H.264 Compression Based Improvement in Hop Count and Power Consumption of MANETs

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Abstract

Power consumption and delay minimization are the two main challenges in wireless networks for multimedia transmission. Furthermore, a large number of hops is essential for strong connectivity of the network. The maximum hop count was just 2 for reasonable performance using Warning Energy Aware ClusterHead (WEAC) protocol [2]. However, the quality of a video traffic is deeply affected with increase in hop count because of exceeding the minimum threshold delay. In this paper, we show how hop count is possible to increase and how power consumption can be minimized without degradation to video quality by making use of a new video standard, H.264. We simulate mobile ad hoc network based on WEAC protocol for H.264 video traffic and then compare these results with the results obtained by H.263 video traffic based on different performance metrics.

1. Introduction

IEEE 802.11b has two modes for wireless networks of which one is infrastructureless mode commonly known as ad hoc network. A mobile ad hoc network does not need any prior infrastructure for communication (Figure 1). Instead, each node acts like a router and plays its role in network stability and maintenance according to its significance (cluster head etc.). The nodes (devices) can freely join and leave the network, thus making the network highly dynamic and susceptible to topological changes. Moreover, wireless networks have very limited bandwidth. Thus high dynamic topology, energy constraint, less physical security, limited bandwidth and autonomous structure create difficulty in reliable communication of a typical MANET. The situation becomes worse when a MANET is exposed to some multimedia traffic such as video. Along with the above mention restrictions, delay minimization becomes the core issue in

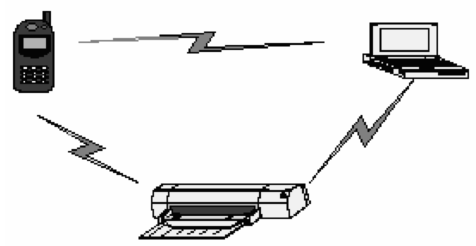

Figure 1. A typical Mobile Ad hoc network

video communication over MANET. Finally, even if video transport over MANET is done successfully, it is extremely difficult to increase the same performance for a reasonable hop count (number of hops traveled) i.e. multihop communication. In our earlier work [2], we showed the feasibility of video over MANET for a few hop counts. In [2], we could only extend single hop communication to two multihop communications. The power consumption was extremely high even with less number of hops. The main reason for that is the large contribution of H.263 compression in overall delay. A similar situation exists in power consumption. In this paper, we compress the modeled video traffic using H.264 standard and observe reasonable improvement in both delay minimization and power consumption.

The rest of the paper is organized as follows. Related work and two selected video standards are described in Section 2 and Section 3 respectively. Section 4 gives a short overview to WEAC routing protocol with local HCB model description. Traffic modeling and simulation results are discussed in Section 5 with concluding remarks and future work.

2. Related Work

The gradual popularity of ad hoc networks especially for certain circumstances such as research conference, war time etc and the need to make all kinds of network suitable for real time traffic are the two driving forces to transport video over MANETs.

An interesting analysis is carried out using H.264 video standard to study video transport over ad hoc networks in [6]. Their simulation shows that packet size of as small as 300 bytes should be used under unfavorable condition as any increase results in degradation of PSNR (Peak Signal to Noise Ratio). For higher error probabilities, even smaller than 300 bytes is good for significant PSNR. Regarding retransmission attempts, 3 attempts per MPDU (Message Protocol Data Unit) gives highest achievable PSNR. Increasing beyond 3 gives no fruit as far as PSNR is concerned. This is a useful analysis and a good approximation to calculate packet size, error probabilities etc. for a given PSNR. The study of [11] implies introduction to a new concept of cross-layer design framework for real time traffic using H.264 codec in their model. The main idea behind this is that the scheme tries to make maximum use of networks resources such as bandwidth etc. where the traffic is in progress (being transmitted). To avoid congestion, traffic flows and link capacities (on the chosen links) are allocated together. Their simulation shows improvement over traditional schemes in terms of data rate and PSNR. The improvement is multiplied further if we combine MPT with cross-layer design.

The performance of H.264 is best analyzed in [3] for ad hoc networks. The authors tested H.264 for different routing protocols (excluding WEAC) and showed by simulation that H.264 is likely to be the most suitable compression for wireless ad hoc networks. However, in contrast with our link speed (5Mbps), they used 11Mbps link speed with very fast average bit rate of 178.64kbps.

3. Compression Schemes

We use two popular video compression schemes for comparsion purpose. H.263 has its value in the industry and there a lot of H.263 based products in the market. H.264 is a new standard but it is supposed to replace its older version (H.263, MPEG4 etc.) due to its less power, less delay, efficient structure and many other new and enhanced features. Here, we briefly describle overview to these standards that might help in understanding simulation results. Furthermore, Table 2 also highlights some key differences of these two standards as far as our simulation is concerned.

H.263 Standard: H.263 was standardized by ITU (International Telecommunications Union) for video data communication in 1995. It performs better for video data where there is little to do with motion such as video conferencing and motionless video communication in MANETs and thus designed for low bit-rate communications, i.e. wireless networks ([1]). It can support five types of resolution (CIF, QCIF, SQCIF, 4CIF, and 16CIF) out of which we use the most common one i.e. QCIF (Quarter Common Intermediate Format). We select QCIF because the resolution efficiency is acceptable and is suitable for our selected bit rate and frame rate (56kbps and 30fps). Architecturally, it is similar to its predecessor standard, H261, but it carries some enhanced features [7]. For instance, improvements in performance and error recovery have been brought about by using half pixel precision (instead of full) and making hierarchical structure optional. It uses discrete cosine transform (DCT) for data representation.

As H.263 has little to do with motion problem, it gives very good performance as far as delay is concerned. If everything goes well, the compression should not exceed 2 frames (frame size) of the delay. But most systems have several layers of buffering and queuing so this delay can even be as large as 10 seconds in some cases!

H.264 Standard: It is a high compression digital video codec standard written by the ITU-T Video Coding Experts Group (VCEG) together with the ISO/IEC MPEG as the product of a collective partnership effort known as the Joint video team [5].

There are many enhanced and new blocks that have been brought into this standard such as multi-picture motion compensation (up to 32 reference pictures can be used, thus allowing improvements in data rate and video quality), variable block size (from 16x16 down to 4x4), quarter pixel precision (precision of $1/8th$ pixel is possible), deblocking filter (for finer tuning in picture shape), 4x4 linear DCT (before it was real, so computationally easy), NAL (network abstraction layer), Data partitioning etc. However, the the main goals of this standardization are to provide compression performance and video representation addressing video telephony and nonconversational (storage, broadcast, or streaming) applications suitable for network environment [10]. Finally, H.264 is equally suitable for wireless application, video-on-demand, LAN and mobile networks.The detailed description and analysis of H.264 can be found in [5].

4. WEAC Potocol with Localized HCB Model

Mobile Ad hoc mobile routing protocols can be divided into three types based on their routing criterion i.e. table driven proactive, on-demand-driven reactive/ source initiated and the hybrid protocols [9]. Warning Energy Aware ClusterHead (WEAC) protocol has hybrid nature based on the idea cluster formation proposed by one of the authors [8]. It was shown [8] that both WEAC and VBS-O pro-

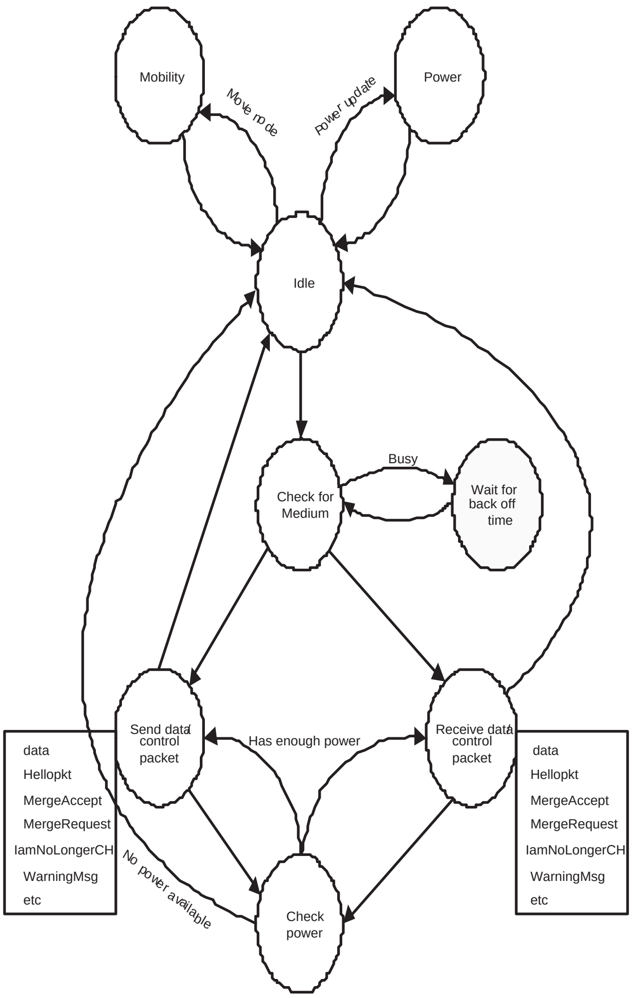

Figure 2. Simulation Strategy with WEAC

tocols scale well to large networks of mobile stations, and they outperform other routing protocols in terms of stability, load balancing and energy saving in a network for non-real time data.

Figure 2 shows the state diagram of our simulation approach to use WEAC protocol for power saving, mobility management and routing purpose. In order to save power, we try to minimize power consumption to an extent that it does not degrade improved delay performance. We use HCB model to minimize power locally (within the neighborhood). In actual HCB model [4], the model minimizes the power locally and then propagates this procedure (using Dijkstra algorithm) till the destination is reached, forming minimum power topology. But upon testing, it was observed that this technique will not benefit us when taken without any change due to increase in number of hops which implies greater delay, despite reduction in power. However, if there is a direct link between the source and

Packet Size	2KByte
Hello Packet Size	1KByte
Other Control Packet Size	100Byte
Frame Size	176x144(QCIF)
Bits per Pixel	0.2
Bit Rate	56kbps
Link Speed	5.5Mbps
Medium Access Technique	CSMA/CA
Maximum Tolerable Delay	250msec
Initial Transmission Energy/Node	100joules

Table 1. Data Specifications

destination within the neighborhood of the source and we use cooperative routing by making use of HCB model (only when useful) from power saving perspective, we can get both on-time packet delivery and power reduction. In other words, there is a trade-off between delay threshold and power reduction. We do not apply HCB model for a destination that is outside the neighborhood of the source node as it is useless to reduce power per packet delivery that causes a packet to reach its final destination after delay threshold ($250msec$). The simulation results show the improvement gained in power with HCB model when the power consumed is normalized by the number of delivered packets.

5. Traffic Modeling and Simulation Results

This section covers traffic modelling specifications for both scenarios (H.263 & H.264), simulation results with their description. Finally, we also put forward our concluding remark in the same section.

5.1. Traffic Specifications

For the sake of comparison between H.263 and H.264, we do not change the intensity of traffic, link speed, number of nodes etc. We use H.263 and H.264 standard parameters for video modeling. We select most widely used frame size, i.e. QCIF. Compression ratio is $10 : 1$ and $7 : 1$ for the same amount of data. After compression, the bits are packetized into fixed packet size of 2KB. The data rate is $3.5pps(56kbps)$ and $4pps(64.76kbps)$ for H.263 and H.264 respectively. Table 1 shows some of the parameters of our simulation experiment whereas Table 2 shows the key dominating differences between H.264 and H.263 that are responsible for delay and power consumption minimization.

We will see in the simulation results section the drastic degradation of network performance after the network is congested (saturation considering no control packets). But before it happens it is worth-noting that the network

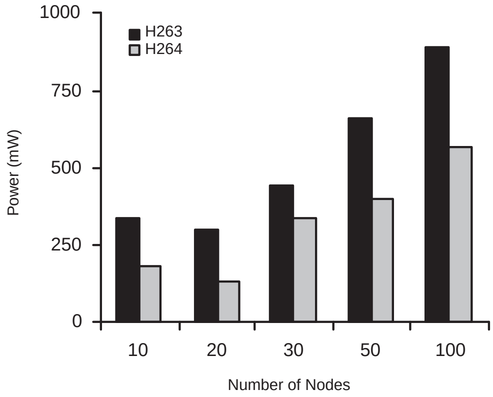

Figure 3. Power Consumed as function of N

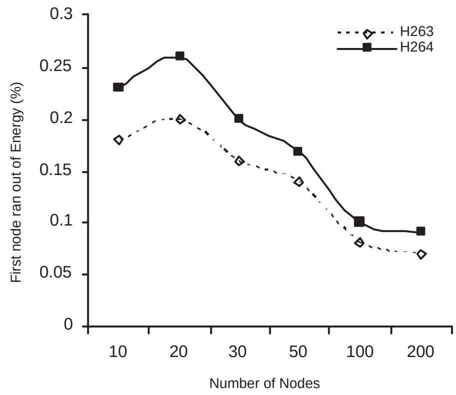

Figure 4. Time first node ran out of energy

is congested even for 50 or 100 nodes. This is because video packets are not the only packets that are being exchanged among the nodes. Instead hello packets waste most of the link bandwidth because of their large size (1KB) and frequency of occurrence compared to the actual data packets. In addition to hello packet, there are $WarningMessage$, $MergeAccept$, $MergeRequest$ and $IamNoLongerYourCH$ etc. messages that also exist in the network and use its resources. Therefore, link speed of at least 5.5 Mbps is highly recommended for true analysis.

5.2 Simulation Results & Analysis

Simulation was carried out assuming that the nodes are present within the square area of 2km (2km x 2km). We vary number of nodes to see the variation in delay and power consumed by the nodes. The nodes are also moving at 5 km / h after every 100 sec.

The *power consumed* by the nodes increases with increase in the number of nodes, (N), as shown in Figure 3. We have normalized power by the number of delivered packets to see the effective power used in the simulation. We see that H.264 consumes less power per packet as compared to H.263. In both cases, there is a gradual rise in power with each increment in the number of nodes because of the increase in number of hello packets, control packets and number of hops traveled for each received packet. Another indication of less power consumption and fairness

	H.263	**H.264**
Data Rate	56kbps	64.76kbps
Average Compression Delay	100msec	75msec
Average Power Consumption	500mW	100mW

Table 2. H.263 and H.264 Comparison

of WEAC protocol is the time at which *first node runs out of energy* in the network. We plot this time versus number of nodes. We can see from Figure 4 that first node takes a little longer time before it runs of energy in case of H.264 compression as compared to H.263 compression. The reason for that is the less usage of power for compression by H.264 (contrary to H.263) and thus nodes do not need to recharge very often (Figure 5). Looking at Figure 4 and Figure 5 simultaneously gives us a clear picture of both the fairness and hence the stability of WEAC protocol and power minimization of H.264 compression scheme when compared against H.263 codec.

Delay is perhaps the most important parameter to be taken care of in case of multimedia traffic (voice / video etc). Figure 6 shows the average delay (normalized by received packets) with the increase in node-numbers. We can see the drastic increase in H.263 case in the delay after the number of nodes goes beyond 100 while H.264 case has rel-

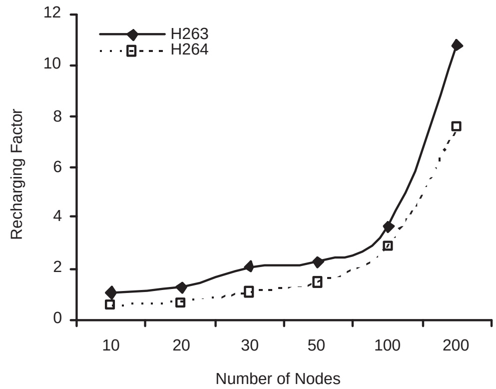

Figure 5. Avg.no.of time a node is recharged

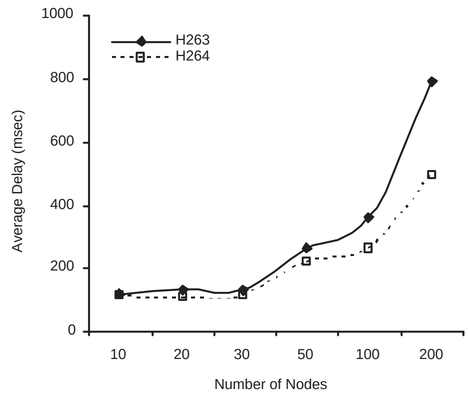

Figure 6. Average delay as a function of N

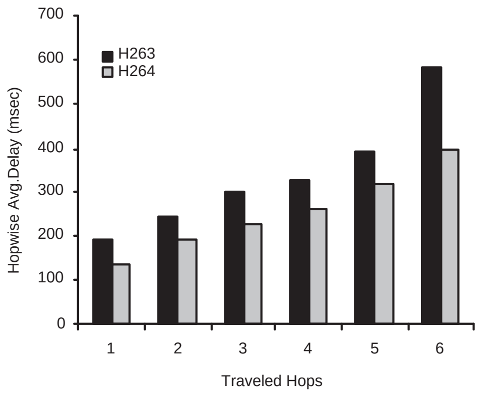

Figure 7. Hopwise delay as a function of N

atively less slope (Figure 6). This is due to less compression delay of H.264 scheme which uses simple wavelets scheme for data representation and 4x4 integer transform. Moreover, if we compare these results with [2] then it gives more insight to the delay improvement obtained by H.264.

Figure 7 compares *Hopwise Average Delay* of H.263 and H.264 schemes. In our earlier work [11], we showed that the supported number of hops by H.263 over WEAC protocol up to 2. We see that H.264 can extend traveled hops to 4 without any degradation in the quality of the received data. All is being achieved due to the elegance, simplicity and efficient scheme of the new codec, H.264.

5.3. Conclusions

In this paper a comparative study between H.263 and H.264 over the ad hoc WEAC protocol has been carried out. WEAC protocol is suitable for video traffic when used with efficient compression scheme such as H.264. The immense compression delay reduces the number of hops dramatically in case of H.263. The simulation results show that H.264 outperforms H.263 in end-to-delay, power consumption and number of hops. It is in agreement with [5] that H.264 should be regarded as the video coding option for the next generation of multimedia.

We intend to use the parameters such as data rate specification etc. used by the authors of [3] in our future work. We expect to get higher hop count with those specifications. Our next research aims at proposing analytical model that gives support to our simulation results.

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