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Several prior studies reported that the Header Compression (HC) achieves several gains like bandwidth savings, faster response time and better reliability. A few other studies reported about loss due to HC. In this short paper, we introduce a single parameter named "power" to measure the gains of HC. We also introduce another single parameter as "effective power" to measure both the gains and the loss of HC. We find that the performance measurement by such single parameters gives more intuitive analysis and understanding of functions of HC.

Indexing terms: Header compression, Performance analysis, Gains & loss, Power, Effective power.

INTRODUCTION

IN any network, higher link utilization, lower transport delay and higher reliable transport are desirable [1-3]. In Internet, these are believed to be achieved with IP overhead reduction [4-9]. The Header Compression (HC) works as follows: (*i*) the compressor running at the transmitter sends packets with full headers with Context Identifier (CID) till the decompressor running at the receiver received full context and gets synchronized, (*ii*) subsequently the compressor sends packets with as minimal as possible headers. Several studies [7-16] reported that HC increases bandwidth savings/link utilization, reduces transfer delay and achieves better reliable transport. These prior works evaluated the gains in terms of individual parameters as stated. There are other works [17,18] that reported the loss of HC, particularly for context establishment. We evaluate the impact of the gains by a single parameter defined as "power" and that of both the gains & loss in term of another single parameter introduced as "effective power." It is further established that the evaluation by a single parameter appears more intuitive and meaningful for performance analysis of HC.

GAINS DUE TO HEADER COMPRESSION

The several studies estimate that the HC reduces IPv4/TCPheaders from 40 bytes to 4 bytes, IPv4/UDP from 28 bytes to 1 byte, IPv6/TCP from 60 bytes to 4 bytes, IPv6/UDP from 48 bytes to 3 bytes and IPv6/UDP/RTP from 84 bytes to 1 byte. The quantification of performance of such huge reduction has been made with different parameters in literatures as below.

Bandwidth Savings/Increased Link Efficiency

In TCP, UDP, RTP, IPv4 and IPv6, the minimum header bytes are respectively 20, 8, 12, 20 and 40. Different studies [9] have established that in the core networks about 55% of packets traversing in the backbone are less than 200 bytes in size. This accounts for a poor coding efficiency. Besides, as the Internet is poised to become a single network for all services, it has to carry multimedia applications where payload size may range from 20 bytes to 160 bytes (example G.7XX codecs). In many applications like VoIP, messaging, interactive games, the payload size is smaller than the headers size. Packets with smaller payloads will result in decrease coding efficiency or increased overhead percentage. The coding efficiency measures the throughput of the link or the link utilization. The packets with smaller payload will be more in the Internet traffic compared with of larger payload with Internet poised as a single transport network for all services and application. The lower coding efficiency therefore resulting from increased Internet traffic with small payload will be the source of poor link efficiency or bandwidth utilization. Compression scheme overcomes this problem of headers of TCP, UDP, RTP and IP.

If H and C are respectively the original header size and the compressed header size in bytes, the increased bandwidth utilization/link utilization/throughput due to the compression will be

$$\Delta\eta = \frac{\frac{\text{payload}}{\text{payload}+C} - \frac{\text{payload}}{\text{payload}+H}}{\frac{\text{payload}}{\text{payload}+H}} \times 100$$

$$= \left(\frac{H-C}{\text{payload}+C}\right) \times 100\%$$

$\frac{H \times \text{Compression Gain}}{\text{payload}+C} \times 100\%$, where $0 < (C/H) \leq 1$ is calledcompression ratio of header and compression gain = (1-compression ratio)

For overall packet compression,

$$\text{Compression ratio } (n) = \frac{\text{Compressed-packetsize}}{\text{Original-packetsize}},$$

with payload + overhead = packet size.

The higher link utilization provides cost effective infrastructure as it provides a solution to accommodate more users per link bandwidth. The benefit of higher bandwidth savings is an essential required parameter for bandwidth constraint link like low to medium speed wired link and wide-area all IP cellular network.

Better response time/lower delay

Less delay in transporting packet from source to destination is essential criterion of any network particularly for time sensitive services like voice and video and/or for the real time transport services. End to end delay is made of packet transmission delay, nodal delay and propagation delay. The packet size has the main effect on the packet transmission delay. With compressed scheme the decreased amount of transmission delay will be

$$\Delta d = \frac{\frac{8X(\text{payload}+H)}{R} - \frac{8X(\text{payload}+C)}{R}}{\frac{8X(\text{payload}+H)}{R}} \times 100\%$$

$$= \left(\frac{H-C}{\text{payload}+H}\right) \times 100\%$$

$$= \frac{H \times \text{Compression Gain}}{\text{payload}+H} \times 100\%, \qquad (2)$$

where R is link capacity in bps.

The reduced delay is highly desirable for long haul links like satellite links. This also improves interactive response time over any low speed wired link. It is studied that 100-200 ms is the maximum tolerable delay that people accept in interactive response. Just a header of 40 bytes of IPv6 requires transmission time of 100 ms over a link of 3200 bps.

Better reliability in transmission

With compression, the packet size will be lowered that will reduce the packet error probability in the link. The reduced packet error probability will be

$$\Delta p = \frac{(1-\alpha)^{(8X(\text{payload}+C))} - (1-\alpha)^{(8X(\text{payload}+H))}}{1-(1-\alpha)^{(8X(\text{payload}+H))}} \times 100\% \qquad (3)$$

when α is the BER (Bit Error Rate) of the link.

MEASUREMENT OF PERFORMANCE OF COMPRESSION BY A SINGLE PARAMETER

Wireless and satellite networks are noisy and offer high BER. It is where the reduced packet error probability achieves benefits. Faster response and better reliable transport improve the QoS (Quality of Service) in the network. Thus, the benefit of compression as enumerated in eqs (1-3) may be assessed by a single parameter. We introduce "power" as a single parameter that is quantitatively defined (with equal measure of importance to each of above defined three individual parameters) as:

$$\text{power} = (1/3)\ \{\Delta\eta + \Delta d + \Delta p\}$$

$$= (1/3) \times \left(\frac{H-C}{\text{payload}+C} + \frac{H-C}{\text{payload}+H} + \frac{(1-\alpha)^{(8X(\text{payload}+C))} - (1-\alpha)^{(8X(\text{payload}+H))}}{1-(1-\alpha)^{(8X(\text{payload}+H))}}\right) \times 100\% \qquad (4)$$

The higher value of "power" refers to higher benefits of compression and vice versa. In [4] it was studied that the header compression gains for a few protocols may be as in Table 1. For the sets of compression, the numerical results of power as per eqn (4) are portrayed in Figs 1,2. It is found that: (*i*) as expected from Fig 1, we find the higher value of power is obtained for lower payload thereby confirming that the benefit of compression is more evident for lower payload, (*ii*) the value of power is higher for lower BER than that for higher BER as found in Fig 1, thereby confronting the established belief that the compression will be more beneficial

TABLE 1: Possible maximum header compression in different protocols

Protocols	Total Header size in bytes	Minimum compressed Header size in bytes	Compression gain in %
TCP/IPv4	40	4	90
TCP/IPv6	60	4	93.3
UDP/IPv6	48	3	93.75
RTP/UDP/IPv6	60	3	95

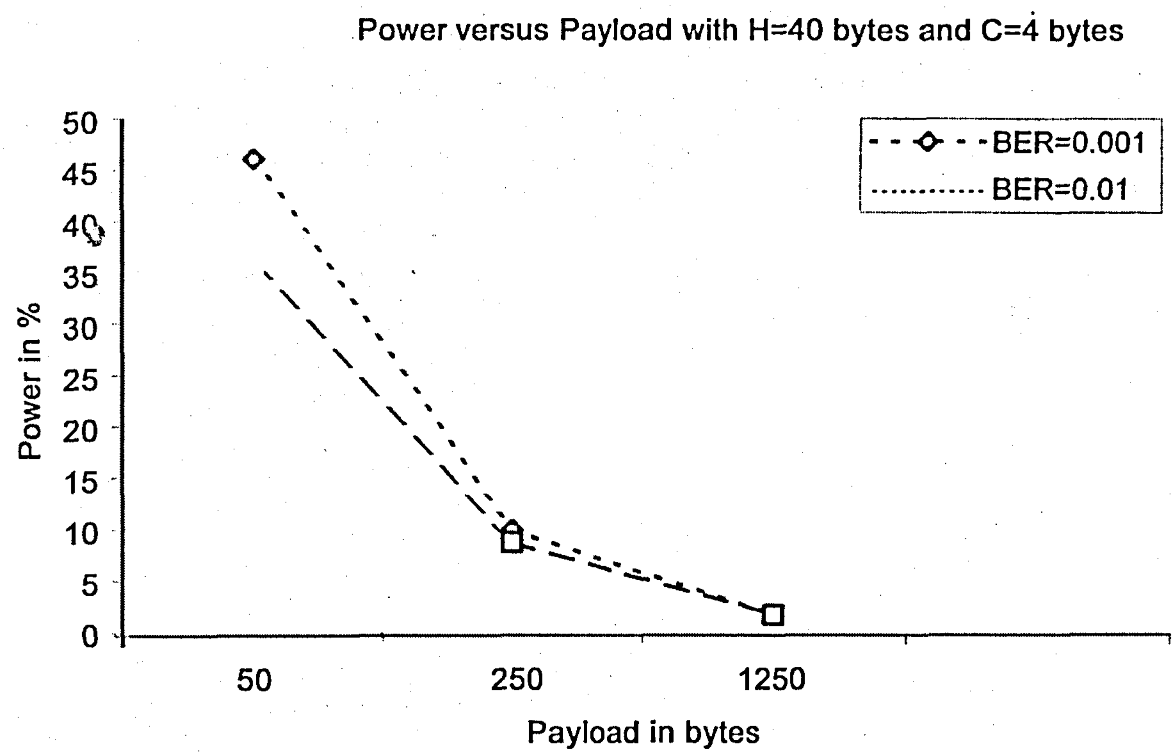

Fig 1 Power versus payload

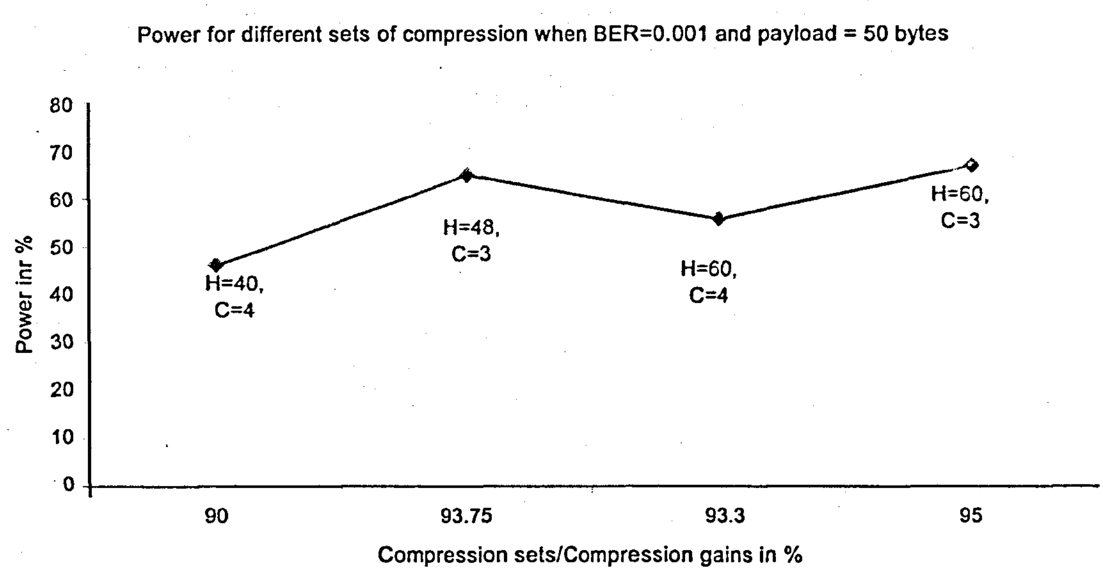

Fig 2 Power versus compression gain

for high error links, but the present results are obtained due to fact that the value of decreases with higher value of BER, (*iii*) although it is expected that the value of power will increase with compression ratio, yet this may not be a general trend as in Fig 2, as because the value of Δd and that of $\Delta\eta$ have a multiplying factor of H along with that of the compression gain, thereby even for a higher compression gain the value of Δd and $\Delta\eta$ may not be higher if H is low, and (*iv*) as expected we find in Fig 1 that the power falls with higher payload and this is mainly due to lower coding efficiency with higher payload. Thus it is conclusively established that the parameter "power" may be most appropriate parameter for evaluation of the gain of compression taking into account of the individual parameters concerned with compression.

LOSS IN IMPLEMENTING HEADER COMPRESSION

The compression is made with a few steps: (*a*) initiation with sending a few packets with full header and context identifier field(CID), (*b*) sending subsequent packets of a stream with compressed headers, and (*c*) refreshing by sending occasionally packets with full headers, and refreshing is require to establish context and synchronization in case of loss of error in packets. The flow context is a collection of information about values, change and pattern of changes of the headers fields of the packets in a flow. The first packet or a few packets in a flow are sent with out compression for establishing the context on both sides.

Loss due to Context Establishment

The context initialization and establishment between the compressor of the transmitter and the decompressor of the receiver is the basis of any header compression scheme. The synchronous operation between the compressor and the decompressor may be either in acknowledged/ explicitly mode or in optimistic/implicitly mode. In both the mode it may require a number of full header packets for context establishment. The large headers so transmitted therefore consume both bandwidth and cost against the very reason of compressed header schemes. Thus for correct gain position of the compressed header schemes, it is required to include the effects of context establishment. In the acknowledged mode, we assume that the decompressor needs minimum n packets to establish the context, and the compressor sends m ($m \geq n$) packets; the probability that the decompressor succeeds in establishing context is [17]:

$$P_{sc} = \sum_{j=n}^{m} \binom{j}{m} p^{j-m}(1-p)^{j} \quad (5)$$

The effect of eqn (5) on the proposed "power" will be estimated by multiplying the value of "power" obtained from eqn (4) by (n / m).

Header refreshing

At some regular interval and in case of error recovery, header refreshing is done. In refreshing, uncompressed headers are sent to reconstruct the context and then revert back to sending compressed headers. If every fth packet in a flow is sent uncompressed, the average header size will be:

$$\text{Average Header Size (AH)} = \frac{H-C}{f} + C \quad (6)$$

in which case the application of eqns (1-4) will be done with C replaced by AH of eqn (6) in each of them. The effect on "power" may be estimated by multiplying the value of "power" obtained from eqn (4) by (C/AH).

EFFECTIVE POWER

Thus the parameter "effective power" to quantify and measure the header compression gain will be:

$$\text{effectivepower} = \text{power} \times (n/m) \times (C/AH) \quad (7)$$

Based on eqn (7) the numerical plots of effective power gain is shown in Figs 3 & 4. It is seen that: (*i*) as expected the effective power is lower than power for any & all sets, but the effective power is much lower compared to the power, (*ii*) for two sets of H and C, the effective power remains constant over wide variation of f, and this is because the difference between H and C is less as this difference is when divided by f, the result makes AH and C nearly same, (*iii*) as expected with increase of f, the effective power increases, (*iv*) as expected as m increases, the effective power decreases.

CONCLUSION

A study has been made to quantify and measure the performance of HC with two parameters, namely power and effective power respectively for gains only and gains & loss combinedly. The analysis of the

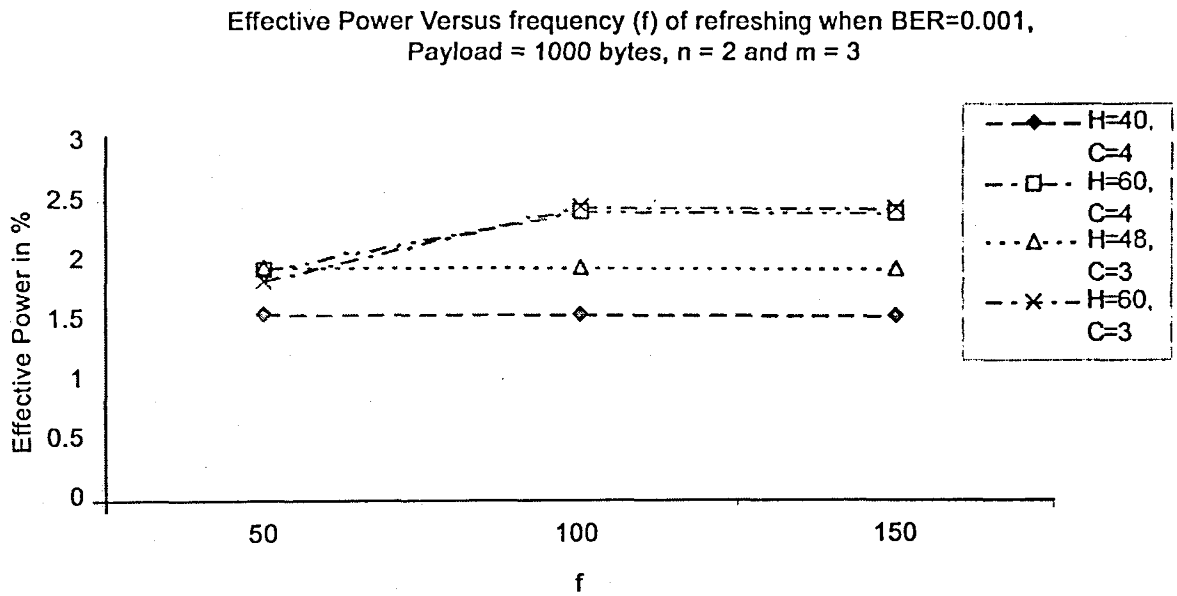

Fig 3 Effective power versus f

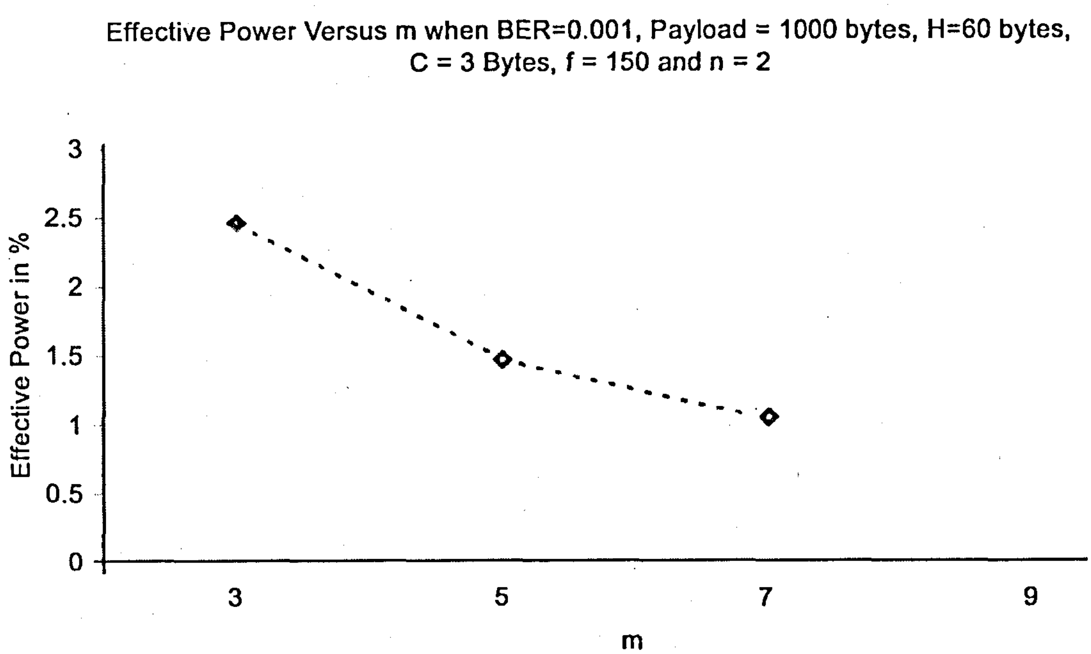

Fig 4 Effective power versus m

numerical results of power and effective power shows that these parameters result in better understanding of gains and loss of HC as it has been found that contrary to the idea that the gain will increase with reduced C, the gain is found to be dependent on the relative values of H and C. We have also seen that the refreshing frequency, f and the context establishment parameter, m have important quantified roles in measurement of effective power. The loss for HC may be measured by including the RTT (Round Trip Time) parameter. This will make the analysis more befitting. In future work we propose to study the same.

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