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Cooperative Header Compression for 4G Wireless Networks

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***Abstract*—In this paper we introduce an cooperative header compression scheme for 4G wireless networks. The main focus is to achieve robustness and low complexity for the compression. Furthermore the header compression scheme should work without any feedback information.**

***Index Terms*—cooperative behavior, header compression, future wireless systems**

INTRODUCTION

COOPERATIVE networking is gaining increasing interest from the wireless community. It opens new possibilities in exploiting different properties of devices in heterogeneous networks. The future cooperative networks are expected to self-organize dynamically to provide the required services to the users. Cooperative behavior can be exploited across the entire protocol stack. Protocol optimization based on cooperative behavior of terminals can lead to significant performance gains.

The cooperative approach can be also successfully applied for IP header compression. In general, header compression schemes yield considerable savings in bandwidth. It is especially important for wireless communications where bandwidth is a limited resource and the efficient utilization of the spectrum is the most desirable. IP layer introduces a large overhead. For multimedia services the overhead using the Real Time Protocol (RTP), the User Datagram Protocol (UDP) and the Internet Protocol (IP) is 40 bytes for the IP version 4 and 60 bytes for IP version 6 (Figure 1). If the packet header can reduced to e.g. 4 bytes, then the bandwidth saving is $S \approx 0.5$ considering GSM-coded audio transmission[1]. This is calculated by using the following formula for bandwidth savings:

$$S = \frac{Comp\ Header + Payload}{Header + Payload}$$

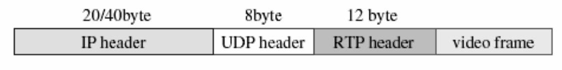

Figure 1 IP communication overhead

Header compression (HC) is possible due to redundancy among the header fields of a packet flow. The main concept is as follows. On the sender side, the compressor removes redundancy from the incoming packet using information from the past packets, called the *context* (it is also sometimes called *base*). The decompressor maintains the context and uses it to reconstruct the header of the incoming packet. This principle is illustrated in Figure 2. The inconsistencies in the contexts of compressor and decompressor lead to the loss in synchronization and failure of the decompression procedure. A context repair mechanism should be applied.

Designing a header compression scheme to work in wireless environment, a special attention should be made to keep the synchronization between the compressor and

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[1] Payload for GSM coded voice is 33 bytes

decompressor. Packet losses caused by channel conditions can easily lead to the loss of the context at the receiver side. If the context is not repaired timely, the subsequent compressed headers can not be decompressed, and for the IP layer they will be lost. Therefore, the context re-synchronization should be avoided. One way is to rely on the feedback from the decompressor. A compressor can learn that the base is lost and the full update of the header will be sent. However, providing feedback can be impractical, if not at all impossible, in some situations. For example, this is the case for multicast services and delay-sensitive applications. It this case periodic updates can be used to avoid loss propagation.

In [4] a header compression scheme, Cooperative Header Compression (COHC), for multichannel communication has been proposed. This scheme is based on cooperative behavior of multiple paths between a sender and a receiver. One multichannel scenario is envisioned for 4G WLAN systems. The base stations are under control of the access controller (AC). The AC is the last IP end point before the wireless terminal. Therefore the header compressor and decompressor are place within the wireless terminal and the access controller. The base stations, or even access points, act only as a bridge. This architecture target omnipresent WLAN such as IEEE 802.11 scenarios as well as future 4G wireless networks (see Figure 3).

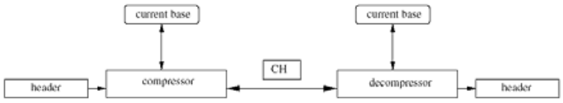

Figure 2 General concept of header compression

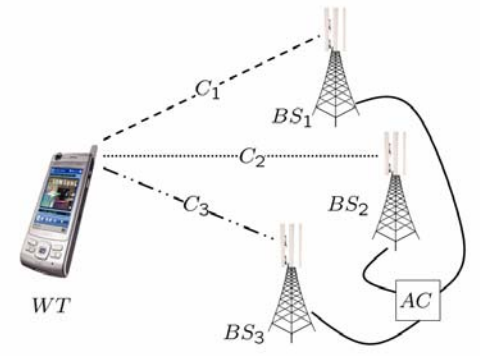

Figure 3 Example of a network supporting multichannel communication

Another possible scenario is close to the already mentioned one, but the multichannel paths are established between base stations and the relay (Figure 4). The relay receives multiple streams that are further forwarded to different wireless terminals. The usage of cooperative header compression for the links between BS and the relay is very bandwidth efficient.

Availability of multiple channels between a sender and a receiver is often a situation for meshed networks. Figure 5 shows a meshed network example with three channels. Each channel is composed of multiple hops between sender and receiver. The channels are characterized by delay, bandwidth and error rate.

In the next section we provide a description of the Cooperative Header Compression approach.

Cooperative Header Compression

Presentation of the concept

In this section we present the framework of the Cooperative Header Compression. As a starting point we consider delta coding compression and consider it's enhancement in the case of multiple channels and no feedback. One should note that the developed framework can be applied in principle to any header compression algorithm that does not rely on the feedback information.

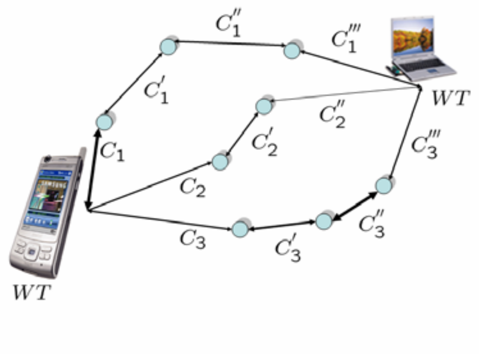

Figure 5 Example of a meshed network

We propose a scheme where each header compression entity is sending a header for its ongoing compression and furthermore carry some additional information for the neighboring channels. We introduce the concept of an additional information container (AIC). The AIC is used to repair a corrupted current base of neighboring compression entities. It is not the purpose of the AIC to repair the whole packet (including the payload) but to retrieve the current base.

In Figure 6 the transmission of the AICs is given. Additionally we show how one AIC can carry information for each header. There is no limitation in the channel or time domain. By introducing AICs we reduce the problem of error propagation and therefore we may reduce the refreshing rate. For efficient coding the design of the AICs is very important. In other words we would like to reduce the overhead and simultaneously minimize the packet error probability. There is a trade-off between these two parameters.

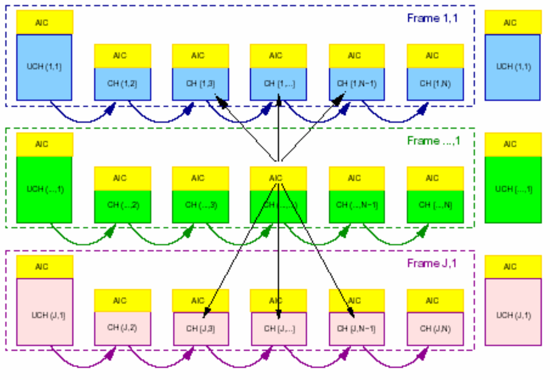

Figure 6 General concept of COHC approach

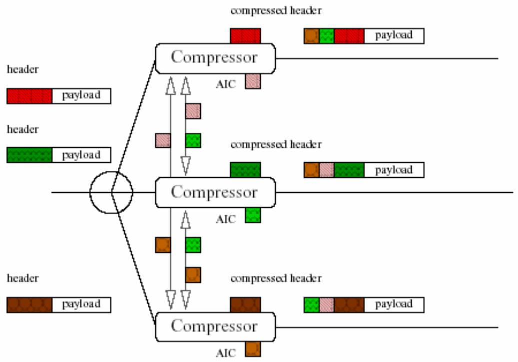

Figure 7 Compressor for COHC

In Figure 7 one possible implementation of piggy-backed information (AIC) for neighboring channels is given. In addition to the normal header for each packet, the header compression entity includes one AIC for each neighboring channel in the same time domain. In this approach only AICs with the same time instants can be used to repair the base in case of packet errors. This helps to reduce the amount of data for the AICs. Note that this seems to be very efficient as long we have synchronous channels. In case of asynchronous channels we should consider the use of time-domain separated AICs.

Performance evaluation

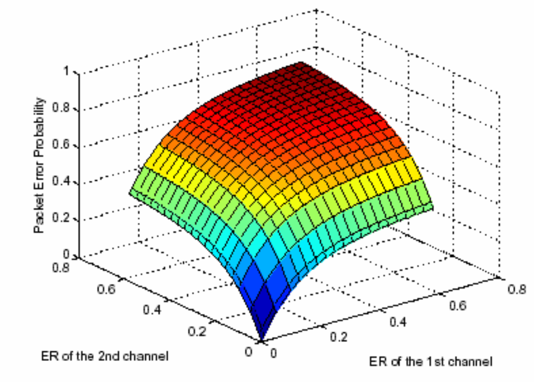

Figure 7 PEP as a function of channel error rates for delta coding.

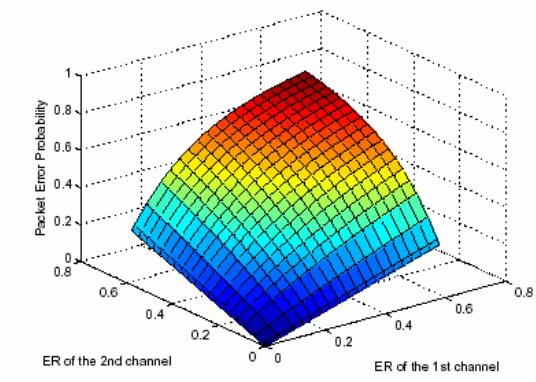

Figure 8 PEP as a function of channel error rates for COHC.

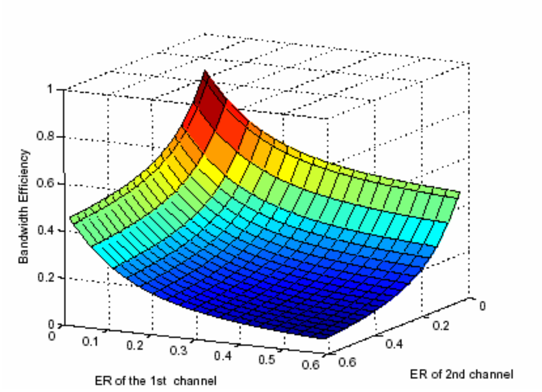

Figure 9 BE as a function of channel error rates for delta coding.

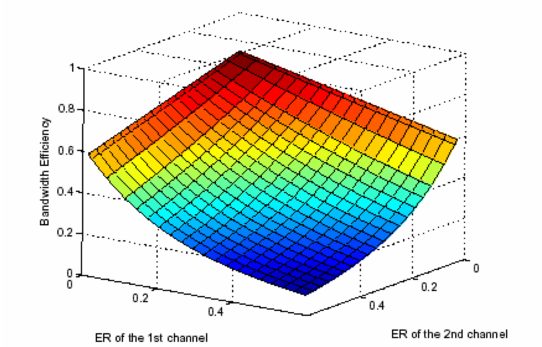

Figure 10 BE as a function of channel error rates for COHC.

In evaluation of the performance of the proposed framework, we consider the following main parameters: packet error probability and the bandwidth efficiency. As a measure of robustness of HC the packet error probability (PEP) is used. One should note that a packet can be lost either because of the error due to bad channel condition or because a receiver does not have a base to decompress the header and therefore a packet is of no use. Both cases lead to loss of a packet on IP layer, and therefore they should be both taken into account estimating PEP. Another important parameter is bandwidth efficiency defined as a ration of correctly received payload to the total amount of information sent. Low PEP is an indication of robustness of a scheme. Bandwidth efficiency reflects both compression gain and error rate.

The presented below results corresponds to the case on uncorrelated channel errors. The impact of the channel errors on the performance of the proposed cooperative scheme is evaluated. As a conventional scheme a simple delta coding applied independently to each of the multiple channels is considered.

A scenario with two channels is considered. Depending on the propagation conditions, these channels differ in terms of quality. We denote as *p* the probability to loose a packet due to the channel conditions on the first channel and *q* is the probability for the second channel. Varying the values for p and q from 0.001 to 0.8 we obtain 3D-graphs for packet error probability (PEP) and the bandwidth efficiency (BE) (Figures 8-11). One should note that a packet can be lost either due to the channel conditions or because the base at the decompressor is lost and the packet can not be decompressed. The effect of both types of errors is included in PEP. The considered system parameters are as follows: the size of the payload is 40 bytes, of uncompressed header 40 bytes, of compressed header 4 bytes. The size of AIC is 2 bytes. The refresh rate is fixed to 12 packets.

In Figures 8 and 9 the relationship between PEP and CEP is shown for delta coding and COHC approaches. First of all, one can notice that the cooperative scheme results in much lower probability to loose a packet. It is interesting to observe the behavior on the edges of the 3D plots, when CEP of one channel is low (meaning a WT finds itself in a good position relative to the BS, e.g. very close to BS). From the figures we see that PEP for COHC stays low even though the conditions of another channel are bad (high CEP values for the second connection). In the case of delta coding the average PEP increases significantly even though one of the channels is good. It shows that in this situation COHC keeps the context for the second channel synchronized, even though the e.g. every second packet is lost when q=0.5. Then wherever a packet is received, it can be also decompressed - this helps to bring PEP as low as possible. The price for this to pay is the increase of header compression size. Therefore, we have also chooser to evaluate the bandwidth efficiency of the schemes. Figures 10 and 11 shows the efficiency for two approached. Again, we observe that cooperative behavior brings the efficiency much higher.

Conclusion

We have proposed a header compression for multichannel communication networks as they are expected to be realized in 4G wireless networks. The header compression scheme is based on cooperating behavior of the parallel channels. This cooperation achieves robustness even without any feedback information.

ACKNOWLEDGMENT

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