Project	IEEE 802.16 Broadband Wireless Access Working Group <**http://ieee802.org/16**>
Title	A Generic Packet Convergence Sublayer (GPCS) for Supporting Multiple Protocols over 802.16 Air Interface
Date Submitted	2005-11-09
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Re:	This is a follow-up contribution on the proposal of a generic packet convergence sublayer.
Abstract	As requested by 802.16g during the comments resolution discussions in session #39, we are submitting a follow-up contribution on our Generic Packet Convergence Sublayer proposal i.e., C802.16g-05/25, by presenting additional supporting materials and integrating suggestions and comments received from other members. We are concerned that the 802.16 protocol cannot easily be extendable to transport new protocols over the 802.16 air interface. It would appear that a convergence sublayer is needed for every type of protocol transported over the 802.16 MAC. Every time a new protocol type needs to be transported over the 802.16 air interface, the 802.16 standard needs to be modified to define a new CS type. We need to have a generic Packet convergence sublayer that can support multi-protocols and which does not require further modification to the 802.16 standard to support new protocols. We believe that this was the original intention of the Packet CS. Furthermore, we believe it is difficult for the industry to agree on a set of CS's that all devices must implement to claim "compliance." Generic Packet Convergence Sublayer (GPCS) solves these problems.
Purpose	The purpose of this contribution is to define a Generic Packet Convergence Sublayer for Supporting Multiple Protocols over 802.16 Air Interface.
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A Generic Packet Convergence Sublayer Supporting Multiple Protocols over 802.16 Air Interface

1. Background

As requested by 802.16g Task Group during the comments resolution discussions in session #39, we are submitting a follow-up contribution on our Generic Packet Convergence Sublayer (GPCS) proposal i.e., C802.16g-05/25, by presenting additional supporting materials and integrating suggestions and comments received from other members.

2. References

[802.16-2004] : IEEE-Std 802.16 – 2004

[16e/D12] : IEEE 802.16e/D12

[16cor1/D5] : IEEE 802.16-cor1/D5

[16g-05/008r1] : IEEE 802.16g-05/008r1

3. Problems with the Current 802.16 Packet Convergence Sublayer

This section describes some problems with the currently-defined packet convergence sublayers.

3.1. Not Upper-Level Protocol Agnostic

A problem with the 802.16 standard is that it tries to address upper layer protocol issues (see section 5.2 in 802.16-2004). For each upper layer protocol, it defines how fields in an upper layer protocol header are used to determine the 802.16 scheduling service type, and thus the 802.16 connection. And the standard goes further to define how upper layer headers should be encoded (e.g., compressed). Our contention is that such issues are best left outside the 802.16 standard.

The authors contend it is difficult for the industry to accept a set of 802.16 convergence sublayers that all devices must implement to be called "compliant." For example, if Ethernet CS, why should a phone have to implement Ethernet frame formats? And if IPv4: why should all 802.16 devices need to participate in IP address assignment, IP mobility, tunneling, etc? And if a vendor implements a proprietary upper layer protocol, how can its 802.16 layer be tested to be compliant? This contribution suggests that a generic packet convergence sublayer can help by simplifying a "compliance profile" that is independent of the upper layer protocol. Other bodies such as the *WiMAX Forum* may benefit from this simplification.

By way of example, some other (successful) link-layer protocol standards which do not address upper layer protocol-header-mapping, encoding and compression are: 802.3, 802.2, 802.11, ATM, Frame Relay. Also, some yet-to-be-successful link protocols follow the same convention of leaving the upper layer standards body

to define its encapsulation: Infiniband, 802.17 (Resilient Packet Ring). For instance, IP datagram encoding and compression for specific link layers is typically left for the IETF to define.

A simple example to consider is IP over Ethernet, which is fairly well understood. The IEEE 802.3 and 802.2 standards do not define how IP packets are mapped to Ethernet links or how IP addresses are assigned or mapped to Ethernet destination addresses. Those functions are specifies by the community, using the well-known protocols ARP and DHCP. Ethernet has a simple way of transporting priority bits (P-bits) in each packet (see 802.1Q) and QoS-aware Ethernet switches use them to schedule packets in the presence of congestion. But 802.1Q does not specify how the IP layer uses the P-bits. Similarly, we do not think 802.16 needs to specify how IPv4 TOS and DSCP fields map to 802.16 scheduling service types (see section 802.16-2004, section 11.13.19.3). However, the authors of this contribution recognize that Ethernet-based QoS took a long time to "get right," and recognize the efforts of 802.16 to "get it right the first time."

Other example IETF RFCs that explain how IP uses a link layer protocol are RFC2684, *Multiprotocol Encapsulation over ATM Adaptation Layer 5*, RFC2464 *Transmission of IPv6 Packets over Ethernet Networks*, RFC2625 *IP and ARP over Fibre Channel*, RFC2516, *A method for transmitting PPP over Ethernet (PPPoE)*. Also refer to work currently under way in the IETF working groups, IP-over-Infiniband (ipoib) and IP-over-Resilient Packet Ring (iporpr).

3.2. No Standard Service API

The 802.16 standard not does specify a thorough MAC service API. Although the MAC SAP is present in Figure 1 of 802.16-2004 (copied below, Figure 1), the MAC service definition found in Annex C is "informative" rather than normative. Instead of a standard service interface definition, 802.16 "prefers" to define "convergence" with upper layer protocols. We think the reason the standard instead chose the convergence layer approach was to foster interoperability by explicitly stating how upper layers' QoS definitions must map to 802.16 scheduling and security services. While this was a noble goal, we think it turned out to be too complicated and the standard as it stands now does not define all the procedures necessary to build many types of interoperable systems.

A standardized service API would provide a clean way to expose 802.16 services to the next layer in a protocol stack, or to 802.16-aware applications. Citations of some other MAC-layer service APIs are: 802.3-2002 section 2, the "MSAP" concept in IEEE Std 802-2001 (Figure 1), IEEE Std 802.11, 1999, section 6.2.

The GPCS can provide access to a standard service API for the case when all classification functions is NULL. Note this is equivalent to what used to be defined as "No Convergence Sublayer" before it was removed in IEEE 802.16-cor1/D5. However, GPCS does not attempt to define a standard service API.

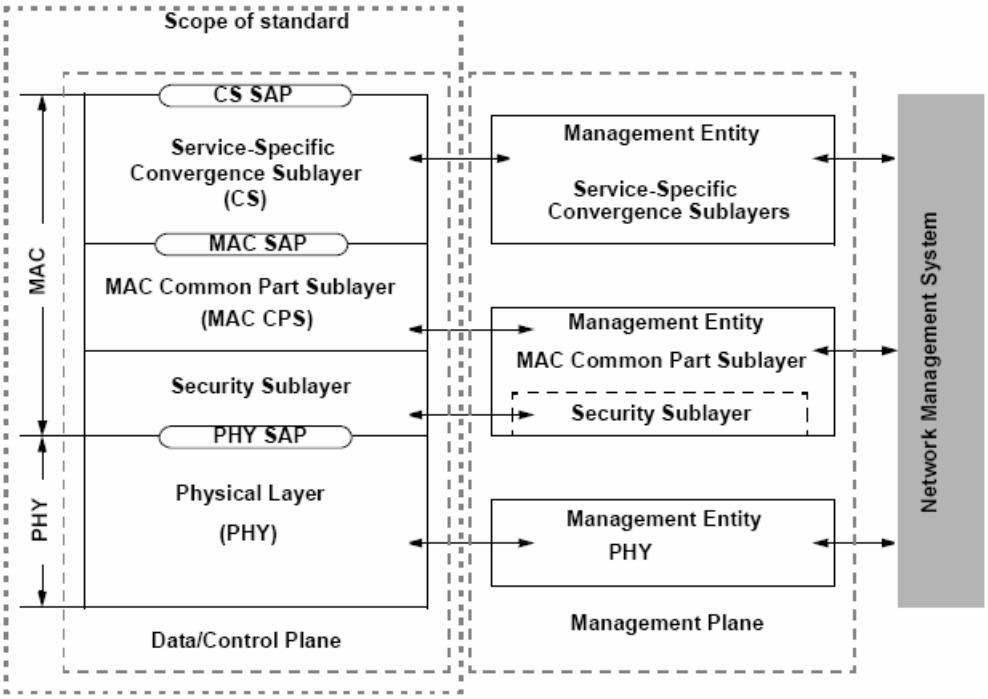

Figure 1: 802.16 Layering Model (copied from 802.16-2004)

3.3. Only One Upper Protocol per Service Flow (per Connection)

The 802.16 convergence sublayers do not define the capability for multiple upper layer protocols to transport the SDUs on a single 802.16 service flow (connection). A service flow, identified by a connection ID (CID), is a valuable resource in both base stations and subscriber stations. An 802.16 system should not be forced to open a different CID for each upper layer protocol if packets for upper layer protocols have the same QoS requirements (802.16 scheduling service types). The generic convergence sublayer provides a simple way to transport multiple protocols over a single 802.16 connection.

3.4. Poor Extendibility

It would appear that a convergence sublayer (CS) is needed for every type of protocol transported over the 802.16 MAC. Every time a new protocol type needs to be transported over the 802.16 air interface, the 802.16 standard needs to be modified to define a new CS type. A good example of the proliferation of CS's is found in Section 11.13.19.1 CS Specification. In 802.16e/D12, there are 4 new convergence sublayers that have been added in order to support IP or Ethernet/802.3 with IETF IETF header compression protocols ROHC and ECRTP. This is in addition to the 8 Convergence Sublayers already defined in 802.16 – 2004, that brings the total of Convergence Sublayers in 802.16e to 12!

802.16 should define an access method that allows for off-the-shelf components, those not even "aware" of 802.16, such as bridges, routers, NAT gateways, and classification engines to be used as components to build 802.16 compliant systems. For instance, bridges can operate just on 48-bit MAC addresses independent of 802.16 and logical link numbers, routers operate on IP addresses and logical link numbers, NAT gateways

translate IP headers without knowledge of underlying link technologies, and classification subsystems can operate on a variety of upper-layer protocol packets to identify QoS flows.

Since the existing 802.16 convergence sublayers attempt to define upper layer protocol header interpretation, the 802.16 layer needs to change whenever upper layer systems are enhanced. This model is not extensible. 802.16 SAP layering should attempt to isolate itself from upper layers so upper layers can be enhanced in standardized or proprietary was and still operate effectively over 802.16.

3.5. Repeating Upper Layer Functions

In the current 802.16 specification, address-based classification rules define how data packets of different users are mapped to different service flows (connections with CIDs), so that the differentiated QoS and/or security provisions can be provided. Particularly, it is critical for the downlink (DL) because the BS typically would use the address-based classification rules to map each packet to a different SS/MS in a point-to-multipoint topology.

The address-based classification rules require the current 802.16 convergence sublayer to maintain the mapping information between upper-protocol-defined addresses (e.g., IP or Ethernet) and CIDs. This ultimately forces the 802.16 CS to implement some upper layer functions.

For example, the IPv4 CS at BS maintains a “mapping state” for IP addresses to CIDs. Whenever there is a change in IP addresses, the mapping state needs to be updated. In non-802.16 systems and protocol stacks, upper layer address assignment and mapping to link layer entities is typically part of a routing function at the network layer.

A trouble with Ethernet headers is the size. So 802.16 has attempted to define a CS PDU format to deal with compress-header Ethernet PDUs (see section 5.2.7 of IEEE-802.16e/D12. Fields in the Ethernet header and additional fields inside the Ethernet payload (e.g., IP header and IP with mobile-IP header) complicate the classification process. Rather than pull-in Ethernet classification to 802.16, it would seem better to enable a system to classify an Ethernet packet before it is compressed. GPCS leaves the choice of classification method outside of 802.16.

Since upper layer protocol (ULP) addresses are used for some 802.16 packet CS classification rules, the packet CS layers must participate in upper layer protocol address-management procedures. When a ULP system changes addresses (mobility re-registration), translates addresses (NAT) or tunnels with nested headers (IPsec and Mobile IP), the 802.16 packet CS must be informed of changes to maintain consistent classification. The authors contend when layers “intertwine,” it is difficult to write a specification that serves a wide enough variety of implementation and ULP layering options, and eventually industry interoperability will suffer.

Also, note that 802.1D bridging can be implemented over 802.16 without Ethernet convergence. For instance, a BS can implement a bridge of VLANs between resilient packet ring and a set of 802.16 non-Ethernet-capable subscribers. 802.16 should not preclude the configuration of such topologies.

The authors of this contribution contend that although Ethernet Packet CS is great for certain classes of devices, interoperable “convergence” is difficult to define because there are so many implementation alternatives. So, Ethernet usage is best left to define “above” 802.16 so an Ethernet-based device can claim 802.16 compliance whether it implements “standard” Ethernet Packet CS or “proprietary” Ethernet CS. 802.16 should not define the use of Ethernet, or preclude flexibility in proprietary implementations.

3.6. Lack of Support for Multiple Header Compression Schemes

Furthermore, we see an architectural issue related to header compression protocols. For example, ROHC compresses all the information used by 802.16 to classify a packet to a CID and thus requiring that the implementation of ROHC (from standardization perspective at least) must be done after the 802.16 classification and thus within the 802.16 protocol stack. Note that 802.16e/D12 attempts to define classification methods for multiple header compression schemes. But it does not allow the use of proprietary header compression methods. The authors of this contribution claim that inclusion, and even mention, of header compression schemes, over-complicates the standard and leaves the standard in a state where new header compression schemes force revision of the standard. We think this will ultimately confuse the industry, and complicate compliance and interoperability tests. The 802.16 standard should allow for any header compression scheme to claim "compliance." Still, compatible and interoperable header compression needs to be defined, and classification methods need to be implemented. But the authors of this contribution contend the procedures do not need to be defined in the 802.16 standard.

4. Generic Packet Convergence Sublayer (GPCS)

To address problems with the current 802.16 packet convergence sublayer, cited in section 3, we propose a Generic Packet Convergence Sublayer (GPCS), defined as follows:

- GPCS provides a generic packet convergence layer. This layer uses the MAC SAP (see 802.16 Annex C) and exposes a new SAP to GPCS applications
- GPCS does not re-define or replace other convergence sublayers. Instead, it provides a SAP that is not protocol specific
- The basic function of the GPCS is still classification. It participates in the process to map upper layer packets (carried in 802.16 MAC SDUs) to appropriate 802.16 connections. But with GPCS, upper layer packet parsing (header inspection and interpretation to locate and extract fields relevant to classification rules) happens "above" GPCS. The results of packet parsing are classification parameters given to the GPCS SAP for "parameterized classification," but upper layer packet parsing is left to the GPCS application
- GPCS defines a set of SAP parameters as the result of upper layer packet parsing. These are passed from upper layer to the GPCS in addition to the data packet. Each is defined in later sections of this contribution
    - LOGICAL_LINK_ID
    - COS_ID (Class of Service ID)
    - PROTOCOL_TYPE
- GPCS provides an optional way to multiplex multiple layer protocol types (e.g., IPv4, IPv6, Ethernet) over the same 802.16 connection/service flow. We call this MULTIPROTOCOL_-ENABLE, a feature which can optionally be activated per CID

- For vendors to build interoperable equipment, each upper layer protocol type needs an interface specification (e.g., IPv4 over 802.16, or Ethernet over 802.16). Such a standard specification can be developed by 802.16 or any other standard bodies, e.g., WiMAX, or IETF. Essentially, some of those specificaitons could be equivalent in function to protocol-specific packet convergence sublayers defined in today's 802.16 standard.

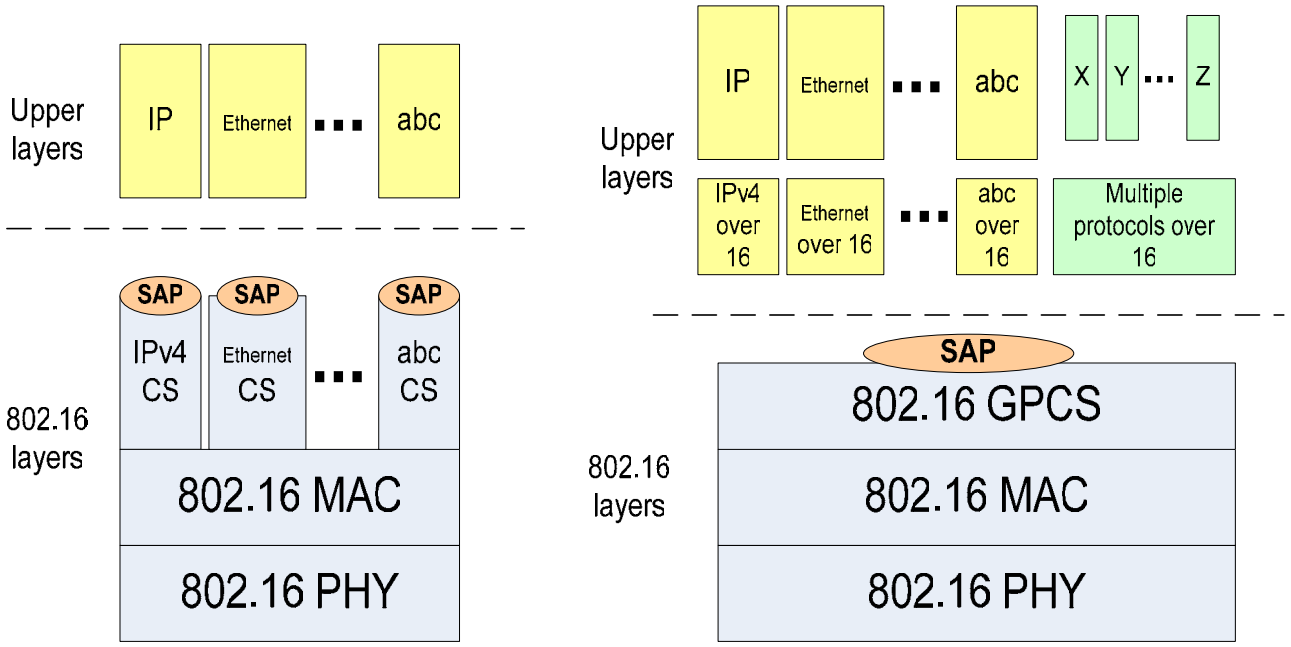

Figure 2: GPCS Layering Model

Figure 2 illustrates GPCS laying similarity to existing packet CS layers. Such a protocol structure of link layer interface to the upper layers has been widely used in some successful link layer protocol standards, e.g., 802.3, 802.2, 802.11, 802.17, ATM, Frame Relay, etc.

Comparing to the current 802.16 packet convergence sublayer, the proposed GPCS:

1. Decouples the 802.16 link layer from the higher layers protocols thus enabling the transport of new multiple upper layer protocol data over 802.16 air interface without requiring any modifications to 802.16 protocol

2. Allows the 802.16 CS to conduct the classification function without the need to interpret (parse) upper layer protocol headers, by allowing the higher layers protocols to pass some available information to the 802.16 CS

3. Avoids the repetitions of upper layer functions at the 802.16 CS

4. Allows multiple protocols over the same 802.16 MAC connection

5. Significantly simplifies the 802.16-comformance test of the packet convergence sublayer, by pushing the solutions to these problems to the upper layer. Although the generic convergence sublayer does not solve interoperability issues for Ethernet-bridging-oriented devices, or IPv4-oriented devices, GPCS provides opportunities for experts of upper protocols, e.g., experts from Ethernet community and experts from IP community such as IETF, to review and adopt standards for using 802.16 to transport IP with differentiated services. **Simple devices that have neither Ethernet nor IP, nor one of the dozen 802.16 convergence sublayers, can use 802.16 with GPCS and be called "compliant" with 802.16.**

A Generic Packet Convergence Sublayer (GPCS) would allow us to decouple the 802.16 link layer protocol from the higher layer protocols. In other words, instead of forcing 802.16 to know much about all the protocols it caries and possibly repeat some of the higher layers protocols functions within the 802.16 layer, the higher layers protocols need only to pass few parameters to enable 802.16 to classify the SDU.

To enable upper protocol independence, we propose two parts: parameters for the 802.16 SAP for the convergence sublayer, and an option per-SDU field prepended to each MAC SDU.

4.1. SAP Parameters

The proposed GPCS SAP parameters enable the upper layer protocol to generically specify 802.16 services without the need for the 802.16 layer to interpret upper layer protocol headers. In other words, since the SAP parameters are explicit, the parsing portion of the classification process is the responsibility of the upper layer. The SAP parameters need to be specified in the standard to provide an interface point where compliance can be measured independent of the upper layer protocol type (Ethernet, IPv4, etc.).

Figure 3 depicts the GPCS SAP parameters model. The figure intends to show how GPCS parameters are chosen in a system. It illustrates that LOGICAL_LINK_ID and COS_ID abstractions can be implementation-specific, locally-defined constructs. We do not think that LOGICAL_LINK_ID and COS_ID need to have code-points assigned and each code-point usage explained in a standard. The reason for such abstraction is to enable a wide variety of system configurations above the GPCS SAP that can be combined in various ways. Off-the-shelf components and subsystems can provide bridging, routing and parsing functions without adhering to a standard. The number of bits and numeric assignments of those parameters are left to the implementation.

Since the GPCS SAP carries abstract parameters, GPCS SAP compliance does not require specific parameter values be standardized. Rather, compliance must be measured by the *results* of GPCS classification. For instance, the GPCS layer in a given vendor's system generates a CID with a certain security profile and 802.16 scheduling service type under known conditions, employing either standard packet-parsing convergence or a proprietary method. A compliance tester can then validate that the CID's security profile is operating correctly and the scheduling service is delivering the required throughput and latency. With GPCS, 802.6/GPCS compliance can be tested independently of specific upper layer classification methods. Without GPCS, 802.16 must define convergence and classification for each method that deserves interoperability and thus compliance.

Considering the variety of possible upper layer protocol stack configurations, and the possibility of proprietary methods, it is difficult if not impossible for all "deserving" systems to claim 802.16 compliance without GPCS.

Note that Figure 3 does not show where header compression is performed. We believe that header compression is a facility that is orthogonal to classification and is best defined separately from the convergence process. For example, a system implementing IPv4 with ROHC could implement header compression in the "Upper Layer Protocol" or a compressor engine could be inserted just below the "Parser/Classifier." Either configuration could result in an ROHC-interoperable system.

Also note that a system could define a *null* function for "Destination Lookup," "Parser/Classifier" and even "Generic Classifier." The upper protocol, or "application" in such a system must be 802.16-aware and provide direct access to the MAC SAP. For instance, a video-over-802.16 device need not define Ethernet or IP convergence function. Other standards could build on 802.16 GPCS, and proprietary systems could be defined. Such systems could be called "Classification Free." The authors think it would be great if they all could achieve 802.16 compliance without requiring modifications to the 802.16 standard.

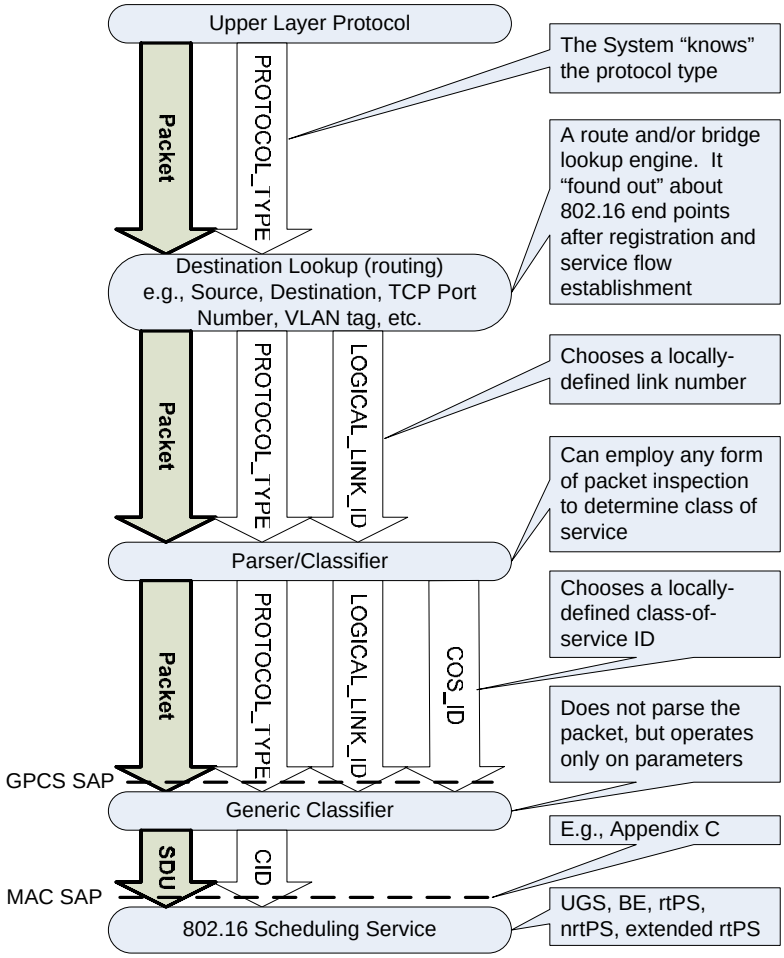

Figure 3: GPCS SAP Parameters Model

GPCS defines SAP parameters abstractly because the authors think their use in a local system is outside the scope of the 802.16 standard. For instance, bit width, code points, error checking, programming language and operating system bindings are not specified. But PROTOCOL_ID, which since it can optionally be transmitted

between 802.16 end points, needs to have code points assigned (such as Ethernet, PPPoE, IPv4, IPv4-ROHC, IPv6, etc.).

SAP Parameters:

- PROTOCOL_TYPE. The protocol type field identifies the upper layer protocol that is immediately above the 802.16 protocols. If MULTI_PROTOCOL_ENABLE is activated, the PROTOCOL_TYPE shall be also carried over-the-air in every SDU, so the 802.16 receiver can demultiplex an SDU and invoke the appropriate upper layer protocol. If MULTIPROTOCOL_ENABLE is not activated, an 802.16 CID can carry only one protocol type, and the PROTOCOL_TYPE field is only communicated during connection establishment. It is thus analogous to the "ethertype" field in an Ethernet packet (http://www.iana.org/-assignments/ethernet-numbers) or the 16-bit PPP data link (DL) layer protocol field in PPP packets (http://www.iana.org/assignments/ppp-numbers)[1]. The authors recommend that 802.16 use the IANA to assign 2-byte 802.16 PROTOCOL_TYPE numbers, and maybe just borrow the number space from PPP. Note that the Ethernet numbers probably should not be used because it has no Ethernet code point which could mean Ethernet-over-802.16. But the PPP numbers might be a good candidate because they include Ethernet, ROHC, IP, etc.

  Note that GPCS with MULTIPROTOCOL_ENABLE is just about like Ethernet Packet CS except no Ethernet addresses are transported.

- LOGICAL_LINK_ID. A link number that is output from a bridging or routing function. It is locally assigned and not exchanged between 802.16 end-points. For instance, an 802.1D bridge agent in a BS could discover a service flow to a specific SS and assign a LOGICAL_LINK_ID number to that service flow plus SS entity. The LOGICAL_LINK_ID can thus become a destination link for an 802.1D bridge. It could transact spanning tree and GARP messages and relay and filter packets based on 48-bit 802 MAC addresses and VLAN tags. The exact mechanism for how this is done is left to the implementation. In 802.1D terminology, the LOGICAL_LINK_ID could be called a "Bridge Port ID," which a locally-assigned number. Note that the process for service flow establishment on the air interface is defined in 802.16, but apart from Appendix C, the end-point's process to communicate service flows is not. An 802.1D compliant bridge can implement SS and service flow discovery however it needs to, and 802.1D-bridging-over-802.16 can still be standardized and interoperable.

- COS_ID (Class of Service ID). A class of service identifier output from a packet-parsing classification function. The class of service could simply identify an 802.16 scheduling service type. Alternatively, a system could define it as a superset of 802.16 scheduling services, and perform local scheduling and/or queuing based on the value. So, instead of specifying COS_ID to mean exactly the 802.16 scheduling service type, it is left as an abstract locally-defined identifier. In either case, an implementation of the "Generic Classifier" takes the COD_ID as input and uses it to determine a CID with matching 802.16 scheduling services.

[1] Note the wide variety of header-compression protocol types defined for PPP. Since PPP is intended for bandwidth-constrained links, it seems to have very similar header compression requirements as 802.16. Also note the set of code points defined for various bridging functions.

- MULTI_PROTOCOL_ENABLE. This parameter is not shown in Figure 3. A local system can optionally choose to activate this feature to enable multiple PROTOCOL_TYPEs to be carried over a single CID. MULTI_PROTOCOL_ENABLE is useful for devices that are constrained to implement a small number of CIDs yet need to carry a variety of protocols using the same 802.16 scheduling service type. For instance, a single best-effort (BE) connection could carry statistically multiplexed packets of IPv6, IPv6-ROHC and Ethernet PROTOCOL_TYPEs.

5. Application Examples of the Proposed Generic Packet CS (GPCS)

This section describes some examples of how GPCS is used, particular for two upper protocols that have lots of interest: Ethernet packets, IPv4, and ROHC header compression.

5.1. IPv4-ROHC over GPCS

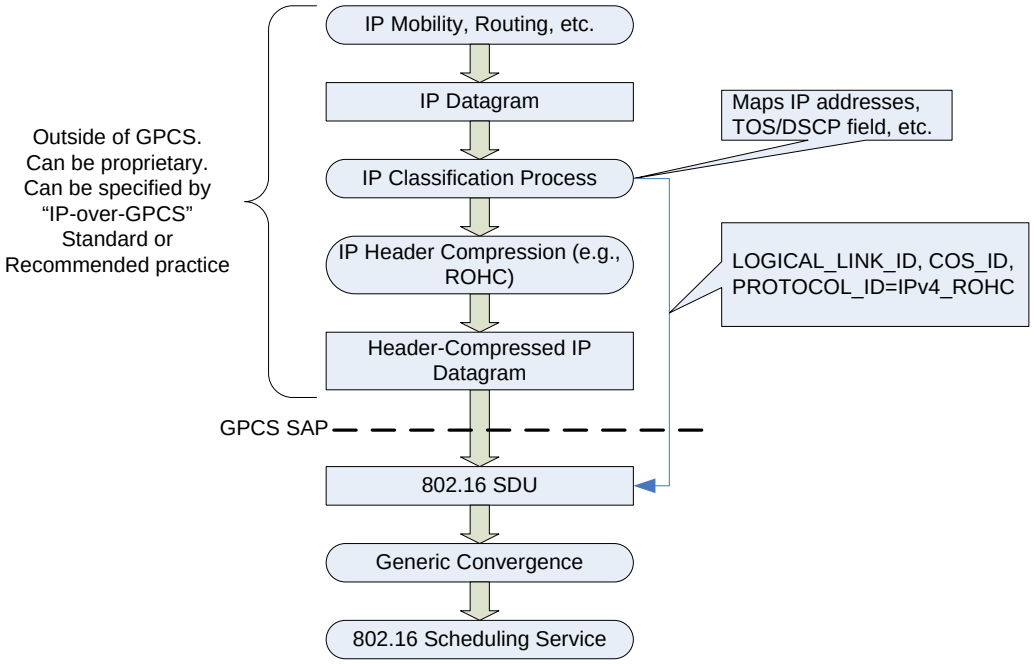

Figure 4: IPv4-ROHC over GPCS

Figure 4 illustrates an example local 802.16 "stack" transmit process.

An IP endpoint or router typically needs to map a destination IP address to an egress link and destination MAC address. For Ethernet, many systems have an IP route lookup process and address resolution (ARP) process. Same for 802.16. An 802.16 BS can implement an IP route process, along with SS discovery and ARP if necessary. Whatever the process, standards-based or proprietary, the output of route and address resolution is a LOGICAL_LINK_ID which identifies a local path from the IP entity to the egress radio for a subscriber station. Note that an implementation can employ a separate route engine to help (even a separate, off-the-shelf, non-802.16-aware IP router subsystem), or can combine IP packet classification (parsing and inspection) with routing.

The parsing and inspection process results in a COS_ID. It may parse single-IP headers, tunneled IP-in-IP headers (e.g., for IP mobility), and even combine network address translation functions. As with routing, standard off-the-shelf subsystems may be employed to choose an appropriate, locally-defined COS_ID.

Header compression can be performed anywhere above the GPCS SAP. In the figure, it is shown last, which may make sense for some systems that translate headers during the packet inspection process. Robust Header Compression (ROHC) (see IETF RFC 3095) can use GPCS. It should have its own protocol type, such as IPv4-ROHC so a receiver can "know" to apply the ROHC algorithm. Other header compression techniques can also be used, such as the "original" Van Jacobsen TCP/IP header compression," RFC1144.

If MULTIPROTOCOL_ENABLE is activated, GPCS requires the transmitter inserts its protocol type (IPv4) as an extended subheader entry so the receiver can de-multiplex: choose the right upper protocol entity (receive SAP).

The Generic Classifier implements a locally-defined function to map PROTOCOL_TYPE (IPv4-ROHC), LOGICAL_LINK_ID, and COS_ID to an appropriate CID. For example, LOGICAL_LINK_ID could be an index to a table in which each entry has a pointer a subscriber station's table of available service classes. COS_ID could be service-class index to a table of CIDs for the subscriber.

5.2. Ethernet over GPCS

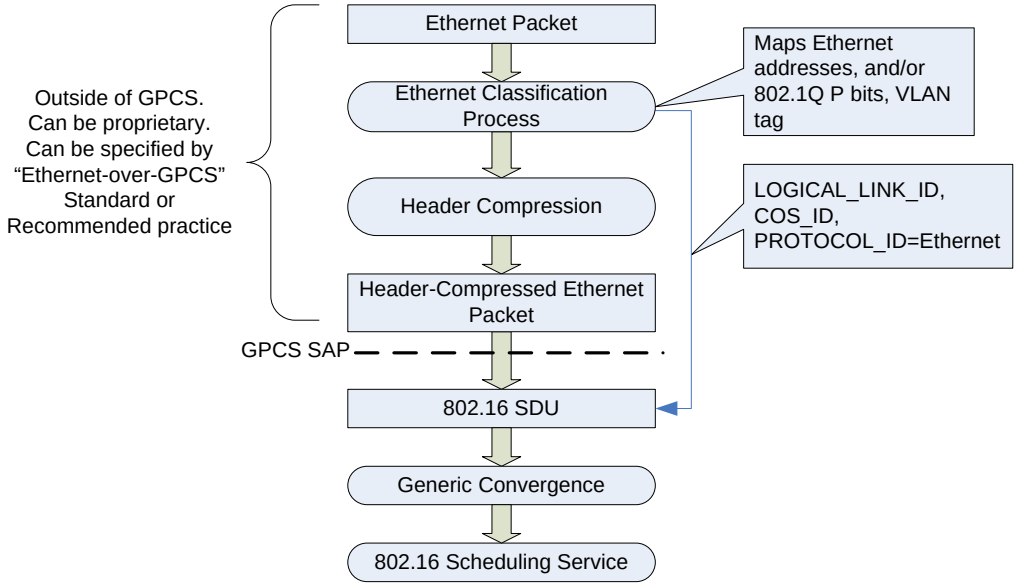

Figure 5: Ethernet over GPCS

6. Suggested Changes

In 802.16g-05/008r1, we propose the following changes (new text in blue):

1. page 3 replace line 1 to line 52 by the following text:

5. Service-Specific CS

5.2 Packet CS

[insert new subclause 5.2.8 and subsequent test below]

5.2.8 Generic Packet Convergence Sublayer (GPCS)

The Generic Packet CS (GPCS) is a upper layer protocol-independent packet convergence sublayer that supports multiple protocols over 802.16 air interface. It is defined as follows:

- GPCS provides a generic packet convergence layer. This layer uses the MAC SAP and exposes a new SAP to GPCS applications
- GPCS does not re-define or replace other convergence sublayers. Instead, it provides a SAP that is not protocol specific
- The basic function of the GPCS is still classification. It participates in the process to map upper layer packets (carried in 802.16 MAC SDUs) to appropriate 802.16 connections. But with GPCS, packet parsing happens "above" GPCS. The results of packet parsing are classification parameters given to the GPCS SAP for "parameterized classification," but upper layer packet parsing is left to the GPCS application
- GPCS defines a set of SAP parameters as the result of upper layer packet parsing. These are passed from upper layer to the GPCS in addition to the data packet. Each is defined in section 5.2.8.1.
    - LOGICAL_LINK_ID
    - COS_ID (Class of Service ID)
    - PROTOCOL_TYPE
- GPCS provides an optional way to multiplex multiple layer protocol types (e.g., IPv4, IPv6, Ethernet) over the same 802.16 connection/service flow. A TLV parameter, MULTIPROTOCOL_ENABLE, is defined in the DSx messages to enable/disable this feature.
- For interoperability, each upper layer protocol type needs an interface specification (e.g., IPv4 over 802.16, or Ethernet over 802.16). Such a standard specification is out of scope of the GPCS.

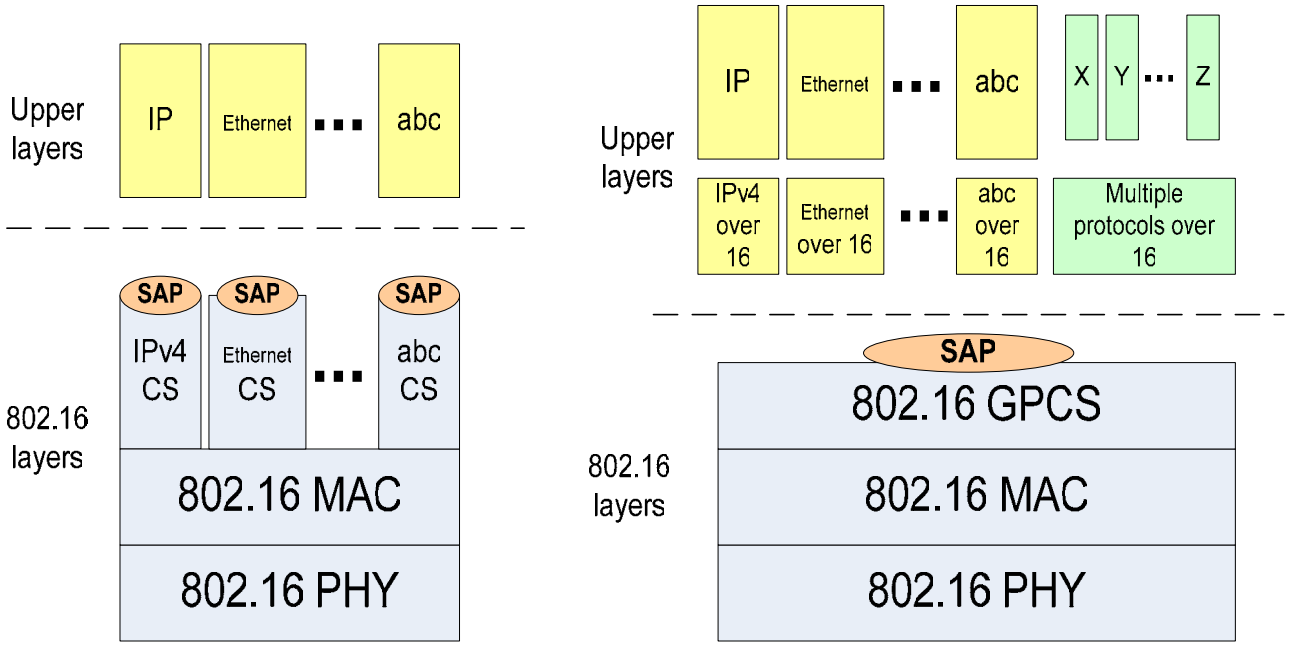

Figure 17c: GPCS Layering Model

5.2.8.1 GPCS Service Access Point (SAP) Parameters

The GPCS SAP parameters enable the upper layer protocols to generically pass information to the GPCS so that the GPCS does not need to interpret upper layer protocol headers in order to mapping the upper later data packets into proper 802.16 MAC connections. Since the SAP parameters are explicit, the parsing portion of the classification process is the responsibility of the upper layer. The SAP parameters need to be specified in the standard to provide an interface point where compliance can be measured independent of the upper layer protocol type (Ethernet, IPv4, etc.).

There are four GPCS SAP parameters: LOGICAL_LINK_ID, COS_ID, PROTOCOL_TYPE, and. Figure 17d depicts the GPCS SAP parameters model. It shows how the first three GPCS parameters, LOGICAL_LINK_ID, COS_ID, and PROTOCOL_TYPE, are chosen in a system. The parameter, MULTI_PROTOCOL_ENABLE, is required for signaling whether or not the multiple protocol packets are transmitted on the same CID.

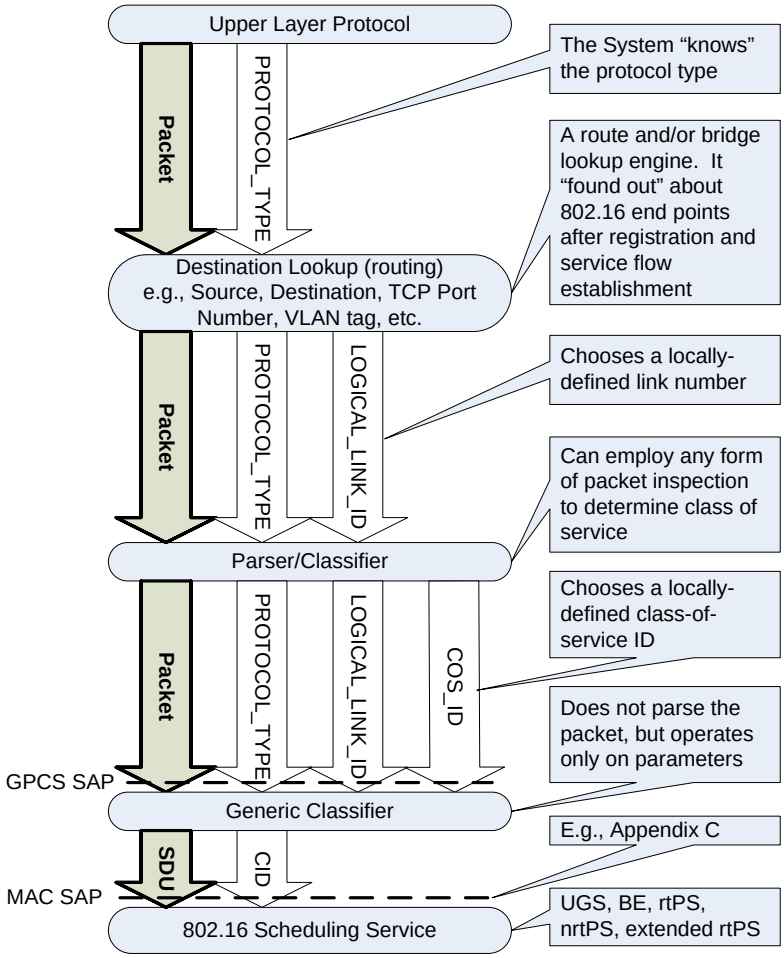

Figure 17d: GPCS SAP Parameters Model

- PROTOCOL_TYPE. The protocol type field identifies the upper layer protocol that is immediately above the 802.16 protocols. If MULTI_PROTOCOL_ENABLE is activated, the PROTOCOL_TYPE shall be also carried over-the-air in every SDU, so the 802.16 receiver can demultiplex an SDU and invoke the appropriate upper layer protocol. If MULTIPROTOCOL_ENABLE is not activated, an 802.16 CID can carry only one protocol type, and the PROTOCOL_TYPE field is only communicated during connection establishment through DSx messages. It is thus analogous to the "ethertype" field in an Ethernet packet or the 16-bit PPP data link (DL) layer protocol field in PPP packets. The GPCS can either uses the IANA to assign 2-byte 802.16 PROTOCOL_TYPE numbers, or maybe just borrow the number space from PPP. Note that GPCS with MULTIPROTOCOL_ENABLE is just about like Ethernet Packet CS except no Ethernet addresses are transported, and so they don't need to be header-compressed.

- LOGICAL_LINK_ID. A link number that is output from a bridging or routing function. It is locally assigned and not exchanged between 802.16 air link. For instance, an 802.1D bridge agent in a BS could discover a service flow to a specific SS and assign a LOGICAL_LINK_ID number to that service flow plus SS entity. The LOGICAL_LINK_ID can thus become a destination link for an 802.1D bridge. It could transact spanning tree and GARP messages and relay and filter packets based on 48-bit 802 MAC address and VLAN tags. The exact mechanism for how this is done is beyond the scope of the GPCS.

- COS_ID (Class of Service ID). A class of service identifier output from a packet-parsing classification function. The class of service could simply identify an 802.16 scheduling service type. Alternatively, a system could define it as a superset of 802.16 scheduling services, and perform local scheduling and/or queuing based on the value. So, instead of specifying COS_ID to mean exactly the 802.16 scheduling service type, it is left as an abstract locally-defined identifier. In either case, the GPCS takes the COD_ID as input and uses it to determine a CID with matching 802.16 scheduling services.

- MULTI_PROTOCOL_ENABLE. This parameter is not shown in Figure 17d. A local system can optionally choose to enable/disable multiple PROTOCOL_TYPEs to be carried over a single CID. MULTI_PROTOCOL_ENABLE is useful for devices that are constrained to implement a small number of CIDs yet need to carry a variety of protocols using the same 802.16 scheduling service type. For instance, a single best-effort (BE) connection could carry statistically multiplexed packets of IPv6, IPv6-ROHC and Ethernet PROTOCOL_TYPEs.

5.2.8.2. GPCS PDU Format

There are two different formats of the GPCS PDU depending on the parameter value of MULTIPROTOCOL_-ENABLE, as shown in Figure 17e. PROTOCOL_TYPE indicates the outermost protocol of the SDU. It is 16-bit number assigned from a set of possible values of the PPP data link (DL) layer protocol numbers. This space of numbers is maintained by the IANA. It shall be communicated to the MAC receiver in every SDU if MULTIPROTOCOL_ENABLE is enabled for a CID.

(a) **GPCS PDU format with MULTIPROTOCOL_ENABLE Disabled**

(b) **GPCS PDU format with MULTIPROTOCOL_ENABLE Enabled**

Figure 17e: GPCS PDU formats Sent to the MAC SAP from the GPCS

2. page 5, line 49, replace from page 5 line 40 to page 8 line37 by the following text:

11.13.19 CS specific service flow encodings

11.13.19.1 CS specification

Type	Length	Value	Scope
[145/146].28	1	~~0: No CS~~ GPCS (Generic Packet Convergence Sublayer) 1: Packet, IPv4 2: Packet, IPv6	DSx-REQ

		3: Packet, 802.3/Ethernet 4: Packet, 802.1Q VLAN 5: Packet, IPv4 over 802.3/Ethernet 6: Packet, IPv6 over 802.3/Ethernet 7: Packet, IPv4 over 802.1Q VLAN 8: Packet, IPv6 over 802.1Q VLAN 9: ATM 10: Packet, 802.3/etherneta with ROHC header compression 11: Packet, 802.3/ethernetb with ECRTP header compression 12: Packet, IP2 with ROHC header compression 13: Packet, IP2 with ECRTP header compression 10 14~255: reserved	

11.13.19.2 CS Parameter encoding rules

CST	CS
98	~~No CS~~ GPCS (Generic Packet Convergence Sublayer)
99	ATM
100	Packet, IPv4
101	Packet, IPv6
102	Packet, 802.3/Ethernet
103	Packet, 802.1Q VLAN
104	Packet, IPv4 over 802.3/Ethernet
105	Packet, IPv6 over 802.3/Ethernet
106	Packet, IPv4 over 802.1Q VLAN
107	Packet, IPv6 over 802.1Q VLAN
108	Packet, IP with header compression (ROHC)
109	Packet, IP with header compression (ECRTP)
110	Packet, IP over 802.3/Ethernet with header compression (ROHC)
111	Packet, IP over 802.3/Ethernet with header compression (ECRTP)

11.13.19.3.4.3 PROTOCOL_TYPE Encoding

The encoding of the value field is that defined in the Internet Assigned Numbers Authority (IANA) document "PPP Numbers" in the section data link layer (DLL) protocol numbers.

Type	Length	Value	Scope
[1445/146].cst.3.3	2	A PPP DLL protocol number	DSx-REQ, DSx-REP

For IPv4, the value of the field specifies a matching value for the IP Protocol field. If this parameter is omitted, then the comparison of the IP header Protocol field for this entry is irrelevant.

For IPv6 (IETF RFC 2460), this refers to next header entry in the last header of the IP header chain. If this parameter is omitted, then the comparison of the IP header Protocol field for this entry is irrelevant.

For a Generic Packet CS, this TLV shall be used to indicate the protocol carried over the connection when the MULTIPROTOCOL_ENABLE is disabled.

11.13.19.3.4.19 MULTIPROTOCOL_ENABLE Encoding

This parameter is used to indicate whether or not multiple upper layer protocol data packets are allowed to be transported over the same service flow when the Generic Packet Convergence sublayer (GPCS) is used. This parameter only applies to GPCS.

If enabled, the service flow can carry multiple upper layer protocols and the PROTOCOL_TYPE field must be prepended to each upper layer data packets for the corresponding CID. See section 5.2.8.2 for the GPCS PDU format. If disabled, a connection must establish the single PROTOCOL_TYPE in use by exchanging the PROTOCOL_TYPE TLV in the DSx messages as specified in section 11.13.19.3.4.3.

Type	Length	Value	Scope
[1445/146].cst.3.20	1	0: MULTIPROTOCOL_-ENABLE is disabled, default value. 1: MULTIPROTOCOL_-ENABLE is enabled	DSx-REQ, DSx-REP