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**Generic Multi-Access (GMA) Convergence Encapsulation Protocols
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Abstract

Today, a device can be simultaneously connected to multiple networks, e.g. Wi-Fi, LTE, 5G, and DSL. It is desirable to combine them seamlessly to improve quality of experience. Such optimization requires additional control information, e.g. Sequence Number, in each (IP) data packet. This document presents a new light-weight and flexible encapsulation protocol for this need. The solution has been developed by the authors based on their experiences in multiple standards bodies including the IETF and 3GPP, is not an Internet Standard and does not represent the consensus opinion of the IETF. This document will enable other developers to build interoperable implementations.

Table of Contents

1. Introduction	2
2. Conventions used in this document	3
3. Use Case	4
4. GMA Encapsulation Format	5
5. Fragmentation	8
6. Concatenation	9
7. Security Considerations	10
8. IANA Considerations	11
9. References	11
9.1. Normative References	11
9.2. Informative References	11

1. Introduction

Figure 1 shows the user-plane Generic Multi-Access (GMA) protocol stack, which has been used in today's multi-access solutions [ATSSS] [MAMS] [LWIPEP] [GRE].

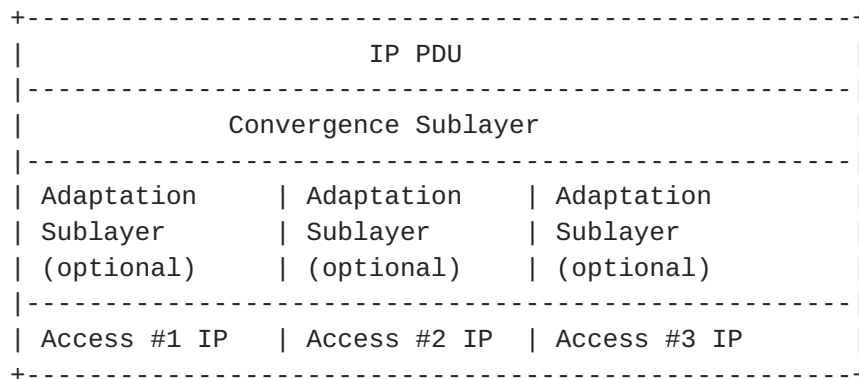


Figure 1: GMA User-Plane Protocol Stack

It consists of the following two Sublayers:

- o Convergence sublayer: This layer performs multi-access specific tasks, e.g., multi-link (path) aggregation, splitting/reordering, lossless switching/retransmission, fragmentation, concatenation, etc.
- o Adaptation sublayer: This layer performs functions to handle tunnelling, network layer security, and NAT (network address translation).

The convergence sublayer operates on top of the adaptation sublayer in the protocol stack. From the Transmitter perspective, a User Payload (e.g. IP packet) is processed by the convergence sublayer first, and then by the adaptation sublayer before being transported over a delivery connection; from the Receiver perspective, an IP packet received over a delivery connection is processed by the adaptation sublayer first, and then by the convergence sublayer.

IP-over-IP tunneling has been used in today's multi-access solutions, e.g. [[LWIPPEP](#)] [[GRE](#)], to insert the GRE header, and then encode additional control information in the GRE header fields, e.g. Key, Sequence Number. However, there are two main drawbacks with this approach: 1) IP-over-IP tunneling leads to higher overhead especially for small packet. For example, the overhead of IP-over-IP/GRE tunneling with both Key and Sequence Number is 32 Bytes, which is 80% of a 40 Bytes TCP ACK packet; 2) It is difficult to introduce new control fields with the GRE header format.

This document presents a light-weight GMA encapsulation protocol for the convergence sublayer. It avoids IP-over-IP tunneling to minimize overhead and introduces new control fields to support fragmentation and concatenation at the convergence sublayer, which are not available in today's GRE-based solutions [[LWIPPEP](#)] [[GRE](#)].

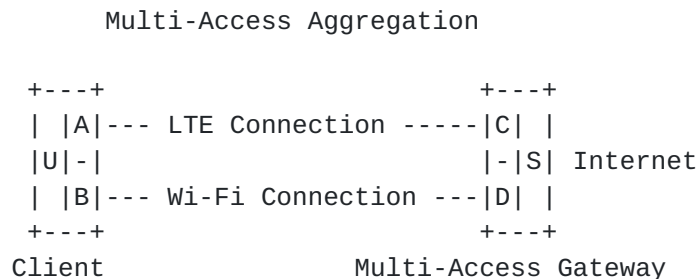
GMA protocol SHALL only operate between endpoints that have been configured to operate with GMA through additional control messages and procedures, for example [[MAMS](#)]. Moreover, UDP or IPSec tunneling MAY be used at the adaptation sublayer to protect GMA operation from intermediate nodes.

2. Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as

described in [BCP 14](#) [[RFC2119](#)] [[RFC8174](#)] when, and only when, they appear in all capitals, as shown here.

3. Use Case



A: The adaptation sublayer endpoint of the LTE connection resides in the client

B: The adaptation sublayer endpoint of the Wi-Fi connection resides in the client

C: The adaptation sublayer endpoint of the LTE connection resides in the Multi-Access Gateway, aka N-MADP (Network Multi-Access Data Proxy) in [[MAMS](#)]

D: The adaptation sublayer endpoint of the Wi-Fi connection resides in the Multi-Access Gateway

U: The convergence sublayer endpoint resides in the client

S: The convergence sublayer endpoint resides in the Multi-Access Gateway

Figure 2: GMA-based Multi-Access Aggregation

As shown in Figure 2, a client device (e.g. Smartphone, Laptop, etc.) may connect to Internet via both Wi-Fi and LTE connections, one of which (e.g. LTE) may operate as the anchor connection, and the other (e.g. Wi-Fi) may operate as the delivery connection. The anchor connection provides the IP address and connectivity for end-to-end Internet access, and the delivery connection provides additional path between client and Multi-Access Gateway for multi-access optimizations.

For example, per-packet aggregation allows a single IP flow to use the combined bandwidth of the two connections. In another example, packets lost due to temporarily link outage may be retransmitted. Moreover, packets may be duplicated over multiple connections to

achieve high reliability and low latency, and duplicated packets should be eliminated by the receiving side. Such multi-access optimization requires additional control information, e.g. Sequence Number, in each IP data packet, which can be supported by the GMA encapsulation protocol described in this document.

The GMA protocol in this document is designed for multiple connections, but it may also be used when there is only one connection between two end-points. For example, it may be used for loss detection and recovery. In another example, it may be used to concatenate multiple small packets and reduce per packet overhead.

4. GMA Encapsulation Format

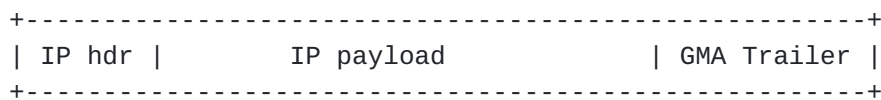


Figure 3: Trailer-based Encapsulation Format

Figure 3 shows the trailer-based encapsulation GMA PDU (protocol data unit) format for the convergence sublayer. A (GMA) PDU may carry one or multiple IP packets, aka (GMA) SDUs (service data unit), in the payload, or a fragment of the SDU.

The Protocol Type field in the IP header of the GMA PDU MUST be changed to 114 (Any 0-Hop Protocol) [[IANA](#)] to indicate the presence of the GMA trailer. The following three IP header fields SHOULD also be changed:

- o IP Length: add the length of "GMA Trailer" to the length of the original IP packet
- o Time To Live (TTL) or Hop-Limit (HL): set the HL field to "0" if the original IP packet is IPv6, and set the TTL field to "1" if the original IP packet is IPv4.
- o IP checksum: recalculate after changing "Protocol Type", "TTL or HL" and "IP Length"

However, if UDP tunnelling is used at the adaptation sublayer to carry the GMA PDU, the above three IP header fields MAY remain unchanged, and the receiver will determine the GMA PDU length based on the UDP packet length.

The GMA (Generic Multi-Access) trailer MUST consist of the following two mandatory fields. The Flags field is at the end of the PDU, and the Next Header field is the second last. The Receiver SHOULD first decode the Flags field to determine the

length of the GMA trailer, and then decode each optional field accordingly.

- o Next Header (1 Byte): the IP protocol type of the (first) SDU in a PDU
- o Flags (2 Bytes): Bit 0 is the most significant bit (MSB), and Bit 15 is the least significant bit (LSB).
 - + Checksum Present (bit 0): If the Checksum Present bit is set to 1, then the Checksum field is present and contains valid information.
 - + Concatenation Present (bit 1): If the Concatenation Present bit is set to 1, then the PDU carries multiple SDUs, and the First SDU Length field is present and contains valid information.
 - + Connection ID Present (bit 2): If the Connection ID Present bit is set to 1, then the Connection ID field is present and contains valid information.
 - + Flow ID Present (bit 3): If the Flow ID Present bit is set to 1, then the Flow ID field is present and contains valid information.
 - + Fragmentation Present (bit 4): If the Fragmentation Present bit is set to 1, then the PDU carry a fragment of the SDU and the Fragmentation Control field is present and contains valid information.
 - + Sequence Number Present (bit 5): If the Sequence Number Present bit is set to 1, then the Sequence Number field is present and contains valid information.
 - + Timestamp Present (bit 6): If the Timestamp Present bit is set to 1, then the Timestamp field is present and contains valid information.
 - + TTL Present (bit 7): If the TTL Present bit is set to 1, then the TTL field is present and contains the valid information.
 - + Reserved (bit 8-12)
 - + Version (bit 13-15): GMA version number, this is set to 0.

The GMA (Generic Multi-Access) trailer MAY consist of the following optional fields:

- o Checksum (1 Byte): to contain the (one's complement) checksum sum of all the 8 bits in the trailer. For purposes of computing the checksum, the value of the checksum field is zero. This field is present only if the Checksum Present bit is set to one.
- o First SDU Length (2 Bytes): the length of the first IP packet in the PDU, only included if a PDU contains multiple IP packets.

- o Connection ID (1 Byte): an unsigned integer to identify the anchor and delivery connection of the GMA PDU.
 - + Anchor Connection ID (MSB 4 Bits): an unsigned integer to identify the anchor connection
 - + Delivery Connection ID (LSB 4 Bits): an unsigned integer to identify the delivery connection
- o Flow ID (1 Byte): an unsigned integer to identify the IP flow that a PDU belongs to, for example Data Radio Bearer (DRB) ID [LWIP] for a cellular (e.g. LTE) connection.
- o Fragmentation Control (FC) (e.g. 1 Byte): to provide necessary information for re-assembly, only needed if a PDU carries fragments.
- o Sequence Number (4 Bytes): an auto-incremented integer to indicate order of transmission of the SDU (e.g. IP packet), needed for lossless switching or multi-link (path) aggregation or fragmentation. Sequence Number SHALL be generated per flow.
- o Timestamp (4 Bytes): to contain the current value of the timestamp clock of the transmitter in the unit of 100 microseconds.
- o TTL (1 Byte): to contain the TTL value of the original IP header if the GMA SDU is an IPv4 packet, and the Hop-Limit value of the IP header if the GMA SDU is an IPv6 packet.

Figure 4 shows the GMA trailer format with all the fields present.

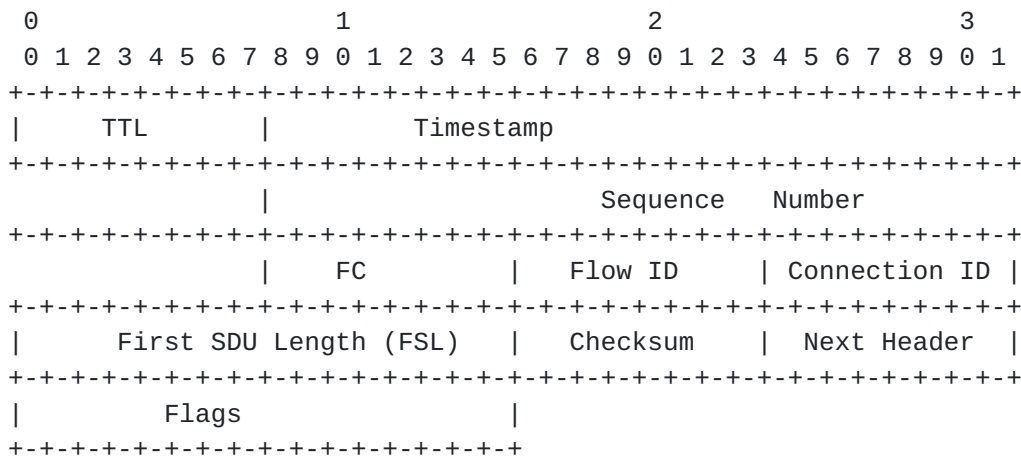


Figure 4: GMA Trailer Format

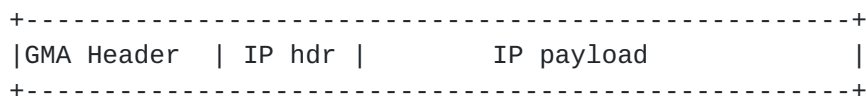


Figure 5: Header-based Non-IP Encapsulation Format

The trailer-based GMA PDU format SHOULD be used as long as implementation allows. However, if the GMA control fields can't be added at the end due to any reason, e.g. implementation constraints, one may use the header-based encapsulation (Figure 5) with the GMA header format (Figure 6). "Flags" is moved to the front. Moreover, "TTL", "FSL", and "Next Header" are removed from the GMA control fields since the IP header fields of the GMA SDU remain unchanged during encapsulation.

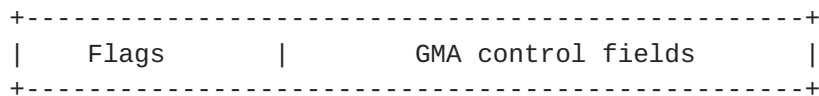


Figure 6: GMA Header Format

If the adaptation sublayer, e.g. UDP tunnelling, supports non-IP packet format, the GMA PDU format as shown in Figure 5 may be used without any modification. Otherwise, the GMA PDU format SHOULD be modified as shown in Figure 7. The IP header of the GMA SDU is moved to the front so that the GMA PDU becomes an IP packet. The IP header fields SHOULD be changed in the same way as the Trailer-based encapsulation (Figure 3) and the GMA control fields may carry "Next Header", "TTL", and "FSL".



Figure 7: Header-based IP Encapsulation Format

The GMA endpoints MAY choose the GMA PDU format (header or trailer) through control signalling or pre-configuration.

5. Fragmentation

The convergence sublayer MAY support fragmentation if a delivery connection has a smaller maximum transmission unit (MTU) than the original IP packet (SDU). The fragmentation procedure at the convergence sublayer is similar to IP fragmentation [[RFC791](#)] in principle, but with the following two differences for less overhead:

- o The fragment offset field is expressed in number of fragments not 8-bytes blocks
- o The maximum number of fragments per SDU is 2^7 (=128)

The Fragmentation Control (FC) field in the GMA trailer (or header) contains the following bits:

- o Bit #7: a More Fragment (MF) flag to indicate if the fragment is the last one (0) or not (1)
- o Bit #0~#6: Fragment Offset (in units of fragments) to specify the offset of a particular fragment relative to the beginning of the SDU

A PDU carries a whole SDU without fragmentation if the FC field is set to all "0"s or the FC field is not present in the trailer. Otherwise, the PDU contains a fragment of the SDU.

The Sequence Number (SN) field in the trailer is used to distinguish the fragments of one SDU from those of another. The Fragment Offset (FO) field tells the receiver the position of a fragment in the original SDU. The More Fragment (MF) flag indicates the last fragment.

To fragment a long SDU, the transmitter creates two PDUs and copies the content of the IP header fields from the long PDU into the IP header of both PDUs. The length field in the IP header of PDU SHOULD be changed to the length of the PDU, and the protocol type SHOULD be changed to 114.

The data of the long SDU is divided into two portions based on the MTU size of the delivery connection. The first portion of the data is placed in the first PDU. The MF flag is set to "1", and the FO field is set to "0". The second portion of the data is placed in the second PDU. The MF flag is set to "0", and the FO field is set to "1". This procedure can be generalized for an n-way split, rather than the two-way split described the above.

To assemble the fragments of a SDU, the receiver combines PDUs that all have the same Sequence Number (in the trailer). The combination is done by placing the data portion of each fragment in the relative order indicated by the Fragment Offset in that fragment's trailer. The first fragment will have the Fragment Offset set to "0", and the last fragment will have the More-Fragments flag reset to "0".

6. Concatenation

The convergence sublayer MAY support concatenation if a delivery connection has a larger maximum transmission unit (MTU) than the original IP packet (SDU). Only the SDUs with the same client IP address, and the same Flow ID MAY be concatenated.

The First SDU Length (FSL) field SHOULD be included in the trailer to indicate the length of the first SDU.



Figure 8: GMA PDU Format with Concatenation

To concatenate two or more SDUs, the transmitter creates one PDU and copies the content of the IP header field from the first SDU into the IP header of the PDU. The data of the first SDU is placed in the first portion of the data of the PDU. The whole second SDU is then placed in the second portion of the data of the PDU (Figure 8). The procedure continues till the PDU size reaches the MTU of the delivery connection. If the FSL field is present in the trailer, the IP length field of the PDU SHOULD be updated to include all concatenated SDUs and the trailer, and the IP checksum field SHOULD be recalculated. However, if UDP tunnelling is used at the adaptation sublayer to carry the GMA PDU, both the IP Length field and the checksum field of the PDU MAY remain unchanged, and the receiver will determine the GMA PDU length based on the UDP packet length.

To disaggregate a PDU, the receiver first obtains the length of the first SDU from the FSL field in the trailer and decodes the first SDU. If the FSL field or the trailer is not present, the receiver obtains the length of the first SDU directly from the IP length field of the PDU. The receiver then obtains the length of the second SDU based on the length field in the second SDU IP header and decodes the second SDU. The procedure continues till no byte is left in the PDU. However, if the header-based Non-IP GMA PDU format (Figure 5) is used, the IP header of the first SDU will not change during the encapsulation process, and therefore the FSL field is not used.

If a PDU contains multiple SDUs, the SN field in the trailer is for the last SDU, and the SN of other SDU carried by the same PDU can be obtained according to its order in the PDU. For example, if the SN field is 6 and a PDU contains 3 SDUs (IP packets), the SN is 4, 5, and 6 for the first, second, and last SDU respectively.

7. Security Considerations

Security in a network using GMA should be relatively similar to security in a normal IP network. The GMA protocol at the convergence sublayer is a 0-hop protocol and relies on the security of the underlying network transport paths. When this cannot be assumed, appropriate security protocols (IPsec, DTLS, etc.) SHOULD be configured at the adaptation sublayer. On the other hand, packet filtering requires either that a firewall looks

inside the GMA packet or that the filtering is done on the GMA endpoints. In those environments in which this is considered to be a security issue it may be desirable to terminate the GMA operation at the firewall.

The balance of local-only packet leak prevention (HL=0) and security (HL=255) SHOULD be on preventing the leak of the local-only GMA PDUs outside the "local domain" to the Internet or to another domain which could use the same IP protocol type, i.e. 114.

8. IANA Considerations

This draft makes no requests of IANA

9. References

9.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [BCP 14](#), [RFC 2119](#), DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in [RFC 2119](#) Key Words", [BCP 14](#), [RFC 8174](#), DOI 10.17487/RFC8174 May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.

9.2. Informative References

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- [IANA] <https://www.iana.org/assignments/protocol-numbers/protocol-numbers.xhtml>
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- [RFC791] Internet Protocol, September 1981
- [ATSSS] 3GPP TR 23.793, Study on access traffic steering, switch and splitting support in the 5G system architecture.

[GRE] [RFC 8157](#), Huawei's GRE Tunnel Bonding Protocol, May 2017

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