Video streaming application over WEAC protocol in MANET

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1. Introduction

To achieve reasonable performance in wired and wireless networks, an earlier infrastructure is needed due to its important requirement and characteristic. MANETs offer mobile infrastructure with limited bandwidth, which is not very much suitable to multimedia traffic such as video data.

There have been many efforts \cite{1,2} to use efficient compression techniques to make optimal use of limited bandwidth which may result in more power consumption. At the same time, there is a maximum tolerable delay and delay jitter requirements for video data. Therefore, numerous MANET algorithms have been proposed aiming at achieving good performance in terms of video quality, throughput, delay and delay jitter \cite{3,4}.

In a typical MANET, the growth of the network directly depends on the number of hops within given constraints (e.g., delay, bandwidth, quality, power, etc.) \cite{5}. This makes the estimation of number of travelled hops for which the delay does not exceed the maximum tolerable value for video data (less than 250 ms) \cite{6}. The transmission of video data over MANET multiplies the sensitivity of these constraints to a great extent. This fact encouraged many researchers to propose a variety of approaches to build a typical MANET \cite{2,7–9}. It is worth-noting that more attention is given to energy consumption of each node, since the battery (energy) of a mobile device is the main driving source to MANET; especially MANET size is largely dependent on it \cite{10}. This makes it clear that energy consumption requires more attention in situations of video transport over MANET \cite{10–12}.

A wireless lightweight protocol to enhance wireless video streaming is proposed in \cite{13}; however, the authors did not perform any delay measures, which is very crucial in multipath video streaming. Another protocol for multipath video in wireless video surveillance networks is proposed in \cite{14}. The authors presented a case study discussed the performance...
of the proposed architecture and compared between single-path and multipath approaches. The authors also provided an end-to-end delay probability distribution function. However, the actual delay was not provided. Moreover, the total number of hops traversed the network was not discussed.

A scheme for motion compensated frame rate up-conversation is proposed in [30]. This scheme composed of two modules: the background/foreground segmentation under inconsistent motion and the hybrid motion compensated interpolation. Because of its limitation, this scheme cannot be applied to mobile multimedia.

In this paper, simulation is carried to show both single hop and multi-hop communication in MANETs under video traffic with both H.263 and H.264 compression schemes. We calculate the maximum number of travelled hops under tolerable delay constraint (i.e., 250 ms) for video traffic. We show how it is possible to increase hop count without degradation to video quality by making use of H.264 video standard. We also estimate the power consumption for each node and analyze the network performance accordingly. Then, we attempt to minimize power usage by applying HCB model within the neighborhood of each node. Afterwards, we work on analyzing the effect of relay node position on the power savings and calculate the average deviation from maximum power savings by simulation.

During simulation, one of the important issues in ad hoc routing is the sudden switching off cluster heads (CHs). Towards this, we observe this effect in our simulation study and building on it, and show a comparative performance analysis of the WEAC protocol. Based on selected performance metrics, a comparison of results is performed when some cluster heads have sudden death to that when there is no switching of cluster heads.

The rest of the paper is organized as follows. In Section 2, we briefly discuss the video standards. Section 3 discusses how we applied HCB model within the node-neighborhood; and not to the entire network. It then explains the strategy we used to calculate the percentage average deviation of maximum power saving. Section 4 provides an overview of our traffic modelling, node mobility model which is controlled by a parameter motion interval (MI) and delay analysis. In Section 5, we analyze and compare our simulation results obtained based on different performance metrics. Finally, Section 6 presents our concluding remarks and proposed future work.

2. The WEAC/VBS-O routing protocol and H.263 & H.264 standards

In this section, we briefly describe the Warning Energy Aware Clusterhead (WEAC)/Virtual Base Station On-demand (VBS-O) routing protocol that is used in our simulation and both video compression standards, including H.263 and H.264.

2.1. The WEAC/VBS-O routing protocol

The Warning Energy Aware Clusterhead (WEAC)/Virtual Base Station On-demand (VBS-O) routing protocol is proposed in [15]. VBS-O runs on top of the WEAC protocol and it acts similar to a local base station in WLANs [15]. In brief, a mobile node is elected from a set of nominees to act as a temporary base station for a period of time within its zone. In each cluster, a token is used to assign the channel among contending Mobile Terminals (MTs). A clusterhead supports multiple classes of services and also manages to minimize collisions. In [15], the characteristics and performance of the WEAC protocol are studied and evaluated by simulation. It is shown that both it scales well to large networks of mobile stations and is proved to perform well for non-real time traffic.

In this paper, we extend the work presented in [15] to optimize the protocol for video data. Along with routing management, we also introduce power and mobility management to further enhance MANET performance for video data. Fig. 1 shows a state diagram of our simulation strategy, which is based on the WEAC algorithm. The routing protocol manages to take care of power and mobility management, along with WEAC based routing. For more details on WEAC protocol, interested readers are referred to [15].

2.2. H.263 standard

In 1995, H.263 is standardized by the International Telecommunications Union (ITU) for video data communication. H.263 performs better for video data where there is little to do with motion such as video conferencing, motionless video communication in MANETs, etc. Thus, it is designed for low bit-rate communications (i.e., wireless networks). It can support five types of resolution (CIF, QCIF, SQCIF, 4CIF, 16CIF) out of which we use Quarter Common Intermediate Format (QCIF). We select QCIF due to its acceptable resolution efficiency and its suitability for our selected bit-rate and frame rate, which provides 56 kbps and 30 fps (frames per second) respectively. Architecturally, it is very similar to its predecessor standard (i.e., H.261), but it carries more enhanced features [16]. For instance, improvements in performance and error recovery are introduced by using half pixel precision instead of full, and making hierarchical structure optional. Detailed description of this standard can be found in [16].

2.3. 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 [17]. There are many enhanced and new blocks that have been proposed in this standard, such as multi-picture motion compensation with up to
32 reference pictures that can be used. Thus, allowing improvements in data rate and video quality, variable block size (from $16 \times 16$ down to $4 \times 4$), quarter pixel precision (precision of $1/8$th pixel is possible), de-blocking filter (for finer tuning in picture shape), $4 \times 4$ linear DCT (before it was real, so computationally easy), network abstraction layer, data partitioning, etc.

The main goals of this standardization are to provide compression performance and video representation addressing video telephony and non-conversational (storage, broadcast, or streaming) applications suitable for network environments [18]. Finally, H.264 is equally suitable for wireless application, video-on-demand, LAN and mobile networks. Detailed description and analysis of H.264 can be found in [17].

3. Power

This section first describes the energy saving models that we used in our simulation, which includes HCB and RM models [19]. Second, it shows how we calculated the average percentage deviation from maximum power saving.

We strongly believe that delay and also delay jitter should be given the highest priority and more attention when dealing with video transport over wireless network. On the other hand, many researchers have focused and emphasized on saving power of the node battery to last for longer time, without recharging [19–22]. In this work, we minimize power to an extent that it does not degrade improved delay performance. In this paper, HCB and RM models are utilized to minimize power within the neighbourhood of each node.

3.1. HCB and RM models

HCB model minimizes the power locally and then propagates this process (using Dijkstra algorithm) till the destination is reached; thus, forming minimum power topology [20].

But upon testing, it is observed that this technique causes redundant increase in the number of hops which, in turn, produces greater delay.
If there are nodes that have a direct link between the source and the destination within the neighborhood of the source, a cooperative routing [22] is introduced. Using cooperative routing, we could get both on-time packet delivery and power reduction by applying HCB model only within the node’s neighborhood but not to the entire network.

There is a trade-off between maximum delay and power reduction. Hence, we do not apply HCB model for a destination that is outside of the neighborhood of the source node. It is useless to minimize power per packet delivery which causes a packet to reach its final destination after exceeding delay limit ($\leq 250$ ms). The simulation results show the power minimization could be achieved with HCB model when the consumed power is normalized by the number of delivered packets. It is reasonable to demonstrate the operation of HCB using an example. For instance, let’s assume that we have three nodes $i$, $j$ and $n$, as shown in Fig. 2.

Suppose that node $i$ wants to send a packet to node $j$, which lies within its neighbourhood. Let’s also assume that node $n$ lies within $i$'s neighborhood for which the following mathematical statement to represent distances between these nodes hold true:

$$\text{dist}(i, j) > \text{dist}(i, n)$$
and

$$\text{dist}(i, j) > \text{dist}(j, n).$$

Where $\text{dist}(i, j)$ refers to the distance between node $i$ and node $j$. Here, we assume that the angle between the sides $(i, n)$ and $(j, n)$ is greater than $\pi/2$; this allows us to derive the following result:

$$\text{dist}^2(i, j) > \text{dist}^2(i, n) + \text{dist}^2(n, j).$$  \(1\)

The following model for transmission power [19] is utilized:

$$P_t(d) = ad^\alpha + c.$$  \(2\)

Where $P_t$ refers to transmission power, $d$ refers to distance, and $a, \alpha, c$ are constants. In HCB model, the constants $a, \alpha$ and $c$ take integer values of 1, 2 and 2 respectively. Whereas, $a = 1$, $\alpha = 4$, and $c = 2 \times 10^8$ in RM model. Both models are meant for power minimization. It is important to note that we cannot always minimize consumed power. Next, the following rule is utilized to ensure the feasibility of Eq. (2) for power minimization [19]. If

$$d \leq \left(\frac{c}{\alpha(1 - 2^{1-\alpha})}\right)^\frac{1}{\alpha},$$  \(3\)

then it is not optimal to send a packet through relay node (e.g. node $n$). Where $\alpha$ refers to path loss gradient. We can minimize power iff Eq. (4) holds true

$$d > \left(\frac{c}{\alpha(1 - 2^{1-\alpha})}\right)^\frac{1}{\alpha}.$$  \(4\)

If it is the case, then the optimal power can be calculated using Eq. (5) described as follows:

$$P_t = dc\left(\frac{\alpha(\alpha - 1)}{c}\right)^\frac{1}{\alpha} + da\left(\frac{\alpha(\alpha - 1)}{c}\right)^\frac{\frac{\text{delay}}{\alpha}}{\alpha}.$$  \(5\)

As mentioned earlier that both models are meant for power minimization with the execution of Eq. (2). If we use RM-model instead of HCB-model [19], the maximum possible hop count is decreased due to larger value of $c$ for small-distance communication (e.g., like in our case). Our simulation results agree with this statement and we will show that it is fruitful to use HCB-model with the WEAC protocol for power minimization under video transport scenario. We will also compare power minimization gained by these two models.

Lastly, it is important to calculate the minimum transmit power required to transmit at a unit distance. We use Friis transmission equation to calculate Transmit Power with the parameters described in Eq. (6). Firstly, the relationship between transmitted power $P_t$, and received power $P_r$ of radio propagation is given by:

$$\frac{P_r}{P_t} = G_r G_t \left(\frac{\lambda}{4\pi d}\right)^n.$$  \(6\)
Fig. 3. Deviation from maximum HCB power saving.

Where $P_r$ is the received power, $P_t$ transmitted power, $G_t$ transmitter antenna gain, $G_r$ receiver antenna gain, $\lambda$ wavelength, and $d$ is the distance between receiver and transmitter. The gains of transmitter and transmitter antennas are unity as gain = 0 dB. The distance, $d$, is taken 1 m to calculate minimum transmit power. Lastly, $\lambda = c/f$ is the wavelength of the transmitted signal where, $c$ is the speed of light, $3 \times 10^8$ m/s, and $f$ is the frequency of these waves which is set into 2.4 GHz in our simulation. The path loss exponent, $n$ is the path loss factor that depends on the medium.

The path loss component is 2 for Friis space communication. For an acceptable performance [20], the desired values for Signal-to-Noise Ratio (SNR) and background noise are normally 18 dBm and $-120$ dBm respectively. Using Eq. (7), the received power $P_o$ at a distance of 1 m equals to $-102$ dBm

$$P_o = \text{SNR} + \text{BackGroundNoise}.$$ (7)

Using Eq. (6) and the derived values so far, we can calculate $P_t$ which equals to $-62$ dBm.

3.2. Power saving calculation

The maximum saving of power consumption is achieved when the relay node lies at equidistantly from the source and destination nodes [19], as shown in Fig. 3. However, the relay node can exist anywhere within the neighborhood of the source node, as previously explained. This means that we seldom get the maximum power saving as the probability of the relay node to be at the center between node $A$ and node $B$ is very low.

Fig. 3 shows a dummy possible location of the relay node $C$, where nodes $A$ and $B$ are considered as the source and destination nodes respectively. We knew from [23] and Eq. (4) revisited again that HCB is applied iff:

$$d > \left( \frac{c}{\alpha(1 - 2^{1-\alpha})} \right)^{\frac{\alpha}{\alpha}}$$ (8)

along with,

$$\text{dist}^2(A, B) > \text{dist}^2(A, C) + \text{dist}^2(B, C).$$ (9)

If the inequalities between Eqs. (8) and (9) hold, then the power consumption is computed as follows [1]:

$$P_t = dc \left( \frac{\alpha(\alpha - 1)}{c} \right)^{\frac{1}{\alpha}} + da \left( \frac{\alpha(\alpha - 1)}{c} \right)^{\frac{1-\alpha}{\alpha}}.$$ (10)

Where $a = 1$, $\alpha = 2$ and $c = 2$ for HCB model [4]. The location of the node depends on the distance $d$ and the value of $\theta$. In order to meet the above conditions, $\theta$ should satisfy the following condition:

$$0 < \theta < \frac{\pi}{2}.$$

The following two pre-conditions are also necessary for the power saving scheme:

$$\text{dist}(A, C) > \text{dist}(A, B)$$

and

$$\text{dist}(B, C) > \text{dist}(A, B).$$

Given the values of all sides of the triangle $ABC$, we can calculate the value of $\theta$, using Eq. (11)

$$\theta = \cos^{-1} \left( \frac{b^2 + c^2 - a^2}{2bc} \right).$$ (11)

For a typical case, if $\theta = 0$ and the relay node $C$ lies at the mid-point of the line $AB$, we get the maximum power saving using Eq. (10). In our simulation section, we show the percentage deviation from this maximum power saving. We find that this deviation does not have a significant impact on the savings of power consumption.
Table 1
Simulation parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packet size</td>
<td>2 Kbyte</td>
</tr>
<tr>
<td>Hello packet size</td>
<td>1 Kbyte</td>
</tr>
<tr>
<td>Other control packet size</td>
<td>100 Byte</td>
</tr>
<tr>
<td>Frame size</td>
<td>$176 \times 144$ (QCIF)</td>
</tr>
<tr>
<td>Bits per pixel</td>
<td>0.2</td>
</tr>
<tr>
<td>Bit rate</td>
<td>56 kbps</td>
</tr>
<tr>
<td>Link speed</td>
<td>5.5 Mbps</td>
</tr>
<tr>
<td>Medium access technique</td>
<td>CSMA/CA</td>
</tr>
<tr>
<td>Maximum tolerable delay</td>
<td>250 ms</td>
</tr>
<tr>
<td>Initial transmission energy/node</td>
<td>100 joules</td>
</tr>
<tr>
<td>Average codec power/packet</td>
<td>500 mW</td>
</tr>
<tr>
<td>Average compression delay</td>
<td>50–60 ms</td>
</tr>
</tbody>
</table>

4. Traffic modelling

In this section, we begin with a description of the specification of traffic modelling. Then, we discuss an analytical measurement of average end-to-end delay. Finally, we discuss the mobility model, followed by a description of selected performance metrics.

4.1. Arrival traffic specifications

Table 1 shows selected parameters for our simulation design. MATLAB is used to simulate the WEAC protocol for packet level simulation. H.263 standard parameters are used for video traffic simulation. We selected QCIF frame size because of its reasonable resolution quality and 56 kbps (low bit-rate) bit streams after compression. Compression ratio is 10 : 1. This is because H.263 is fit for motionless video conforming to our intuition. Hence, it can compress to such a high ratio. After compression, the bits are packetized into fixed packet size of 2 KB. As mentioned earlier, the data rate is 3.5 packets per seconds (56 kbps). 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 standards parameters for video modelling. After compression, the bits are packetized into fixed packet size of 2 KB. The data rate is 3.5 pps (56 kbps) and 4 pps (64.76 kbps) for H.263 and H.264 respectively.

In the simulation results, the drastic degradation of network performance is observed after the network is congested (saturation considering no control packets). But before it happens, it is worth-noting that the network is congested even for 50 and 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 (1 KB), and the frequency of occurrence compared to the actual data packets. In addition to hello packets, there are other control messages that are also exists in the network and use its resources such as IamNoLongerYourCH, WarningMessage, MergeAccept and MergeRequest, etc. Based on our preliminarily experimental results, we noticed that 2 Mbps is not enough for video traffic and it is incumbent to use a higher data transfer rate (more than 2 Mbps). Therefore, we used 5.5 Mbps to ensure the feasibility of video traffic over MANETs.

4.2. Delay modelling

Video data is very sensitive to delay. In order for the communication to be meaningful, the data has to be received before a maximum threshold of delay (i.e. 250 ms) where the reception of data is of no use. Therefore, special care must be carried out to minimize the delay as much as possible. In our experiments, the following seven delays constitute the overall delay including compression/decompression delay, routing delay, CSMA/CA delay, propagation delay, transmission delay and queuing delay. This can be described by the sum of all delays as follows:

$$\text{Total Delay} = \text{Delay of (Compression + Decompression + Routing + CSMA/CA + Propagation + Transmission + Queuing)},$$

where Propagation Delay = $d_h$/Link Speed, where $d_h$ is the distance between two nodes or 1-hop distance, and Transmission Delay per Packet = Packet Size/Link Speed.

CSMA/CA delay depends on the network environment and varies accordingly. But, its average value approximately varies around 0.3 ms for an infinite traffic [24]. To calculate the minimum delay, the minimum CSMA/CA delay is set to 0.3 ms. Out of these seven delays, propagation delay is negligible and thus can be ignored. In order to have an idea of lower and upper bounds, we can also ignore per packet transmission delay. Although, it is negligible when compared with compression/decompression delays that are much larger than it, it is considered in our simulation. For H.263, if everything goes well, compression delay should be delayed by around 2 frames [25] which equals to 66.66 (1000 × 2/30) ms. There are only two types of delays (routing and queuing) that vary significantly. Both of them vary proportional to the traffic injected.
into the network, number of nodes, network conditions, etc. So, if the addition of compression and decompression is about 60–80 ms, then an approximate minimum value of total delay is equal to 90.3 \( (80 + 0.3 + 10) \) ms.

Where 10 ms represents the total value for routing and other types of delays. For acceptable performance, this gives a lower bound and implies that the delay should vary according to the following relation:

\[
90 \leq \text{Total Delay} \leq 250 \quad \text{(maximum tolerable delay [6])}.
\]

There is another approach which deals with an approximate value of average delay per packet, instead of delay interval. We know that there is no compression/decompression delay at intermediate nodes. Therefore, only processing and CSMA/CA delay add to the overall average delay at intermediate nodes which is approximately 6 ms in our case and we denote it by \( D_1 \). We can intuitively approximate the delay, where each packet is supposed to undergo by the following relation [26]:

\[
\text{Delay} = \frac{1}{\text{Linkspeed}} (\text{PktSize} \ast N_{\text{link}}^{\text{RT}}) n_h + (n_h - 1) D_1.
\]

Where \( N_{\text{link}}^\text{RT} \) is the number of retransmissions per packet and \( n_h \) is the number of hops traveled. Since there is seldom need of retransmission for video packets, retransmission variable is zero in most of the cases. We will provide more discussion on these two delays in the results section and verify our proposed analytical formulas.

4.3. Mobility model

In many research papers, synthetic models show that mobility and traffic have a significant effect on protocol performance [29]. It is common in wireless networks that the devices move within a certain range. In order to model such environment, we establish a mobility model in which the nodes can freely move. The nodes move with an average velocity of 5 km/h after a short interval (controllable). We can change the mobility effect by changing this interval. For instance, if the motion interval (MI) is 30 this means that the nodes move with 5 km/h after every 30 seconds. If MI is reduced to 10, then the frequency of the motion increases (i.e. after every 10 s the nodes move). Thus, decreasing the interval yields too many disconnections which results in more drop in the network and vice versa.

4.4. Performance metrics

The delay constituents are compression, transmission, propagation, routing and CSMA/CA delay for medium access. Since the receiver power is negligible compared to transmission power, we also ignore it in our simulation. Table 1 lists some of the values used in our simulation as per two selected video standards. We also assumed that the maximum coverage area never exceeds 2000 meters on each side. We concentrated on the following metrics:

- Delay: End-to-end delay is the time taken for a packet to be transmitted across a network from source to destination. More precisely, it is the time required for a packet to reach its final destination from the time when it is generated. We plotted average end to end delay versus number of nodes and versus frame size, but we changed only one parameter for a single run. In order to see the maximum number of supported hops, we drew hop wise delay versus hop under different mobility proportion, i.e. for different motion interval (MI). This means that we have also analyzed the delay variation due to mobility by changing MI to 100, 60, 30 and 10 seconds respectively.
- Consumed power: We plotted the mean of total consumed power by all nodes after simulation against the number of nodes. We show power savings of HCB and RM models by plotting against each other versus the number of nodes. The effect of mobility is also analyzed by changing the velocity of the nodes.
- Successful transmission percentage: It is insignificant to look at delivered packets percentage to analyze the network performance. Therefore, we normalized delivered packets with sent packet.
- Delay jitter: The inter-arrival time of a packet at the receiver is not constant, fluctuates. Delay jitter is a measure of the difference between two consecutive packets delay coming from the same source. It is mainly caused by the queuing and medium access delays in the source node, all transit node delays, and the receiver buffer delay in the destination node. Similar to the above metrics, we evaluated the behavior of delay jitter by changing the number of nodes and mobility proportion.
- Hop wise packet delivery: It indicates the hop by hop percentage of received packets. It will help us to know at which hop the delivery is maximum for video.
- Average number of cluster heads: This number shows the uniform distribution of nodes within clusters. This number gives clear significance of this study when compared with the previous one as it should be less in the current case.
- Time to first node running out of energy: It is the time at which the first node ran out of its energy in the network. This time has been normalized by the total simulation time in the simulation results. This number indicates the stability and uniform distribution of the nodes. The node runs out of its energy earlier in case of poor connectivity.
5. Simulation results and analysis

This section provides discussions on the achieved simulation results with all considered parameters, including delay, power consumed, deviation of power saving, successful transmissions, delay jitter, number of hops, number of cluster heads and distribution of load on nodes.

5.1. Delay

Delay is one of the most important parameters to be considered for video traffic. The variation in average delay with respect to an increase of the number of nodes is shown in Fig. 4. For up to 50 nodes, the delay varies approximately between 100 and 270 ms, which is very close to the acceptable range (i.e., 250 ms).

Fig. 4 shows the average delay (normalized by received packets) with the increase in the number of nodes. We can notice that there is a drastic increase with H.263 in the delay after the number of nodes goes beyond 100.

However, H.264 has relatively less delay. This is due to less compression delay of H.264 model which uses simple wavelets scheme for data representation and $4 \times 4$ integer transform.

In addition if we compare these results with the results presented in [12], we draw more insights to the delay improvement obtained by H.264.

We also performed experiments to demonstrate the relation between delay and node mobility that resulted to an increase in delay due to node mobility. We can easily observe the performance of H.263 from Fig. 5 that the greater the mobility, the higher the delay and vice versa. It is interesting to note from Fig. 5 that the mobility does not degrade the
This makes it difficult to predict the behavior of the network before reasonable connectivity. Sometimes there is less routing delay if the packet obtains desired connectivity, but at times the failure to desired connectivity results in packet drop and hence larger overall delay. For instance, in Fig. 5 the delay for mobility interval when MI = 60 is larger than that for MI = 100. However, as the network gets congested with number of nodes, there will be more cluster formation and hence more available paths for a packet to reach its final destination. This will add to more routing delay. Therefore, we see more delay for larger values of nodes. Delay is perhaps the most important parameter to be taken care of in case of multimedia traffic (i.e., voice/video, etc.).

Fig. 6 highlights hopwise delay versus number of hops travelled. We observe that the delay quality is within the acceptable range till two hops after which it goes out of delay bounds. This provides us with the fact that the WEAC protocol can support up to two hops for a video traffic, with compression using H.263 standard. In addition, as the mobility of the nodes increases, the number of hops slightly drops down to 1.5 (i.e., 1-hop). However, the hop count can be increased to 3- or 4-hops if the maximum threshold limit is relaxed to 400 ms, as it is acceptable in certain circumstances [25]. Lastly, we also note that the maximum travelled hops during simulation approximately equals to $\Theta(\sqrt{N})$ ($N$ is the number of nodes) for most of the values of $N$. This observation validates the hypothetical model presented in [26].

A comparison between H.263 and H.264 schemes using hopwise average delay and travelled hops is shown in Fig. 7. In our previous work [23], we showed that the supported number of hops by H.263 over WEAC protocol is up to two. We noticed that H.264 can extend travelled hops to four 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. It is interesting to point out that we did check these simulation values of hopwise delay with those obtained using the following expression, where little differences is observed.

\[ \text{Delay} = \frac{1}{\text{LinkSpeed}} \left( \text{PktSize} \times N_{\text{link}}^{n_h} \right) + (n_h - 1)D_1. \]

Next, the effect of sudden demise of clusterheads is observed on overall average delay. The end-to-delay performance is deeply influenced by the sudden (probability based) demise of clusterheads, as depicted in Fig. 8. The performance keeps on deteriorating as \( N \) increases because the network is highly connected with large \( N \). Thus, switching off a single CH means far many disconnections in the network and network takes time to regain its stable connectivity. This results in an increase in the delay to a great extent, as shown in Fig. 8. In addition, the sudden demise of CH is also responsible for extra overhead of control packets that are communicated among the nodes in search for a new eligible CH.

5.2. Power consumed

It is worth-mentioning that we plot power versus nodes normalized by delivered packets. We also subtract compression/decompression power. This is because it hides power improvement by HCB on account of being far greater than the power used in transmission of different video and control packets. The network connectivity is improved with an increase in \( N \) and there is more exchange of successfully received packets. Hence, we observe that as the number of nodes increases, so does the power consumed and vice versa, as shown in Fig. 9.

Furthermore, we also plot RM-model and HCB model to observe the improvement gained by HCB model due to the different values of \( \alpha \). It is interesting to note that the simulation results show more power saving for HCB model for small
distance communication, due to small value of constant $c$. This point can be enhanced if the network stays for longer interval of time (i.e. simulation time) and with more number of nodes, say $N = 200$, as shown in Fig. 9.

Fig. 10 shows normalized power by the number of delivered packets to see the effective power used under both video schemes. It is clear that H.264 consumes less power per packet as compared to H.263. In both cases, there is a gradual increase in power with each increment in number of nodes. This is a result of an increase in number of hello packets, control packets and number of hops travelled for each received packet.

5.3. Percentage deviation from maximum power saving

The percentage deviation of power consumption from maximum power saving is shown in Fig. 11. We can see from this figure that on average there is no significant loss in maximum power saving; maximum is $< 0.4\%$, if the position of the relay node lies other than the midway between the source and the destination. Its instantaneous effect may be significant for some cases, but averaging the values leaves little change in power saving. Furthermore, the deviation keeps decreasing slightly as shown in Fig. 11. Since the area for the nodes is fixed at $2 \times 2$ square km, the inter-nodal distance becomes shorter and shorter with large $N$.

5.4. Successful transmissions

In $2 \times 2$ square km area, high disconnectivity is palpable when the number of nodes is less than 30, especially if they stay far away from each other. This behavior has been shown in Fig. 12 for nodes less than 40. We observe the highest output as the number of nodes exceeds 40, because of maximum connectivity. The output again decreases for larger number of nodes because the network gets congested with too many hello and other control packets. This causing queuing (buffering) delay to increase drastically, which results in drop once the delay exceeds the limits for certain packets. Access to the medium
also becomes difficult with such a large number of nodes. In addition, the drop is proportional to the mobility. Hence, we get less successful transmissions when the mobility is high (i.e., MI = 10).

Lastly, Fig. 13 shows the effect of sudden demise of CH(s) on overall successful transmissions. We can clearly see that this effect further deteriorates the performance and this percentage keeps on decreasing, as explained earlier.

5.5. Delay jitter

Delay jitter is an important parameter to judge QoS of the network performance. Fig. 14 shows the variation in delay jitter with an increase in number of nodes. The jitter almost remains constant after some transient period where the nodes are not enough and their small number is the major cause of network disconnectivity. Fig. 14 shows that the network has the best performance when \( N = 50 \), which is the optimal number of nodes in this scenario.

It is acceptable delay (less than 150 ms) for low mobility (\( MI = 100 \) and 60), but increases beyond the limit for high mobility. It is even acceptable if we compromise a little on the video quality, which normally happens in wireless networks.

5.6. Hopwise delivery proportion

For video traffic case, most of the packets are delivered in the first hop communication, as shown in Fig. 15. This happens mostly due to the following two reasons. Firstly, the network connectivity plays a vital role for multi-hop communication. Less connectivity is responsible for poor multi-hop communication, as shown in Fig. 15 for small \( N \).

In addition, we can observe the successive improvement in multi-hop delivery with the increase in number of nodes. Secondly, there may be more packets sent using more than one hop, but they were dropped due to exceeding threshold or excessive CSMA/CA delay. As the number of nodes increases, multi-hop scenario is dominant over single hop. In turn, we
do lose network performance in terms of received traffic as shown in Fig. 15 and Fig. 12 for large $N$, and delay as shown in Fig. 7.

5.7. Average number of cluster heads

The average number of cluster heads (CHs) that are present in the network is shown in Fig. 16. The CHs leave with certain probability during simulation which results in reduction of CH. Since the probability is fixed, this average number of CHs is reduced with an increase in $N$. Therefore, the average value of this number gradually improves in CHs die case and becomes comparable after $N > 30$. For $N < 30$, this number is very small when compared with the case when there is no CH dies. This is because there are a few nodes left that are capable of becoming CHs due to small $N$.

5.8. Time to first node depleted of energy

One of the key requirements of ad hoc network routing protocols is to provide uniform distribution of the loads among the devices (i.e. nodes). Fig. 17 shows the normalized time, by total simulation time, at which the energy of first node is expired. It can be observed that the uniformity of the load is also disturbed on the CH demise. Fig. 17 shows that the first node loses its energy earlier when compared with the case when no CH dies [4].

This is again due to the excessive exchange of control packets that are necessary after CH sudden demise to maintain virtual infrastructure of the network. This results in an early battery discharge of the node. Furthermore, this time keeps on decreasing with larger $N$ in both cases with the same scenario. Because the overhead increases as $N$ increases, with the exception when $N = 20$, but this value can be regarded as random increase. This implies that the random position of the nodes in some areas is such that there is no CH demise. Also, the connectivity is stronger whose impact is very significant on overall stability of the network. Thus, averaging this parameter yields to a little more value in comparison with $N = 10$. 
6. Conclusion and future work

This paper presented the WEAC protocol performance subject to video traffic. It also derived and discussed a number of interesting results. Firstly, it is found that 2 Mbps is not suitable for video traffic. Instead, 5.5 Mbps link speed is necessary for acceptable performance. Secondly, this protocol could support up to 3 hops without any serious degradation in the video quality. Thirdly, it is possible to save a significant amount of power using HCB model within the neighborhood. Finally, relaxing the maximum threshold limit to 400 ms allows an increase of up to 4 hop count. The power saving loss due to the deviation from maximum power savings is demonstrated and the effect of random demise of CHs for the WEAC protocol based MANET is discussed. It is found that there is no significant loss in average power saving due the random location of the relay node, where the effect is only instantaneous and on average. In addition, the effect of CH demise badly deteriorates the protocol performance in terms of delay and other chosen performance metrics. The metric showed the reduction in CH number which implies that either there are more number of free mobile terminals MTs in the network due to the none availability of proper CH in their neighborhood or there are more number of zone MTs per CH; thus, increasing overhead per CH. Both of these two cases yielded poor connectivity, extensive increase in the average delay and fast discharge of the battery of the nodes. This paper also showed comparative study between H.263 and H.264 schemes. The simulation results showed that H.264 outperforms H.263 in end-to-end delay, power consumption and number of hops. It is in agreement with [17] that H.264 should be regarded as the video coding option for the next generation of multimedia.

In the future, we plan to investigate the affect of different compression schemes on the protocol performance. We also plan to explore alternative suitable solutions to resolve the sudden demise of cluster head issue. One possible solution to consider is machine learning techniques such as reinforcement learning [27] that can be used to validate this problem. Finally, we plan to use more parameters such as data rate specification, etc. discussed in [28] to hopefully get higher hop count.
Acknowledgments

The authors would like to thank King Fahd University of Petroleum & Minerals (KFUPM) for their support with which the project number IN070377 was carried out successfully. The authors would also like to thank Research and Graduate Office of Acadia University and the Natural Sciences and Engineering Research Council of Canada (NSERC) for their support.

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