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# Delivering Live-Action to Handheld Devices: Experimental Results and Recommendations

George ZAGGOULOS, David HALLS, Andrew NIX and David BULL

**Abstract** - This paper addresses the broadcast capabilities of WiFi systems transmitting to handheld devices. The analysis includes a comparison of different antennas at the access point (AP) in terms of received signal strength indication (RSSI) for different channel conditions and handset orientations. An H.264 AVC encoder and IP packetisation unit is used to broadcast IP video streams to mobile clients. Measurement and simulation results show that body shadowing and handset orientation can seriously degrade the video quality. The use of dual polarized antennas at the AP is shown to enhance range and video performance. A shadowing and depolarisation margin of around 14dB is required to ensure high quality broadcast reception.

## I. INTRODUCTION

The use of wireless local area networks (WLANs) has become an everyday part of our daily life. Wireless connectivity is widely available in households and offices, as well as coffee shops, restaurants, and airports. In recent years WiFi transceivers have been integrated into smart phones, personal digital assistants (PDAs) and portable game consoles. It is now possible to select and receive video streams using WiFi enabled handsets. The use of WiFi is attractive to the consumer since there are no additional airtime charges. Support for live and interactive video remains a challenge because the use of Application or MAC layer retransmission produces unacceptable fixed and variable delays [1, 2]. Furthermore, to support large numbers of users it is not efficient to use multiple unicast streams. Finally, broadcast IP protocols do not permit the retransmission of lost packets and this can result in poor video performance.

In a Non-Line-of-Sight (NLoS) multipath environment the received signal level fluctuates rapidly over time as a result of fast fading. Moreover, the location and orientation of the handset can result in additional body shadowing and polarisation mismatch losses. Unlike other portable devices such as laptops, mobile devices are often held in landscape mode to view video (as opposed to the more common portrait mode for voice calls).

Over the last two years the VISUALISE<sup>1</sup> project has examined via simulations and field trials the transmission of live multi-channel video to handheld devices. This work has confirmed that broadcast video over WiFi, especially to handheld devices, is not a straight forward process. It was observed that video quality is often unacceptable (as a result of high packet loss), even at short distances from the access point (AP). Based on results from simulations and experimental investigations, this paper shows the impact of body loss and depolarization and demonstrates improvements in the broadcast of WiFi video services using dual polarized

<sup>1</sup> The VISUALISE project aims to enhance the spectator's experience at large scale events by offering mobile access to live video feeds, statistics and archive material via any IP based network (i.e. WiFi, HSPA and WiMAX).

antennas. These gains are particularly noticeable in LoS locations where a doubling in the operating range is observed.

## II. VISUALISE TRIALS AND RAY TRACING SIMULATIONS

A number of video transmission trials were performed at the Walter's Arena stage of the World Rally Championship (WRC). During these trials four live video feeds were made available to spectators via WiFi for viewing on their PDAs and mobile phones. From the first trial in 2006 it was obvious that broadcast IP protocols were necessary for two reasons: 1) to provide low latency video content, and 2) to efficiently enable video reception by a crowd of people. The WiFi AP used to broadcast the video streams had an effective isotropic radiated power (EIRP) of 20 dBm. This was well within the regulations that govern WiFi operation in the UK. In certain cases, the range at which the video streams could be successfully received was limited to just 30m. These cases tended to involve the user and/or the surrounding crowd blocking the signal path back to the AP.

To verify the practical results observed at the WRC trial the radio coverage was modelled using a detailed 3D ray tracing model. The terrain and foliage data for the stage was acquired in the form of a digital elevation model. High resolution ortho-photography was used to accurately assess distances.

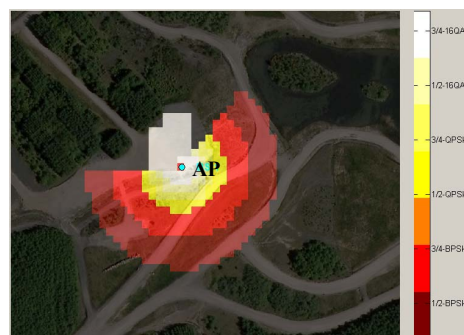


Figure 1: WiFi coverage in broadcast mode versus link-speed

Figure 1 shows the predicted connectivity for a WiFi enabled PDA or mobile phone in an 800m x 600m area. The link was modelled using the 802.11g receiver sensitivities as quoted in the standard [3]. The following system parameters were used (EIRP: 20dBm, Tx and Rx antenna type: vertical monopoles, Rx Antenna Gain: 0dBi, Tx/Rx antenna height: 4.5m/1.5m). A single AP was located next to the VIP hospitality tent (AP in figure 1). A PDA requires an RF signal level of around -82dBm in a non-fading AWGN channel to connect to the access point. However, to cover fast fading, polarisation mismatch and body shadowing a 20dB link margin was applied. The prediction tool estimates coverage up to 75m from the AP. If the 20dB margin is removed (i.e. the

PDA is correctly aligned in a clear LoS) then links up to 500m from the AP are possible.

### III. RESULTS FROM MEASUREMENTS

In order to experimentally verify the findings from our system trials and subsequent RF predictions, two sets of additional measurements were performed in different open outdoor environments. These were performed by connecting the WiFi AP used in the WRC trials (via Ethernet cable) to a video compression and IP server box. The PDA was replaced with a laptop PC and an external WiFi card. This allowed us to connect an external monopole antenna and thus vary its orientation and polarisation. The RSSI, PER and GPS location were recorded at different Tx-Rx separation distances. At each location the effects of polarisation mismatch and body shadowing were measured; the former by rotating the monopole antenna from vertical to horizontal orientation (in two steps), and the latter by standing in front of the laptop to block the LoS. Six different sets of data were recorded at each location; each with a duration of 60 seconds. The average RSSI values are presented in figure 2 for two different separation distances. It can be observed that polarisation mismatch on its own causes high signal loss in an open outdoor environment (since there is one dominant LoS and only a small number of reflections to shift the transmitted polarisation). Additionally, the blockage of the LoS component by the user's body indicates an additional loss of approximately 10 dB at 2.45GHz. As expected, the body shadowing losses are much lower for the horizontally oriented Rx antenna since the depolarised signal arrives from a spread of angles (rather than a single LoS direction). Comparing the recorded signal levels in the first and last columns of figure 2 we can confirm the worst case 20dB link margin (which covers body shadowing and depolarisation) used in the earlier coverage predictions.

Considering the above findings, a second set of measurements was performed using two additional antenna structures. The idea was to minimize polarisation mismatch and thus increase range for an arbitrary terminal orientation. All data collected was compared with that acquired previously using the vertical monopole antenna. The two new antennas were patch devices offering dual polarization. One antenna transmitted with +/- 45 degree polarisation, while the other emitted in vertical and horizontal polarizations. Although each antenna has its own radiation pattern, all three had a gain of 7dBi in the direction facing the client. In general, from the RSSI comparison presented in figure 3, it is clear that the dual polarized antennas maintain a higher RSSI level compared to the earlier vertically polarized monopole. Looking now at the differences in each orientation, it is obvious that the third antenna, which transmits on vertical and horizontal polarizations, provides the highest power levels in five out of the six different receiver orientations. However, the results from the other dual polarized antenna are more consistent across the orientations; thus showing that the RSSI is less dependent on the orientation of the receiving monopole antenna. The measurements imply that dual polarization at the AP helps to overcome signal level variations as a function of different receiver orientations. A gain of more than 6dB has

been added to the link budget with the use of dual polarised antennas. This translates into at least a doubling of range. This gain can also be used to improve the WiFi broadcast quality; particularly for LoS links. Based on our experimental data, a mean RSSI of -65dBm (assuming clear LoS) was necessary to ensure high-quality broadcast video. This high power level is necessary to allow for terminal orientation and body shadowing losses. To further reduce this margin, some form of additional error protection can be applied. For example, every IP packet could be sent twice from the AP with a suitable time delay that exceeds the channel coherence time. Each receiver would then only need to correctly receive one of the two transmitted packets. This technique increases the probability that IP packets will be successfully received in a broadcast scenario.

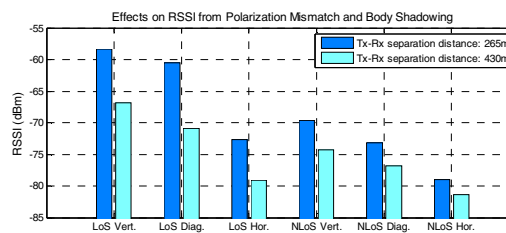


Figure 2: Polarisation mismatch and body shadowing effects

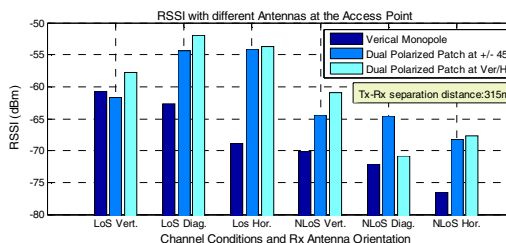


Figure 3: Polarisation mismatch and body shadowing effects with different antennas at the AP

### IV. CONCLUSIONS

This paper has analysed the broadcast of WiFi video streams from an AP to handheld devices. The lack of retransmission mechanisms in a broadcast stream makes the video prone to packet loss. Measurements have shown that body-shadowing and terminal polarisation mismatch can reduce the operating range by an order of magnitude. To protect the link, an additional margin of 20dB is required with a monopole antenna at the AP. This margin can be reduced to 14dB if dual polarized antennas are used at the AP, enhancing both the performance and range of broadcast WiFi.

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