Paper

Wireless at the "Connected Games": How the London 2012 Olympic and Paralympic Games Utilized the Latest Wi-Fi Technology

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Abstract—The London 2012 Olympic and Paraolympic Games drew together tens of thousands of people in the form of athletes, organisers, media, VIPs, public and many more groups and individuals. With the growth in smart phones and tablets coupled with the ever expanding volume and range of content accessed via Aps and browsers, this huge volume of people expected connectivity from their mobile devices during their time on the Olympic sites. It was BT's role in the games as the official communications services partner to deliver Wi-Fi connectivity across the venues, covering the range of users from the public, athletes, organisers and ticket scanners. This paper examines this state of the art Wi-Fi solution.

Keywords*—*high density Wi-Fi, Olympics, paralympics, Wi-Fi, wireless.

1. Introduction

The London 2012 Olympic Games was coined the "Connected Games", as never before there were so many systems, user groups and individuals associated with the Olympics demanding network connectivity to each other and the wider world. British Telecom (BT) as the official communications services partner to the London 2012 rolled out a national network to support the games, overlaid with different services for different requirements. Wi-Fi was just one such service, but a service which was very high profile in terms of being visible to how well it was performing due to the personal connectivity it provides, as well as being an ever growing area due to the increasing numbers of smart phones, tablets and the ever expanding content and services available online.
The paper examines the London 2012 Wi-Fi, looking at the requirements and the nature of the deployment including High Density Wi-Fi, and then examines its operation and how it performed.

2. The Requirements

The Wi-Fi requirements for the London 2012 Olympics were demanding and unique. The solution had got to be on a national level, providing a centralised Wi-Fi deployment to both sporting and non-sporting venues, 27 in total. The solution had to be able to scale up and scale down fast, as venues were built, used for a test event, or the real event, and then taken away, in some cases over a matter of days. The solution had to be secure, and centrally managed, monitored and operated from the London 2012 Technical Operations Centre. The Wi-Fi radio frequencies also had to be carefully planned with the London Organising Committee of the Olympic and Paralympic Games (LOCOG), to make sure different systems did not interfere with one another. This also included games systems such as for fencing and taekwondo which had wireless transmitters operating in

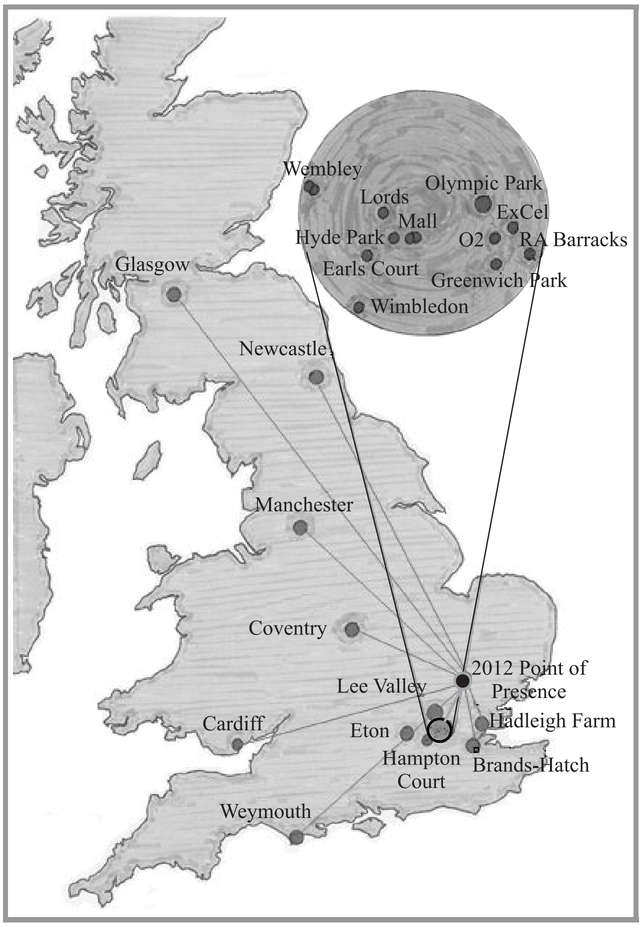

Fig. 1. Olympic sporting venues networked together.

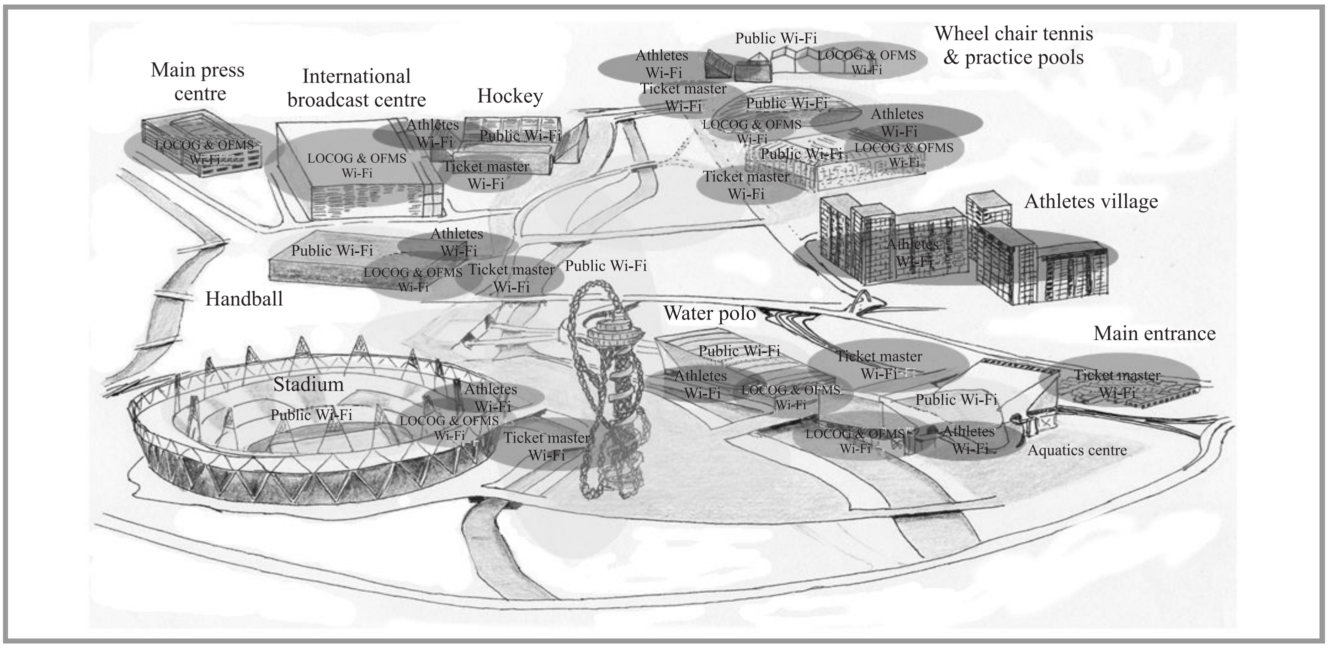

Fig. 2. Wi-Fi services rolled out across the Olympic Park.

the Wi-Fi spectrum range built into the competitors clothing to relay hits back to the scoring system.

The solution also had to be reliable and resilient. All the venues were dual homed to BT's resilient points of presence dedicated for the games, and the wireless traffic once taken into the wired network via the access points on the venue where sent over this extensive backhaul network which linked all the venues together. Figure 1 shows just the sporting venues which were linked together, providing the backbone for the wireless network. The solution also had to cater for multiple user groups which are outlined in the below section.

3. User Groups

Public. The public increasingly wanted and expected Wi-Fi to be available for their general use to get to the internet, to had the ability to quickly upload photos and get to social media sites such as Facebook and twitter to share their experiences at the games.

LOCOG. LOCOG required a Wi-Fi service within the admin areas of venues, both sporting and non-sporting for general use. This service was also be purchased for use by the press, or other associated groups or individuals.

Machines (ticketing). A Wi-Fi service was required for the mobile ticket scanners which were operated by ticket master at the entrance areas.

Athletes. As part of the general facilities for athletes, a good Wi-Fi service was required to be available for them both within sporting venues and the Olympic Village.

Mobile Data Offload. Samsung had partnered with the Olympic organisers and had produced an Olympic Family range of mobile phones which were used by organisers and VIPs on the park and in venues. These OFMS (Olympic Family Mobile Service) phones required data offload via Wi-Fi when in designated areas.

4. Wi-Fi Deployment Across the Olympic Park

The different user groups required different Wi-Fi set-ups depending on physical location and logical configuration. Broadly speaking, the Wi-Fi was split into "front of house" services and "back of house" services. Front of house services were in areas where the public would be to watch the games or were in transit, so these Wi-Fi services would include public, OFMS, and ticket master. The back of house services were mainly for use in areas the public would not be, but athletes, organiser and press would, these Wi-Fi services included LOCOG, OFMS and athlete's Wi-Fi.

The coverage areas across the venues were clearly dependent on where the user groups would require, or desire access to Wi-Fi, and therefore different areas had different wireless services rolled out. This applied to all venues, both on and off the park. The diagram below shows the main coverage areas specifically for the park so as to provide an overview of how the services were laid out in differing logical patterns, but all were sharing the same centralised physical infrastructure.

The most significant deployment in terms of differences in physical and logical configuration was the public Wi-Fi located in the seating bowls of the venues. This was High Density Wi-Fi, and will be explained in more detail in the following section.

5. High Density Wi-Fi

High Density Wi-Fi is a form of Wi-Fi deployment which is designed to provide good Wi-Fi coverage to groups of users in a densely packed group, for example, seating next to one another in a sports stadium. Standard Wi-Fi deployments will fail to provide good service in such environments once there are significant numbers of Wi-Fi clients, as the access points and their associated radio channels will become congested by the volume of connections. Simply adding in more conventional access points into the environment will not necessarily make things better, as the radio footprint of additional access points will overlap with others and can in turn cause even more congestion.

The principle of High Density Wi-Fi (HD Wi-Fi) is that it is engineered to create lots of small radio footprints so as to be able to cater for pockets of clients in localised areas of the stadium. This means the radio traffic between the client and access point can be kept to lower volume and power, thus to avoiding the access point becoming swamped by too many clients and minimising radio interference from surrounding access points and their associated client traffic. Figure 3 below illustrates the way HD Wi-Fi is designed to cover seats in a stadium seating bowl.

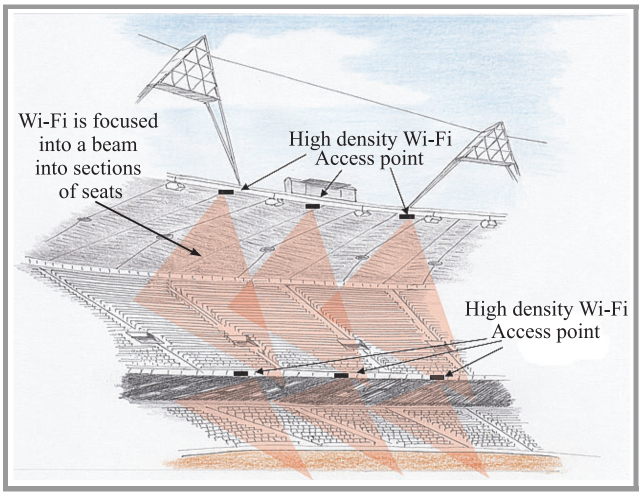

Fig. 3. High Density Wi-Fi in the stadium.

There are four areas of physical and logical configuration detail which gives HD Wi-Fi access points their smaller radio footprint:

Antenna. A directional antenna is used to focus the radio waves from the access point onto a specific area, in a similar way the lens of a torch is used to focus light. For the 2012 deployment, the Cisco 3502P access point combined with the Cisco AIR-ANT25137NP-R grayling antenna was used. This can be seen in Fig. 4.

Power. The power of the access point is reduced to a level where it can adequately cover its designated area, but not much further. This helps to avoid its signal over spilling into other access point’s coverage areas.

Fig. 4. Cisco 3502P AP with grayling antenna.

Minimum Supported Data Rate. The further away the client, the less strong the signal, thus the lower the data rate which can be achieved by the client to the access point. Therefore the minimum supported data rate of the access point is raised to prevent clients which are further away, outside of the access points catchment area connecting.

Coverage Threshold. The minimum coverage threshold is reduced to make it more stringent, only allowing clients with a good Receive Signal Strength Indicator to connect to the access point. This helps keep clients local to the access point.

The small radio footprints means the access points must be designed and deployed carefully so as to avoid black spots but also not overlap too much with each other. In total, 176 HD Wi-Fi access points have been deployed in the seating bowl of the olympic stadium. When mounting access points within the infrastructure of a venue, it is necessary to work with the features of the venue so as to find the best mounting positions. In the case of the hockey stadium, there is no roof or over-hanging gantry, so the access points were mounted underneath the seats pointing upwards. A photo showing an access point in this deployment is shown below in Fig. 5.

Once the access points have been positioned physically, and the antennas angled to cover the desired areas of seating or other high density area, then the solution is optimised via testing and then tuning of the configuration parameters above.

One of the challenges with the public Wi-Fi in the seating bowl is how to test it, to accurately simulate a crowd of people for testing. The short answer is there is no precisely accurate way to simulate a crowd of people, due to the random nature of user behaviours and different individual’s technology. So BT organised test events to create a controlled crowd of users, who could then be monitored and their experiences fed back for further optimisation. Rehearsals in the stadium also were taken advantage of for the testing and monitoring of the performance of the solution. Once the install and optimisation is completed, it is then

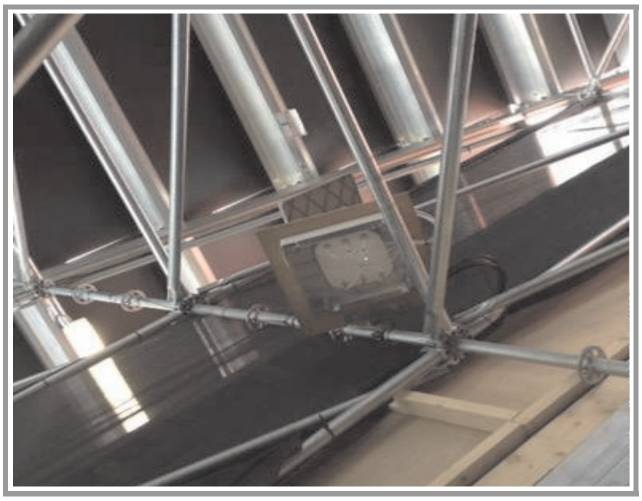

Fig. 5. Access point with external antenna directed upwards under the seats in the hockey venue.

necessary to police and monitor the radio spectrum in the Wi-Fi space for sources of interference which could disrupt the service.

6. Policing of the Wi-Fi Spectrum

As Wi-Fi uses unlicensed radio spectrum in the 2.4 GHz and 5 GHz ranges, it is subject to all kinds of interference. This can come in the forms of other Wi-Fi access points, as well as many other non-Wi-Fi forms such as wireless cameras, Bluetooth devices, and also anything that can transmit radio waves as a side effect of their main job such as microwave ovens.

In a distributed Wi-Fi network the scale and breadth of the Olympic Games, it is impossible to prevent all the sources of interference. However, it is important to pick up on the service affecting sources of interference, identify them quickly, and also have the political measures and planning in place to deal with them.

A good example of interference was during the Wi-Fi optimisation of the hockey stadium, it was noticed that the Wi-Fi access was being intermittently knocked out. Upon investigation the source of the interference was tracked down to a crane operating nearby. The crane had a wireless camera on its boom which relayed pictures using the 2.4 GHz spectrum to the a TV screen in the drivers cab. Every time the crane was operated, the signal was so powerful it knocked out the ability of the Wi-Fi in the hockey stadium to operate. In this example, once the source was identified, it was not a problem as the crane would only be there before games time. But it does show the importance of being able to pin down sources of disruption so as to be able to understand and highlight the cause, and asses and mitigate any impact it may have on service.

Early on in planning for the Olympics, it was necessary to work with LOCOG to understand what measures were being taken to regulate within the Olympic venues the radio spectrums, so as to be able to plan the successful deployment of Wi-Fi. With the large numbers of press, TV and broadcasting bodies descending on the park just before the games, there was huge scope for transmission equipment to disrupt the Wi-Fi services. Equipment of this kind therefore had to be approved by LOCOG for use, and plans on how to deal with sources of disruption formulated.

The BT Wi-Fi solution was monitored centrally from London 2012's Technical Operations Centre by BT, so any sources of disruption could be picked up pro-actively. A team on the ground with mobile spectrum analysers could then be dispatched to the location of the problem, and the exact cause could then be pinned down. How to deal with the cause depends on what it was, but the important thing was finding it so as to be able to rule out other technical problems for the service disruption.

7. Results – the Wi-Fi in Operation

The 2012 Wi-Fi performed well across all services during the games. The LOCOG service was used during the years and months running up to games, mainly from the organising offices for the general day to day build and preparation during the games, predictably the other services overtook the LOCOG Wi-Fi as most popular, with the public BT Wi-Fi being the most utilised, followed by the athletes Wi-Fi. The ticket master Wi-Fi was built for consistent support for the mobile ticket scanners, which it provided throughout the games.

The pattern of utilisation is clearly shown below in Fig. 6, with the athletes Wi-Fi client counts during the games, with the number of clients ramping up over the preceding days of the games, peaking during the middle, and then tailing off to the end. This pattern was reflected across all the services apart from ticket master which was consistent with the number of scanners throughout.

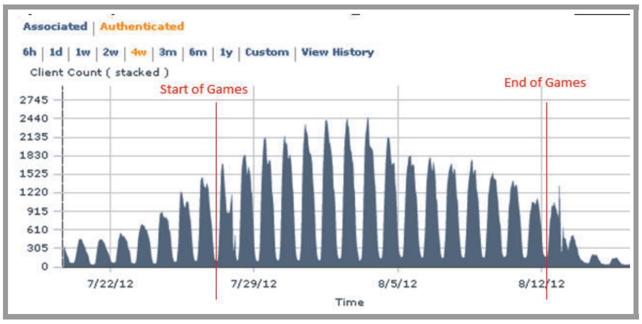

Fig. 6. Client count for the athlete's Wi-Fi service.

Out of the 2.4 GHz and the 5 GHz Wi-Fi spectrum, the 2.4 GHz was most heavily used. This is because the majority of handheld Wi-Fi devices only support 2.4 GHz, such as the iPhone. As a result, in areas of dense utilisation, the 2.4 GHz had slower speeds, where are the 5 GHz devices (such as iPads and the Samsung OFMS phones) had better performance as there was less congestion in the air.

The HD Wi-Fi performed as designed in the seating bowls of the venues it was installed, creating smaller Wi-Fi footprints, being able to deal with dense crowds better than conventional Wi-Fi.

The traffic patterns during popular events showed an interesting trend. It was originally thought that during popular events, upload traffic out the venue where the event was being held would be the most predominant traffic on the 2012 Wi-Fi solution, with people uploading pictures, messages and videos of the event to the internet. In reality however, the predominant traffic trend during a popular event such as the 100 meter final was in the download direction. When the download traffic was drilled into, it was seen to be destined for other venues with people in, but not the venue where the popular event was being held. So in the case of the 100 meter final, the traffic spike was in the basketball and handball arenas. Figure 7 shows the traffic spike into the basketball arena when the 100 meter final was being run in the stadium.

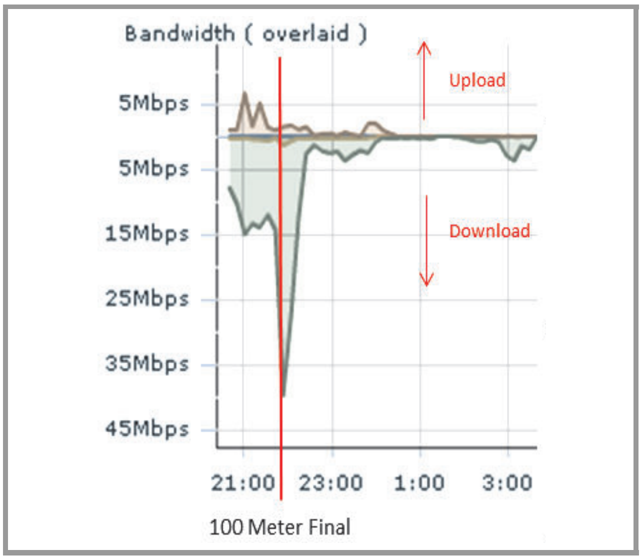

Fig. 7. Wi-Fi download spike into the basketball arena during the 100 meter final.

The reason for this is that spectators in the other venues were streaming the live footage and results of the popular event to their mobile devices, taking a short break from watching the event they had tickets to, to not miss out on the big events happening nearby.

8. Conclusions

The extensive use of Wi-Fi at the London 2012 Olympics by multiple user groups shows that as would be expected, the demand for wireless communications is strong. This is driven by the growth in smart phones and tablets, and the ever growing availability of content, and interactive social media. It is therefore expected that this demand for wireless connectivity and bandwidth will continue to grow and be demanded at other such events which draw people together.

In order for a Wi-Fi deployment on this scale and with such diversity to be successfully deployed, including HD Wi-Fi, the strategy should follow the below sequence:

Design. This includes site surveys to identify the best positions for access points, and the backhaul infrastructure.

Build & Deployment. The backhaul infrastructure should be built first, and then the access points should be commissioned last.

Optimisation & Testing. This is an especially critical phase for HD Wi-Fi. During optimisation the parameters outlined in section V are tuned so as create the optimum Wi-Fi cell sizes, with the best physical locations and angles of the antennas tweaked and adjusted as necessary. Continual testing is required to make sure and confirm what effects the changes are having in the overall performance of the Wi-Fi. Test events should be conducted to see how the Wi-Fi performs in realistic crowded situations.

Policing and Monitoring. After optimisation and testing has settled on the set-up of the Wi-Fi solution, then it needs to be policed. This means the radio spectrum needs to be monitored for sources of interference to the Wi-Fi, and if appropriate, acted upon. What is acted upon depends on what has been agreed with the organisers (LOCOG in the case of London 2012), but the main thing is being able to pin down any radio interference issues to their cause, so appropriate action if required is an option.

In areas congested with Wi-Fi clients, devices which operated within the 5 GHz channels performed better. This is due to less congestion, as less device types operate on 5 GHz frequencies, and there are more channels available in this spectrum range. As time passes however, it is expected more devices will support 5 GHz, so this advantage they have at the moment will diminish with the growth in 5 GHz devices.

Wi-Fi traffic patterns observed during the most popular Olympic events reveal that the most noticeable trend was downloads to the venues where people were present, but the popular event was not taking place. This was due to people streaming live video of the event taking place elsewhere to their mobile devices. This is probably a phenomenon unique to the Olympics, or other such multi venue sporting events.

Conventional Wi-Fi using a normal omnidirectional antenna does not operate effectively in areas with dense numbers of clients such as the stadium seating bowl. High Density Wi-Fi provides a better service by providing smaller but more frequent wireless cell sizes thus cutting back on the volume of clients associated to an AP, keeping the traffic local and minimising congestion.

Peter Leonhardt after graduating from the University of York, has worked through progressive roles in British Telecom, winning various awards for his work with the London 2012 project and major business customers along the way. He was a lead IP Consultant for BT during the build London 2012, a LAN/WAN Lead Consultant phase during the games itself, and is now a consultant for BT's Rapid Response Unit. He has completed a M.Sc. in business and Telecoms from UCL, achieving a Distinction, and won the award for the best paper at the 2012 FITCE Congress in Poznań, Poland. He is also involved in projects developing appropriate communication systems for developing countries, assisting with projects in Africa.

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