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WHITE PAPER

An introduction to IP header compression

FEBRUARY 2004

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An introduction to IP header compression

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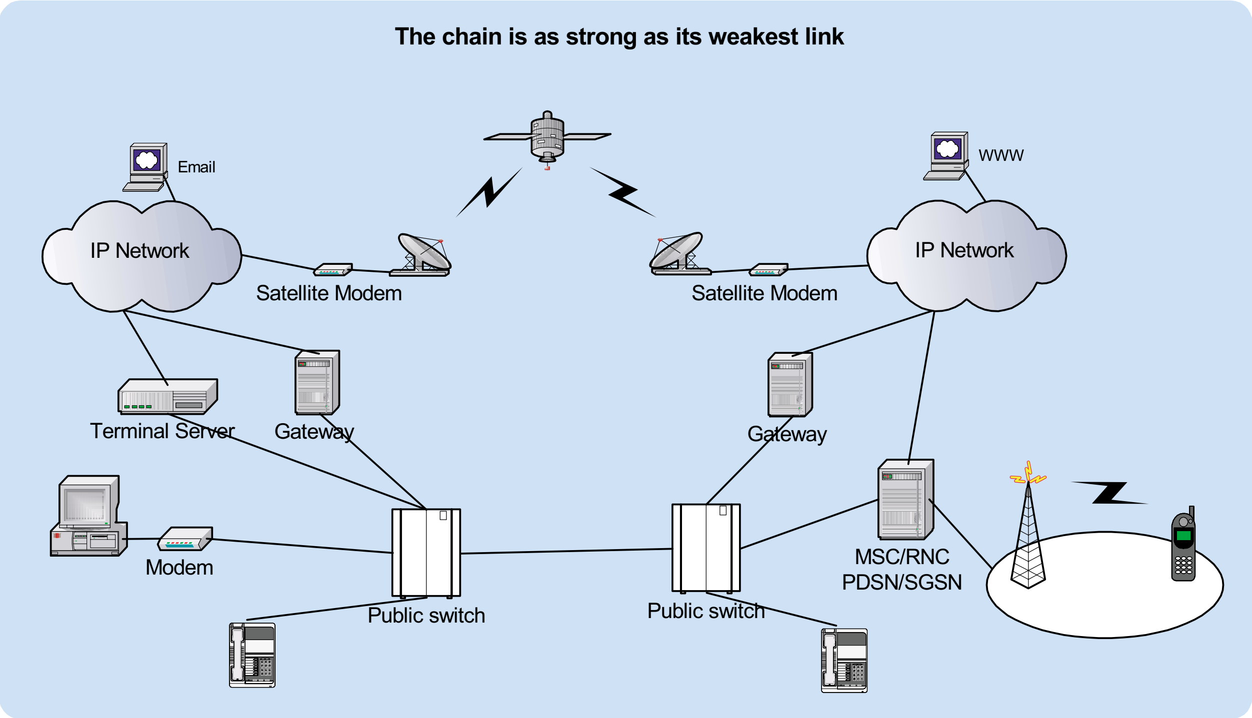
The need for IP header compression

The Internet Protocol (IP) is the choice of transport protocol both on wired and wireless networks and this choice is leading to the convergence of telecommunication and data networks. These converged networks will be the building blocks of the All-IP vision.

As the networks evolve to provide more bandwidth, the applications, services and the consumers of those applications all compete for that bandwidth. For the network operators it is important to offer a high quality of service (QoS) in order to attract more customers and encourage them to use their network as much as possible, thus providing higher average revenue per user (ARPU).

As for wireless networks with their high bit error rates (highly prone to interference) and high latency (long round trip times), it is difficult to attain those high bandwidths required. When all these factors are taken into account it means that the available resources must be used as efficiently as possible.



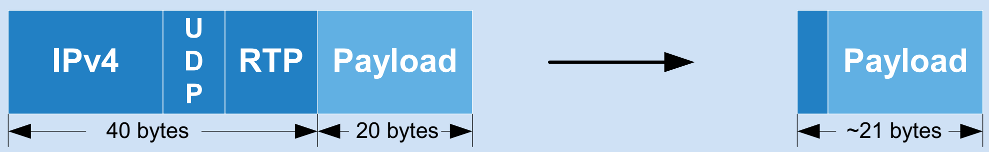
In many services and applications e.g., Voice over IP, interactive games, messaging etc, the payload of the IP packet is almost of the same size or even smaller than the header. Over the end-to-end connection, comprised of multiple hops, these protocol headers are extremely important but over just one link (hop-to-hop) these headers serve no useful purpose. It is possible to compress those headers, providing in many cases more than 90% savings, and thus save the bandwidth and use the expensive resources efficiently. IP header compression also provides other important benefits, such as reduction in packet loss and improved interactive response time.

In short, IP header compression is the 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. It is possible to compress the protocol headers due to the redundancy in header fields of the same packet as well as consecutive packets of the same packet stream.

Header compression is about link efficiency

Let us look at some examples of how much compression (or bandwidth savings) we can achieve using header compression. The IP version 4 header is 20 bytes and when carrying UDP (8 bytes) and RTP (12 bytes, at least), the packet header becomes 40 bytes. A header compression scheme usually compresses such headers to 2 – 4 bytes. On an average, considering a few uncompressed packets and a few relatively large packets, more than 80% savings can be observed. When compared with the payload being carried, in such cases as voice where payload size is usually static and in the range of 20 – 60 bytes, the header size represents a huge overhead. Using header compression in such cases results in major bandwidth savings. The IP version 6 with a header size of 40 bytes is gaining wide acceptance and has been included in Release 5 and onwards versions of 3G wireless networks. In this case, header compression will result in even more savings.

The basic technology of header compression:



On low bandwidth networks, using header compression results in better response times due to smaller packet sizes. A small packet also reduces the probability of packet loss due to bit errors on wireless links resulting in better utilization of the radio spectrum. It has been observed that in applications such as video transmission on wireless links, when using header compression the quality does not change in spite of lower bandwidth usage. For voice transmission, the quality increases while utilizing lower bandwidth. In short header compression improves network transmission efficiency, quality and speed with:

- *Decrease in packet header overhead (bandwidth savings)*
- *Reduction in packet loss.*
- *Better interactive response time.*
- *Decrease in infrastructure cost, more users per channel bandwidth means less infrastructure deployment costs.*

The header compression gains:

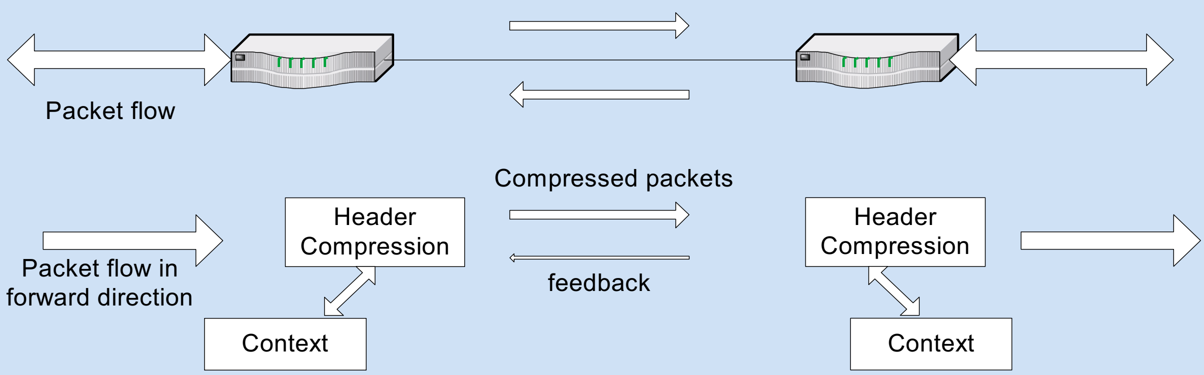
Protocol headers	Total header size (bytes)	Min. compressed header size (bytes)	Compression gain (%)
IP4/TCP	40	4	90
IP4/UDP	28	1	96.4
IP4/UDP/RTP	40	1	97.5
IP6/TCP	60	4	93.3
IP6/UDP	48	3	93.75
IP6/UDP/RTP	60	3	95

These benefits lead to improved QoS in the network and the possibility for operators to improve their ARPU. The operators will be able to retain and attract customers with better QoS on the network and more services and content on the links.

Header compression explained

The IP protocol together with transport protocols like TCP or UDP and optional application protocols like RTP are described as a packet header. The information carried in the header helps the applications to communicate over large distances connected by multiple links or hops in the network. The information comprises of source and destination addresses, ports, protocol identifiers, sequence numbers, error checks etc. As long as the applications are communicating most of this information carried in packet headers remains the same or changes in specific patterns. By observing the fields that remain constant or change in specific patterns it is possible either not to send them in each packet or to represent them in a smaller number of bits than would have been required originally. This process is described as compression.

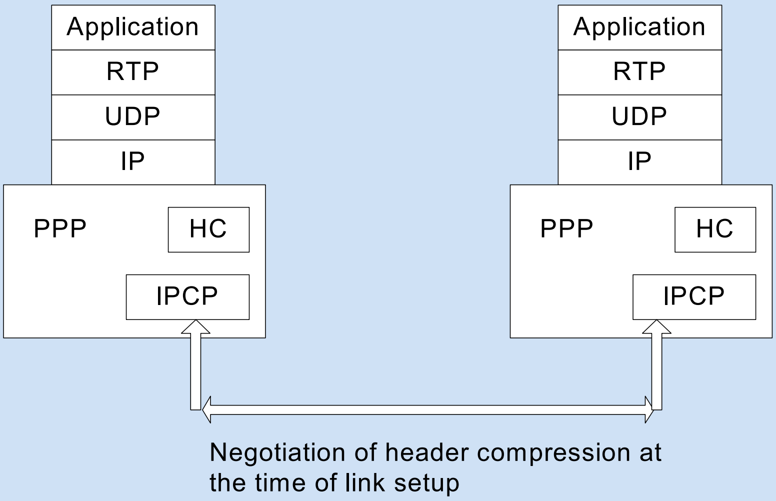
The concept of flow context in header compression:



The process of header compression uses the concept of flow context, which is a collection of information about field values and change patterns of field values in the packet header. This context is formed on the compressor and the decompressor side for each packet flow. The first few packets of a newly identified flow are used to build the context on both sides. These packets are sent without compression. The number of these first few packets, which are initially sent uncompressed, is closely related to link characteristics like bit error rate (BER) and round trip time (RTT). Once the context is established on both sides, the compressor compresses the packets as much as possible. By taking into account the link conditions and feedback from the decompressor, the compressed packet sizes vary. At certain intervals and in the case of error recovery, uncompressed packets are sent to reconstruct the context and revert back to normal operational mode, which is sending compressed packets.

The header compression module is a part of the protocol stack on the devices. It is a feature, which must be negotiated before it can be used on a link. Both end points must agree if they support header compression and on the related parameters to be negotiated.

An example of application of header compression in a protocol stack:



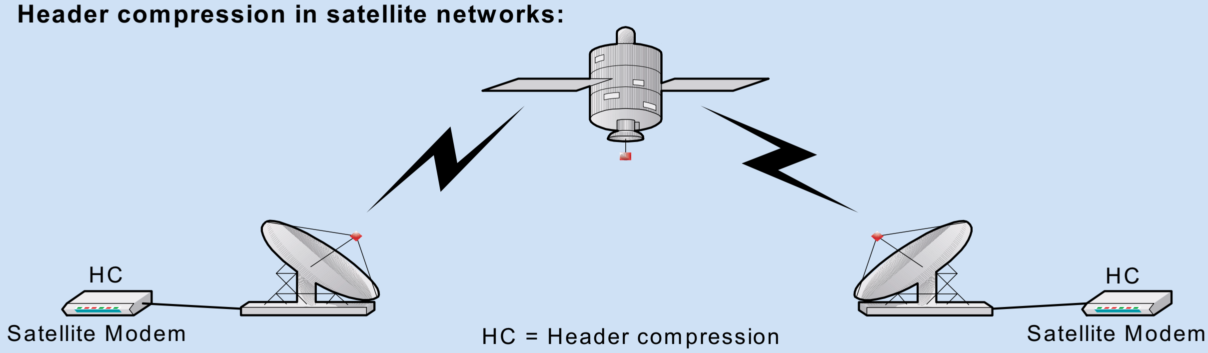
The above diagram shows the location of the header compression module in a protocol stack. The link layer for example PPP, uses the IPCP protocol to negotiate the use of header compression and related parameters at the time of the link set-up.

Header compression application areas

In keeping with the principle of end-to-end connectivity over IP, the header compression does not introduce any changes in the fields when it compresses and decompresses the header (reconstructing the header as it was before compression). The header compression is a hop-to-hop process and not applied end-to-end. At each hop in the IP network, it becomes necessary to decompress the packet to be able to perform the operations like routing, QoS etc. Header compression is best suited for specific links in the network characterized by relatively low bandwidth, high bit error rates and long round trip times.

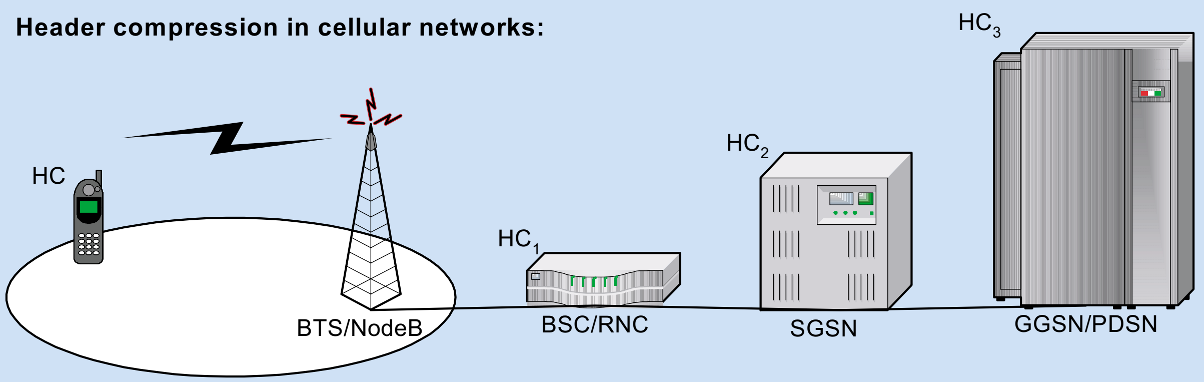
Realizing that the chain is as strong as its weakest link, header compression is the solution to improve the efficiency (strength) of this link and provide a better utilization of the network and improve user experience. Below are a few examples of such links and networks where header compression can be applied.

Header compression in satellite networks:



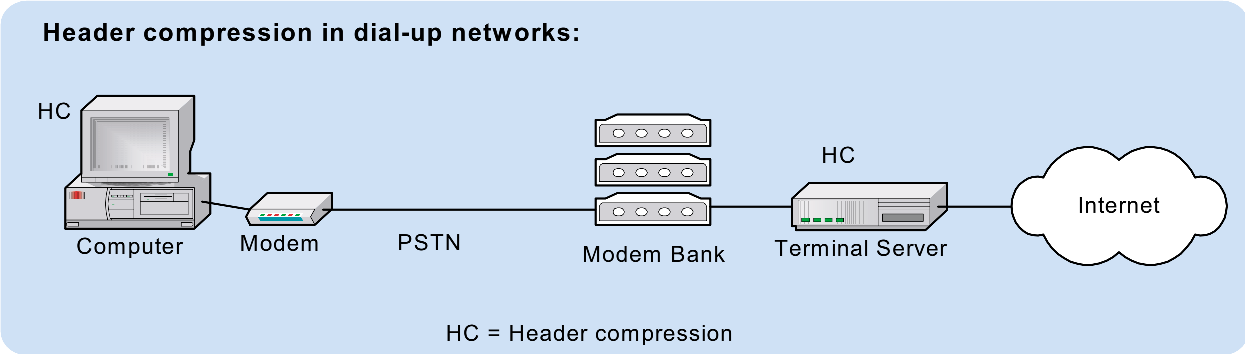
Satellite links have high bit error rates and high delays (delay varies from more than 500 milliseconds (ms) for geo-synchronous to a few ms for lower earth orbit satellites). The header compression module is part of satellite modem as shown above.

Header compression in cellular networks:

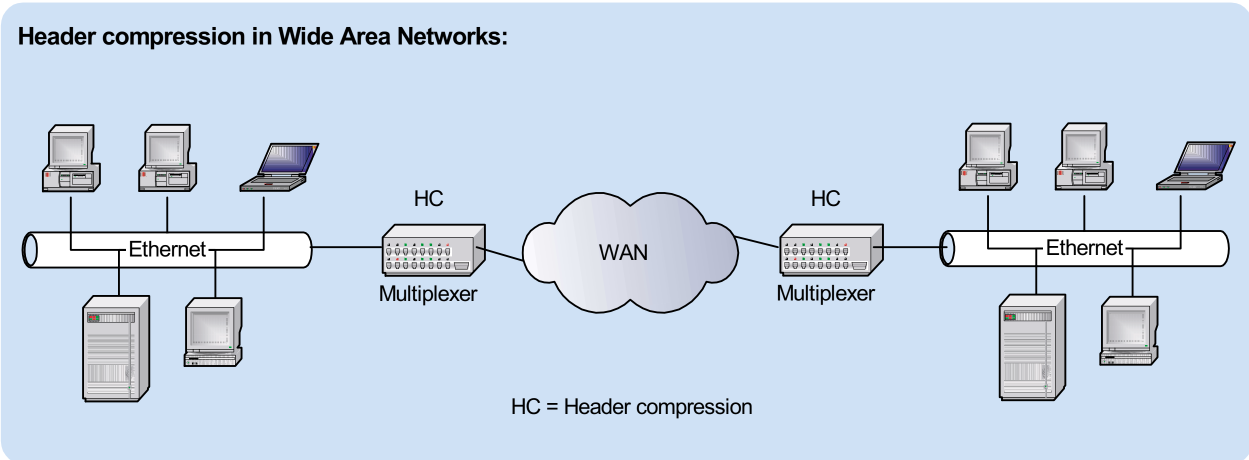


HC = Header compression
HC is always used in the terminal according to all the standards together with:
1. RNC as per UMTS standard, or
2. SGSN as per GPRS standard, or
3. PDSN as per CDMA2000 standard.

In 2.5G (GPRS) or 3G (WCDMA/CDMA2000) networks, the radio link has high bit errors. The standards specifications include the use of header compression for better utilization of the radio resource. In some applications, like IMS – IP Multimedia Subsystem, it is a critical component for successful operation. The header compression module is used in RNC as per the UMTS standard or SGSN as per the GPRS standard or PDSN as per the CDMA2000 standard together with the mobile terminal as specified in all the standards.



Internet access often uses modems and PSTN links, which have low bandwidth. To improve performance for interactive applications like Telnet, web services as well as Voice over IP, usage of header compression results in bandwidth savings. The header compression module is a part of the end user's computer operating system and the Terminal Server (PPP link end points) as shown in the diagram above.



Many multi-location offices are connected with WAN links that have comparatively high bandwidth (compared to PSTN links) and usually carry high data traffic. With the cost benefit of convergence of telephone and data networks, applications like voice and video over IP are competing for these WAN links. One of the best ways to save bandwidth is header compression (in this case with tunnelling and multiplexing features), which will remove unnecessary protocol overheads. The header compression module is a part of the routers/multiplexers connected to WAN.

Header compression standards

The Internet Engineering Task Force (IETF) was formed in 1986 to foster collaboration on the development and evolution of the Internet and related networking technologies. The IETF develops and standardizes header compression schemes.

The header compression standards are evolving and the following standards represent the steps in that evolution process:

Comparison of the IETF header compression standards:

IETF standard	RFC 1144 (VJ, CTCP)	RFC 2507 (IPHC)	RFC 2508 (CRTP)	RFC 3095 (ROHC)
Headers	IPv4/TCP	IPv4 (including options and fragments), IPv6 (including extension headers), AH, Minimal Encapsulation header, Tunnelled IP headers, TCP (including options), UDP, ESP	IPv4, IPv6 (including extension headers), AH, Minimal Encapsulation header, Tunnelled IP headers, UDP, RTP	IPv4 (including options and fragments), IPv6 (including extension headers), AH, Minimal Encapsulation headers, GRE, Tunnelled IP headers, UDP, RTP, ESP
Header compressed to minimum	2 bytes	2 bytes	2 bytes	1 byte
Link Type (BER, RTT)	Dial-up (Low, Short)	Dial-up and wireless (Low to medium, Short to medium)	Dial-up and wireless (Low to medium, Short to medium)	Wireless (High, Long)
Encoding	Differential	Differential	Differential	Window-based Least Significant Bit
Error recovery (Feedback)	TCP based (No)	TWICE (Yes)	TWICE (Yes)	Local repair (Yes)
Recommended in (standards)	-	UMTS Release 99 onwards CDMA2000 Release B onwards	-	UMTS Release 4 onwards CDMA2000 Release B onwards

- *The RFC 1144 (CTCP) header compression standard was developed by V. Jacobson in 1990. It is commonly known as VJ compression. It describes a basic method for compressing the headers of IPv4/TCP packets to improve performance over low speed serial links. VJ compression is the most commonly used header compression scheme in IP protocol stacks today. However, the evolution towards all IP networks has created new demands on header compression. Consequently, newer standards have developed with superior error recovery mechanisms, which work well on links that exhibit both non-trivial round-trip times and significant loss.*

- *The RFC 2507 (IPHC) was developed in 1999 by scientists, closely related to Effnet, of the Luleå University of Technology. This technique compresses, on a hop-by-hop basis, multiple IP headers including IPv4 and IPv6, TCP, UDP, ESP headers. The compression algorithms are specifically designed to work well over links with non-trivial packet-loss rates.*

- *The RFC 2508 (CRTP) standard, developed in 1999, was justified primarily by the specific problem of sending audio and video over low speed serial links. CRTP compresses the headers of IP/UDP/RTP packets used for audio and video, reducing overhead on a hop-by-hop basis. CRTP performs best on local links with low round-trip times.*

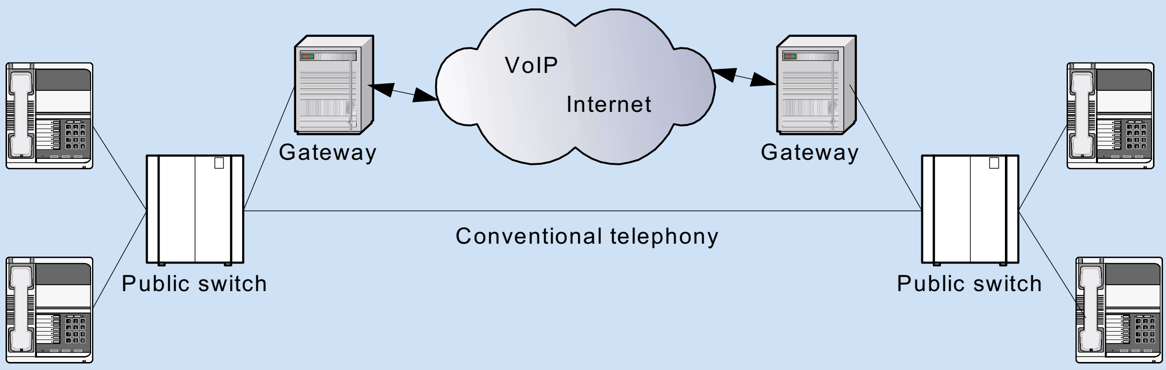
- *The RFC 3095 (ROHC) was developed in 2001. This standard can compress IP/UDP/RTP headers to just over one byte, even in the presence of severe channel impairments. This compression scheme can also compress IP/UDP and IP/ESP packet flows. ROHC is intended for use in wireless radio network equipment and mobile terminals to decrease header overhead, reduce packet loss, improve interactive response, and increase security over low-speed, noisy wireless links. ROHC has been adapted to work with link layer characteristics like those of GSM and CDMA and is known as Link Layer Assisted-ROHC (ROHC-LLA).*

These header compression schemes are widely adopted by various standardization bodies including the 3rd Generation Partnership Project (3GPP) and 3GPP2. The 3GPP and 3GPP2 standardize the specifications for 2.5G and 3G wireless networks. The header compression schemes such as IPHC and ROHC are already part of the Release 4 specifications of the 3GPP. These schemes are an essential ingredient for the success of the Release 5 and 6 specifications, which introduce IPv6 and IP Multimedia Subsystem. The header compression technology has also been adopted by satellite communication networks, low bandwidth wired networks and some special links like Frame Relay etc as well as unique networks like the Terrestrial Trunked Radio (TETRA).

Roadmap for future developments

The convergence of networks is making ubiquitous computing a reality. To meet the demands of users, operators and manufacturers, the header compression schemes are also evolving. The ROHC working group within IETF has added the Signalling Compression (RFC 3320) scheme to compress protocols like SIP (Session Initiation Protocol). This scheme is flexible enough to be able to compress similar signalling protocols in the future. The ROHC working group is working on standardizing the IP-Only profile, the UDP-Lite profile and the TCP profiles to be added to the ROHC framework. For more details about ROHC, see the Effnet white paper on Robust Header Compression at www.effnet.com

New developments, new opportunities



The Compressed RTP (CRTP) standard has been enhanced to support links with high delays, packet loss and reordering. This new standard is ECRTP (RFC 3545). Work is in progress to standardize tunnelling of CRTP flows to get maximum benefit for applications such as VoIP supporting a large number of users. As shown in the diagram above, the long distance telecom operators are moving from traditional connectivity between PSTN networks to the Internet. The gateway connecting public switch and Internet converts circuit switched voice to packet switched voice and vice versa, which is carried over Internet. It is possible to support a large number of users over medium bandwidth links by the use of header compression, which may save up to 50% bandwidth per connection.

There is continued effort going on to standardize the use of header compression schemes over a wide array of network access technologies. Previously, we saw an example of the negotiation of header compression over a PPP (Point-to-Point Protocol) link. There are now standards available for IPHC over PPP (RFC 2509) and ROHC over PPP (RFC 3241). The success of Wireless LAN (WLAN) and broadband connections over digital video broadcasting (DVB) has prompted standardization bodies to also look for ways to use header compression over these links to save bandwidth and be able to support a large number of users.

The All-IP network, a concept put forward by the 3GPP takes one step closer to convergence of all types of networks including Internet, PSTN, cellular, satellite etc. It ushers in the era of ubiquitous computing, providing access to services anytime and anywhere. In this mix of networks and services, some are expensive resources, high bandwidth consuming services and low bandwidth networks as well. All of these resources must be used efficiently to cater to a large number of users with attractive services at an acceptable quality of service. The header compression schemes are essential components to achieve better efficiency, better utilization and better experience (quality of service).

The Effnet Header Compression product family

Effnet offers a variety of header compression products. They are used in many types of IP networks such as 2.5G and 3G cellular networks, satellite networks, dial-up modem links, wide area networks etc.

Effnet's header compression products are designed to be easily adapted to a variety of operating systems and hardware platforms. The implementations are developer-friendly and available both in user space for debugging and testing (with Effnet HC-Sim™). They have been successfully integrated in link layers such as the PPP according to the standards.

The Effnet Header Compression products:

Effnet products	Effnet IPHC™	Effnet CRTP ™	Effnet ROHC™
IETF standard	RFC 2507 (IPHC)	RFC 2508 (CRTP)	RFC 3095 (ROHC)
Application areas	Cellular, satellite, WAN and dial-up networks	Satellite, WAN and dial-up networks	Cellular, satellite, wireless and WAN networks

The Effnet Header Compression product family:

- Software which is fully compliant with the IETF header compression standards
- Highly portable products with source code implementations in ANSI C
- Platform, endianness and byte-order independent
- Highly configurable with many compile and run time options to attain optimal performance
- Support for multi-threading with re-entrant code
- Extensively tested, in-house as well as during interoperability and field tests

Effnet IPHC™

- Fully compliant with IETF RFC 2507
- Header compression for web, email and file transfer traffic (mainly TCP/IP traffic) over low BER links
- Compresses TCP, UDP, ESP with IPv4 and IPv6 headers

Effnet CRTP™

- Fully compliant with IETF RFC 2508
- Header compression for real time multimedia traffic for low BER links with short RTT
- Compresses RTP/UDP with IPv4 and IPv6 headers

Effnet ROHC™

- Fully compliant with IETF RFC 3095
- Header compression framework for real time multimedia, interactive and secure traffic over high BER links with long RTT
- Compresses RTP, UDP, ESP with IPv4 and IPv6 headers

Effnet HC-Sim™

- Header compression simulator for simulating traffic and link conditions
- Unique test specification language creating different simulation conditions
- Extensive logging of packets, events and statistics
- Support for internal as well as external packet sources and destinations
- Runs in one- or two-machine modes

Glossary of acronyms

2.5G	2.5 Generation wireless networks
3G	3rd Generation wireless networks
3GPP	3rd Generation Partnership Project
3GPP2	3rd Generation Partnetship Project 2
ARPU	Average Revenue Per User
BER	Bit Error Rate
BSC	Base Station Controller
BTS	Base Transceiver Station
CDMA2000	Code Division Multiple Access 2000 network
CRTP	Compressing IP/UDP/RTP Headers for Low Speed Serial Links (RFC2508)
CTCP	Compressing TCP/IP headers for low-speed serial links (RFC1144)
DVB	Digital Video Broadcasting
ECRTP	Enhanced Compressed RTP (CRTP) for Links with High Delay, Packet Loss and Reordering (RFC3545)
EDGE	Enhanced Data rates for GSM Evolution
FTP	File Transfer Protocol
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Service
GSM	Global System for Mobile telecommunication
HC	Header Compression
IETF	Internet Engineering Task Force
IMS	IP based Multimedia Subsystem
IP	Internet Protocol
IPCP	The PPP Internet Protocol Control Protocol (RFC1332)
IPHC	Internet Protocol Header Compression (RFC 2507)
OSI	Open Systems Interconnections
PDSN	Packet Data Serving Node
PPP	Point-to-Point Protocol
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RFC	Request For Comments
RNC	Radio Network Controller
ROHC	Robust Header Compression (RFC3095)
RTP	Real-Time Transport Protocol
RTT	Round Trip Time
SIP	Session Initiation Protocol
SGSN	Serving GPRS Support Node
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
VoIP	Voice over Internet Protocol
WCDMA	Wideband Code Division Multiple Access
WLAN	Wireless Local Area Network
xDSL	Digital Subscriber Line including Asymmetric, Very high rate etc.

For more information about header compression and the Effnet header compression products, please see our library of white papers and data sheets at www.effnet.com, or contact the Effnet sales office.

About Effnet AB

Since its beginnings in 1997, Effnet has been involved in research and development of technologies that improve the performance and efficiency of IP based networks. The Effnet Header Compression product family saves bandwidth and improves quality of service. Effnet is the leading independent provider of header compression products and is committed to continue to provide leading edge IP technology.

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