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## PPP Over Asynchronous Transfer Mode Adaptation Layer 2 (AAL2)

### Status of this Memo

This document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "Internet Official Protocol Standards" (STD 1) for the standardization state and status of this protocol. Distribution of this memo is unlimited.

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### Abstract

The Point-to-Point Protocol (PPP) provides a standard method for transporting multi-protocol datagrams over point-to-point links.

This document describes the use of ATM Adaptation Layer 2 (AAL2) for framing PPP encapsulated packets.

### Applicability

This specification is intended for those implementations which desire to use the facilities which are defined for PPP, such as the Link Control Protocol, Network-layer Control Protocols, authentication, and compression. These capabilities require a point-to-point relationship between the peers, and are not designed for the multi-point relationships which are available in ATM and other multi-access environments.

## 1. Introduction

PPP over AAL5 [2] describes the encapsulation format and operation of PPP when used with the ATM AAL5 adaptation layer. While this encapsulation format is well suited to PPP transport of IP, it is bandwidth inefficient when used for transporting small payloads such as voice. PPP over AAL5 is especially bandwidth inefficient when used with RTP header compression [3].

PPP over AAL2 addresses the bandwidth efficiency issues of PPP over AAL5 for small packet transport by making use of the AAL2 Common Part Sublayer (CPS) [4] to allow multiple PPP payloads to be multiplexed into a set of ATM cells.

## 2. Conventions

The keywords MUST, MUST NOT, REQUIRED, SHALL, SHALL NOT, SHOULD, SHOULD NOT, RECOMMENDED, MAY, and OPTIONAL, when they appear in this document, are to be interpreted as described in [6].

## 3. AAL2 Layer Service Interface

The PPP layer treats the underlying ATM AAL2 layer service as a bit-synchronous point-to-point link. In this context, the PPP link corresponds to an ATM AAL2 virtual connection. The virtual connection MUST be full-duplex, point to point, and it MAY be either dedicated (i.e., permanent, set up by provisioning) or switched (set up on demand). In addition, the PPP/AAL2 service interface boundary MUST meet the following requirements.

Interface Format - The PPP/AAL2 layer boundary presents an octet service interface to the AAL2 layer. There is no provision for sub-octets to be supplied or accepted.

Transmission Rate - The PPP layer does not impose any restrictions regarding transmission rate on the underlying ATM layer traffic descriptor parameters.

Control Signals - The AAL2 layer MUST provide control signals to the PPP layer which indicate when the virtual connection link has become connected or disconnected. These provide the "Up" and "Down" events to the LCP state machine [1] within the PPP layer.

In the case of PPP over AAL2, the state of the link can be derived from the type 3 fault management packets carried in-band within a given AAL2 CID flow.

#### 4. PPP Operation with AAL2

PPP over AAL2 defines an encapsulation that uses the Service Specific Segmentation and Reassembly Sublayer (SSSAR) [5] for AAL type 2. The SSSAR sub-layer is used to segment PPP packets into frames that can be transported using the AAL2 CPS. The SSSAR sub-layer uses different AAL2 UUI code-points to indicate whether a segment is the last segment of a packet or not.

The encapsulation of PPP over AAL2 provides a 16-bit CRC for PPP payloads. There are 2 UUI code points assigned from SSSAR to indicate intermediate fragments of a packet and the last fragment of a packet. Code point 27 indicates intermediate frames of a fragmented packet and code point 26 indicates the last frame of a packet. The encapsulation format is more fully described in section 6.2.1.

An implementation of PPP over AAL2 MAY use one or more AAL2 Channel Identifiers (CIDs) for transport of PPP packets associated with each PPP session. Multiple CIDs could be used to implement a multiple class real time transport service for PPP using the AAL2 layer for link fragmentation and interleaving. A companion document [10] describes class extensions for PPP over AAL2 using multiple AAL2 CIDs.

#### 5. Comparison of PPP Over AAL2 with Existing Encapsulations

This document proposes the substitution of AAL2 transport for PPP in scenarios where small packets are being transported over an ATM network. This is most critical in applications such as voice transport using RTP [9] where RTP Header compression [3] is used. In applications such as voice transport, both bandwidth efficiency and low delay are very important.

This section provides justification for the PPP over AAL2 service for ATM transport by comparing it to existing PPP encapsulation formats used for transport over ATM. Two encapsulation formats will be examined here: PPP over AAL5 [2], and PPP with PPPMUX [8] over AAL5.

##### 5.1 Comparison With PPP Over AAL5

This proposal uses ATM AAL2 [4] rather than AAL5 as the transport for PPP. SSSAR along with the AAL2 CPS generates less ATM encapsulation overhead per PPP payload. The payload encapsulation consists of a 2 byte CRC. The AAL2 CPS header consists of 3 bytes, and the AAL2 Start Field (STF) is 1 byte. This is a total encapsulation overhead of 6 bytes. This compares to 8 bytes of overhead for the AAL5 trailer used for PPP over AAL5.

The multiplexing function of the AAL2 CPS layer allows more bandwidth efficient transport of PPP frames by multiplexing multiple PPP frames into one or more ATM cells using the AAL2 CPS function. This removes the pad overhead of AAL5 when used to transport short frames.

## 5.2 Comparison with PPPMUX over AAL5

PPP Multiplexing (PPPMUX) [8] is a new method for doing multiplexing in the PPP layer. PPPMUX provides functionality similar to the CPS based multiplexing function of AAL2. Using PPP multiplexing, a PPP stack would look like PPP/PPPMUX/AAL5.

Both PPP/PPPMUX/AAL5 and PPP/AAL2 use multiplexing to reduce the overhead of cell padding when frames are sent over an ATM virtual circuit. However, the bandwidth utilization of PPP/AAL2 will typically be better than the bandwidth used by PPP/PPPMUX/AAL5. This is because multiplexed frames in PPP/PPPMUX/AAL5 must always be encapsulated within an AAL5 frame before being sent. This encapsulation causes an additional 8 bytes of AAL5 trailer to be added to the PPPMUX encapsulation. In addition to the 8 bytes of AAL5 trailer, PPPMUX will incur an average of 24 additional bytes of AAL5 PAD. These 2 factors will end up reducing the effective efficiency of PPPMUX when it is used over AAL5.

With PPP/AAL2, the AAL2 CPS layer treats individual PPP frames as a series of CPS payloads that can be multiplexed. As long as PPP frames arrive at the CPS layer before the CPS TIMER\_CU expires, all ATM cells coming from the CPS layer will be filled. Under these conditions, PPP/AAL2 will have no PAD associated with it. When the AAL2 CPS function causes no PAD to be generated, PPP/AAL2 will be more bandwidth efficient than PPP/PPPMUX/AAL5.

In PPP/PPPMUX/AAL5, the AAL5 SAR and the PPP MUX/DEMUX are performed in two different layers. Thus, the PPPMUX/AAL5 receiver must reassemble a full AAL5 frame from the ATM layer before the PPPMUX layer can extract the PPP payloads. To derive maximum PPP Multiplexing efficiency, many PPP payloads may be multiplexed together. This increases the size of the multiplexed frame to many ATM cells. If one of these ATM cells is lost, the whole PPPMUX packet will be discarded. Also, there may be a significant delay incurred while the AAL5 layer waits for many ATM cell arrival times until a full frame has been assembled before the full frame is passed up to the PPP Multiplexing layer where the inverse PPP demux then occurs. This same issue also applies to PPPMUX/AAL5 frames progressing down the stack.

With AAL2, both the segmentation and reassembly and multiplexing functions are performed in the AAL2 CPS layer. Because of the definition of the AAL2 CPS function, a multiplexed payload will be extracted as soon as it is received. The CPS receiver does not wait until the many payloads of an AAL2 multiplexed frame are received before removing payloads from the multiplexed stream. The same benefit also applies to AAL2 CPS sender implementations. Also, the loss of an ATM cell causes the loss of the packets that are included in that cell only.

The AAL2 CPS function provides multiplexing in AAL2. This function often needs to be implemented in hardware for performance reasons. Because of this, a PPP/AAL2 implementation that takes advantage of an AAL2 SAR implemented in hardware will have significant performance benefits over a PPP/PPPMUX/AAL5 implementation where PPPMUX is implemented in software. Also, the AAL2 specification has been available significantly longer than the PPP Multiplexing specification and because of this, optimized software and hardware implementations of the AAL2 CPS function are further in development than PPP Multiplexing implementations.

## 6. Detailed Protocol Operation Description

### 6.1 Background

#### 6.1.1 AAL2 Multiplexing

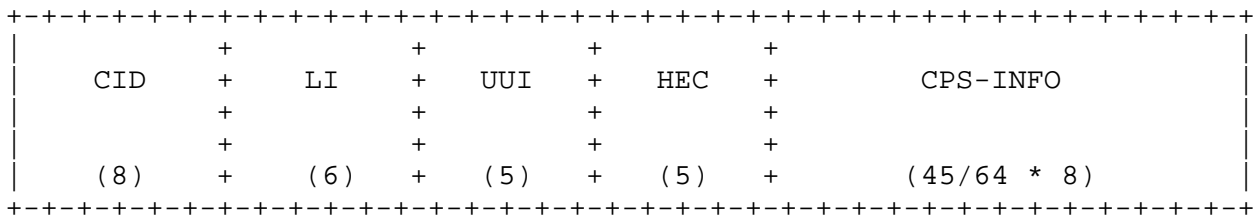
ITU-T I.363.2 specifies ATM Adaptation Layer Type 2. This AAL type provides for bandwidth efficient transmission of low-rate, short and variable length packets in delay sensitive applications. More than one AAL type 2 user information stream can be supported on a single ATM connection. There is only one definition for the sub-layer because it implements the interface to the ATM layer and is shared by more than one SSCS layer.

#### 6.1.2 AAL2 Service Specific Convergence Sub-layers

ITU-T I.366.1 and I.366.2 define Service Specific Convergence Sub-layers (SSCS) that operate above the Common Part Sub-layer defined in I.363.2. This layer specifies packet formats and procedures to encode the different information streams in bandwidth efficient transport. As the name implies, this sub-layer implements those elements of service specific transport. While there is only one definition of the Common Part Sublayer for AAL2, there can be multiple SSCS functions defined to run over this CPS layer. Different CIDs within an AAL2 virtual circuit may run different SSCSs.

### 6.1.3 AAL2 CPS Packet (CPS-PKT) Format

The CPS-PKT format over AAL2 as defined in I.363.2:



Note: The size of the fields denote bit-width

The Channel ID (CID) identifies the sub-stream within the AAL2 connection. The Length indication (LI) indicates the length of the CPS-INFO payload. The User-to-User Indication (UII) carries information between the SSCS/Application running above the CPS. The SSSAR sub-layer as defined in I.366.1 uses the following code points:

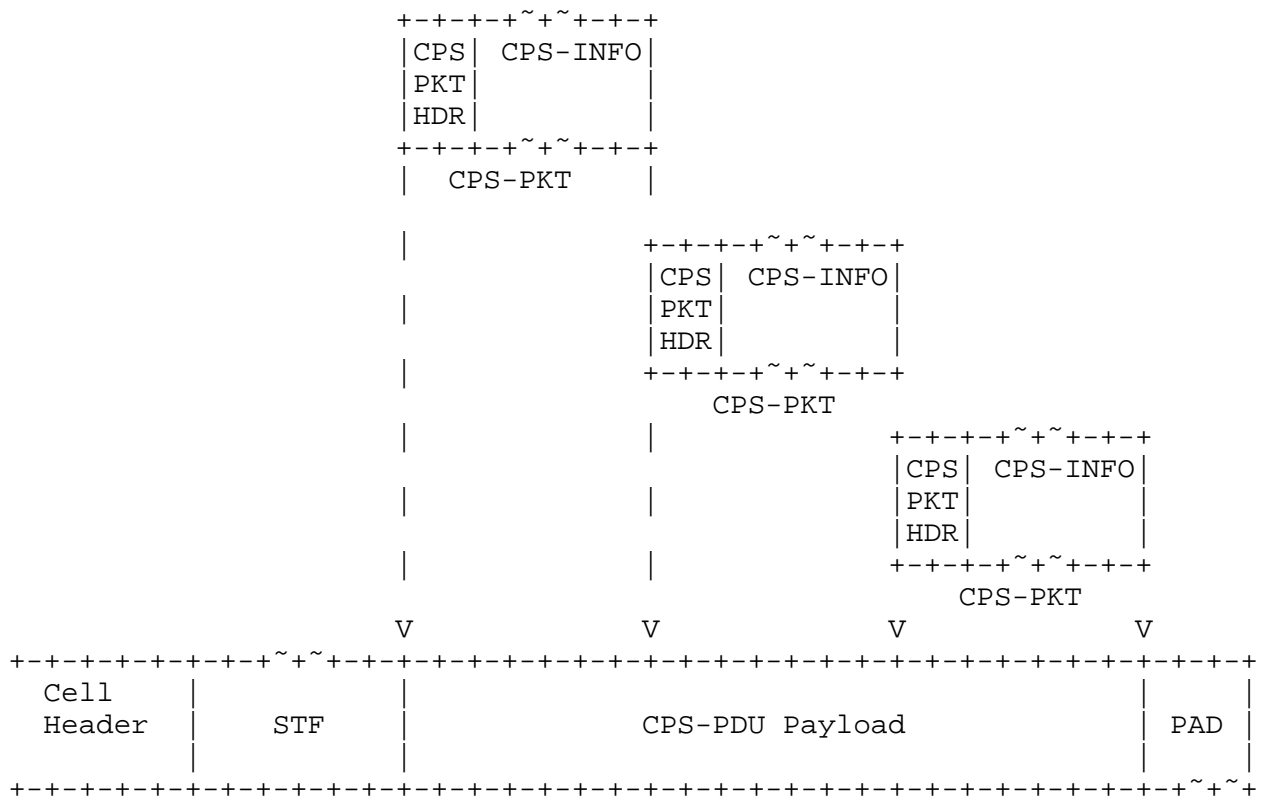
| UII Code-point<br>+++++ | Packet Content<br>+++++         |
|-------------------------|---------------------------------|
| 0-26                    | Framed mode data, final packet. |
| 27                      | Framed mode data, more to come. |

This proposal uses two UII code-points as follows:

| UII Code-point<br>+++++ | Packet Content<br>+++++ |
|-------------------------|-------------------------|
| 27                      | non-final packet.       |
| 26                      | final packet.           |

#### 6.1.4 AAL2 CPS-PDU Format

The CPS-PDU format over AAL2 as defined in I.363.2:



Note: The size of the fields denote bitwidth

The CPS-PDU format is used to carry one or more CPS-PKT's multiplexed on a single CPS-PDU. The CPS header contains enough information to identify the CPS packets within a CPS-PDU. In the event of cell loss, the STF field is used to find the first CPS-PKT in the current cell.

## 6.2 PPP Over AAL2 Encapsulation

PPP encapsulation over AAL2 uses the AAL2 CPS with no change.

Some PPP encapsulated protocols such as RTP header compression require that the link layer provide packet error detection. Because of this, PPP over AAL2 defines a 16-bit CRC that is used along with the SSSAR sub-layer of I.366.1 to provide packet error detection. The encapsulation format is described below.

### 6.2.1 PPP Payload Encapsulation Over AAL2 with 16-bit CRC (CRC-16).

The payload encapsulation of PPP appends a two byte CRC to each PPP frame before using the SSSAR layer to send the PPP packet as a series of AAL2 frames.

The format of a PPP over AAL2 packet is shown in the diagram below. Note that the diagram below shows the payload encapsulation when the packet is not segmented (UUI=26). When the PPP packet is segmented, the PPP Protocol ID, Information field, and CRC-16 fields will be split across multiple SSSAR frames. In this case, the UUI field will be set to 27 for all frames except the last frame. In the last frame, the UUI field will be set to 26.

## Payload Encapsulation

|     |     |     |     |          |    |             |        |
|-----|-----|-----|-----|----------|----|-------------|--------|
| CID | LI  | UUI | HEC | Protocol | ID | Information | CRC-16 |
| (8) | (6) | (5) | (5) | (8/16)   |    |             | (16)   |

Note: The size of the fields denote bit-width

The algorithms used for computing and verifying the CRC-16 field are identical to the algorithms specified for the Frame Check Sequence (FCS) field in Q.921 [13]. The algorithms from Q.921 are included in this section for ease of access.

The CRC-16 field is filled with the value of a CRC calculation which is performed over the contents of the PPP packet, including the PPP Protocol ID and the information field. The CRC field shall contain the ones complement of the sum (modulo 2) of:

- 1) the remainder of  $x^k (x^{15} + x^{14} + \dots + x + 1)$  divided (modulo 2) by the generator polynomial, where  $k$  is the number of bits of the information over which the CRC is calculated; and



- 2) the remainder of the division (modulo 2) by the generator polynomial of the product of  $x^{16}$  by the information over which the CRC is calculated.

The CRC-16 generator polynomial is:

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

The result of the CRC calculation is placed with the least significant bit right justified in the CRC field.

As a typical implementation at the transmitter, the initial content of the register of the device computing the remainder of the division is preset to all "1"s and is then modified by division by the generator polynomial (as described above) on the information over which the CRC is to be calculated; the ones complement of the resulting remainder is put into the CRC field.

As a typical implementation at the receiver, the initial content of the register of the device computing the remainder of the division is preset to all "1"s. The final remainder, after multiplication by  $x^{16}$  and then division (modulo 2) by the generator polynomial of the serial incoming PPP packet (including the Protocol ID, the information and the CRC fields), will be 0001110100001111 ( $x^{15}$  through  $x^0$ , respectively) in the absence of transmission errors.

### 6.3 Use of AAL2 CPS-PKT CIDs

An implementation of PPP over AAL2 MAY use a single AAL2 Channel Identifier (CID) or multiple CIDs for transport of all PPP packets. In order for the endpoints of a PPP session to work with AAL2, they MUST both agree on the number, SSCS mapping, and values of AAL2 CIDs that will be used for a PPP session. The values of AAL2 CIDs to be used for a PPP session MAY be obtained from either static provisioning in the case of a dedicated AAL2 connection (PVC) or from Q.2630.2 [7] signaling in the case of an AAL2 switched virtual circuit (SPVC or SVC).

Using this proposal it is possible to support the use of conventional AAL2 in CIDs that are not used to support PPP over AAL2. This proposal allows the co-existence of multiple types of SSCS function within the same AAL2 VCC.

#### 6.4 PPP over AAL2 Operation

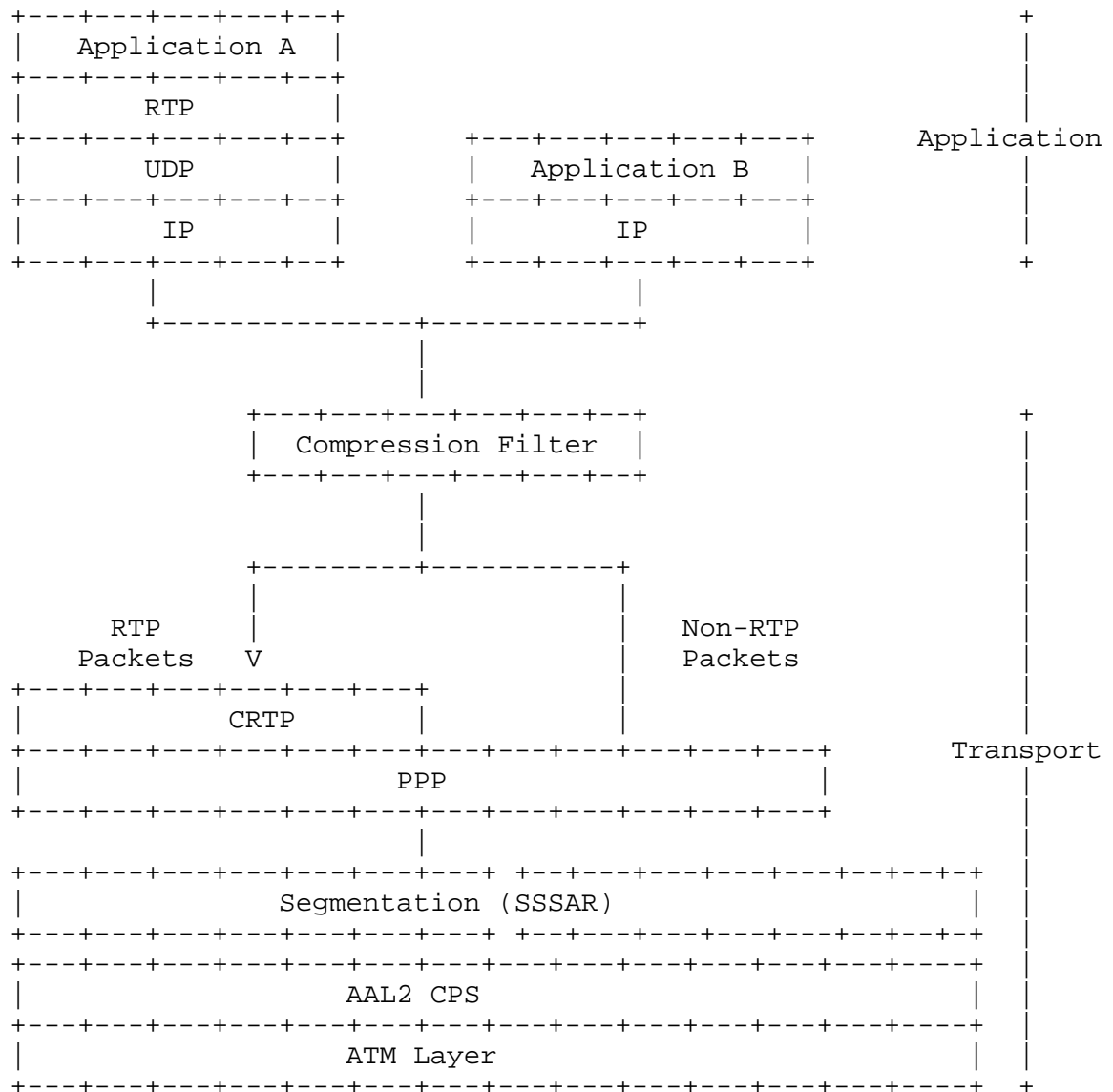
PPP operation with AAL2 will perform basic PPP encapsulation with the PPP protocol ID. A 16-bit CRC is calculated as described above and appended to the payload. The SSSAR sub-layer of AAL2 is used for transport.

Applications implementing PPP over AAL2 MUST meet all the requirements of PPP [1].

#### 7. Example implementation of PPP/AAL2

This section describes an example implementation of how PPP can be encapsulated over AAL2. The example shows two application stacks generating IP packets that are sent to the same interface running PPP/AAL2. One Application stack is generating RTP packets and another application is generating IP Datagrams. The PPP/AAL2 interface shown in this example is running an RFC 2508 compliant version of RTP header compression.

Here are the paths an Application packet can take in this implementation:



In the picture above, application A is an RTP application generating RTP packets. Application B is an IP application generating IP datagrams. Application A gathers the RTP data and formats an RTP packet. Lower level layers of application A add UDP and IP headers to form a complete IP packet. Application B is generating datagrams to the IP layer. These datagrams may not have UDP or RTP headers.

In the above picture, a protocol stack is configured to apply CRTP/PPP/AAL2 compression on an interface to a destination host. All packets that are sent to this interface will be tested to see if they can be compressed using RTP header compression. As packets appear at the interface, they will be tested by a compression filter to determine if they are candidates for header compression. If the compression filter determines that the packet is a candidate for compression, the packet will be sent to the CRTP compressor. If the packet is not a candidate for compression, it will be sent directly to the PPP layer for encapsulation as an IP packet encapsulated in PPP.

The destination UDP port number and packet length are examples of criteria that may be used by the compression filter to select the interface.

In this example, packets from application A will be passed to the CRTP compressor which then hands the compressed packet to the PPP layer for encapsulation as one of the compressed header types of CRTP. The PPP layer will add the appropriate CRTP payload type for the compressed packet.

Packets from application B will be sent directly to the PPP layer for encapsulation as an IP/PPP packet. The PPP layer will add the PPP payload type for an IP packet encapsulated in PPP.

PPP packets are then segmented using I.366.1 segmentation with SSSAR.

The resulting AAL2 frame mode PDU is passed down as a CPS SDU to the CPS Layer for multiplexing accompanied by the CPS-UI and the CPS-CID. The CPS Layer multiplexes the CPS-PKT onto a CPS-PDU. CPS-PDUs are passed to the ATM layer as ATM SDUs to be carried end-to-end across the ATM network.

At the receiving end, the ATM SDU's arrive and are passed up to the AAL2 CPS. As the AAL2 CPS PDU is accumulated, complete CPS-PKT's are reassembled by the SSSAR SSSC. Reassembled packets are checked for errors using the CRC algorithm.

At this point, the PPP layer on the receiving side uses the PPP payload type to deliver the packet to either the CRTP decompressor or the IP layer depending on the value of the PPP payload type.

## 8. LCP Configuration Options

By default, PPP over AAL2 will use the 16 bit CRC encapsulation for all packets.

The default Maximum-Receive-Unit (MRU) is 1500 bytes.

## 9. Security Considerations

This memo defines mechanisms for PPP encapsulation over ATM. There is an element of trust in any encapsulation protocol: a receiver should be able to trust that the sender has correctly identified the protocol being encapsulated and that the sender has not been spoofed or compromised. A receiver should also be able to trust that the transport network between sender and receiver has not been compromised.

A PPP session that runs over an ATM Virtual Circuit must follow the PPP link operation state machine described in RFC 1661 [1]. This state machine includes the ability to enforce the use of an authentication phase using the PAP/CHAP authentication protocols before any network layer packets are exchanged. Using PPP level authentication, a PPP receiver can authenticate a PPP sender.

System security may also be compromised by the attacks of the ATM transport network itself. The ATM Forum has published a security framework [11] and a security specification [12] that define procedures to guard against common threats to an ATM transport network.

PPP level authentication does not guard against man in the middle attacks. These attacks could occur if an attacker was able to compromise the security infrastructure of an ATM switching network. Applications that require protection against threats to an ATM switching network are encouraged to use authentication headers, or encrypted payloads, and/or the ATM-layer security services described in [12].

When PPP over AAL2 is used on a set of CIDs in a virtual connection, there may be other non PPP encapsulated AAL2 CIDs running on the same virtual connection. Because of this, an end point cannot assume that the PPP session authentication and related security mechanisms also secure the non PPP encapsulated CIDs on that same virtual connection.

## 10. Acknowledgements

The authors would like to thank Rajesh Kumar, Mike McLaughlin, Pietro Schicker, James Carlson and John O'Neil for their contributions to this proposal.

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