# Multi-Path Video Streaming with Redundant Frames over a MANET

Nadia N. Qadri & M. Altaf
[1]CIIT, Islamabad, Pakistan
[2]University of Essex,
Colchester, UK
+44 1206-872-817
{nnawaz, maltaf}@essex.ac.uk

Martin Fleury
University of Essex
Wivenhoe Park
Colchester, UK
+44 1206-872-817
fleum@essex.ac.uk

Mohammed Ghanbari
University of Essex
Wivenhoe Park
Colchester, UK
+44 1206-872-234
ghan@essex.ac.uk

## ABSTRACT

It has become feasible to stream video across a mobile network ad hoc network (MANET). This paper proposes using the H.264 codec's 'redundant frames' video delivery over multi-paths and compares their performance to Video Redundancy Coding, another multi-path technique. The paper reports that 'redundant frames' result in as much as 10 dB improvement in delivered video quality. An interesting secondary result that emerged from experiments was that for all performance indicators Location-Aided Routing (LAR) provides superior performance to the well-known AODV routing protocol.

## Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design–*Wireless communication*

## General Terms

Algorithms, Performance, Experimentation

## Keywords

MANET, multi-paths, redundant frames, VRC

## 1. INTRODUCTION

Wireless mobile ad hoc networks (MANETs), working alongside cellular networks, can [1]: relieve congested cells, extend coverage, and service dead-spots. As new 'push' multimedia services have been introduced into 3G networks, the same services may be extended into ad hoc networks. Therefore, this paper considers effective multi-path ways to stream video within a MANET. A feature of MANETs is that multi-path routing (routing over multiple paths) is possible. The primary contribution of this paper is a practical multi-path scheme for video streaming with 'redundant frames'. The proposed scheme is relatively simple to implement and does not require modification of the H.264/Advanced Video Codec (AVC). We have compared our proposal with Video Redundancy Coding (VRC) [2], which is a simplified method for Multiple Description Coding (MDC). We have found that using 'redundant frames' will result in superior video quality even if more packets are lost than in VRC. This counter-intuitive result arises because some of those packets may carry redundant frames.

Notice that in this work our goal is to achieve sufficient quality to provide a useable video service. Inevitably, in providing redundant frames there will be some loss of spectral efficiency but if the video quality is not sufficient the video service would not be taken up by users. Notice also that many forms of error control exist. However, those based on Automatic Repeat Request (ARQ) introduce delay to delay-intolerant video streaming, whereas those that introduce Forward Error Control (FEC) risk duplicating physical layer protection. Therefore, at the application layer it is the choice of error resilience method that is important. We now consider multi-path video.

Due to the volatility of wireless channels and the propensity for wireless links to be broken multi-path communication is more attractive than attempting to select an optimal single path through the network. In fact, all paths might be unattractive, even if one was marginally optimal. The calculation of that path could also tax the limited processing power of the network nodes. In this work, we make the common assumption for simplicity that there are just two streams exploiting path diversity. The advantage of that arrangement is that two disjoint paths are more likely to be present.

The H.264/AVC currently provides high coding efficiency along with many flexible features, including redundant frames [3]. Unfortunately, the H.264 Scalable Video Coding extension is unlikely to be suitable for this application, because of complex inter-frame dependencies, making reconstruction difficult if frames are lost. On the other hand, redundant frames are encoded with reduced quality compared to the original frames. They can act as replacements of the original frames, if those frames are lost in transmission. It appeared to us that redundant frames might have a role in MDC and simulations have confirmed the value of this proposal. In MDC [4], two or more versions or descriptions of the same video stream are sent over different, preferably disjoint, routes across a network. Either description can serve to reconstruct the video but enhanced quality is produced by combining both descriptions. Therefore, if packet loss occurs on one of the paths then this can be compensated by the encoded bit-stream arriving from other paths. MDC also may reduce the bandwidth requirement for any one route through an ad-hoc network, at a cost in increased coding redundancy.

## 2. VIDEO STREAMING AND MULTIPATH

In general, MDC is difficult and computationally complex [4], because it requires synchronization between encoder and decoder in order to reduce motion estimation error drift. Various forms of

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.
*FIT'09*, December 16–18, 2009, CIIT, Abbottabad , Pakistan.
Copyright 2009 ACM 978-1-60558-642-7/09/12…$10.00.

splitting can occur including in the spatial and frequency domain but we consider temporal splitting in which a number of practical solutions have been proposed, such as VRC [2].

VRC, though originally intended for exploitation of path diversity over wired or infrastructure networks, is an important simplification of MDC. In VRC two independent streams are formed from encoding odd and even frame sequences and they are sent over different paths. By insertion of intra-coded I-frames (spatially coded frames with no removal of temporal redundancy through motion compensation) either sequence can be resynchronized at the decoder, at a cost in increased data redundancy compared to sending a single stream.

To improve error resilience in both paths, ‘redundant frames’ intended for error resilience in H.264 can serve to better reconstruct frames received in error. We have examined ‘redundant frames’ as they are a new feature of the H.264/AVC codec that have had comparatively little investigation. Redundant frames (or strictly redundant slices [3] making up a frame) are coarsely quantized frames that can avoid sudden drops in quality, marked by freeze frame effects if a complete frame (or slice) is lost. The main potential weakness of the redundant frame solution for single path communication is that these frames are discarded if not required. However, the redundancy is still likely to be less than including extra I-frame synchronization, as redundant frames exploit temporal redundancy through motion estimation and compensation. A potential weakness is the delay that may arise in encoding and transmitting redundant frames, making it less suitable for interactive applications. However, redundant frames still have a role in one-way streaming over an ad hoc network.

Fig.1 illustrates the schemes compared in this paper. The frame numbers indicate the raw video frame order from which coded frames are constructed. Frames are decoded with motion compensation from reference frames in the same stream. Fig. 1a illustrates single stream delivery. A single stream or description is sent as an I-frame followed by a series of P-frames in the computationally lightweight Baseline Profile of H.264/AVC. Fig. 1b illustrates dual stream delivery with VRC. To achieve VRC within H264/AVC, the skip frame(s) facility was taken advantage of. The Main profile of H.264 allows bi-predictive B-frames with greater coding efficiency than if only P-frames were to be employed. B-frames may be dropped with no impact on later frames. In Fig. 1c, redundant frames in the proposed MDC scheme are sent in each stream, at a cost in latency but a potential gain in delivered video quality. There is only one initial I-frame as upon loss of the first I-frame or a subsequent P-frame, its matching redundant frame (if not lost) is available as a substitute. In experiments, when B-frames were used, the Group-of-Picture structure was the usual IBBPBBP… with an intra-refresh rate of 15.

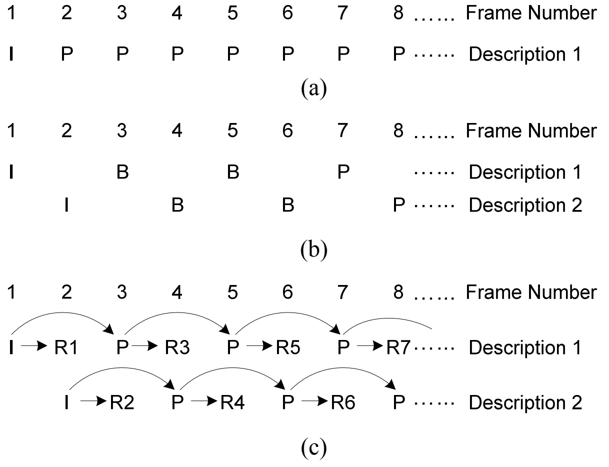


**Figure 1. Schemes tested: a) Single stream b) VRC with odd and even descriptions, c) Two streams with redundant frames**

The reference Foreman clip in Quarter Common Intermediate Format (QCIF) (suitable for mobile devices) was encoded as a test sequence. Foreman, intended to illustrate communication between mobile devices, exhibits the typical features of a hand-held camera, with a final panning sequence. All streams, including the single stream versions were H.264/AVC Constant Bit-Rate (CBR)-encoded at close to 52 kbps. As buffer memory significantly contributes to energy consumption, actively during access, and passively due to the need for refresh of DRAM, the playout buffer size was set to three frames (with buffer sharing for two stream schemes). We have evaluated the video streaming performance by simulation, as, because of the numerous factors involved (speed, network size or density, routing protocol,…), simulation is the predominant form of assessment in MANET research.

## 3. EVALUATION METHOD

The Global Mobile System Simulator (GloMoSim) was used the evaluation of the ‘redundant frames’ proposal. Total simulation time was 400 s. GloMoSim was developed based on a layered approach similar to the OSI seven-layer network architecture. IP framing with UDP transport was simulated by us, as TCP transport can introduce unbounded delay, which is obviously not suitable for delay-intolerant video streaming. The parameters for the simulations are summarized in Table 1. GloMoSim provides a two-ray path loss model, with antenna height hardwired at 1.5 m and with a Friss free-space model with parameters (exponent, sigma) = (2.0, 0.0) for near line-of-sight and plane earth path loss (4.0, 0.0) for far line-of-sight. The radio range was set to 250 m according to the assumed IEEE 802.11b standard and 1 Mbps shared maximum data-rate was configured. Setting the bandwidth capacity to the latter value in the simulation allows modeling of a limited available bandwidth.

The well-known random waypoint mobility model was employed with 50 nodes in a roaming area of $1000 \times 1000$ $m^2$. In this model, nodes are usually placed randomly in the simulated area. After pausing, the node moves to another random destination at a speed between a minimum and maximum speed. The pause time (time spent once a node reaches its destination) was set to 5 s. The minimum speed was 0 m/s, while the maximum node speed ranged from 1 to 36 m/s, i.e. from a slow walk to fast motorbike speeds. However in the initial placement of the nodes, manual intervention occurred by us in such a way that ensured disjoint paths were found by the simulator. After, the initial node placement no further intervention took. Two cross- traffic sources were set up sending 100 packets each at intermittent intervals during the simulation period. It is certainly true that cross-traffic will be present, yet such sources can generate large control packet overheads which interfere with the traffic of interest.

**Table 1. Parameters for multipath simulations**

| Parameter | Value |
|---|---|
| Wireless technology | IEEE 802.11 |
| Channel model | Two-ray |
| Max. range | 250 m |
| Roaming area | 1000 × 1000 m$^2$ |
| Pause time | 5 s |
| No. of nodes | 20 |
| Min. speed | 0 m/s |
| Max. speed | 1 – 35 m/s |
| Mobility model | Random waypoint |

Two multi-hop routing protocols were tested. The well-known Ad-hoc On-demand Distance Vector (AODV) routing protocol does not transmit periodic routing messages, which can result from proactive, table-driven protocols in greater control overhead unless network traffic is high. Location-Aided Routing (LAR) [5] requires geographical information but as GPS is increasingly included on mobile devices, this information is readily available. The main advantage that LAR brings compared to AODV is that it is able to reduce the flooding area for propagation, causing the number of routing requests to be reduced. As a result, the number of control overhead packets is likely also to be reduced.

For the video source described in Section 2, each frame was generally coded as a single slice and encapsulated in a Network Abstraction Layer unit (NALU) before being placed in a single RTP-headed packet. However for the larger I-frames, two packets were employed. An I-frame may occupy as much as 1 kB, whereas a B-frame will commonly be encoded in less than 100 B. Of course, though encoder CBR mode was selected, an encoder output's is never completely CBR as rapid changes in quality would result. If one of the I-frame packets arrives before the playout deadline but the other does not this is counted as "acceptable", as partial decoding can still take place while the other packet arrives.

In our arrangement, all three videos are played out at 15 Hz (frame/s) as is necessary for the reduced capacity of a MANET [6]. The single stream was coded at coded at 15 Hz, whereas both streams are coded at 15 Hz in the two description schemes and played out at 15 Hz. This allows for substitution of frames within the final merged two stream sequences should a frame(s) be lost. Of course, substitution of frames can only take place if the appropriate reference frame or redundant frame (if needed) is available. As is normal for comparison purposes, previous or 'freeze frame' error concealment was turned on at the decoder, rather than more complex concealment.

# 4. RESULTS

Fig. 2 records the ratio of bad frames in single path transfer of the Foreman video stream. A bad frame occurs either because a packet bearing a video frame is lost in radio transmission or the frame is delivered too late for its display deadline. Packet losses above 10% are likely to make video quality doubtful. From the Figure, it will be seen that the level of bad frames hovers about this value, depending on node speed and choice of routing protocol. Variations in performance with speed result in less packet loss at certain speeds. This phenomenon is also reported in other studies described in Section 2. If nodes are on average in proximity to each other for sufficient time for packet transfer then less packet loss occurs. Clearly travelling at speed gives an advantage while at walking pace frame loss is higher, which implies a dual path solution may give rise to better quality video as it gives more opportunity for packets to be transferred.

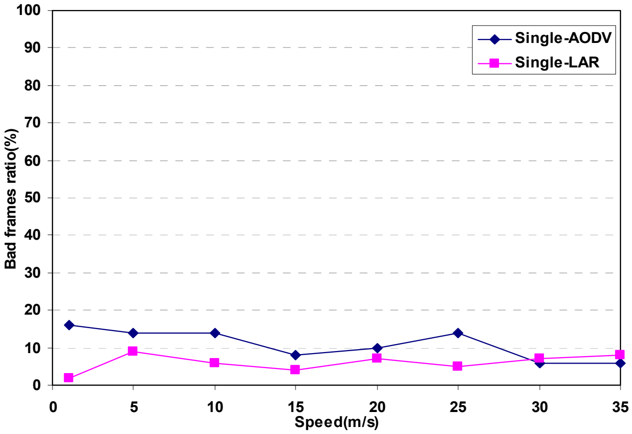
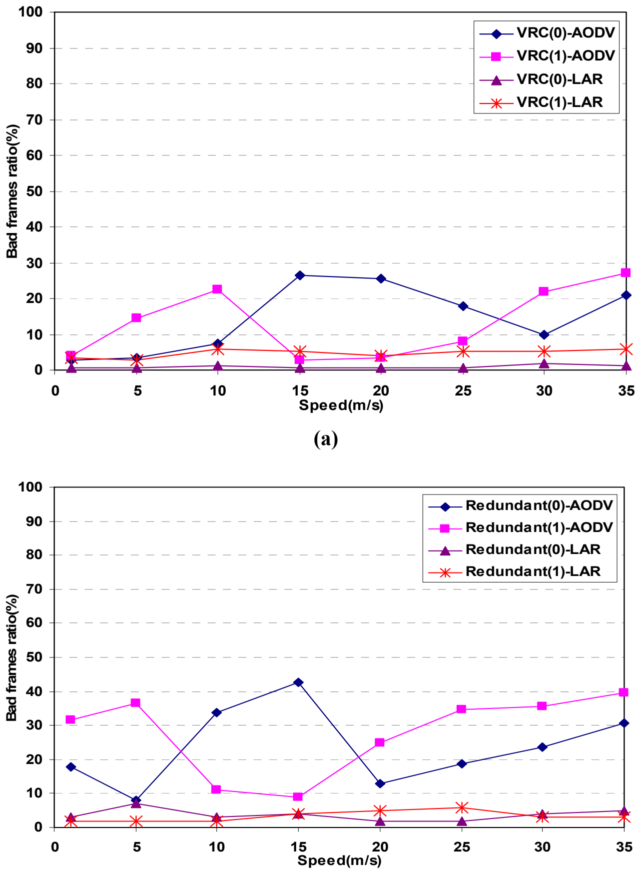


**Figure 2. Bad frame ratio with variation in node speed for single stream transfer.**

The results from VRC streaming over dual paths are represented in Fig. 3a. From Fig. 3a it is apparent that when one stream suffers bad frames another can compensate. Moreover, the lower level of loss is below 10% for AODV and is lower than 10% at all speeds for LAR. From detailed inspection, the major cause of 'bad frames' is packet loss rather than missed arrival deadlines. From Fig. 3b for dual path streaming with redundant frames, it is apparent that there is again a compensatory pattern of bad frames occurring when AODV and LAR are used, so that the weakness of one path can be balanced by the strength of the other. Again the LAR performance improves over AODV because of LAR's use of location information. In 'redundant frames', the number of frames dropped through late arrival is generally higher than for VRC streaming, but this should not be surprising as additional redundant frames are now being sent. However in general, sending redundant frames results in greater packet loss and consequently more bad frames than for VRC streaming. This is not necessarily a problem if a majority of redundant frames are lost, as these do not contribute to the decoded video sequence, except when they are used to replace lost P-frames.

The resulting delivered video quality (PSNR) is compared for the Foreman clip in Fig. 4. The delivered video quality is considerably better with the insertion of redundant frames in multi-path routing, whether AODV (Fig. 4a) or LAR routing (Fig. 4b) is employed. Small differences in quality at zero frame loss are explained by the differences between encoding with and without B-frames. By way of a casual visual check, for AODV routing, Fig. 5 shows a sample frame with no errors in Fig. 5a. It is very apparent from Fig. 5b that the quality is unacceptable below 20 dB for single path delivery, whereas a small gain in dB makes Fig. 5c for VRC acceptable for this frame. However, for example, around the hat, degradation in quality is apparent, whereas the hat is crisper in outline in Fig. 5d, though there are still some errors, even with 'redundant frames'.



(a)

(b)

**Figure 3. Bad frame ratio with variation in node speed for (a) VRC dual stream, (b) 'redundant frames' transfer.**

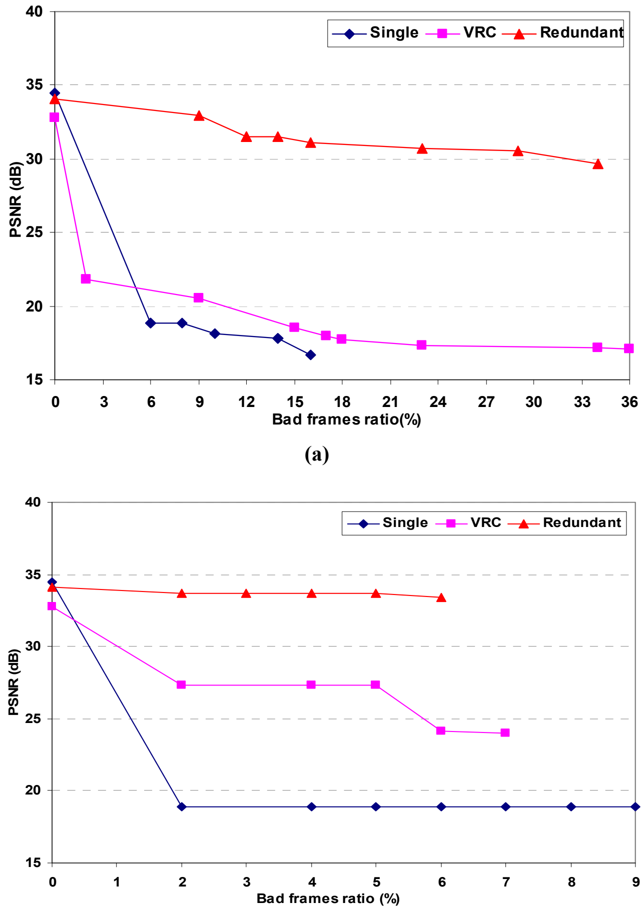
# 5. CONCLUSION

Perhaps surprisingly, given that the number of bad frames is higher than from VRC transport, inserting redundant frames allows lost or dropped predictive frames to be reconstructed, resulting in a considerable improvement in video quality over single path transfer within a MANET. This is the case whether location-aided routing is used or not. However, there is a considerable advantage if it can be utilised. Therefore, in outdoor scenarios, GPS-enabled LAR routing should allow more reliable video transfer. The 'redundant frames' multi-path scheme proposed by this paper shows that video transfer is possible and is practical, whereas previous MDC schemes tend to be complex to implement on a mobile device.

# 6. REFERENCES

[1] Wu, H., Qiao, C., De, S. and Tonguz, O. 2001. Integrated cellular and ad hoc relaying service: iCAR. IEEE J. on Sel. Areas in Comms. 19, 10 (2001), 2105-2113.

[2] Wenger, S., Knorr, G. D., Ou, J. and Kossentini, F. 1998. Error resilience support in H.263+. IEEE Trans. Circuits Syst. Video Technol., 8, 7 (1998), 867-877.



(a)

(b)

**Figure 4. 'Foreman' PSNR using (a) AODV, (b) LAR routing.**

(a) (b) (c) (d)

**Figure 5. Frame with AODV routing and 15% error for (a) no error ( b) single stream (c) VRC, and (d) redundant frames.**

[3] Tillo, T., Grangetto, M. and Olmo, G. 2008. Redundant slice optimal allocation for H.264 multiple description coding. IEEE Trans. Circuits Syst. Video Technol*.*, 18, 1 (Jan. 2008), 59 – 70.

[4] Wang, Y., Reibman, A. R., and Lee, S. 2005. Multiple description coding for video delivery. Proc. of the IEEE, 93, 1 (2005), 57-70.

[5] Ko, Y. B. and N. H. Vaidya, N. H. 1998. Location-Aided-Routing (LAR) in mobile ad-hoc networks. In Proceedings of ACM/IEEE MOBICOM, (1998) 66-67.

[6] Karlsson, J., Li, H. and Erikson, J. 2005. Real-time video over wireless ad-hoc networks. In Proceedings of 14th Int'l Conf. on Comp. Comms. & Networks, (Oct. 2005) 596-60.