HEADER COMPRESSION SCHEME IN POINT-TO-POINT LINK MODEL OVER HYBRID SATELLITE-WIMAX NETWORK

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ABSTRACT

The demand for anytime-anywhere connectivity has accelerated the emergence of new technologies and integrated networks for better quality of service (QoS). With the introduction of IEEE802.16, mobility in broadband services has become reality. Whilst broadband services in urban area are common, it is deemed luxury service in rural and remote area. Since satellite network provides wider geographical coverage, a hybrid network between satellite and IEEE 802.16 will be the key to affordable broadband connectivity to rural and remote area. In this paper, a header compression scheme is proposed over hybrid satellite-WiMAX network. The proposed header compression scheme (Hybrid-ROHC) will enable the saving of resources over the hybrid network where bandwidth is a premium.

KEYWORDS

IEEE 802.16, Satellite Network, Header Compression, Hybrid Network, Hybrid-ROHC

1. INTRODUCTION

The integration of satellite and terrestrial wireless system such as IEEE 802.16 WiMAX [1] plays a significant role in providing broadband connectivity in wide geographical area. Although hybrid satellite-WiMAX system seems to be an ideal network, transporting IP based packet can be a challenge. Long propagation delay and significant packet losses often cause performance degradation in the satellite network. Moreover the high header overhead will seriously consume the bandwidth and lower the transmission efficiency. This is further complicated by the definition of commercial network models which extends the IEEE802.16 MAC transport connection all the way to an access router by using a tunnel between the base station and the access router [2]. Thus it is vital to use the scarce radio resources for the hybrid network efficiently by applying header compression to the IP traffic.

Header compression is a process of compressing excess protocol headers before transmitting them on a link and uncompressing them to their original state on reception at the other end of the link. Due to the redundancy in header fields of the same packet as well as consecutive packets of the same packet stream, it is possible to compress the protocol headers and reduces the network overhead. There are a number of header compression mechanisms that can be used to compress the headers of IP traffic namely Robust Header Compression (ROHC) [3] and Payload Header

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Suppression (PHS). In this paper, we proposed header compression scheme based on ROHC algorithm due to its ability to tolerate losses and errors.

The main contribution of this paper is to propose an algorithm were ROHC can be used in a hybrid satellite-WiMAX network. NS-2 [4] simulator is used to model the network behaviour and the performance enhancement from Hybrid-ROHC is investigated for CBR traffic. In the evaluation, it is noted that ROHC reduces the protocol overhead for voice transmission with IPv6. On top of bandwidth savings, ROHC improves the voice quality in the hybrid network with better improvement in delay and throughput.

This paper is organized as follows: Section 2 presents related works on hybrid satellite-WiMAX network and header compression. Section 3 briefly describes the principles and integration of ROHC in the IP protocol stack. Section 4 presents the hybrid network architecture used. Section 5 presents the proposed header compression scheme over the hybrid network. Experiments and analysis of results are presented in Section 6. Section 7 concludes the proposal and ideas for future work.

2. RELATED WORK

A large number of literatures on mobility and QoS management solution for hybrid satellite-WiMAX network have been published in the past years. Centoza and McCann [5] presented a hybrid network solution which employs DVB-RCS domains as a backhaul for content delivery to WiMAX domains. Two different radio network choices were proposed for corporation in the hybrid network environment. Mobility and QoS management solution for the hybrid network were tabled as well.

Fan et al. [6] presented an IP-based reference architecture which supports a range of transport requirements. It focused on the requirements and design constraints that were faced in the design of the network-layer of the reference system. Gur, Bayhan and Alagoz [7] discussed a heterogeneous system of satellite-WiMAX network for efficient delivery of multimedia services. Enhancements in WiMAX Base Station and Multicast Broadcast Service Controller (MBSC) which allows interworking in multimedia delivery context was also proposed.

Despite the great interest in hybrid satellite-WiMAX technology, the large majority of studies focused on mobility, QoS or multicast capabilities. None has used header compression over the hybrid network. This paper which is an extension from our previous work [8] will fill this gap by proposing a header compression scheme over hybrid satellite-WiMAX network.

Although there are two header compression mechanisms that can be used to compress header overhead in WiMAX, Nuaymi et al. [9] shows that ROHC has better efficiency over PHS in WiMAX. PHS process defined for IEEE 802.16 has the advantage of being restricted to MAC layer. Teh et al. [10] presented ROHC over ULE encapsulation in order to reduce the overhead of the packet and it was shown that with ROHC, the number of SNDU packet can fit into MPEG-2 TS packet will significant increase thus it will increase the efficiency of the packets transmission.

Since the compression scheme for hybrid network need to work not only over wireless network, it must be robust enough in error-prone satellite link. Although ROHC is more complex than PHS in terms of implementation, previous studies show that ROHC is more suitable for both satellite and WiMAX network.

3. OVERVIEW OF ROBUST HEADER COMPRESSION

Before a packet is sent over a network, several layers of encapsulations may be applied to the packet. These encapsulations which are in the form of headers are added to the payload forming an IP packet. Throughout duration of a flow, many header fields such as source and destination addresses remain static and the additional overheads can cost a waste in bandwidth.

ROHC makes classification of the header fields in order to compress the header. ROHC stores the values of these static header fields as static context at the decompressor. For dynamic fields in the IP header, ROHC uses linear functions based on the packets' sequence numbers to derive the values of the dynamic header fields. The parameters characterization of the linear functions are stored and updated as full context at the decompressor. In RFC 3095, three operation modes are defined for maintaining the context namely unidirectional mode (U-mode), bidirectional optimistic mode (O-mode) and bidirectional reliable mode (R-mode).

The unidirectional mode is designed for systems where feedback channel are not available. In short, packets are sent in one direction only from compressor to decompressor. Transitions between compressor states are only performed based on periodic timeouts and irregularities in the header field change patterns in the compressed packet streams.

Bidirectional optimistic mode and bidirectional reliable mode are designed for systems where feedback channel are available. In bidirectional optimistic mode, 3-bit cyclic redundancy check (CRC) code is used to detect bit errors in the compressed header whereas in bidirectional reliable mode, a more complex error detection and correction is used. Bidirectional reliable mode is far the most robust mode in ROHC where it can minimize the probability of CONTEXT invalidation or header loss especially for a link with long delay.

ROHC is located in between the network layer and link layer in a standard protocol stack as shown in Figure 1. In IEEE 802.16 standard [11], ROHC compressor and decompressor are part of the Subscriber Station (SS) and corresponding ASN-GW.

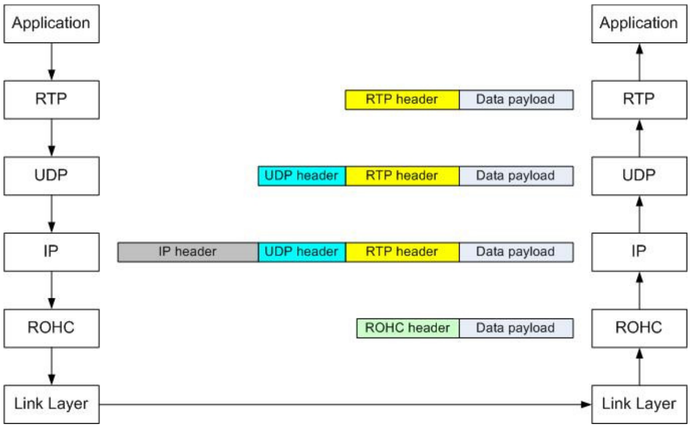


Figure 1. Protocol stack for ROHC

ROHC implements Window-based Least Significant Bits (WLSB) encoding, a timer-based encoding. When the compressor is unable to determine the exact reference value used by the decompressor, the compressor maintains a sliding window of possible reference values. These values will then be used to calculate the number of LSB. This process will reduce the probability of propagation error.

4. HYBRID SATELLITE-WIMAX NETWORK ARCHITECTURE

As shown in Figure 2, WiMAX SS is integrated with WiMAX radio interface and access is made at MAC level through the setup of connections with the WiMAX Base Station (BS). SS will negotiate the QoS parameters with BS and if it grants the process, a MAC connection is established at WiMAX level. Dynamic bandwidth allocation is used in the satellite subnetwork for optimization. The WiMAX class of services is then mapped onto the DVB-RCS capacity requests.

Return Channel Satellite Terminal (RCST) is the gateway to/from the access network to the satellite gateway (satGW). It setup DVB-RCS channels and ensure the correct communication over satellite link. DVB-S2 is used on the forward link whereas DVB-RCS is used on return link transmission. DVB-S2 is used because it supports Adaptive Coding and Modulation (ACM) and adapts per-time slot basis depending on the Signal-to-Noise-plus-Interference Ration (SNIR) at the destination terminal whereas on the return link, MF-TDMA and adaptive coding is used to enable bidimentional framing [12].

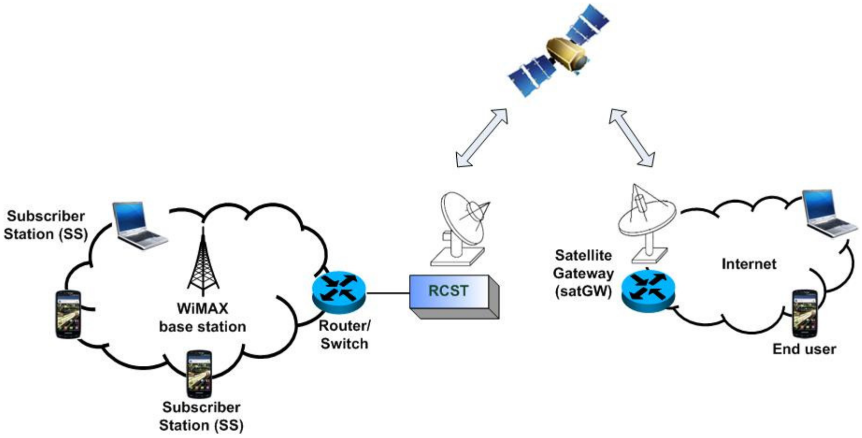


Figure 2. Hybrid satellite-WiMAX network architecture

ULE [13], a data link protocol as defined in RFC 4326 is used to transport the IP packet directly over MPEG2 transport stream (TS). The payload is first wrapped into a Sub-Network Data Unit (SNDU) structure with a 4-byte SNDU header. The SNDU header consists of destination address present field (D), length and payload type. If D is enabled, additional 6 bytes Destination Network Point of Attachment (NPA) Address will be allocated after the payload type. The receiver destination NPA Address is used to identify the receiver within MPEG2-TS transmission network

5. HYBRID-ROHC IN POINT-TO-POINT LINK MODEL

IEEE802.16 is a connection oriented access technology without bi-directional native multicast support. It has defined only downlink multicast support which may be a problem for some IPv6 protocols such as IPv6 Neighbour Discovery (ND) and ARP [14]. One of the ways to deploy IP protocols that traditionally assume the availability of multicast at the link layer is by treating the IEEE802.16 MAC (Message Authentication Code) transport connections between a SS and BS as point-to-point IP links so that the IP protocols can be run without any problems.

In this model, WiMAX BS is anchored with an Access Router (AR) located at the RCST. The WiMAX Subnet consists of a single BS/AR and multiple SS. Each link between as SS and AR is allocated a separate, unique prefix or a set of unique prefixes by the AR. Generic Routing Encapsulation (GRE) is used as the tunnelling protocol for the data plane between BS and AR shown in Figure 3. The payload is encapsulated in a GRE packet and the resulting packet is then encapsulated again in IP protocol.

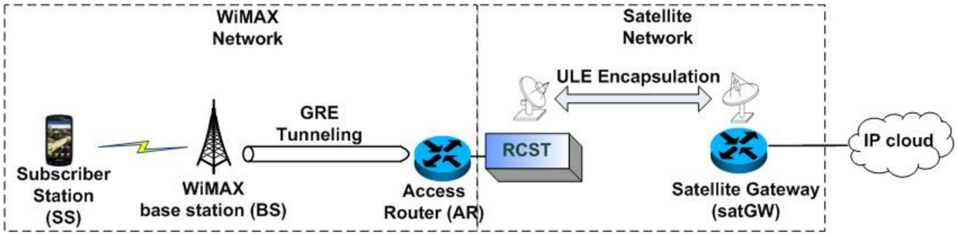


Figure 3. Base Station connecting with Access Router through GRE tunnelling

The GRE protocol is used without Checksum and Routing option. Therefore Checksum Present and Routing Present bit are set to zero. The fields Reserved0 and Reserved1 are set to 0. Since it is not using PPTP, the 3 bits GRE protocol version is also cleared to 0. Figure 4 shows the GRE Header setting used in the hybrid network.

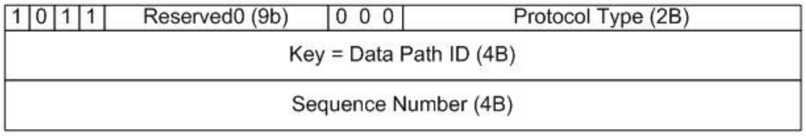


Figure 4. GRE header format

The BS maps the 802.16e Connection ID (CID) on the GRE tunnels for both upstream and downstream traffic. There is a 1 to 1 correspondence between 802.16e connections and GRE keys. Sequence Number field is set for handover optimizations. Due to double headers (IP/IP), the GRE tunnelling adds overhead between the endpoints. For example, for each IPv4 packet transmitted, the extra overhead due to GRE tunnel is 20 bytes plus GRE Header which is 12 bytes. This leads to great wastage of resource. Thus here are two parts of compression that need to be dealt with; inner header compression and outer header compression.

In the WiMAX network, ROHC function is collocated with Anchor Data Path Function to perform header compression and decompression. ROHC channel will be mapped one-to-one to a service flow (SF). At the SS, in order to classify the IP packet into a proper service flow for uplink traffic towards the IP cloud, the classifier performs classification function as shown in Figure 5. If the 5-tuple of the incoming packet belongs to the ROHC SF, it will forward the packet to the ROHC function. The Convergence Sublayer (CS) PDU which consists of compressed ROHC header and IP payload are then encapsulated in 802.16 MAC frames.

For downlink IP packet, the AR identifies the corresponding ROHC decompressor associated with the ROHC SF by the transport CID assignment, through the MAC-SAP. The CS PDU from the MAC-SAP, which consists of ROHC Header and IP Payload is decompressed by the decompressor. The decompressed IP packet will then be sent to the IP layer. If the decompressor in SS needs to send a feedback packet to the AR for the downlink ROHC channel, it will use the uplink ROHC SF.

In the BS, the CS PDU is encapsulated within GRE packet where they are carried over to the access router. The Data Path ID in the GRE header is used to determine the address MSID as well as the particular SFID. Since 8 out of the 12 bytes of GRE headers are static (except for GRE sequence number) and do not change during the duration of the flow, ROHC over GRE is extremely simple to implement. Here, GRE header can be seen as part of extension header chains. By removing static fields from most of the messages, exploiting dependencies and the predictability of other fields, the total header size can be reduced significantly. The sequence number field in the GRE header contains a counter value for a GRE tunnel. The sequence number in the GRE header linearly increases with each new encapsulated IP datagram per GRE key, and when the compressor (BS) is confident that the decompressor (AR) has received the pattern, the sequence number will not be sent again. The decompressor will then apply linear extrapolation to reconstruct the sequence number in the GRE header.

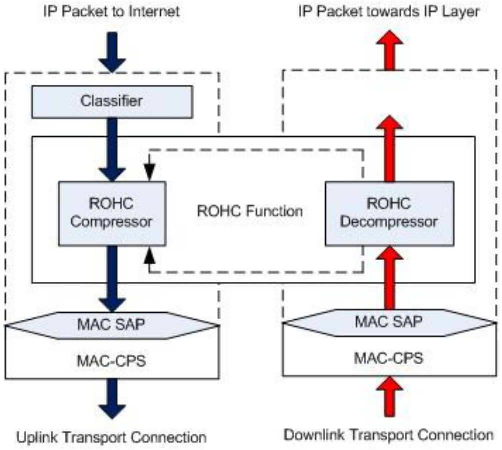


Figure 5. Data Plane in SS

The AR will decompress both the outer and inner IP layer before forward the packet to the RCST where the IP packet will be compressed using ROHC before encapsulates it in ULE SNDU. To differentiate between streams of uncompressed and compressed packets, the compressed packets carry payload type 0x00AC instead of using 0x8000 for IPv4 packet and 0x86DD for IPv6 packets. The resulting SNDU is further encapsulated in MPEG2-TS packet which has a fixed-length of 188 bytes consisting 4 byte header.

6. PERFORMANCE EVALUATION

In order to test the performance of Hybrid-ROHC over hybrid satellite-WiMAX network, simulation was executed using simulator ns-2 version 2.34. Although ns2 supports many useful network technologies, its default package does not implement definitive IP over MPEG2-TS and IEEE 802.16. The IP over MPEG2-TS module used in this simulation is adopted from the version provided by the European Space Agency (ESA)[15]. Although there are many different public domain IEEE 802.16 modules available, the IEEE 802.16 module by WiMAX Forum [16] is used because it had the distinction between nodes.

Hybrid-ROHC was implemented within WiMAX MAC CS and data path tunnel. The ROHC module runs on subscriber station, base station, access router and sat-GW. Simulation was performed to evaluate the efficiency and robustness of Hybrid-ROHC over hybrid satellite-WiMAX network. The network topology of the simulation scenario is depicted in Figure 6.

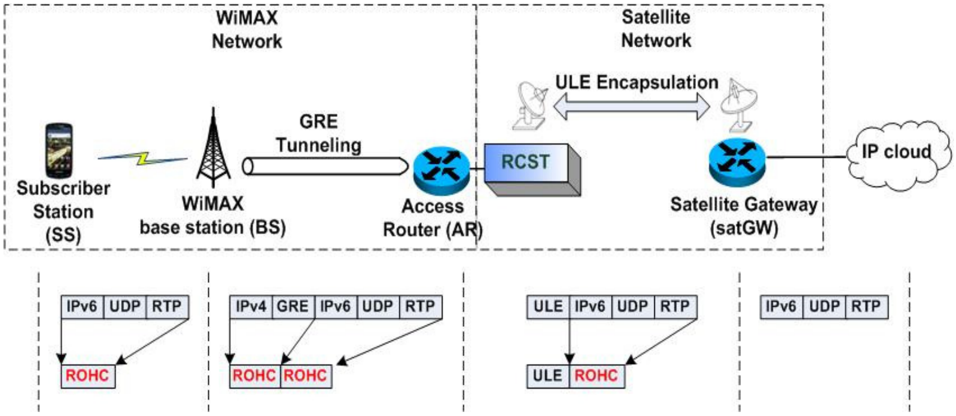


Figure 6. Network topology

The main focus of this simulation lies on the IP packet being sent from source to destination node in hybrid satellite-WiMAX network. During the simulation, the traffic source is attached to an application generating voice traffic. The voice traffic uses Constant Bit Rate (CBR) model running over RTP with total header size of 60 bytes (40 bytes of IPv6 header, 8 bytes of UDP header and 12 bytes of RTP header). The simulations were run with different distributions of packet size starting from minimum of 160 bytes which is voice payload size for G.711 code until a maximum of 140 bytes to determine the transmission efficiency of Hybrid-ROHC. The satellite and WiMAX parameters used in the simulation are presented in Table 1 and Table 2 respectively.

Table 1. Simulation parameters for satellite network

Parameters	**Value**
Traffic Type	RTP Traffic
Traffic load	100 kbps to 1000 kbps
Satellite Type	Geostationary bent-pipe satellite
Satellite Uplink	2Mbps
Satellite Downlink	28Mbps
Encapsulation method	ULE
Queue Type	FIFO Queue
Link queue size	50

Table 2. Simulation parameters for WiMAX network

Parameters	**Value**
PHY Layer	OFDMA
Frame duration (T_f)	5 ms
DL/UL ratio	3:1
Channel bandwidth	10 MHz
MCS	16 QAM ¾
Link Queue Size	50
Fast Fourier Transform (FFT) size	1024
Uplink data rate	4.032 Mbps

Several QoS parameters were analyzed to investigate the performance between uncompressed and Hybrid-ROHC packets namely average one way delay, average throughput and interarrival jitter. Figure 7 shows values for average one way delay for different RTP packet size. As expected, Hybrid-ROHC shows improvement in terms of average one way delay for the 4 different packet sizes. High compression gains lower the packet header size thus improving the time spent to send the packet through the channel. The compression gains is most significant at high bit rate due to the fact that when the traffic generation rate increases, the time for router to forward the packet will approach link capacity. Smaller packet header size will generally reduce queuing delay thus improving the average delay.

When payload size is smaller (e.g 160 Bytes), average one way delay was lower with Hybrid-ROHC as compared to bigger payload size. This improvement was due to the ratio of packet header to size of payload for Hybrid-ROHC is larger than uncompressed header for small payload size. As the packet payload size increases, the impact of the packet overhead is smaller thus the transmission time for larger packets is almost identical with and without Hybrid-ROHC. In summary, the improvement using Hybrid-ROHC is not significant for large payload size.

The results of the simulation demonstrated that Hybrid-ROHC improved the average throughput significantly as shown in Figure 8. When packet size is 160 Bytes, Hybrid-ROHC achieved 31% higher average throughput then uncompressed packet. Using Hybrid-ROHC, the number of packets that can be sent through a single stream increases thus provide better efficiency in terms of throughput. However as the packet size increases, the improvement in terms of average throughput between uncompressed and Hybrid-ROHC reduces.

For the 4 different scenarios, when the packet generation rate increases, the average throughput for both uncompressed and Hybrid-ROHC increases at a linear rate but when as it approach the link capacity, the average throughput will remains a constant level. This is due to the fact that packet drop occurred when the packet generation rate reaches the link capacity.

Although there are various formulas to compute jitter, interarrival jitter is used to reflect the statistical variance of the RTP data packet appropriately [17]. The interarrival jitter is calculated as follows:

$$J(i) = J(i-1) + \left(|D(i-1,i)| - J(i-1)\right)/16$$

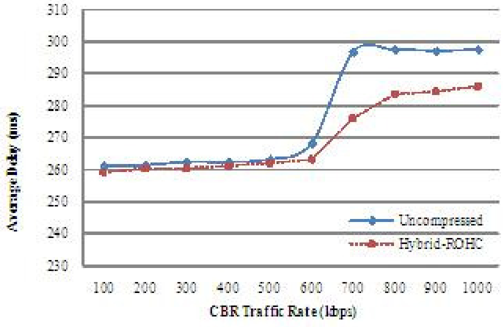
where

$$D(i,j) = \left(R_j - S_j\right) - \left(R_i - S_i\right)$$

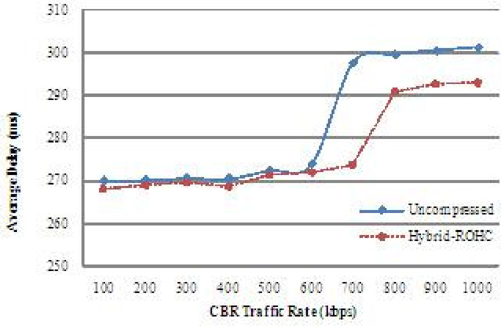
S_j is the timestamp from the packet i and R_i is the time of arrival for packet i. As is evident from Figure 9, Hybrid-ROHC decreased the interarrival jitter especially for small packet size. At small packet size, the reduction in certain bit rate can goes up to as much as 36%.

7. CONCLUSION AND FUTURE WORK

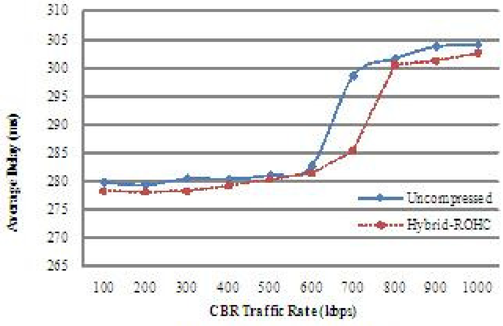
Results from our experiments showed that the proposed approach can impact positively in the behaviour of RTP traffic in hybrid satellite-WiMAX network. Average one-way delay, average throughput and interarrival jitter were used to show the impact of header compression mechanisms in the traffic. Our approach showed best values for all the three QoS parameters. With the increase of usage in TCP traffic, future work would focus on investigating the performance of TCP profile performance over the hybrid satellite-WiMAX network.



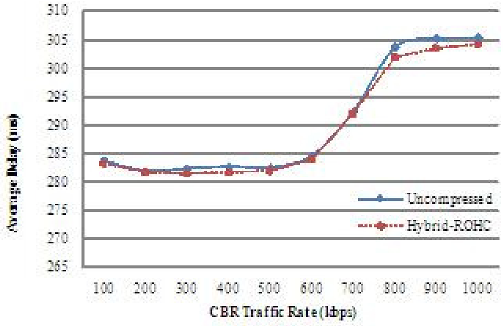
(a) Payload Size = 160 Bytes



(b) Payload Size = 512 Bytes

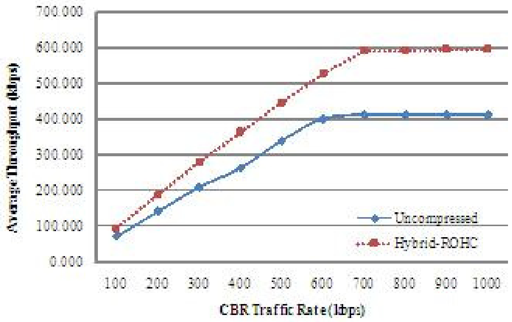


(c) Payload Size = 1024 Bytes

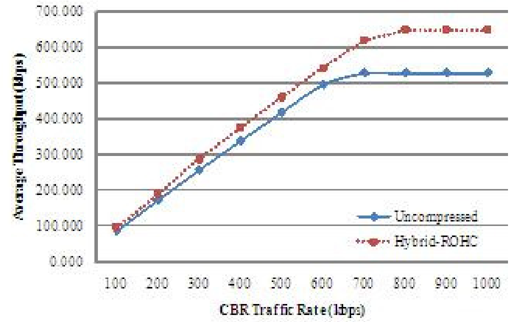


(d) Payload Size = 1400 Bytes

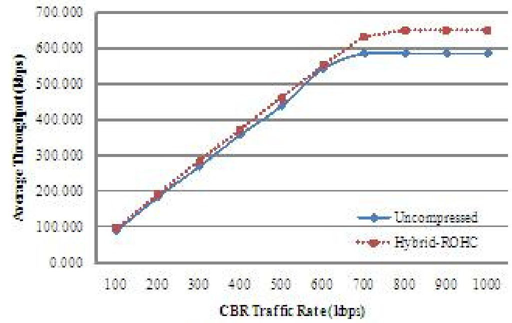
Figure 7. Average one way delay for different RTP packet size with and without Hybrid-ROHC



(a) Payload Size = 160 Bytes



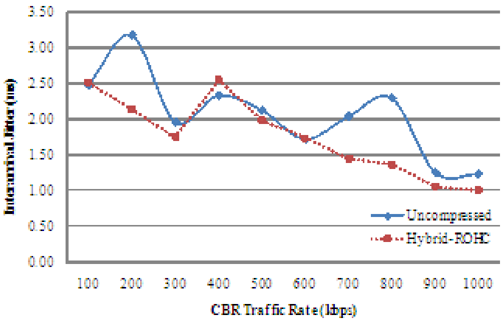
(b) Payload Size = 512 Bytes



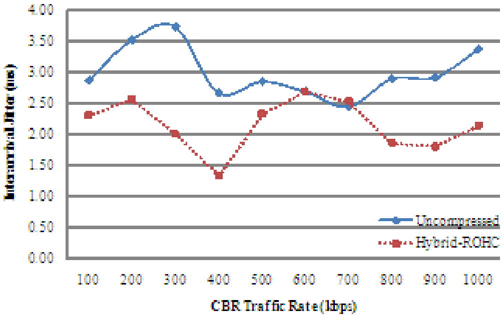
(c) Payload Size = 1024 Bytes

(d) Payload Size = 1400 Bytes

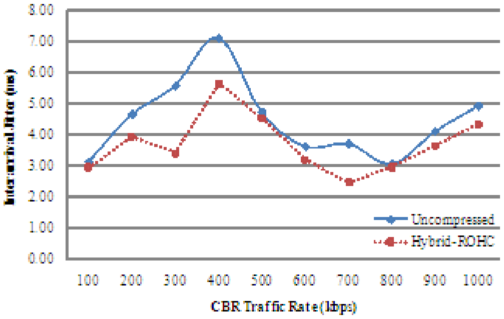
Figure 8. Average data throughput for different RTP packet size with and without Hybrid-ROHC



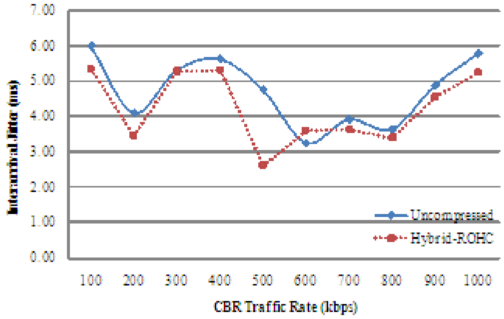
(a) Payload Size = 160 Bytes



(a) Payload Size = 512 Bytes



(a) Payload Size = 1024 Bytes



(a) Payload Size = 1400 Bytes

Figure 9. Interarrival jitter for different RTP packet size with and without Hybrid-ROHC

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