Infrastructure-Dependent Wireless Multicast over 802.11n WLAN

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Abstract: In this paper the concept of infrastructure-dependent wireless multicasting (IDWM) is presented. IDWM aims to enhance the reliability of multicasting by modifying the infrastructures without requiring any modifications to the receiver’s transceiver chain or its network layer stack. This paper presents packet error rate (PER) results measured from a testbed equipped with 802.11n nodes, when multicasting video through (i) one AP equipped with one antenna (ii) one AP equipped with two antennas which are co-sited, and (iii) one AP with two antennas located 23.4m apart. Empirical results are presented highlighting the improvement achieved in the PER when two transmitting sources, in this case two antennas are used to share the burden of multicasting data packets by halving the coverage area.

1. INTRODUCTION

Every Wireless Local Area Network (WLAN) receiver connected to a transmitter via the same frequency can listen to the transmission from that source. In fact, security schemes are used to overcome network attacks by users with malicious intentions. However, even though the wireless medium is of broadcast nature, broadcasting and multicasting experience a larger packet error rate (PER) as shown by previous studies [1–3] and confirmed as a by-product of this work. This is because the wireless medium is an unreliable medium affected by attenuation, multi-path fading and shadowing. Despite these features, multicasting is transmitted without feedback and retransmissions.

The IDWM concept is part of a study focusing on increasing the reliability of multimedia multicast over 802.11 WLANs. Since multicasting can be beneficial to throughput as it transmits one packet of data to a number of nodes simultaneously, multimedia multicasting is also one of the enhancements tackled by TGaa. The current IEEE 802.11a/b/g/n standards use one of the rates in the basic service set (BSS) basic rate set to transmit multicast data packets [4]. If a robust modulation and coding scheme (MCS) is used than the physical layer (PHY) data rate can satisfy the needs of the worst receiver and can cover a larger range than that covered by a higher MCS. But this will result in the "rate anomaly problem" [5]. On the other hand if a faster PHY data rate is used, than the PER will increase.

Video multicasting over WLAN is useful to a wide spectrum of applications, from home entertainment to video conferencing and lecturing. But with the increase in sales of smart phones equipped with WiFi transceivers, video multicasting is also beneficial during live events such as concert and football matches, to receive direct footage on your own mobile device from various angles. However, the problem in such setups is that the receivers are heterogeneous and hence there is always the question of which MCS should be used. If the most error-resilient MCS is used than receivers with good channel quality, experience a lower video quality in order to lower the PER at those receivers which are experiencing frequent packet loss. On the other hand the use of a faster PHY data rate will prohibit multicast video reception at the weakest receiver.

The lack of data rate adaptation is not the only problem that multimedia multicasting has to face. Request to Send (RTS) and Clear to Send (CTS) handshaking is not used by multicasting, hence multicast transmission is also prone to errors due to the hidden node problem, since the transceivers that are not members of the multicast group cannot set their network allocation vector (NAV); a virtual carrier sense mechanism used to increase reliability of unicast transmission over WLANs. The transmitter of a multicast transmission relies solely on the Clear Channel Assessment to reduce the probability of collision. Moreover, receivers do not transmit an acknowledgement (ACK) to inform the source of successful reception, therefore, the wireless access point (AP) always assumes that the packets were received when it transmits multicast data packets, eliminating the possibility of a retransmission. The fact that ACK is not used in multicast transmission means that an AP transmitting a multicast packet cannot perform rate adaptation and backoff procedures when there are collisions and therefore current multicast implementations are unfair to unicast transmission as shown by [2].

This study aims to analyse whether dividing the coverage area in half among two antennas connected to the same wireless card, transmitting the same information, results in a lower PER. Hence it investigates whether receivers can...
experience a better channel quality by modifying solely the infrastructure. The effect of multiple antennas on point-to-point long-distance links using 802.11n devices has already been highlighted in [6]. The current work attempts to extend the benefits of multiple antennas to aid multimedia multicast over WLAN by using a novel deployment of antennas. Transmitters with more than one antenna are common now-a-days since the 802.11n draft release of APs and wireless network adapters, and hence this technique can be implemented with very little added cost.

An introduction to the IDWM is presented in Section 2, while Section 3 explains the testbed created to test whether IDWM results in a better performance when compared to a single transmitter with or without transmit diversity. The results are presented in Section 4 followed by the conclusion which includes an outline of future work.

2. INFRASTRUCTURE-DEPENDENT WIRELESS MULTICASTING

Although spatial correlation has been proved to feature in wireless transmission [7], multicast group members will not experience exactly an identical channel quality. The reason lies in the factors that cause channel quality degradation i.e. attenuation, multi-path fading and shadowing, which depend on the position of the receiver relative to the source. Thus, the same receiver may have experienced a better channel quality if it was located closer to the source.

If one considers multicasting in a lecture theatre or at a concert, it is not possible for all the receivers to be located close to the wireless source, if one source is used. Therefore, IDWM aims to reduce the distance between the source and the receiver by adding more sources. However, the sources are not added in the middle of the coverage range as proposed previously by [8] and shown in Fig. 1, but at the edge of the coverage range as shown in Fig. 2.

Therefore, the nodes which in Fig. 2, are outside of the inner circle are, still far from the AP in the middle but they are not far from one of the AP at the edges. Therefore, the difference in this proposal from previous proposals which used relays to reduce the PER are:

1. the additional sources are part of the infrastructure and not other multicast group members, aiding their neighbours
2. the additional sources are not placed in the middle of the coverage range but at the edge of the coverage range, ensuring that besides halving the coverage range, the nodes which are the furthest from any source, can actually receive transmission from two sources with equal transmission strength.

Note that the aim of IDWM is not to increase coverage area by ensuring that the coverage area of the additional sources do not overlap with the AP in the middle, but to increase reliability by ensuring that each receiver is located close to one of the APs.

Since the aim of the IDWM is to force all the changes at the sources, causing minimal changes at the receivers, the APs must use the same frequency, same MCS, and also the same BSSID. The additional APs transmit the same data packet simultaneously with the original AP. Each receiver does not need to know which AP is aiding it to receive the data packets and hence as far as the receiver knows, the system consists of only one AP.

3. METHOD

To study the concept of IDWM, we start by focusing on one sector of the coverage range. Therefore, in this empirical investigation two omni-directional transmitting antennas were used connected to an AP via extension cables, and placed at opposite ends of the coverage area. Since the two antennas are connected to the same transmitter they transmit the same data packet using the same frequency and MCS. Moreover, the nodes do not distinguish which of the two antennas transmitted the data packet. Hence, this testbed
although simple can test whether the IDWM concept is beneficial or not. The testbed used to test the IDWM concept is explained in further detail below.

3.1 Testbed

The testbed consists of three nodes, an MSI GT740 laptop, an Eee Asus netbook and a Pentium IV desktop computer each having a draft 802.11n adapter as indicated in Table 1. Another station, an MSI M670 laptop is connected via an Ethernet cable to a wireless router. The wireless router is a Pentium I 1GHz computer running RouterOS v5 operating system [9], having an Ethernet card and a 3x3 802.11n D-Link DWA-547 wireless card. Using RouterOS this card was configured as an AP using Greenfield mode. The 802.11n D-Link DWA-547 is not capable of STBC and hence when it uses multiple antennas to transmit 1 spatial stream it uses Spatial Expansion. Moreover, via a spectrum analyzer, it was confirmed that the transmit power of the antennas is not halved when two antennas are used, hence the transmit power is doubled when two transmit antennas are used. The antennas used in this analysis were 5dBi omni-directional antennas connected by extension cables to the RouterOS. RouterOS was chosen for its flexibility with respect to turning on and off antennas. Another reason why RouterOS was used is the ability to change the MCS used to transmit multicast data. In this analysis the MCSs used were mcs-0, mcs-1, mcs-2 with 800 ns Guard Interval and 1 Spatial Stream. The parameters of the mentioned MCSs are tabulated in Table 2. Transmission was performed using Channel 2 i.e. 2417MHz, since this channel was not used by any other BSS.

In total three antenna configuration were tested:
1. Configuration A: The AP uses only one antenna placed at Location A as shown in Fig. 3.
2. Configuration B: The AP uses two antennas both located at Location A, and separated by 1.1m i.e. $8.86\lambda$, whilst still maintaining the distance of 1.8m from Node A and 11.7m from Node B as shown in Fig. 4.
3. Configuration C: Uses two antennas connected to the 802.11n D-Link DWA-547 card as shown in Fig. 5. Configuration A served as a baseline, against which to compare the other two configurations. Configuration B is used to test whether a single source with multiple antennas, is better than a single antenna transmitter. Configuration C allows the IDWM concept to be tested by placing one of the antennas at Location A and the other at Location B. Therefore, the antenna at Location B is placed near the node furthest from location A.

Attention was also paid to the wireless cards configuration of each node making sure that the computer cannot switch them off for power save purposes.

3.2 Software

Two C++ transmitter and receiver applications were developed using multicast socket programming, employing User Datagram Protocol (UDP) sockets. The transmitter sent UDP packets of size 1324 bytes. The payload was formed by extracting 1310 bytes from a video source. However in order to identify which packets were lost, the 1310 video bytes are concatenated with a 6 byte index, which is incremented sequentially starting from 0 for each data packet transmitted. The transmissions lasted 304 seconds.

The receiver outputs for each socket used, an index file, a count file and two video files. The index file indicates which

<table>
<thead>
<tr>
<th>Node</th>
<th>Wireless Network Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Pentium IV desktop computer</td>
<td>Conceptronic C300Ri 3x2 PCI Card</td>
</tr>
<tr>
<td>B: Eee Asus Netbook</td>
<td>AR9285 single-stream wireless chipset</td>
</tr>
<tr>
<td>C: MSI GT740</td>
<td>Intel® Wifi Link 5100 AGN 2x2 chipset</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2 - MCS Parameters [4]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulation Type</td>
</tr>
<tr>
<td>mcs-0</td>
</tr>
<tr>
<td>mcs-1</td>
</tr>
<tr>
<td>mcs-2</td>
</tr>
</tbody>
</table>
packets were correctly received, and the count file logged the total number of packets received. The first video file, concatenated the received payload sequentially, after removing the preceding 6 byte index, whereas the second video file was created by placing the payload in the position indicated by the index. Those packets which are not received are replaced by bytes having a zero value.

The video source file used was a Quicktime Generic MPEG-4 file [10] with bit rate of 2.16Mbps. The video had duration of 18.889 seconds and hence to generate 304 second transmissions, the same video was repeatedly transmitted 48 times. Each experiment was repeated six times. Therefore for each antenna configuration, a video sequence having a video bitrate of 2.16Mbps was repeatedly transmitted for 6 times considering each MCS specified in Table 2.

4. RESULTS

In this section we present the results obtained from this set of experiments. Table 3 tabulates the average PER measured from the six runs for the three antenna configurations considering the three MCSs.

From these measurements, it is clear that the amount of PER experienced by the receivers, depends not just on the distance but also on their hardware. One can note that the middle node B, i.e. the netbook with a single-stream Atheros chipset, outperforms the other nodes independently of the MCS considered and also the antenna configuration considered. Even with one antenna at Location A, it experienced a much lower PER than that experienced by Node A, which was closer to the antenna at Location A than the netbook. This is in agreement with the work by Heide et al. [11], who found through their measurement campaign that packet loss is not only related to the location of the receiver but also to the hardware used.

4.1 Configuration B vs Configuration A

Node C benefitted from the increase of another antenna at Location A as can be observed from mcs-0 and mcs-1, even though STBC was not implemented but spatial expansion was, which can provide only a theoretical 2dB gain at 1% PER for one spatial stream [12]. However, there was also an increase in transmit power when two antennas were used. Therefore, the improvement at Node A and Node C is due to the increase in transmit power and the diversity gain possible through the use of multiple receive antennas at those nodes. With mcs-2 this node however, experienced a degradation compared to Configuration A when Configuration B was tested. Even though Node B maintained its low PER relative to the other two nodes, its PER degraded with the use of two front antennas when compared to just one antenna, since its chipset does not provide receive diversity. The only node which always observed an improvement when compared to the use of one antenna but using two antennas at the front was Node A, as expected. One can hence note that there was no significant reduction in PER by going from one antenna to two co-located, but statistically independent antennas.

4.2 Configuration C vs Configuration A and B

From the tabulated PER values, it is clear that the furthest node, node C benefitted most from the use of the IDWM concept with a minimum average improvement of 2.5 times over the other two configurations, across all the three tested MCSs. At the same time, Nodes A and B did not experience a degradation in PER. This proves that the IDWM concept can reduce the PER by reducing the distance that each node has from the source. From these results, one can also note, that the furthest node i.e. node C experience a better PER than that observed by Node A, with two antennas at the front, showing that the degradation in quality experienced by node C when one or two antennas were used at location A, was solely due to the distance. The fact that it did not achieve the low PER experienced by the netbook is related to the chipset used. The netbook which was located in the middle of the area, also experienced an improvement when the IDWM concept was employed, obtaining half the PER experienced with two antennas at the front. Hence one can conclude that via space diversity, IDWM reduces the aggregate PER experienced by the multicast receivers, without requiring STBC or transmit beamforming, resulting in simple transmitter and receiver.

The only node which did not observe an improvement when the IDWM concept was Node A, which was always located close to the antenna at location A. This node returned a similar PER to that experienced when only one antenna was located at Antenna A. However, it experienced a degradation when compared to the PER resulting from the use of two antenna at the front, which is expected since with Configuration B there was a doubling in transmit power at Location A. However, if one considers the overall PER

<table>
<thead>
<tr>
<th>Configuration</th>
<th>mcs-0</th>
<th>mcs-1</th>
<th>mcs-2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Node A</td>
<td>Node B</td>
<td>Node C</td>
</tr>
<tr>
<td>A – one antenna at the front</td>
<td>4.36%</td>
<td>0.21%</td>
<td>10.64%</td>
</tr>
<tr>
<td>B – two antennas at the front</td>
<td>3.61%</td>
<td>0.30%</td>
<td>8.84%</td>
</tr>
<tr>
<td>C – one antenna at the front and one antenna at the back</td>
<td>4.39%</td>
<td>0.14%</td>
<td>3.99%</td>
</tr>
</tbody>
</table>

Table 3 - Average Packet Error Rate
experienced by the nodes, it is clear that the use of IDWM is superior to the other two antenna configuration.

4.3 Heterogeneity in the PER measured

The use of the worst receiver as a leader to notify the source of successful reception and hence also of lost packets is a common approach in leader-based protocols (LBP) [2, 13], used to mitigate packet errors in wireless multicasting. One can note from Table 3 that if Node C, i.e. the weakest node for Configuration A and B, was elected to request retransmissions of lost packets, it would cause the other three nodes a considerable degradation in quality as it experienced a much greater packet loss. Hence it is clearly not beneficial to use the worst receiver as the leader. However, with the use of IDWM, this discrepancy in the PER experienced by the weakest receiver is reduced. Therefore, IDWM concept is also beneficial to LBPs.

IDWM is also advantageous to cooperative error recovery schemes, where a node recovers its errors from its neighbouring nodes. Using IDWM, it would request a lower number of retransmissions than it would if the source is located at one location. Reducing the number of retransmissions from neighbours is not only beneficial for bandwidth saving purposes but also if one considers that a node may be battery therefore battery saving is of utmost importance.

5. CONCLUSIONS

From this empirical investigation we have shown that the infrastructure layout can be responsible for delivering better channel quality to the receivers without requiring any modification to the latter. Besides highlighting the large PER inherent of multicasting, this investigation has shown that multicast packet loss is not only related to the distance between the source and the receiver but also to the hardware considered. This study also highlighted the heterogeneity with respect to PER that can be experienced by the nodes, showing that relying on neighbours for reliability may be a large burden on those receivers experiencing good channel quality. Moreover, given that wireless network adapters may differ in their capability, it is important to consider “quasi-reliability” [14] rather than guaranteeing reliability.

Our future work includes the use of a master and a slave AP, where the slave AP functions only to improve multicast. Moreover, a study highlighting whether simultaneous transmission from the two APs is better than redundantly transmitting the same data packet first from the Master and then the Slave AP, will follow, similar to IEEE TGaa proposal - Advanced Groupcast with retries (GCR)-Unsolicited-Retry [15].

REFERENCES