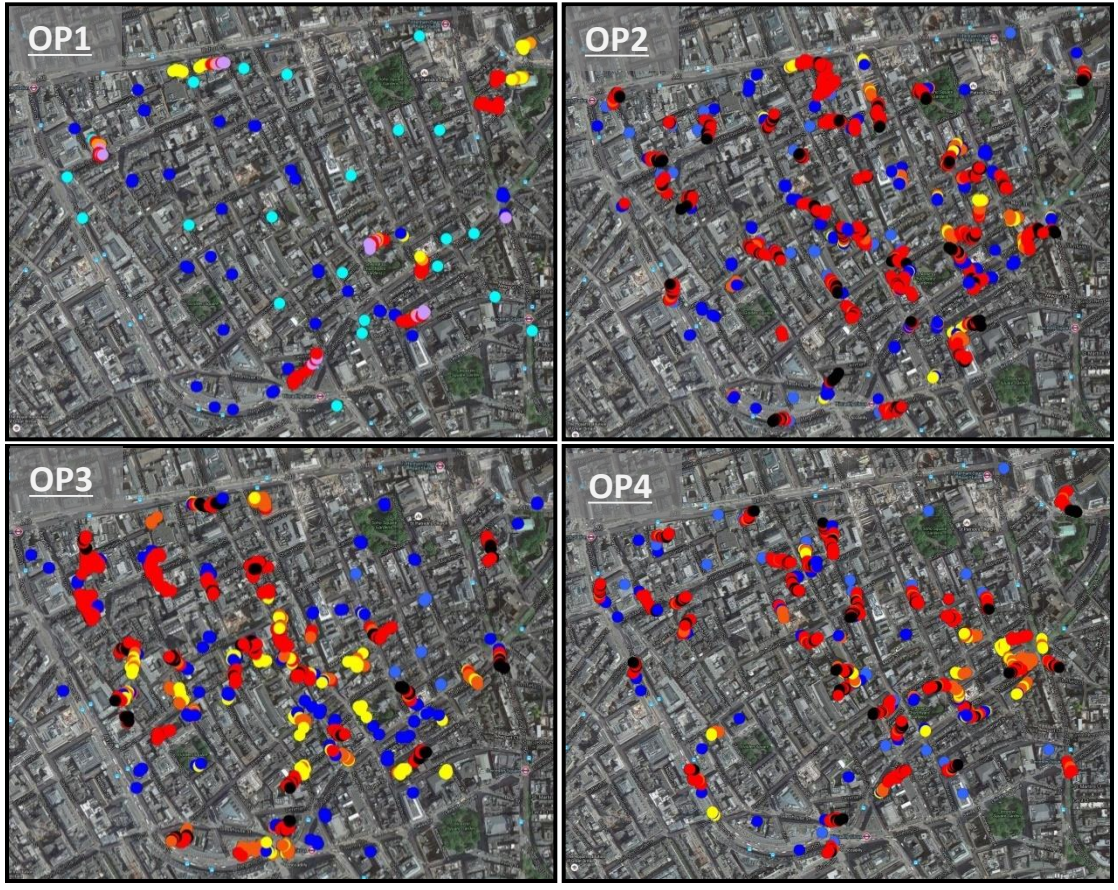


- Heat maps show the overall user experience as measured during the entire walk test, with test samples received on both 3G and 4G technologies.
- Fewer number of throughput samples were recorded for OP1. This is due to its higher throughput which enables it to complete downloading files at a faster rate

Throughput [0-15Mbps]
>= 15
>= 10 and < 15
>= 5 and < 10
>= 1 and < 5
>= 0.5 and < 1
>= 0.1 and < 0.5
>= 0.001 and < 0.1
< 0.001

Quality of User Experience(2 of 7)

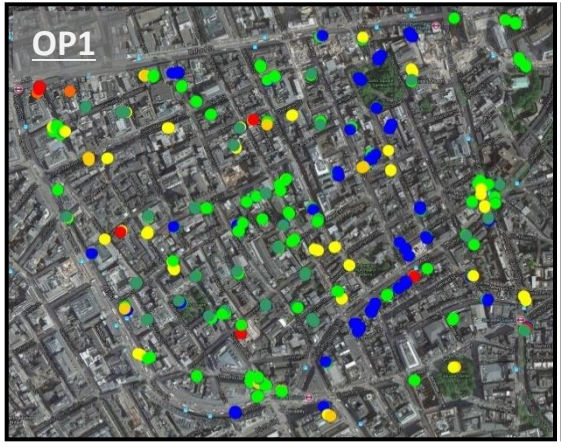
FTP Upload Throughput

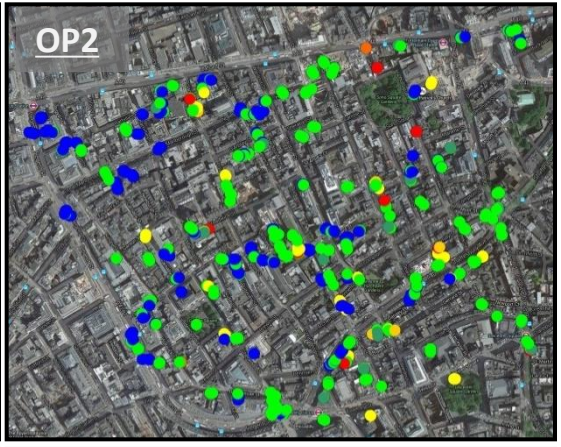


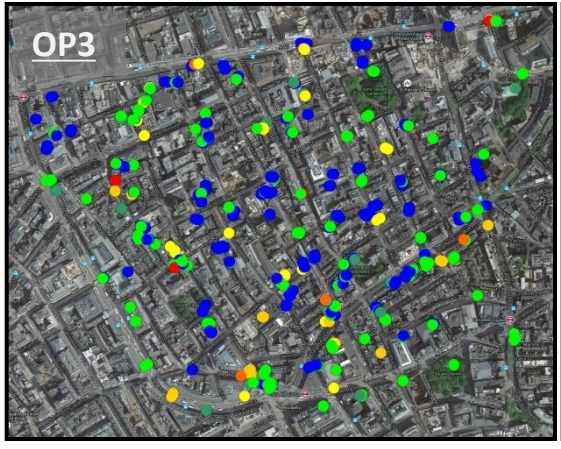
- Overall user experience as measured during the entire walk test, with test samples received on both 3G and 4G technologies
- Fewer number of throughput samples were recorded for OP1. This is due to its higher throughput which enables it to complete uploading files at a faster rate.

Quality of User Experience(3 of 7)

Latency



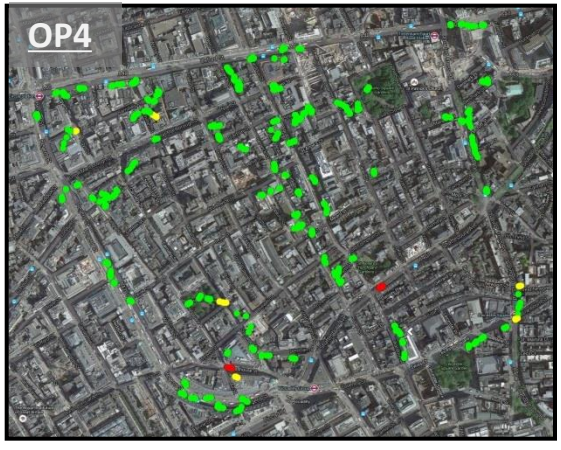




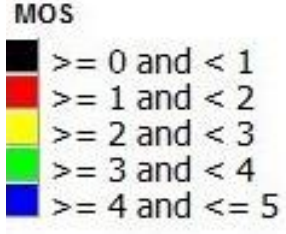
- Overall user experience as measured during the entire walk test, with test samples received on both 3G and 4G technologies

Quality of User Experience(4 of 7)

Voice Quality

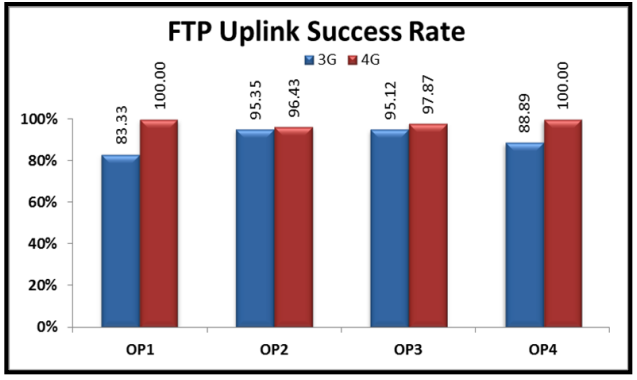


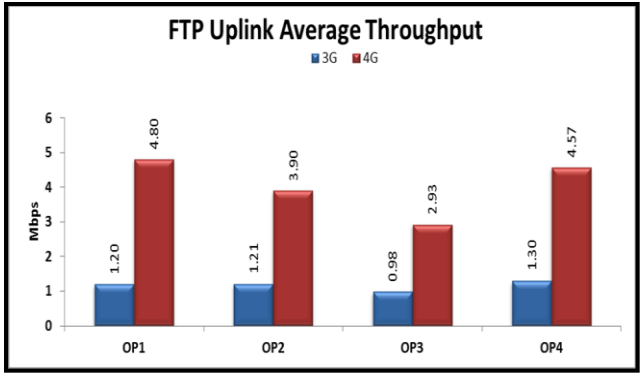
- OP3 had the best voice quality in the test area
- OP2 has the lowest MOS average

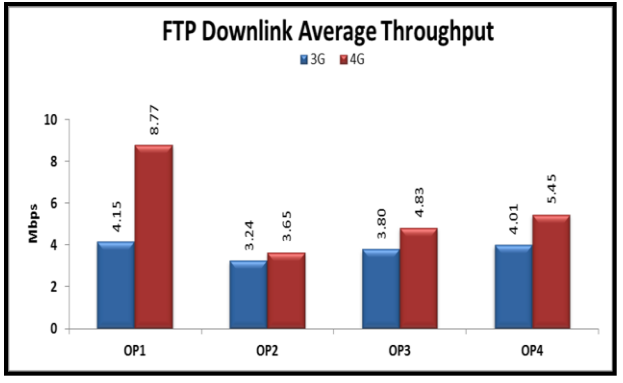


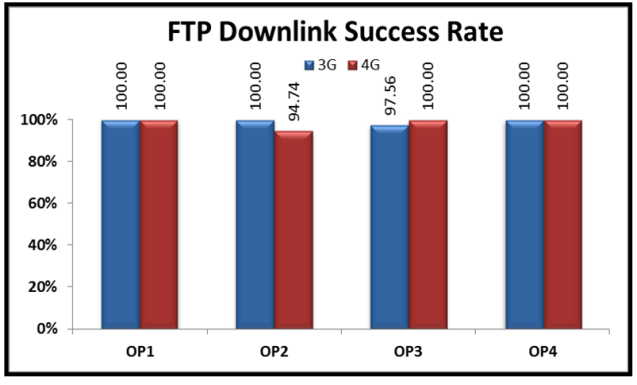
Quality of User Experience(5 of 7)

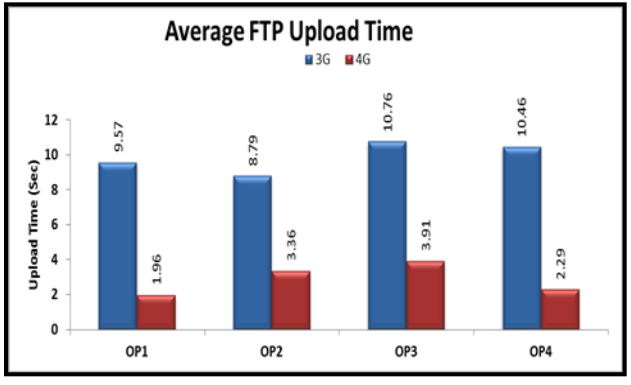
FTP DL/UL Statistics

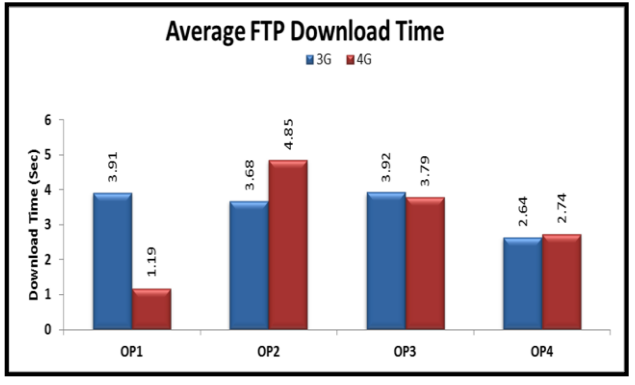








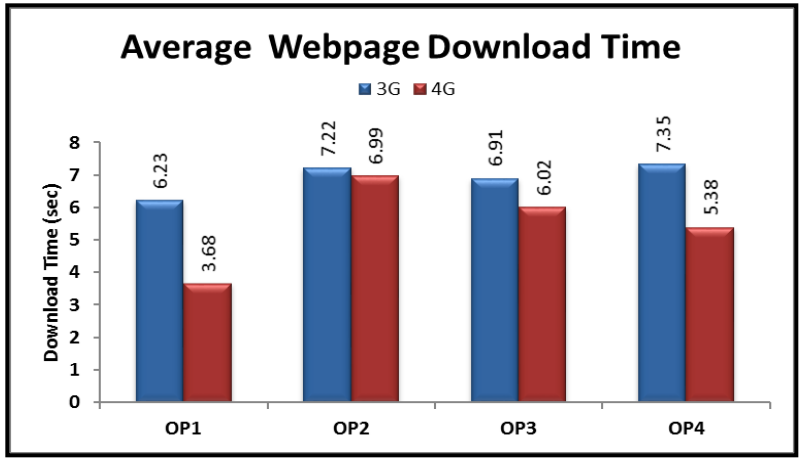


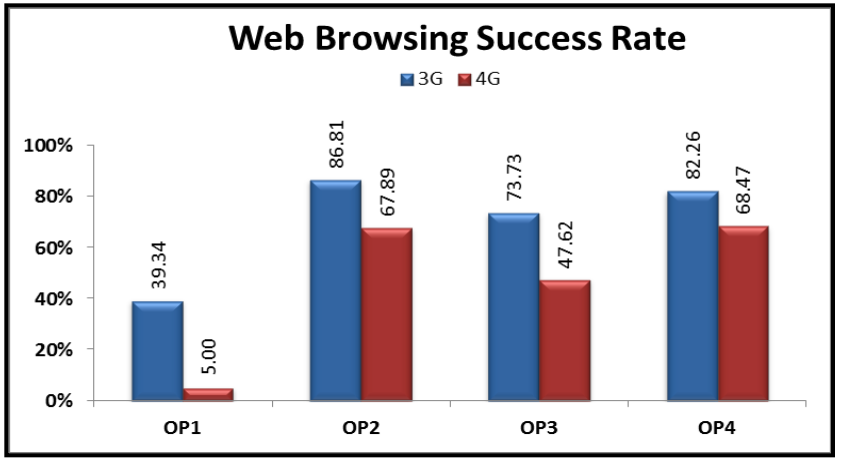


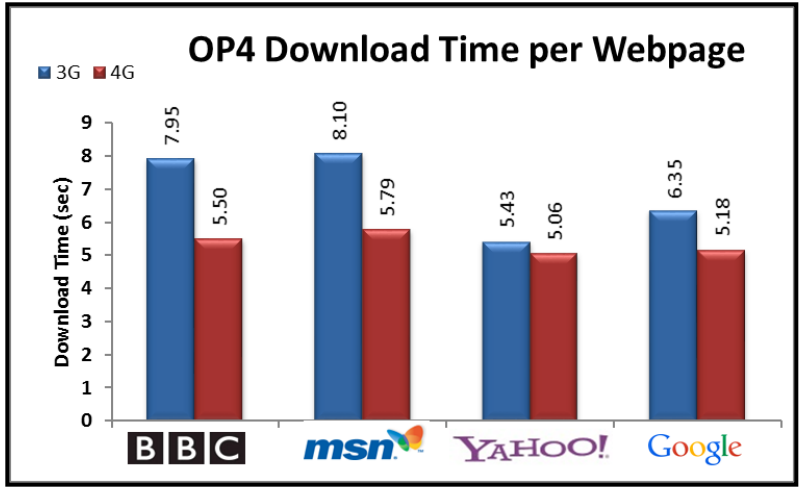
OP1 has the highest 4G FTP UL & DL average throughput

Quality of User Experience(6 of 7)

Web Browsing Statistics



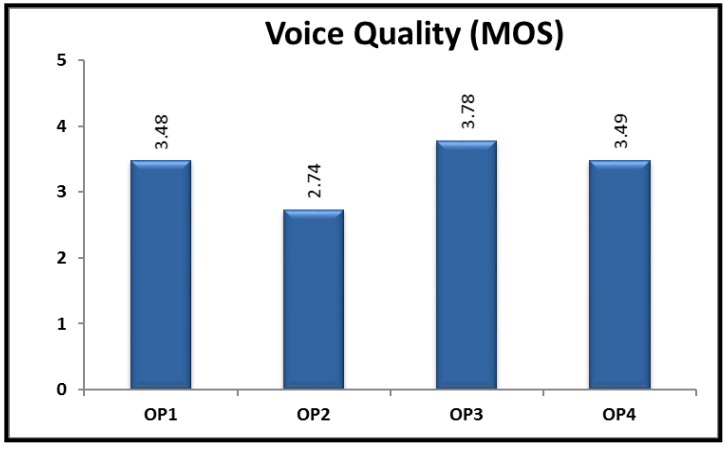


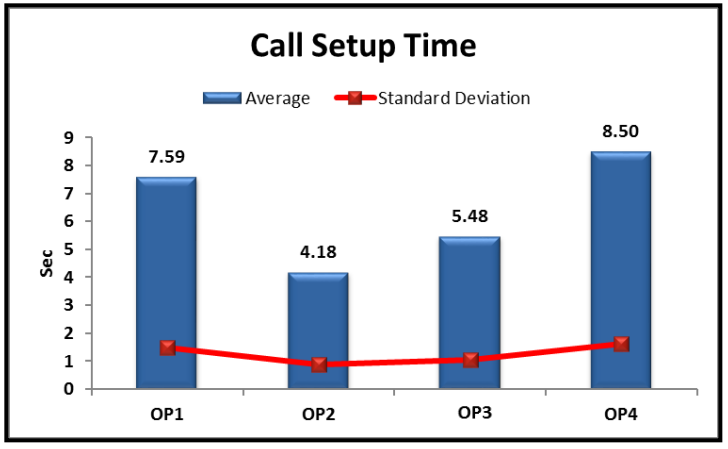


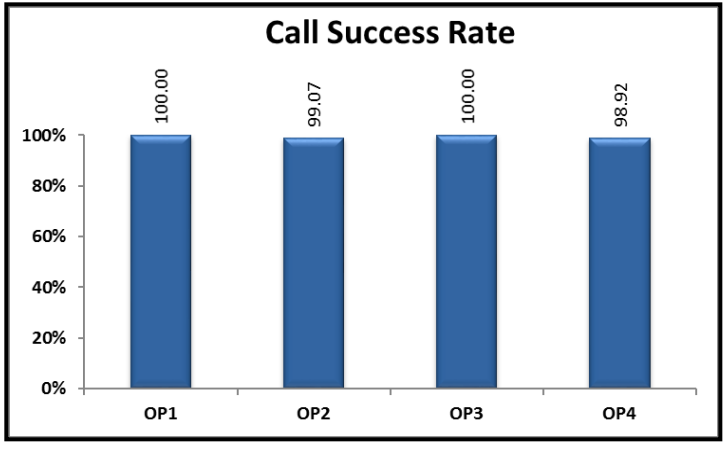
- OP1 has the fastest webpage load times for both 3G and 4G
- OP4 has the highest browsing success rate on 4G
- OP2 has the highest browsing success rate on 3G
- uk.yahoo.com was the fastest website to load on OP4 for both 3G and 4G

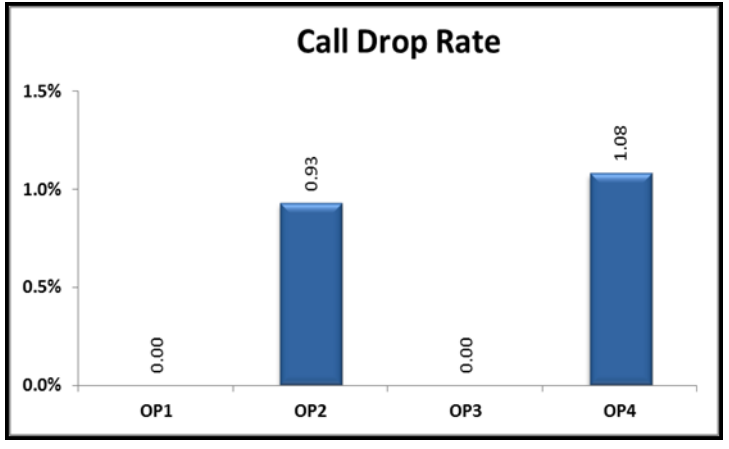
Quality of User Experience(7 of 7)

Voice Quality and Call statistics





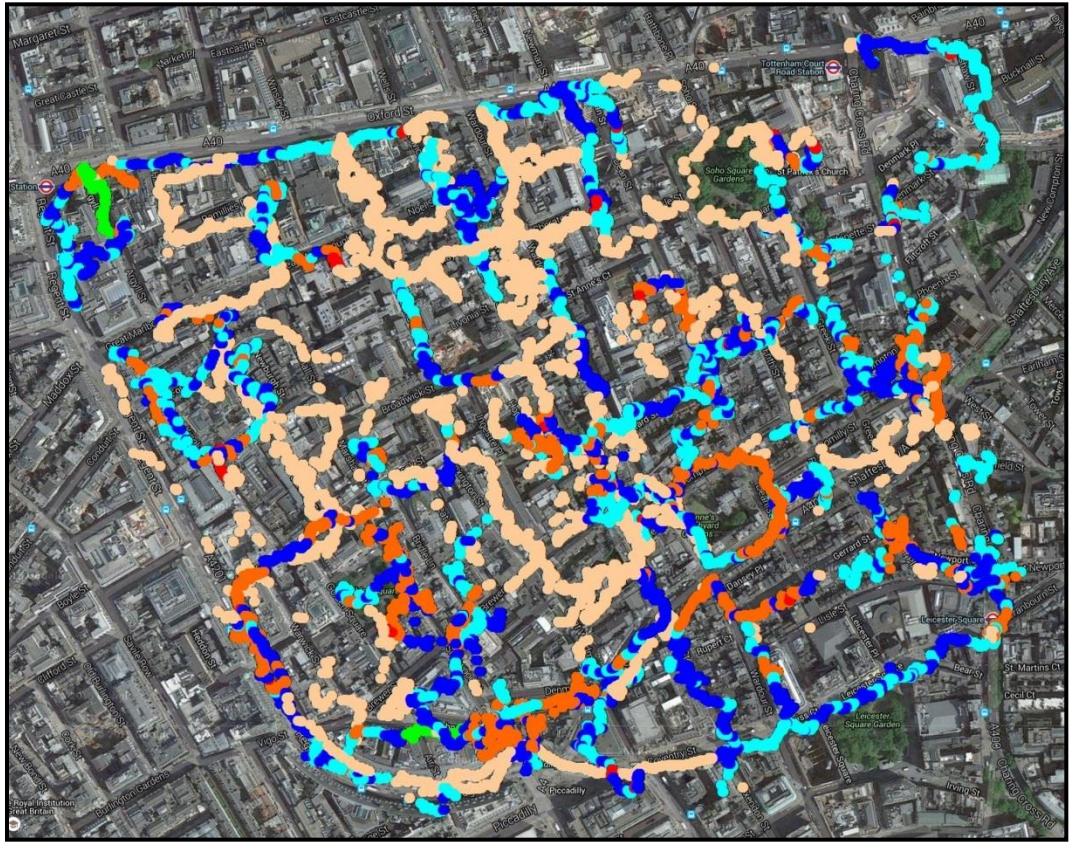




- OP3 has the best voice call performance
- OP4 and OP2 had one call drop during the entire test period.
- OP2 has the fastest call set-up time

Packet Technology during data transfer (1 of 4)

OP1



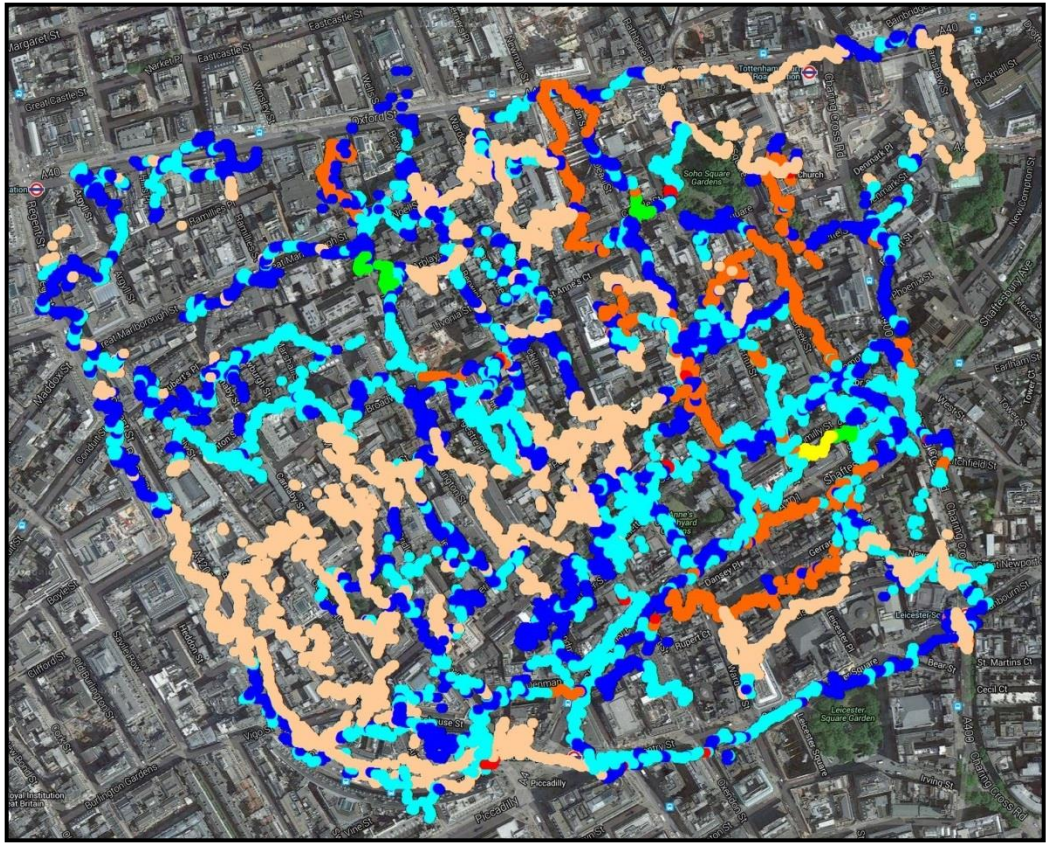
- 40% of all samples for OP1 were captured on LTE technology.
- 59% of all samples for OP1 were captured on 3G technology.
- Less than 1% of the samples for OP1 were captured on 2G

Packet Technology

= 1	81	0.70% GPRS
= 2	0	0.00% EDGE
= 4	2687	23.38% UMTS
= 8	84	0.73% HSDPA
= 128	0	0.00% HSUPA
= 136	2557	22.24% HSPA
= 16384	1478	12.86% HSPA DC
= 1024	4608	40.09% LTE

Packet Technology during data transfer (2 of 4)

OP2



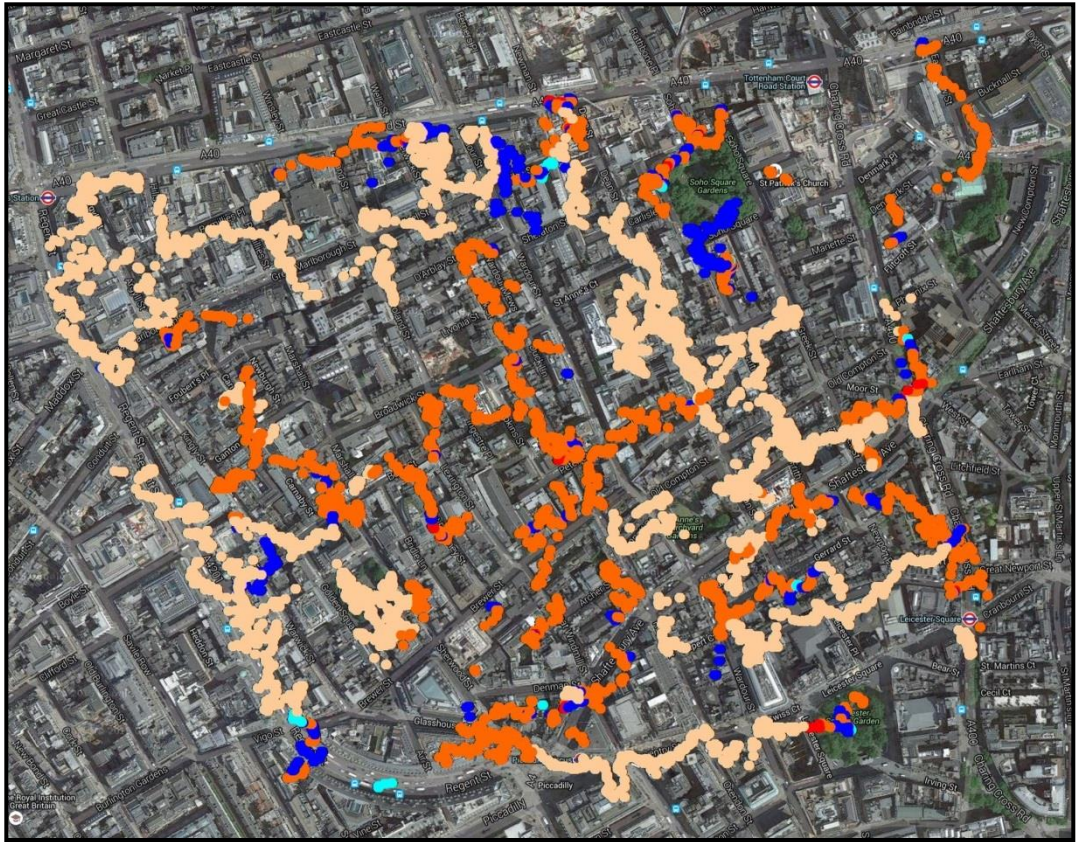
- 33% of all samples for OP2 were captured on LTE technology.
- 66% of all samples for OP2 were captured on 3G technology.
- 1% of the samples for OP2 were captured on 2G

Packet Technology

= 1	100	0.69%	GPRS
= 2	70	0.49%	EDGE
= 4	4079	28.24%	UMTS
= 8	59	0.41%	HSDPA
= 128	0	0.00%	HSUPA
= 136	4256	29.46%	HSPA
= 16384	1179	8.16%	HSPA DC
= 1024	4701	32.55%	LTE

Packet Technology during data transfer (3 of 4)

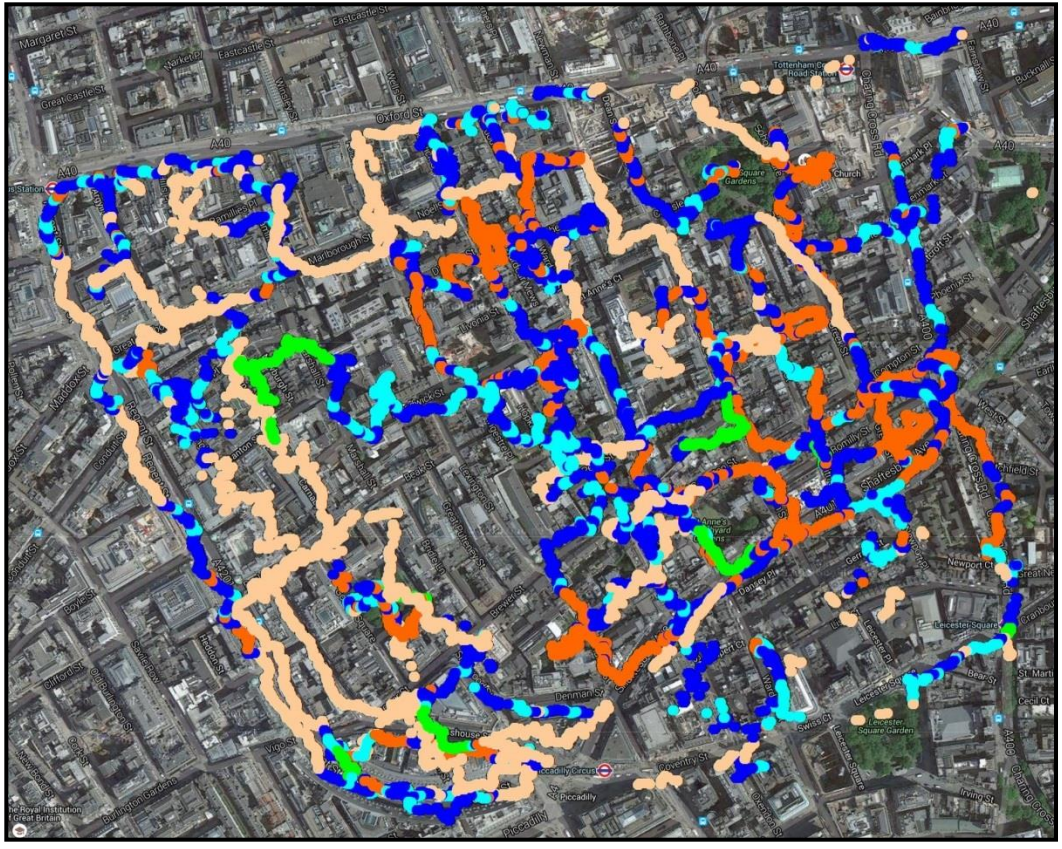
OP3



- 54% of all samples for OP3 were captured on LTE technology.
- 46% of all samples for OP3 were captured on 3G technology.
- No samples for OP3 were captured on 2G

Packet Technology during data transfer (4 of 4)

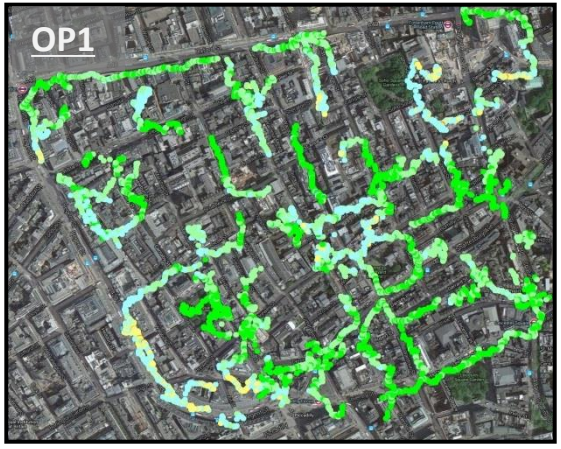
OP4

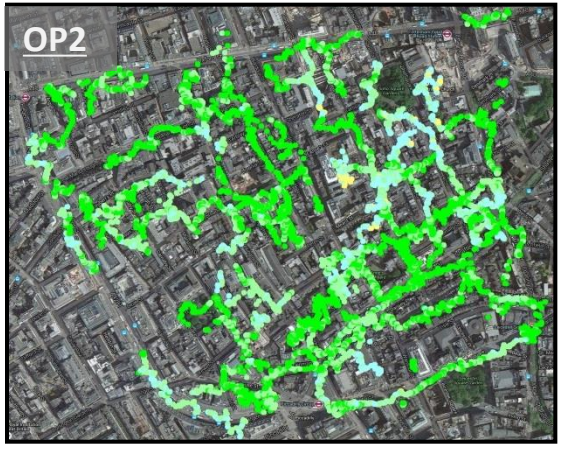


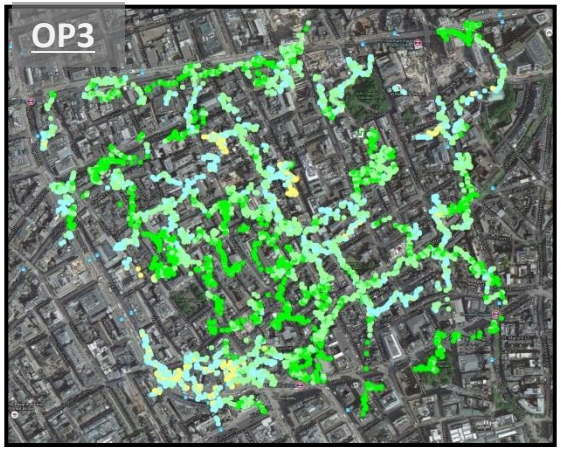
- 31% of all samples for OP4 were captured on LTE technology.
- 66% of all samples for OP4 were captured on 3G technology.
- 3% of the samples for OP4 were captured on 2G

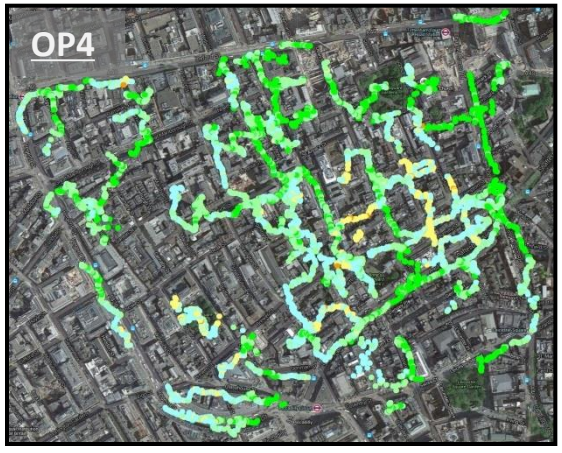
3G Radio Report

RSCP









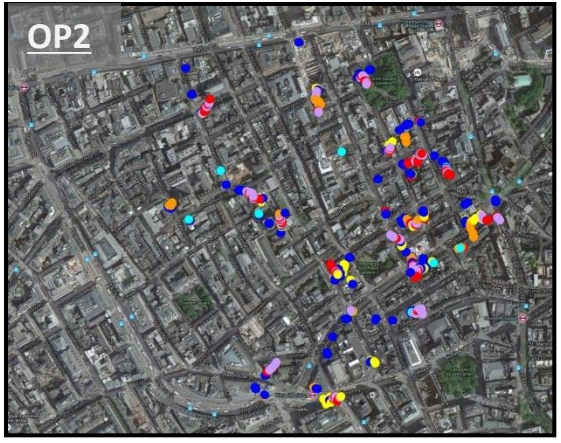
- 3G coverage was excellent for all operators in the test area
- OP2 has the best 3G coverage in the test area

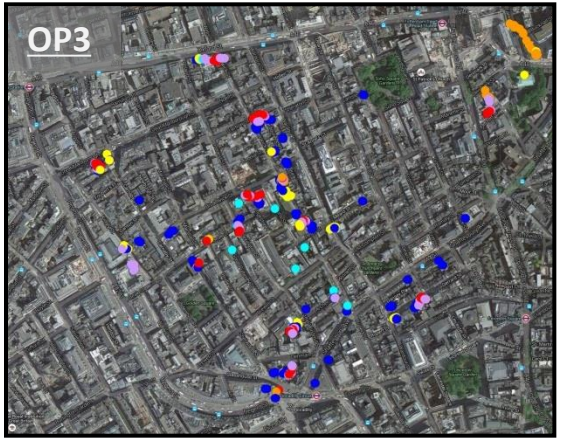
RSCP [dBm]

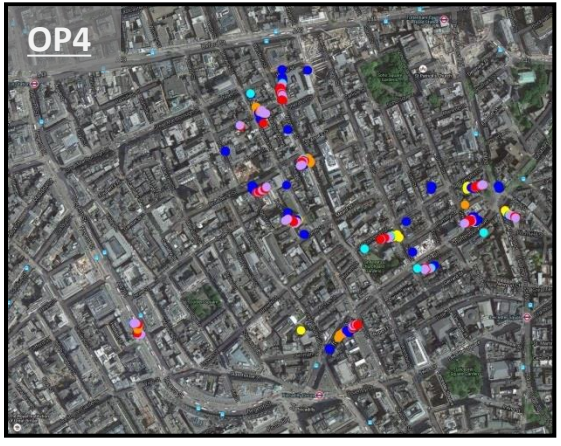
- < -50 and >= -65
- < -65 and >= -75
- < -75 and >= -85
- < -85 and >= -95
- < -95 and >= -105
- < -105 and >= -120
- < -120 and >= -150

3G File Transfer (1 of 2)

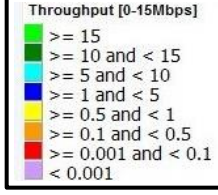
FTP Download





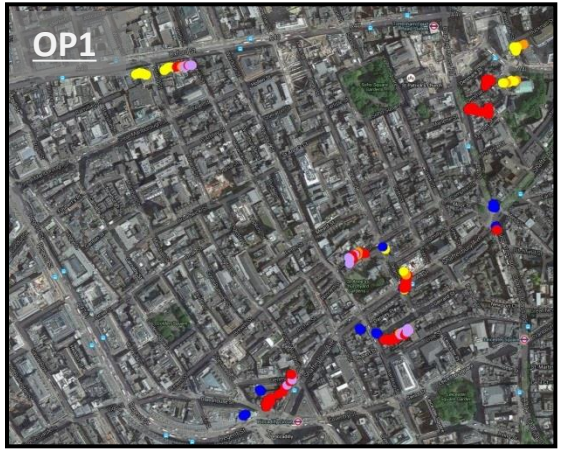


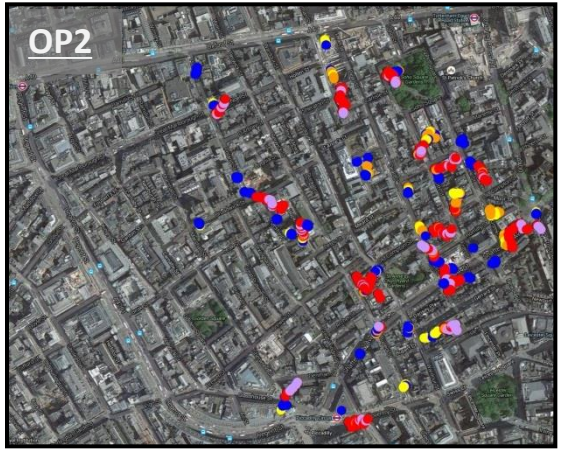
- OP1 has the highest download throughput on 3G
- OP4 has the second highest download throughput on 3G

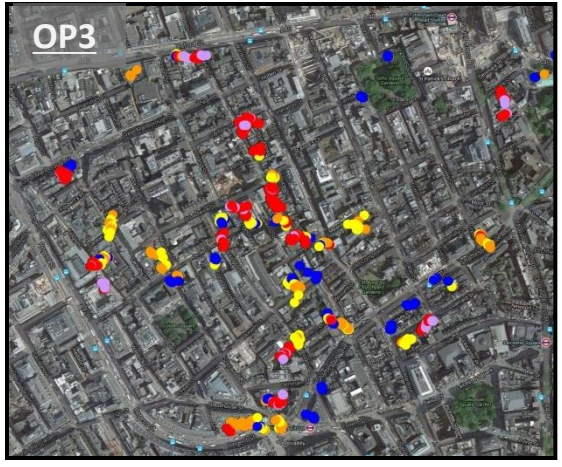


3G File Transfer (2 of 2)

FTP Upload







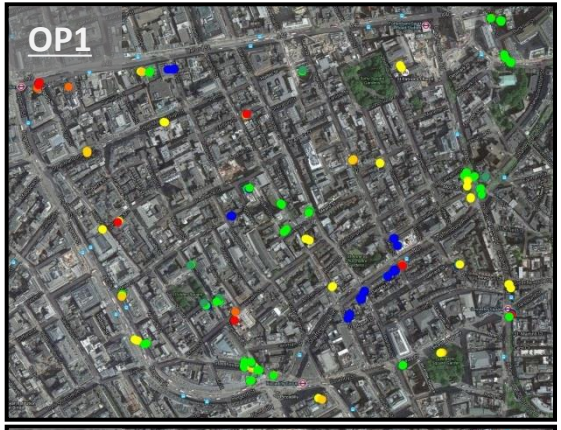
- OP1 has the highest upload throughput on 3G but also has the least number of upload samples in 3G

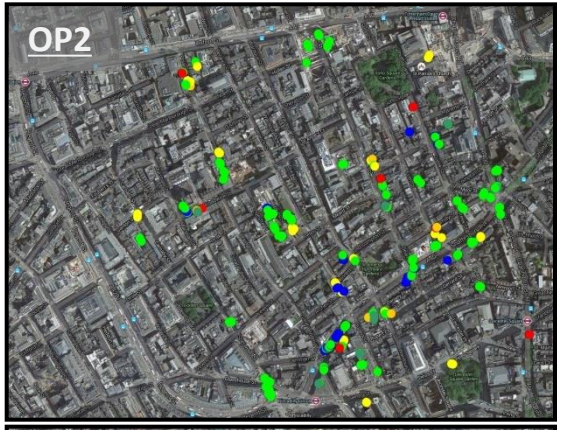
Throughput [0-15Mbps]
>= 15
>= 10 and < 15
>= 5 and < 10
>= 1 and < 5
>= 0.5 and < 1
>= 0.1 and < 0.5
>= 0.001 and < 0.1
< 0.001

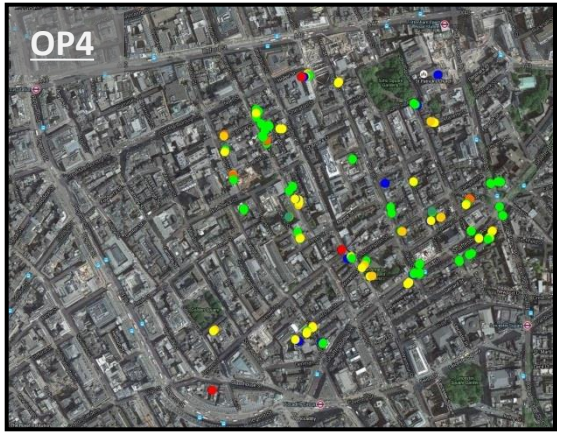
Walk route

3G Latency

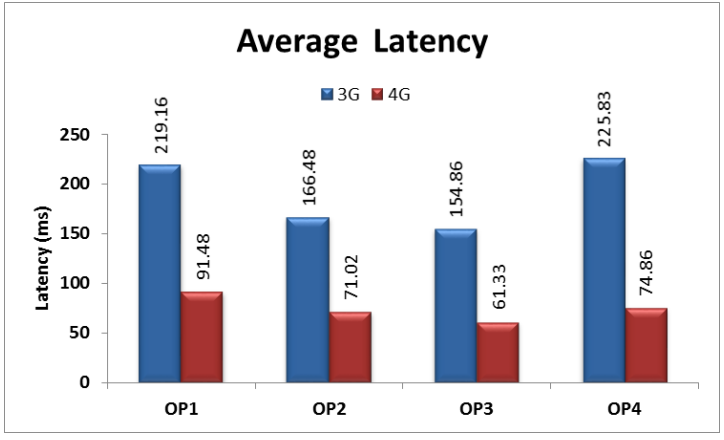
Round Trip Time (ms)





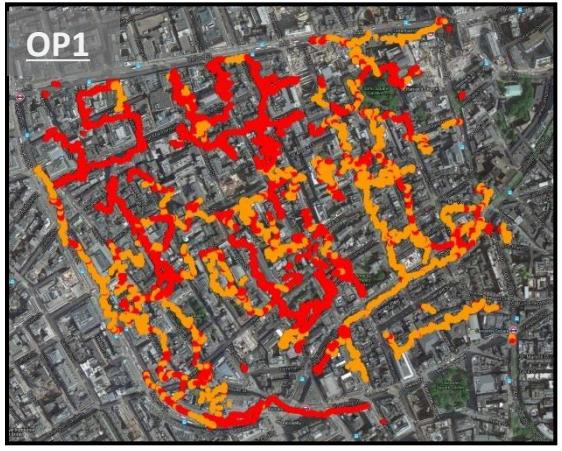


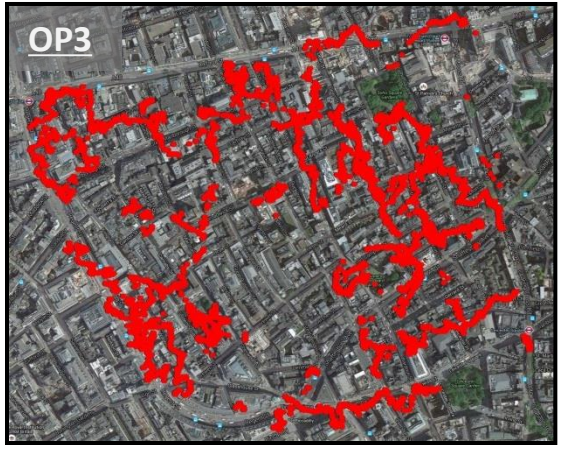
- Heat maps shows OP3 has the lowest network latency for 3G among all the operators



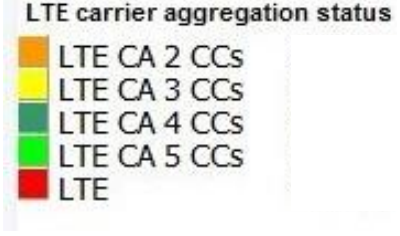
Carrier Aggregation

LTE Carrier Aggregation Heat maps



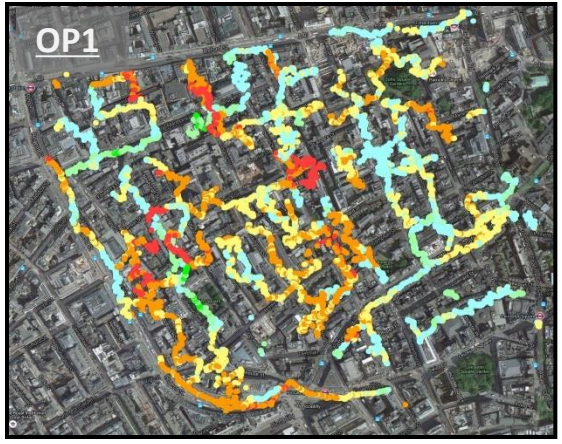


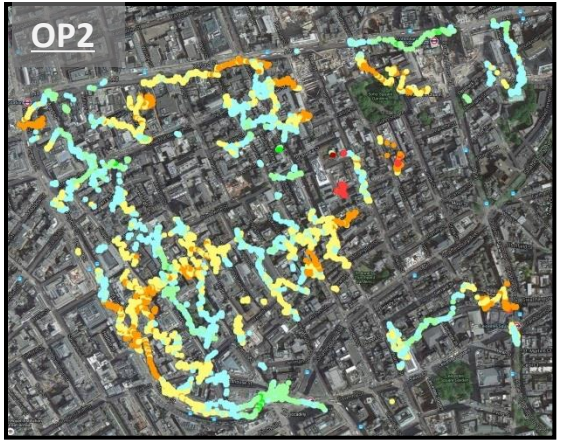
- OP3 was the only operator in the test area not to have implemented carrier aggregation .
- OP1 has the highest percentage of LTE carrier aggregation among all the networks tested.
- Tests conducted -while on 4G carrier aggregation- preformed better, with higher throughput and fewer timeouts than while on LTE only.

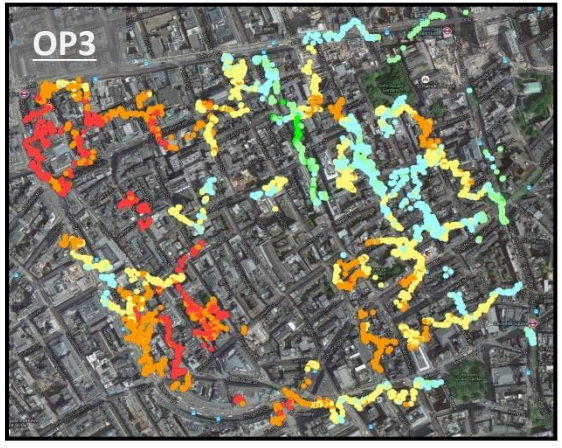


4G Radio Report

RSRP







- OP2 has the best 4G coverage among the operators.
- OP3 has a particularly low 4G coverage around oxford circus.

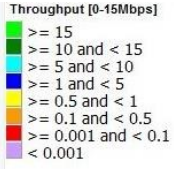
RSRP [dBm]

- < -50 and >= -65
- < -65 and >= -75
- < -75 and >= -85
- < -85 and >= -95
- < -95 and >= -105
- < -105 and >= -120
- < -120 and >= -150

4G File Transfer (1 of 2)

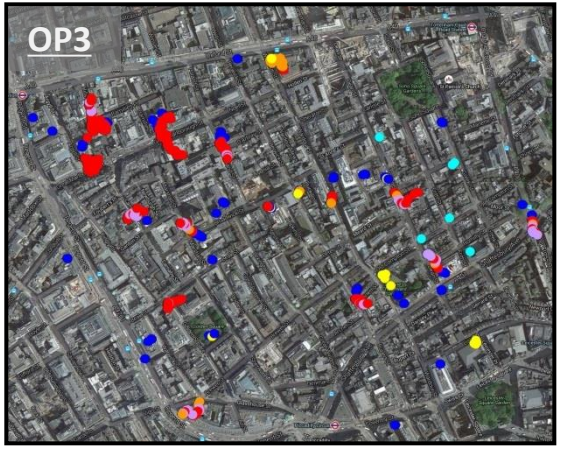
FTP Download

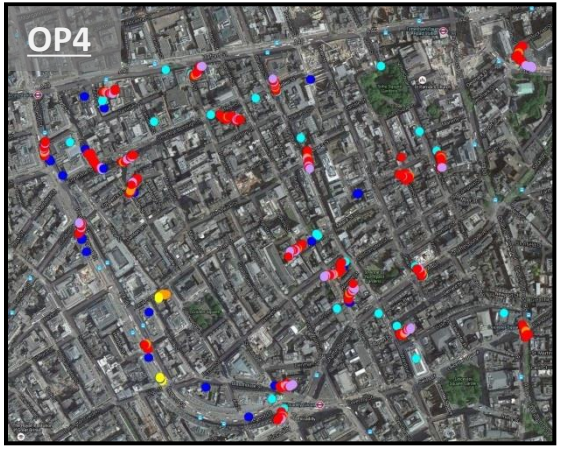
- Heat maps shows 4G FTP download samples for all operators in test area
- Fewer number of samples were recorded for OP1. This is due to its higher throughput which enables it to complete downloading files at a faster rate.



4G File Transfer (2 of 2)

FTP Upload





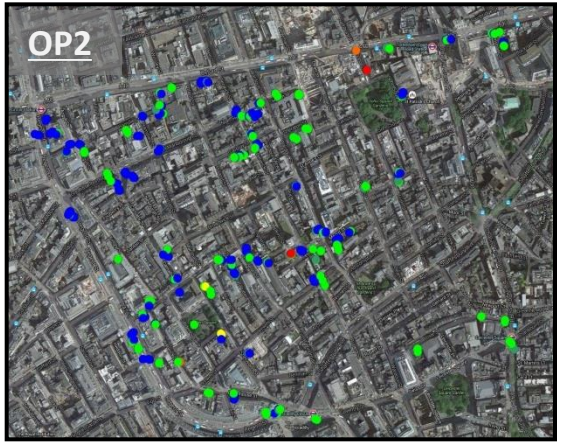
- Heat maps shows 4G FTP upload samples for all operators in test area

Throughput [0-15Mbps]
- >= 15
- >= 10 and < 15
- >= 5 and < 10
- >= 1 and < 5
- >= 0.5 and < 1
- >= 0.1 and < 0.5
- >= 0.001 and < 0.1
- < 0.001

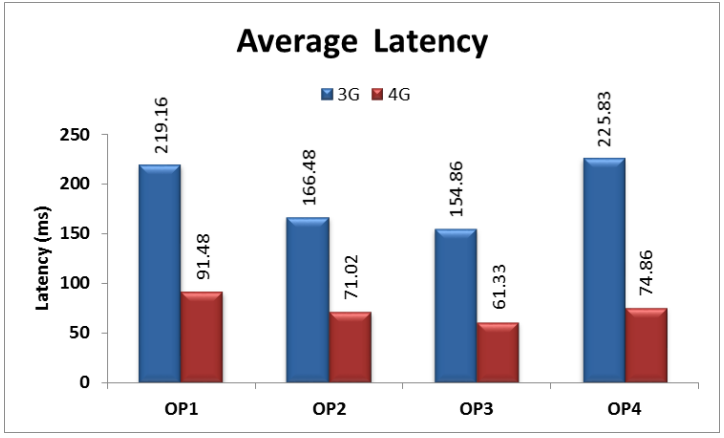
Walk route

4G Latency

Round Trip Time (ms)



- Heat maps shows OP3 has the lowest network latency for 4G among all the operators



Summary of Findings (2 of 3)

3G Summary of Results

OPERATOR	OP1	OP2	OP3	OP4
SERVICE AVAILABILITY (%)	100	100	100	100
TELEPHONY				
Call attempt success rate (%)	98.7	99.07	100	95.88
Call drop rate (%)	0	0.93	0	1.08
Call completion rate (%)	100	99.07	100	98.92
Call setup time (s)	7.59	4.18	5.48	8.5
Speech quality (MOS-LQO)	3.48	2.74	3.78	3.49
DATA				
WEB-PAGE DOWNLOAD				
Success ratio (%)	39.34	86.81	73.73	82.26
Avg. session time (s)	6.23	7.22	6.91	7.35
FILE DOWNLOAD (5MB)				
Success ratio (%)	100	100	97.56	100
Avg. session time (s)	3.91	3.68	3.92	2.64
Avg. file download speed (Mbps)	4.15	3.24	3.80	4.01
FILE UPLOAD (1MB)				
Success ratio (%)	83.33	95.35	95.12	88.89
Avg. session time (s)	9.57	8.79	10.76	10.46
Avg. file upload speed (Mbps)	1.20	1.21	0.98	1.30
LATENCY				
Ping success ratio (%)	100	100	100	100
Ping round trip time (ms)	219.16	166.48	154.86	225.83
YOUTUBE HD (15 second video)				
Success ratio (%)	0	76.19	61.11	75
Video access time (s)	13.13	9.73	9.73	12.14
Download Time (s) (60 sec timeout)	60.01	24.78	22.25	26.55

Summary of Findings (3 of 3)

4G Summary of Results

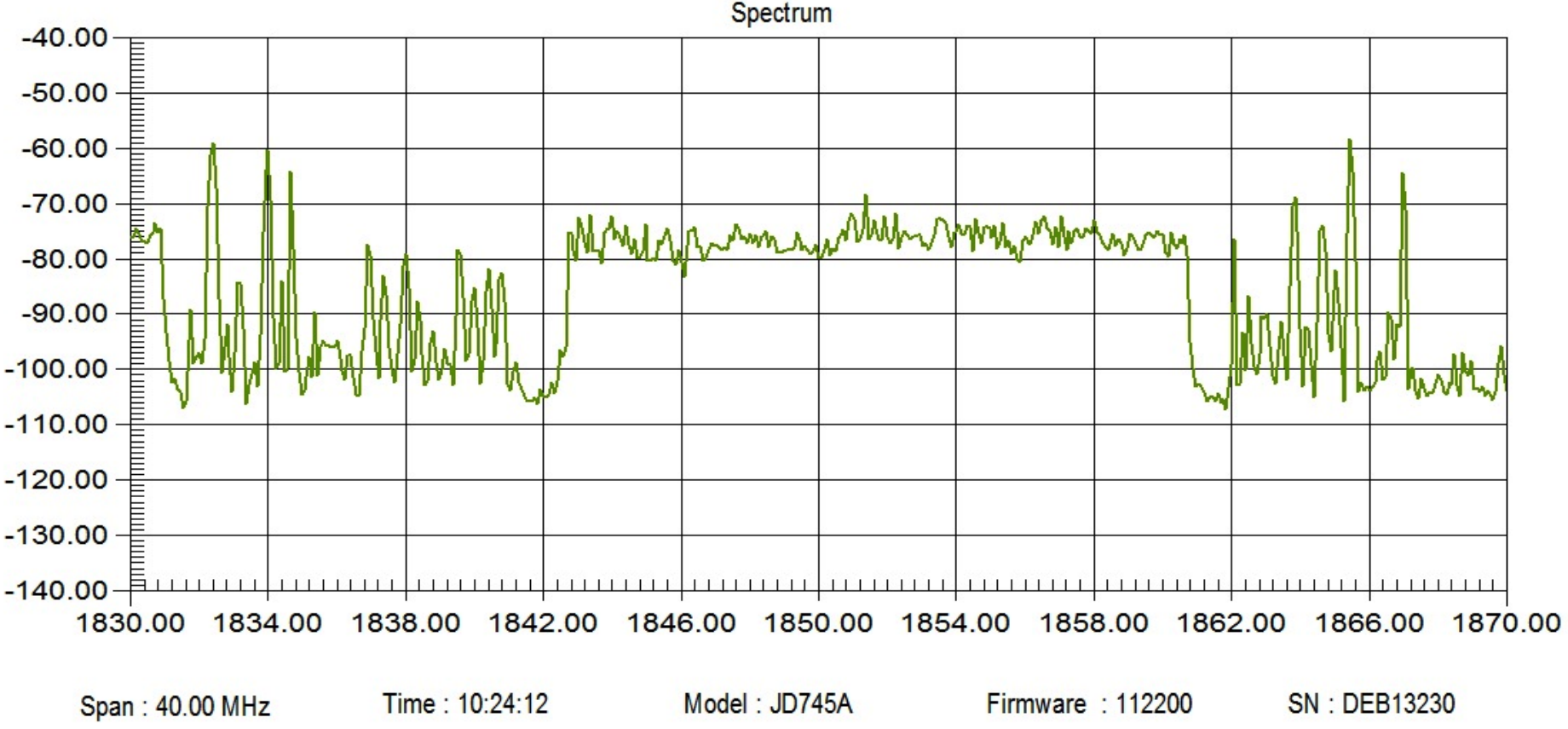
OPERATOR	OP1	OP2	OP3	OP4
SERVICE AVAILABILITY (%)	100	100	100	100
DATA				
WEB-PAGE DOWNLOAD				
Success Ratio (%)	5	67.89	47.62	68.47
Avg. Session Time (s)	3.68	6.99	6.02	5.38
FILE DOWNLOAD (5MB)				
Success Ratio (%)	100	94.74	100	100
Avg. Session Time (s)	1.19	4.85	3.79	2.74
Avg. file download speed (Mbps)	8.77	3.65	4.83	5.45
FILE UPLOAD (1MB)				
Success Ratio (%)	100	96.43	97.87	100
Avg. Session Time (s)	1.96	3.36	3.91	2.29
Avg. file upload speed (Mbps)	4.80	3.90	2.93	4.57
LATENCY				
Ping Success Ratio (%)	100	100	100	100
Ping Round Trip Time (ms)	91.48	71.02	61.33	74.86
YOUTUBE HD (15 second video)				
Success Ratio (%)	0	83.33	56.25	76
Video access time (s)	7.62	8.81	9.04	8.56
Download Time(s)(60 sec timeout)	60.83	26.32	23.58	23.05

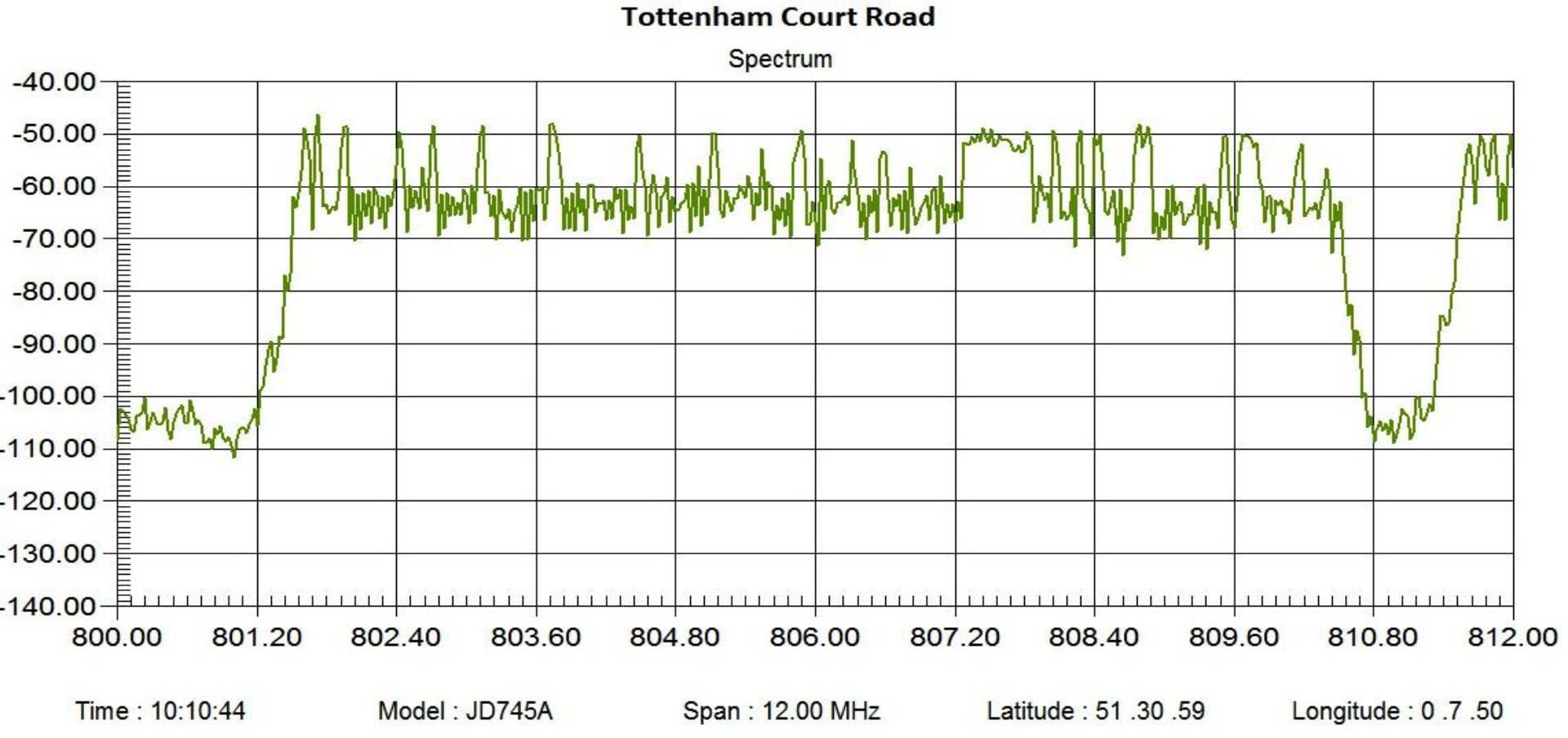
Summary of Findings (1 of 3)

Performance Leader board

Test	OP1		OP2		OP3		OP4		Comments
	3G	4G	3G	4G	3G	4G	3G	4G	
Voice call success rate									100% call completion for OP1 and OP3
Voice setup time									Only network under 5 sec call setup time
Voice quality									MOS scores measured using POLQA
Latency									OP3 has the lowest network latency
FTP UL Speed									Measured at the 90th percentile
FTP DL Speed									Measured at the 90th percentile
HTTP time to Load									Average webpage download time
Streaming download time									OP3 fastest on 3G & OP4 fastest on 4G

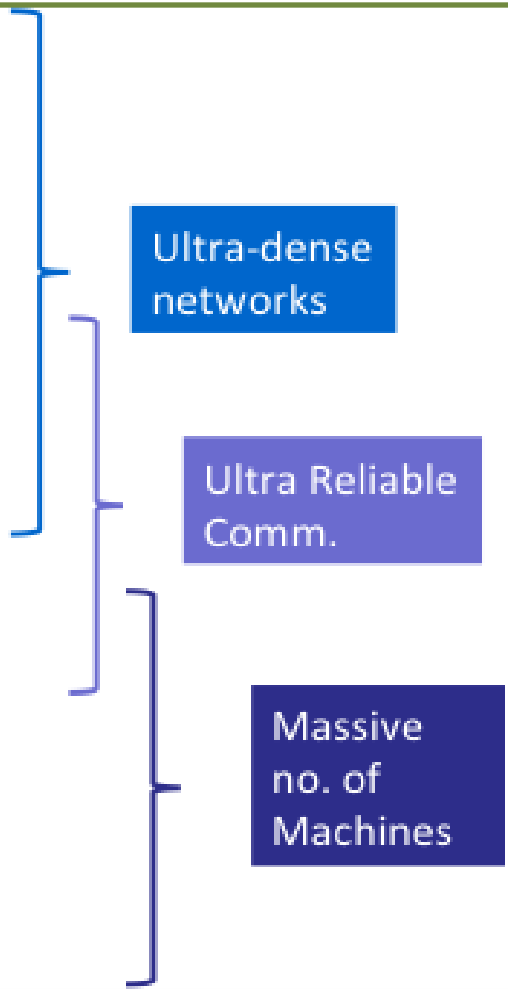
Leicester Square Station




Tottenham Court Road
Spectrum
-40.00
-50.00
-60.00
-70.00
-80.00
-90.00
-100.00
-110.00
-120.00
-130.00
-140.00
800.00
801.20
802.40
803.60
804.80
806.00
807.20
808.40
809.60
810.80
812.00
Time : 10:10:44
Model : JD745A
Span : 12.00 MHz
Latitude : 51 .30 .59
Longitude : 0 .7 .50

5G- What to Expect ?

Data rates	1-10Gbps (resp.100s of Mbps)
Capacity	36TB/month/user (resp. 500 GB)
Spectrum	Higher frequencies & flexibility
Energy	~10% of today's consumption
Latency reduction	~ 1ms (e.g. tactile internet)
D2D capabilities	NSPS, ITS, resilience, …
Reliability	99.999% within time budget
Coverage	>20 dB of LTE (e.g. sensors)
Battery	~10 years
Devices per area	300.000 per access node



Thank You

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