

High-bandwidth Digital Content Protection System

Mapping HDCP to DiiVA

Revision 2.0

March 23, 2010

Notice

THIS DOCUMENT IS PROVIDED "AS IS" WITH NO WARRANTIES WHATSOEVER, INCLUDING ANY WARRANTY OF MERCHANTABILITY, NONINFRINGEMENT, FITNESS FOR ANY PARTICULAR PURPOSE, OR ANY WARRANTY OTHERWISE ARISING OUT OF ANY PROPOSAL, SPECIFICATION OR SAMPLE. Intel Corporation disclaims all liability, including liability for infringement of any proprietary rights, relating to use of information in this specification. No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted herein.

The cryptographic functions described in this specification may be subject to export control by the United States, Japanese, and/or other governments.

Copyright © 1999-2008 by Intel Corporation. Third-party brands and names are the property of their respective owners.

Acknowledgement

Intellectual Property

Implementation of this specification requires a license from the Digital Content Protection LLC.

Contact Information

Digital Content Protection LLC
C/O Vital Technical Marketing, Inc.
3855 SW 153rd Drive
Beaverton, OR 97006

Email: info@digital-cp.com

Web: www.digital-cp.com

Revision History

1. Introduction	5
1.1 Scope	5
1.2 Definitions	5
1.3 Overview	8
1.4 Terminology	9
1.5 References	9
2. Authentication Protocol	10
2.1 Overview	10
2.2 Authentication and Key Exchange	11
2.2.1 Pairing	14
2.3 Locality Check	15
2.4 Session Key Exchange	16
2.5 Authentication with Repeaters	17
2.6 Link Synchronization	21
2.7 Authentication Failures	21
2.8 Key Derivation	21
2.9 HDCP Transmitter State Diagram	22
2.9.1 Main HDCP Transmitter Function	26
2.10 HDCP Receiver State Diagram	28
2.11 HDCP Repeater State Diagrams	29
2.11.1 Propagation of Topology Errors and Receiver Connected / Disconnected Indication	30
2.11.2 HDCP Repeater Downstream State Diagram	31
2.11.3 HDCP Repeater Upstream State Diagram	34
2.12 Converters	37
2.12.1 HDCP 2 – HDCP 1.x Converters	37
2.12.2 HDCP 1.x – HDCP 2 Converters	38
2.13 Session Key Validity	38
2.14 Random Number Generation	39
3. HDCP Encryption	40
3.1 Description	40
3.2 AV Stream	40
3.3 HDCP Cipher	41
3.3.1 HDCP Cipher for Audio Stream	41
3.3.2 HDCP Cipher for Video Stream	43
3.4 HDCP Encryption Indication	56
3.5 HDCP Cipher Block	57
3.6 Uniqueness of k_s and r_{iv}	58
4. Authentication Protocol Messages	60
4.1 Control / Status Stream	60
4.2 Message Format	60
4.2.1 AKE_Init (Transmitter to Receiver)	60
4.2.2 AKE_Send_Cert (Receiver to Transmitter)	60
4.2.3 AKE_No_Stored_km (Transmitter to Receiver)	61
4.2.4 AKE_Stored_km (Transmitter to Receiver)	61
4.2.5 AKE_Send_rrx (Receiver to Transmitter)	61
4.2.6 AKE_Send_H_prime (Receiver to Transmitter)	61
4.2.7 AKE_Send_Pairing_Info (Receiver to Transmitter)	62
4.2.8 LC_Init (Transmitter to Receiver)	62
4.2.9 RTT_Ready (Receiver ready for RTT challenge)	62
4.2.10 RTT_Challenge (Transmitter to Receiver)	62
4.2.11 RTT_Response (Receiver to Transmitter)	62

4.2.12	SKE_Send_Eks (Transmitter to Receiver)	63
4.2.13	RepeaterAuth_Send_ReceiverID_List (Receiver to Transmitter)	63
5.	Renewability	64
5.1	SRM Size and Scalability	65
5.2	Updating SRMs	66
Appendix A.	Confidentiality and Integrity of Values.....	68
Appendix B.	DCP LLC Public Key.....	70
Appendix C.	Bibliography (Informative).....	71
Appendix D.	Test Vectors	72
D.1.	Facsimile Keys.....	72
D.2.	Authentication Protocol.....	76
D.3.	Audio Stream Encryption	82
D.4.	Video Stream Encryption.....	84

1. Introduction

1.1 Scope

This specification describes the mapping of High-bandwidth Digital Content Protection (HDCP) system, Revision 2.00 to Digital Interactive Interface for Video and Audio (DiiVA).

For the purpose of this specification, it is assumed that the Audiovisual content is transmitted over a DiiVA-based display link. In an HDCP System, two or more HDCP Devices are interconnected through an HDCP-protected Interface. The Audiovisual Content flows from the Upstream Content Control Function into the HDCP System at the most upstream HDCP Transmitter. From there the Audiovisual Content encrypted by the HDCP System, referred to as HDCP Content, flows through a tree-shaped topology of HDCP Receivers over HDCP-protected Interfaces. This specification describes a content protection mechanism for: (1) authentication of HDCP Receivers to their immediate upstream connection (i.e., an HDCP Transmitter), (2) revocation of HDCP Receivers that are determined by the Digital Content Protection, LLC, to be invalid, and (3) HDCP Encryption of Audiovisual Content over the HDCP-protected Interfaces between HDCP Transmitters and their downstream HDCP Receivers. HDCP Receivers may render the HDCP Content in audio and visual form for human consumption. HDCP Receivers may be HDCP Repeaters that serve as downstream HDCP Transmitters emitting the HDCP Content further downstream to one or more additional HDCP Receivers.

Unless otherwise specified, the term “HDCP Receiver” is also used to refer to the upstream HDCP-protected interface port of an HDCP Repeater. Similarly, the term “HDCP Transmitter” is also used to refer to the downstream HDCP-protected interface port of an HDCP Repeater

Except when specified otherwise, HDCP 2.0-compliant Devices must interoperate with other HDCP 2.0-compliant Devices connected to their HDCP-protected Interface Ports using the same protocol. HDCP Transmitters must support HDCP Repeaters.

The state machines in this specification define the required behavior of HDCP Devices. The link-visible behavior of HDCP Devices implementing the specified state machines must be identical, even if implementations differ from the descriptions. The behavior of HDCP Devices implementing the specified state machines must also be identical from the perspective of an entity outside of the HDCP System.

Implementations must include all elements of the content protection system described herein, unless the element is specifically identified as informative or optional. Adopters must also ensure that implementations satisfy the robustness and compliance rules described in the technology license. Additionally, HDCP Transmitters may be subject to additional robustness and compliance rules associated with other content protection technologies.

Device discovery and association, and link setup and teardown, is outside the scope of this specification.

1.2 Definitions

The following terminology, as used throughout this specification, is defined as herein:

Active line. A video field (or frame) is composed of blanking lines and active lines. The active lines deliver the video pixel data to be displayed.

Audiovisual Content. Audiovisual works (as defined in the United States Copyright Act as in effect on January 1, 1978), text and graphic images, are referred to as *AudioVisual Content*.

Authorized Device. An HDCP Device that is permitted access to HDCP Content is referred to as an *Authorized Device*. An HDCP Transmitter may test if a connected HDCP Receiver is an Authorized Device by successfully completing the following stages of the authentication protocol – Authentication and Key Exchange (AKE) and Locality check. If the authentication protocol successfully results in establishing authentication, then the other device is considered by the HDCP Transmitter to be an Authorized Device.

DCL (DiiVA Control Layer). DCL is one of the sub-channels to send and receive special packets to configure and control DiiVA devices.

Device Key Set. An HDCP Receiver has a Device Key Set, which consists of its corresponding Device Secret Keys along with the associated Public Key Certificate.

Device Secret Keys. For an HDCP Transmitter, Device Secret Key consists of the secret global constant. For an HDCP Receiver, Device Secret Keys consists of the secret global constant and the RSA private key. The Device Secret Keys are to be protected from exposure outside of the HDCP Device.

downstream. The term, *downstream*, is used as an adjective to refer to being towards the sink of the HDCP Content stream. For example, when an HDCP Transmitter and an HDCP Receiver are connected over an HDCP-protected Interface, the HDCP Receiver can be referred to as the *downstream* HDCP Device in this connection. For another example, on an HDCP Repeater, the HDCP-protected Interface Port(s) which can emit HDCP Content can be referred to as its *downstream* HDCP-protected Interface Port(s). See also, *upstream*.

Frame. In the DiiVA video stream, a frame corresponds to a video frame in the progressive mode and a video field in the interlaced mode. One Frame Info Packet must be transferred every frame in the DiiVA video stream.

Global Constant. A 128-bit random, secret constant provided only to HDCP Adopters and used during HDCP Content encryption or decryption

HDCP 1.x. *HDCP 1.x* refers to, specifically, the variant of HDCP described by Revision 1.00 (referred to as HDCP 1.0), Revision 1.10 (referred to as HDCP 1.1), Revision 1.20 (referred to as HDCP 1.2) and Revision 1.30 (referred to as HDCP 1.3) along with their associated errata, if applicable.

HDCP 1.x-compliant Device. An HDCP Device that is designed in adherence to HDCP 1.x, defined above, is referred to as an *HDCP 1.x-compliant Device*.

HDCP 2. *HDCP 2* refers to, specifically, the variant of HDCP mapping for all HDCP protected interfaces (including DiiVA) described by Revision 2.00 and higher versions along with their associated errata, if applicable.

HDCP 2.0. *HDCP 2.0* refers to, specifically, the variant of HDCP mapping described by Revision 2.00 of this specification along with its associated errata, if applicable.

HDCP 2.0-compliant Device. An HDCP Device that is designed in adherence to HDCP 2.0 is referred to as an *HDCP 2.0-compliant Device*.

HDCP Content. *HDCP Content* consists of Audiovisual Content that is protected by the HDCP System. *HDCP Content* includes the Audiovisual Content in encrypted form as it is transferred from an HDCP Transmitter to an HDCP Receiver over an HDCP-protected Interface, as well as any translations of the same content, or portions thereof. For avoidance of doubt, Audiovisual Content that is never encrypted by the HDCP System is not *HDCP Content*.

HDCP Device. Any device that contains one or more HDCP-protected Interface Port and is designed in adherence to HDCP is referred to as an *HDCP Device*.

HDCP Encryption. *HDCP Encryption* is the encryption technology of HDCP when applied to the protection of HDCP Content in an HDCP System.

HDCP Receiver. An HDCP Device that can receive and decrypt HDCP Content through one or more of its HDCP-protected Interface Ports is referred to as an *HDCP Receiver*.

HDCP Repeater. An HDCP Device that can receive and decrypt HDCP Content through one or more of its HDCP-protected Interface Ports, and can also re-encrypt and emit said HDCP Content through one or more of its HDCP-protected Interface Ports, is referred to as an *HDCP Repeater*. An *HDCP Repeater* may also be referred to as either an HDCP Receiver or an HDCP Transmitter when referring to either the upstream side or the downstream side, respectively.

HDCP System. An *HDCP System* consists of an HDCP Transmitter, zero or more HDCP Repeaters and one or more HDCP Receivers connected through their HDCP-protected interfaces in a tree topology; whereas the said HDCP Transmitter is the HDCP Device most upstream, and receives the Audiovisual Content from one or more Upstream Content Control Functions. All HDCP Devices connected to other HDCP Devices in an *HDCP System* over HDCP-protected Interfaces are part of the *HDCP System*.

HDCP Transmitter. An HDCP Device that can encrypt and emit HDCP Content through one or more of its HDCP-protected Interface Ports is referred to as an *HDCP Transmitter*.

HDCP. *HDCP* is an acronym for High-bandwidth Digital Content Protection. This term refers to this content protection system as described by any revision of this specification and its errata.

HDCP-protected Interface Port. A physical connection point on an HDCP Device that supports an HDCP-protected Interface is referred to as an *HDCP-protected Interface Port*. A single connection can be made over an HDCP-protected interface port.

HDCP-protected Interface. An interface for which HDCP applies is described as an *HDCP-protected Interface*.

Public Key Certificate. Each HDCP Receiver is issued a Public Key Certificate signed by DCP LLC, and contains the Receiver ID and RSA public key corresponding to the HDCP Receiver.

Receiver Connected Indication. An indication to the HDCP Transmitter that an active receiver has been connected to it. The format of the indication or the method used by the HDCP Transmitter to connect to or disconnect from a receiver is outside the scope of this specification.

Receiver Disconnected Indication. An indication to the HDCP Transmitter that the receiver has been disconnected from it. The format of the indication or the method used by the HDCP Transmitter to connect to or disconnect from a receiver is outside the scope of this specification.

Receiver ID. A 40-bit value that uniquely identifies the HDCP Receiver. It has the same format as an HDCP 1.x KSV i.e. it contains 20 ones and 20 zeroes.

Upstream Content Control Function. The HDCP Transmitter most upstream in the HDCP System receives Audiovisual Content to be protected from the *Upstream Content Control Function*. An instance of the *Upstream Content Control Function* transmits a content stream to the HDCP Transmitter. The *Upstream Content Control Function* is not part of the HDCP System, and the methods used, if any, by the *Upstream Content Control Function* to determine for itself the HDCP System is correctly authenticated or permitted to receive the Audiovisual Content, or to

transfer the Audiovisual Content to the HDCP System, are beyond the scope of this specification. On a personal computer platform, an example of an *Upstream Content Control Function* may be software designed to emit Audiovisual Content to a display or other presentation device that requires HDCP.

upstream. The term, *upstream*, is used as an adjective to refer to being towards the source of the HDCP Content stream. For example, when an HDCP Transmitter and an HDCP Receiver are connected over an HDCP-protected Interface, the HDCP Transmitter can be referred to as the *upstream* HDCP Device in this connection. For another example, on an HDCP Repeater, the HDCP-protected Interface Port(s) which can receive HDCP Content can be referred to as its *upstream* HDCP-protected Interface Port(s). See also, *downstream*.

1.3 Overview

HDCP is designed to protect the transmission of Audiovisual Content between an HDCP Transmitter and an HDCP Receiver. The HDCP Transmitter may support simultaneous connections to HDCP Receivers through one or more of its HDCP-protected interface ports. The system also allows for HDCP Repeaters that support downstream HDCP-protected Interface Ports. The HDCP System places the following constraints on the number of HDCP Devices and levels of HDCP Repeaters in the topology.

1. Up to four levels of HDCP Repeaters and as many as 32 total HDCP Devices, including HDCP Repeaters, are allowed to be connected to an HDCP-protected Interface port; and
2. An instance of an Upstream Content Control Function transmits a content stream to the HDCP Transmitter. For every such content stream received and encrypted by the HDCP System, the HDCP Transmitter is allowed to transmit the generated HDCP Content stream to up to four levels of HDCP Repeaters and as many as 32 total HDCP Devices, including HDCP Repeaters.

Figure 1.1 illustrates an example connection topology for HDCP Devices.

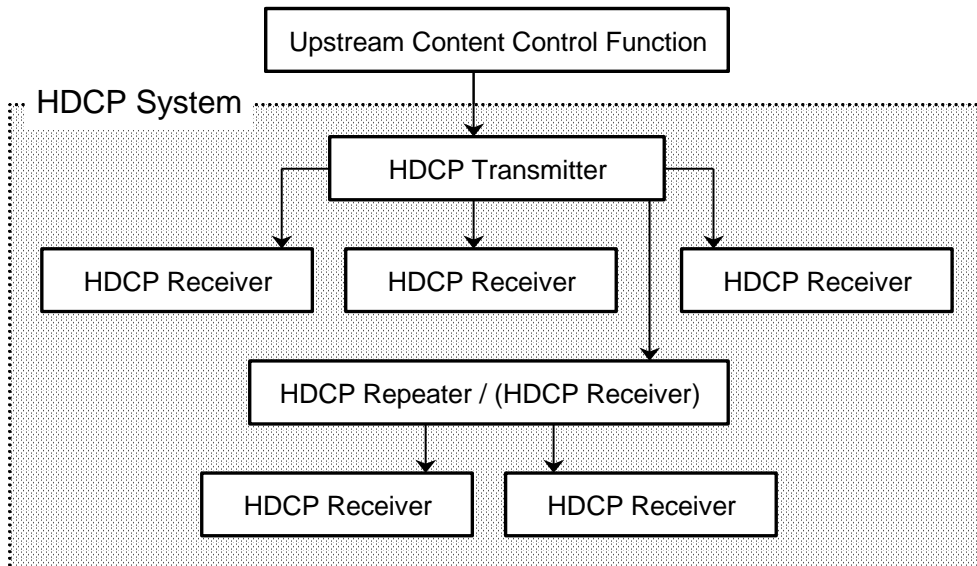


Figure 1.1. Sample Connection Topology of an HDCP System

There are three elements of the content protection system. Each element plays a specific role in the system. First, there is the authentication protocol, through which the HDCP Transmitter verifies that a given HDCP Receiver is licensed to receive HDCP Content. The authentication protocol is implemented between the HDCP Transmitter and its corresponding downstream HDCP Receiver.

With the legitimacy of the HDCP Receiver determined, encrypted HDCP Content is transmitted between the two devices based on shared secrets established during the authentication protocol. This prevents eavesdropping devices from utilizing the content. Finally, in the event that legitimate devices are compromised to permit unauthorized use of HDCP Content, renewability allows an HDCP Transmitter to identify such compromised devices and prevent the transmission of HDCP Content.

This document contains chapters describing in detail the requirements of each of these elements. In addition, a chapter is devoted to describing the cipher structure that is used in the encryption of HDCP Content.

1.4 Terminology

Throughout this specification, names that appear in *italic* refer to values that are exchanged during the HDCP cryptographic protocol. C-style notation is used throughout the state diagrams and protocol diagrams, although the logic functions AND, OR, and XOR are written out where a textual description would be more clear.

This specification uses the big-endian notation to represent bit strings so that the most significant bit in the representation is stored in the left-most bit position. The concatenation operator ‘||’ combines two values into one. For eight-bit values a and b , the result of $(a || b)$ is a 16-bit value, with the value a in the most significant eight bits and b in the least significant eight bits.

1.5 References

- [1]. Digital Content Protection (DCP) LLC, High-bandwidth Digital Content Protection System, Revision 1.3, December 21, 2006.
- [2]. Digital Content Protection (DCP) LLC, HDCP Specification 1.3 – Amendment for DisplayPort, Revision 1.0, December 19, 2006.
- [3]. National Institute of Standards and Technology (NIST), *Advanced Encryption Standard (AES)*, FIPS Publication 197, November 26, 2001.
- [4]. RSA Laboratories, *RSA Cryptography Standard*, PKCS #1 v2.1, June 14, 2002.
- [5]. National Institute of Standards and Technology (NIST), *Secure Hash Standard (SHS)*, FIPS Publication 180-2, August 1, 2002.
- [6]. Internet Engineering Task Force (IETF), *HMAC: Keyed-Hashing for Message Authentication*, Request for Comments (RFC) 2104, February 1997.
- [7]. DiiVA Licensing LLC, Digital Interactive Interface for Video and Audio (DiiVA) Specification, Revision 1.1, <TBD>
- [8]. National Institute of Standards and Technology (NIST), Recommendation for Random Number Generation Using Deterministic Random Bit Generators, Special Publication 800-90, March 2007

2. Authentication Protocol

2.1 Overview

The HDCP Authentication protocol is an exchange between an HDCP Transmitter and an HDCP Receiver that affirms to the HDCP Transmitter that the HDCP Receiver is authorized to receive HDCP Content. It is comprised of the following stages

- Authentication and Key Exchange (AKE) – The HDCP Receiver’s public key certificate is verified by the HDCP Transmitter. A master key k_m is exchanged.
- Locality Check – The HDCP Transmitter enforces locality on the content by requiring that the Round Trip Time (RTT) between a pair of messages is not more than 3 ms.
- Session Key Exchange (SKE) – The HDCP Transmitter exchanges session key k_s with the HDCP Receiver.
- Authentication with Repeaters – The step is performed by the HDCP Transmitter only with HDCP Repeaters. In this step, the repeater assembles downstream topology information and forwards it to the upstream HDCP Transmitter.

Successful completion of AKE and locality check stages affirms to the HDCP Transmitter that the HDCP Receiver is authorized to receive HDCP Content. At the end of the authentication protocol, a communication path is established between the HDCP Transmitter and HDCP Receiver that only Authorized Devices can access.

All HDCP Devices contain a 128-bit secret global constant denoted by lc_{128} . All HDCP Devices share the same global constant. lc_{128} is provided only to HDCP Adopters.

The HDCP Transmitter contains the 3072-bit RSA public key of DCP LLC denoted by $k_{pub_{dcp}}$.

The HDCP Receiver is issued 1024-bit RSA public and private keys. The public key is stored in a Public Key Certificate issued by DCP LLC, denoted by $cert_{rx}$. Table 2.1 gives the fields contained in the certificate. All values are stored in big-endian format.

Name	Size (bits)	Bit position	Function
Receiver ID	40	4175:4136	Unique receiver identifier. It has the same format as an HDCP 1.x KSV i.e. it contains 20 ones and 20 zeroes
Receiver Public Key	1048	4135:3088	Unique RSA public key of HDCP Receiver denoted by $k_{pub_{rx}}$. The first 1024 bits is the big-endian representation of the modulus n and the trailing 24 bits is the big-endian representation of the public exponent e
Reserved	16	3087:3072	Reserved for future definition. Must be 0x0000
DCP LLC Signature	3072	3071:0	A cryptographic signature calculated over all preceding fields of the certificate. RSASSA-PKCS1-v1_5 is the signature scheme used as defined by PKCS #1 V2.1: RSA Cryptography Standard. SHA-256 is the underlying hash function

Table 2.1. Public Key Certificate of HDCP Receiver

The secret RSA private key is denoted by $k_{priv_{rx}}$. The computation time of RSA private key operation can be reduced by using the Chinese Remainder Theorem (CRT) technique. Therefore, it is recommended that HDCP Receivers use the CRT technique for private key computations.

2.2 Authentication and Key Exchange

Authentication and Key Exchange (AKE) is the first step in the authentication protocol. Figure 2.1 and Figure 2.2 illustrates the AKE. The HDCP Transmitter (*Device A*) can initiate authentication at any time, even before a previous authentication exchange has completed. The HDCP Transmitter initiates a new HDCP Session by sending a new r_{tx} as part of the authentication initiation message, AKE_Init. Message formats are defined in Section 4.2.

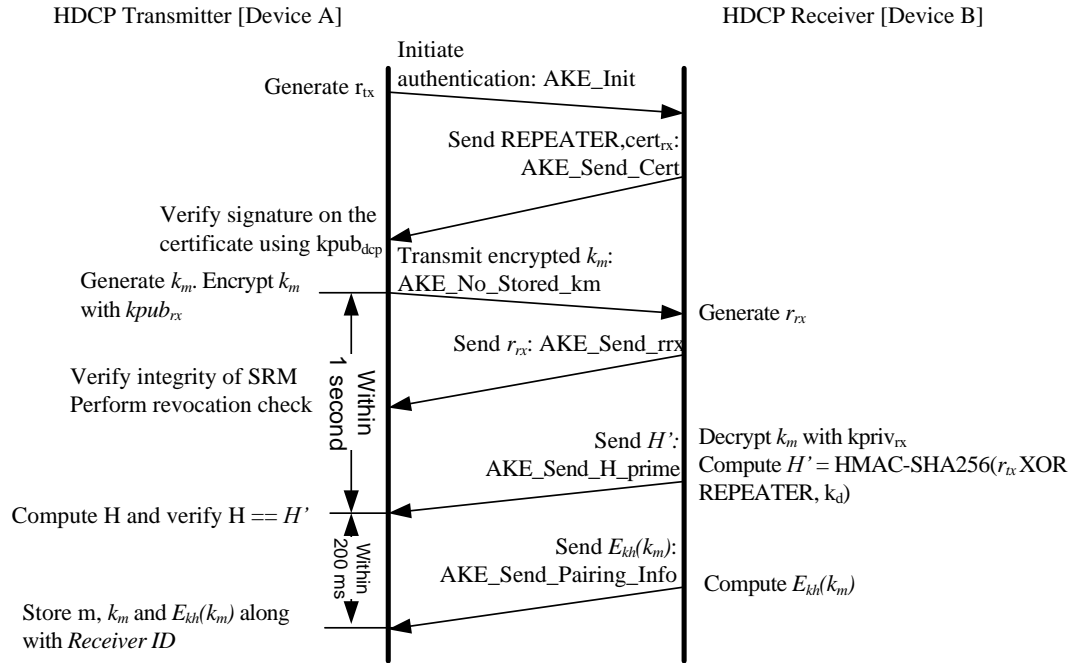


Figure 2.1. Authentication and Key Exchange (Without Stored k_m)

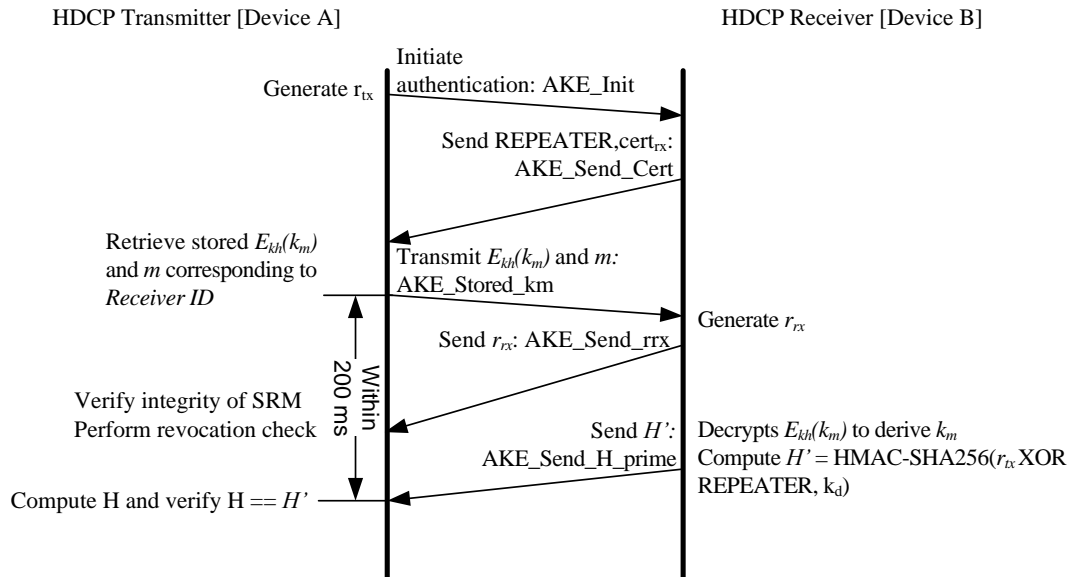


Figure 2.2. Authentication and Key Exchange (With Stored k_m)

The HDCP Transmitter

- Initiates authentication by sending the initiation message, AKE_Init, containing a 64-bit pseudo-random value (r_{tx}).
- Receives AKE_Send_Cert from the receiver containing REPEATER and $cert_{rx}$ values. REPEATER indicates whether the connected receiver is an HDCP Repeater
- Extracts *Receiver ID* from $cert_{rx}$
 - If the HDCP Transmitter does not have a 128-bit master key k_m stored corresponding to the *Receiver ID* (See Section 2.2.1)
 - Verifies the signature on the certificate using $k_{pub_{dcp}}$. Failure of signature verification constitutes an authentication failure and the HDCP Transmitter aborts the authentication protocol (See Section 2.7 on handling authentication failures).
 - Generates a pseudo-random 128-bit master key k_m . Encrypts k_m with $k_{pub_{rx}}$ ($E_{k_{pub}}(k_m)$) and sends AKE_No_Stored_km message to the receiver containing the 1024-bit $E_{k_{pub}}(k_m)$. RSAES-OAEP encryption scheme must be used as defined by PKCS #1 V2.1: RSA Cryptography Standard. SHA-256 is the underlying hash function. The mask generation function used is MGF1 which uses SHA-256 as its underlying hash function.
 - Verifies integrity of the System Renewability Message (SRM). It does this by checking the signature of the SRM using $k_{pub_{dcp}}$. Failure of this integrity check constitutes an authentication failure and causes the HDCP Transmitter to abort authentication protocol (See Section 2.7 on handling authentication failures).

The top-level HDCP Transmitter checks to see if the *Receiver ID* of the connected device is found in the revocation list. If the *Receiver ID* of the connected HDCP Device is found in the revocation list, authentication fails and the authentication protocol is aborted (See Section 2.7 on handling authentication failures). SRM integrity check and revocation check are performed only by the top-level HDCP Transmitter.

- Receives AKE_Send_rrx message from the receiver containing the 64-bit pseudo-random value (r_{rx}).
- Performs key derivation as explained in Section 2.8 to generate 256-bit k_d . $k_d = dkey_0 \parallel dkey_1$, where $dkey_0$ and $dkey_1$ are derived keys generated when $ctr = 0$ and $ctr = 1$ respectively. $dkey_0$ and $dkey_1$ are in big-endian order.
- Computes 256-bit $H = \text{HMAC-SHA256}(r_{tx} \text{ XOR REPEATER}, k_d)$ where HMAC-SHA256 is computed over $r_{tx} \text{ XOR REPEATER}$ and the key used for HMAC is k_d . REPEATER is XORed with the least significant byte of r_{tx} .
- Receives AKE_Send_H_prime message from the receiver containing the 256-bit H' . This message must be received within one second after

sending $E_{k_{pub}}(km)$ (AKE_No_Stored_km) to the receiver. Authentication fails and the authentication protocol is aborted if the message is not received within one second or there is a mismatch between H and H' (See Section 2.7 on handling authentication failures).

- If the HDCP Transmitter has a 128-bit master key k_m stored corresponding to the *Receiver ID* (See Section 2.2.1)
 - Sends AKE_Stored_km message to the receiver with the 128-bit $E_{k_d}(k_m)$ and the 128-bit m corresponding to the *Receiver ID* of the HDCP Receiver
 - Verifies integrity of the System Renewability Message (SRM). It does this by checking the signature of the SRM using k_{pub_dcp} . Failure of this integrity check constitutes an authentication failure and causes the HDCP Transmitter to abort the authentication protocol.

The top-level HDCP Transmitter checks to see if the *Receiver ID* of the connected device is found in the revocation list. If the *Receiver ID* of the connected HDCP Device is found in the revocation list, authentication fails and the authentication protocol is aborted.

- Receives AKE_Send_rrx message from the receiver containing the 64-bit pseudo-random value (r_{rx}) from the receiver.
- Performs key derivation as explained in Section 2.8 to generate 256-bit k_d . $k_d = dkey_0 \parallel dkey_1$, where $dkey_0$ and $dkey_1$ are derived keys generated when $ctr = 0$ and $ctr = 1$ respectively. $dkey_0$ and $dkey_1$ are in big-endian order.
- Computes 256-bit $H = \text{HMAC-SHA256}(r_{rx} \text{ XOR REPEATER}, k_d)$ where HMAC-SHA256 is computed over $r_{rx} \text{ XOR REPEATER}$ and the key used for HMAC is k_d . REPEATER is XORed with the least significant byte of r_{rx} .
- Receives AKE_Send_H_prime message from the receiver containing the 256-bit H' . This message must be received within 200 ms after sending the AKE_Stored_km message to the receiver. Authentication fails and the authentication protocol is aborted if the message is not received within 200 ms or there is a mismatch between H and H' (See Section 2.7 on handling authentication failures).

The HDCP Receiver

- Sends AKE_Send_Cert message in response to AKE_Init
- Generates and sends 64-bit r_{rx} as part of the AKE_Send_rrx message immediately after receiving either AKE_No_Stored_km or AKE_Stored_km message from the transmitter. r_{rx} must be generated only after either AKE_No_Stored_km or AKE_Stored_km message is received from the transmitter.
 - If AKE_No_Stored_km is received, the HDCP Receiver
 - Decrypts k_m with k_{priv_rx} using RSAES-OAEP decryption scheme.

- Performs key derivation as explained in Section 2.8 to generate 256-bit k_d . $k_d = dkey_0 \parallel dkey_1$, where $dkey_0$ and $dkey_1$ are derived keys generated when $ctr = 0$ and $ctr = 1$ respectively. $dkey_0$ and $dkey_1$ are in big-endian order.
- Computes $H' = \text{HMAC-SHA256}(r_{tx} \text{ XOR REPEATER}, k_d)$. Sends `AKE_Send_H_prime` message immediately after computation of H' to ensure that the message is received by the transmitter within the specified one second timeout at the transmitter.
- If `AKE_Stored_km` is received, the HDCP Receiver
 - Computes 128-bit $k_h = \text{SHA-256}(k_{priv_{rx}})[127:0]$
 - Decrypts $E_{kh}(k_m)$ using AES with the received m as input and k_h as key in to the AES module as illustrated in Figure 2.3 to derive k_m .
 - Performs key derivation as explained in Section 2.8 to generate 256-bit k_d . $k_d = dkey_0 \parallel dkey_1$, where $dkey_0$ and $dkey_1$ are derived keys generated when $ctr = 0$ and $ctr = 1$ respectively. $dkey_0$ and $dkey_1$ are in big-endian order.
 - Computes $H' = \text{HMAC-SHA256}(r_{tx} \text{ XOR REPEATER}, k_d)$. Sends `AKE_Send_H_prime` message immediately after computation of H' to ensure that the message is received by the transmitter within the specified 200 ms timeout at the transmitter.

On a decryption failure of k_m with $k_{priv_{rx}}$, the HDCP Receiver does not send H' and simply lets the timeout occur on the HDCP Transmitter.

2.2.1 Pairing

To speed up the AKE process, pairing must be implemented between the HDCP Transmitter and HDCP Receiver in parallel with AKE. When `AKE_No_Stored_km` message is received from the transmitter, it is an indication to the receiver that the transmitter does not have k_m stored corresponding to the receiver. In this case, after computing H' , the HDCP Receiver

- Computes 128-bit $k_h = \text{SHA-256}(k_{priv_{rx}})[127:0]$.
- Generates 128-bit $E_{kh}(k_m)$ by encrypting k_m with k_h using AES as illustrated in Figure 2.3.
- Sends `AKE_Send_Pairing_Info` to the transmitter containing the 128-bit $E_{kh}(k_m)$.

On receiving `AKE_Send_Pairing_Info` message, the HDCP Transmitter

- Persistently stores m (which is r_{tx} appended with 64 0s), k_m and $E_{kh}(k_m)$ along with *Receiver ID*. k_m and $E_{kh}(k_m)$ must be stored securely.

If `AKE_Send_Pairing_Info` is not received by the HDCP Transmitter within 200 ms of the reception of `AKE_Send_H_prime`, authentication fails and the authentication protocol is aborted (See Section 2.7 on handling authentication failures).

Note: The HDCP Transmitter must store in its non-volatile storage m , k_m and $E_{kh}(k_m)$ along with corresponding *Receiver IDs* of all HDCP Receivers with which pairing was implemented by the HDCP Transmitter.

Figure 2.3 illustrates the encryption of k_m with k_h .

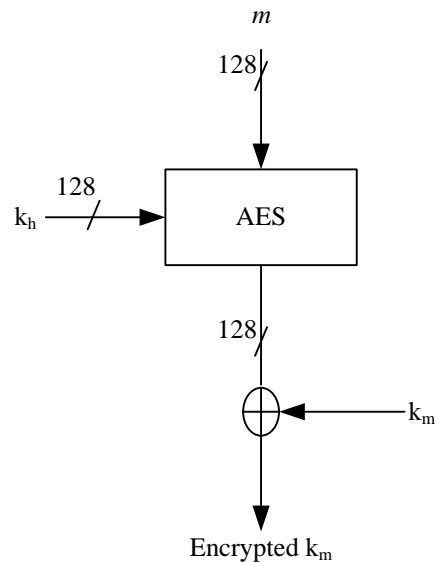


Figure 2.3. $E_{k_h}(k_m)$ Computation

128-bit m is constructed by appending 64 0s to r_{rx} , r_{rx} is in big-endian order.

2.3 Locality Check

Locality check is performed after AKE and pairing. The HDCP Transmitter initiates locality check by sending a 64-bit pseudo-random nonce r_n to the downstream receiver. The HDCP Transmitter

- Initiates locality check by sending LC_Init message containing a 64-bit pseudo-random nonce r_n to the HDCP Receiver.
- Computes 256-bit $L = \text{HMAC-SHA256}(r_n, k_d \text{ XOR } r_{rx})$ where HMAC-SHA256 is computed over r_n and the key used for HMAC is $k_d \text{ XOR } r_{rx}$, where r_{rx} is XORed with the least-significant 64-bits of k_d .
- Waits for the RTT_Ready message from the receiver for up to 200 ms.
- Sends an RTT_Challenge message containing the least significant 128-bits of L .
- Sets its watchdog timer to 3 ms. Locality check fails if the watchdog timer expires before RTT_Response message is received.

On receiving RTT_Response message the HDCP Transmitter compares the received value with the most significant 128-bits of L and locality check fails if there is a mismatch. An HDCP Repeater initiates locality check on all its downstream HDCP-protected interface ports by sending unique r_n values to the connected HDCP Devices.

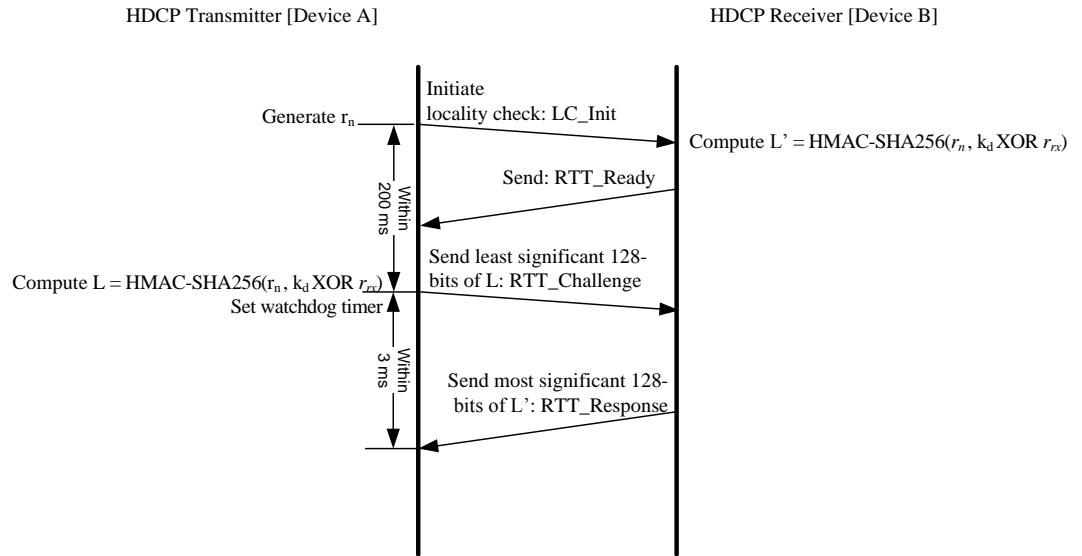


Figure 2.4. Locality Check between HDCP Transmitter and HDCP Receiver

An HDCP Receiver

- Computes 256-bit $L' = \text{HMAC-SHA256}(r_n, k_d \text{ XOR } r_{rx})$
- Sends `RTT_Ready` message to the transmitter when completed L' calculation and is ready for the `RTT_Challenge`.
- On receiving the `RTT_Challenge` message from the transmitter with the correct 128 LSB bits of L' , sends an `RTT_Response` message containing the most significant 128-bits of L' .

In the case of a locality check failure due to expiration of the watchdog timer at the HDCP Transmitter, locality check must be reattempted by the HDCP Transmitter 1023 additional times (for a total of 1024 trials) with the transmission of an `LC_Init` message containing a new r_n . Failure of locality check due to timeout for 1024 trials results in an authentication failure and the authentication protocol is aborted (See Section 2.7 on handling authentication failures). A locality check failure due to mismatch of the 128-bit value received in the `RTT_Response` message with the most significant 128-bits of L also results in an authentication failure and the authentication protocol is aborted. However, once a single `RTT_Response` with correct L' is received before the watchdog timer expires, the locality check terminates successfully with no further retries for that locality check.

2.4 Session Key Exchange

Successful completion of AKE and locality check stages affirms to HDCP Transmitter that the HDCP Receiver is authorized to receive HDCP Content. Session Key Exchange (SKE) is initiated by the HDCP Transmitter after a successful locality check. The HDCP Transmitter sends encrypted session key to the HDCP Receiver and enables HDCP Encryption 200 ms after sending encrypted session key. Content encrypted with the session key k_s starts to flow between the HDCP Transmitter and HDCP Receiver. HDCP Encryption must be enabled only after successful completion of AKE, locality check and SKE stages.

During SKE, the HDCP Transmitter

- Generates a pseudo-random 128-bit session key k_s and 64-bit pseudo-random number r_{iv} .

- Performs key derivation as explained in Section 2.8 to generate 128-bit $dkey_2$ where $dkey_2$ is the derived key when $ctr = 2$.
- Computes 128-bit $E_{dkey}(k_s) = k_s \text{ XOR } (dkey_2 \text{ XOR } r_{rx})$, where r_{rx} is XORed with the least-significant 64-bits of $dkey_2$.
- Sends SKE_Send_Eks message containing $E_{dkey}(k_s)$ and r_{iv} to the HDCP Receiver.

On receiving SKE_Send_Eks message, the HDCP Receiver

- Performs key derivation as explained in Section 2.8 to generate 128-bit $dkey_2$ where $dkey_2$ is the derived key when $ctr = 2$.
- Computes $k_s = E_{dkey}(k_s) \text{ XOR } (dkey_2 \text{ XOR } r_{rx})$

2.5 Authentication with Repeaters

Figure 2.5 illustrates authentication with repeaters. The HDCP Transmitter executes authentication with repeaters after session key exchange and only when REPEATER is ‘true’, indicating that the connected HDCP Receiver is an HDCP Repeater. Authentication with repeaters is implemented in parallel with the flow of encrypted content and Link Synchronization. The Link Synchronization process is explained in Section 2.6. The authentication with repeaters stage assembles a list of all downstream *Receiver IDs* connected to the HDCP Repeater through a permitted connection tree, enabling revocation support upstream.

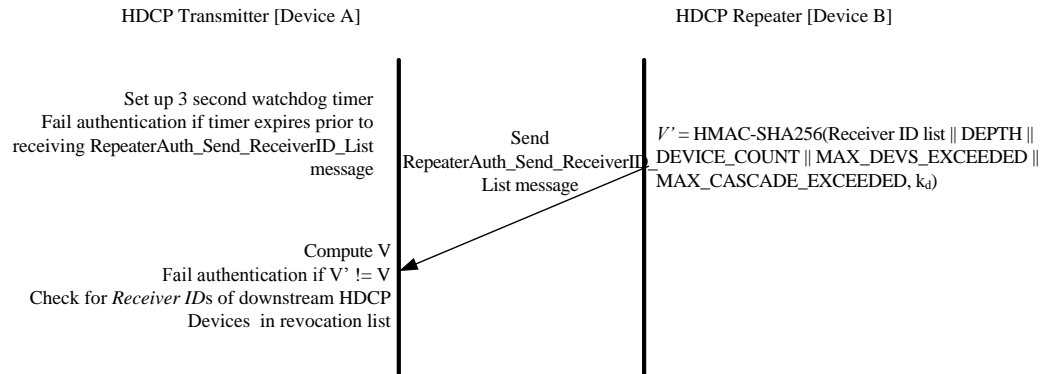


Figure 2.5. Authentication with Repeaters

HDCP Repeaters assemble the list of all connected downstream HDCP Receivers as the downstream HDCP-protected Interface Ports of the HDCP Repeater successfully complete the Authentication and Key Exchange and Locality check stages with connected HDCP Receivers. The list is represented by a contiguous set of bytes, with each *Receiver ID* occupying five bytes stored in big-endian order. The total length of the Receiver ID list is five bytes times the total number of connected and active downstream HDCP Devices, including downstream HDCP Repeaters. An HDCP-protected Interface Port with no active device connected adds nothing to the list. Also, the *Receiver ID* of the HDCP Repeater itself at any level is not included in its own Receiver ID list. An HDCP-protected Interface Port connected to an HDCP Receiver that is not an HDCP Repeater adds the *Receiver ID* of the connected HDCP Receiver to the list. HDCP-protected Interface Ports that have an HDCP Repeater connected add the Receiver ID list received from the connected downstream HDCP Repeater, plus the *Receiver ID* of the connected downstream HDCP Repeater itself.

In order to add the Receiver ID list of the connected HDCP Repeater, it is necessary for the HDCP Repeater to verify the integrity of the list by computing V and checking this value against V'

received as part of the RepeaterAuth_Send_ReceiverID_List message from the connected downstream HDCP Repeater. If V does not equal V' , the downstream Receiver ID list integrity check fails, and the HDCP Repeater must not send the RepeaterAuth_Send_ReceiverID_List message to the upstream HDCP Transmitter. Upstream HDCP Transmitters will detect this failure by the expiration of a watchdog timer set in the HDCP Transmitter. On expiration of the watchdog timer, authentication fails, the authentication protocol must be aborted and HDCP Encryption must be disabled (See Section 2.7 on handling authentication failures).

When the HDCP Repeater has assembled the complete list of connected HDCP Devices' *Receiver IDs*, it computes the 256-bit verification value V' .

$$V' = \text{HMAC-SHA256}(\text{Receiver ID list} \parallel \text{DEPTH} \parallel \text{DEVICE_COUNT} \parallel \text{MAX_DEVS_EXCEEDED} \parallel \text{MAX_CASCADE_EXCEEDED}, k_d)$$

HMAC-SHA256 is computed over the concatenation of Receiver ID list, DEPTH, DEVICE_COUNT, MAX_DEVS_EXCEEDED and MAX_CASCADE_EXCEEDED where Receiver ID list is formed by appending downstream *Receiver IDs* in big-endian order. The key used for HMAC is k_d . When the Receiver ID list, V' , DEPTH and DEVICE_COUNT are available, the HDCP Repeater sends RepeaterAuth_Send_ReceiverID_List message to the upstream HDCP Transmitter.

The HDCP Transmitter, having determined that REPEATER received earlier in the protocol is 'true', sets a three-second watchdog timer. When the RepeaterAuth_Send_ReceiverID_List message is received, the HDCP Transmitter verifies the integrity of the Receiver ID list by computing V and comparing this value to V' . If V is not equal to V' , authentication fails, the authentication protocol is aborted and HDCP Encryption is disabled (See Section 2.7 on handling authentication failures).

If the RepeaterAuth_Send_ReceiverID_List message is not received by the HDCP Transmitter within a maximum-permitted time of three seconds after transmitting SKE_Send_Eks message, authentication of the HDCP Repeater fails. With this failure, the HDCP Transmitter disables HDCP Encryption and aborts the authentication protocol with the HDCP Repeater (See Section 2.7 on handling authentication failures).

The HDCP Repeater propagates topology information upward through the connection tree to the HDCP Transmitter. An HDCP Repeater reports the topology status variables DEVICE_COUNT and DEPTH. The DEVICE_COUNT for an HDCP Repeater is equal to the total number of connected downstream HDCP Receivers and HDCP Repeaters. The value is calculated as the sum of the number of directly connected downstream HDCP Receivers and HDCP Repeaters plus the sum of the DEVICE_COUNT received from all connected HDCP Repeaters. The DEPTH status for an HDCP Repeater is equal to the maximum number of connection levels below any of the downstream HDCP-protected Interface Ports. The value is calculated as the maximum DEPTH reported from downstream HDCP Repeaters plus one (accounting for the connected downstream HDCP Repeater).

In Figure 2.6, R1 has zero downstream HDCP Devices and reports a value of zero for both the DEPTH and the DEVICE_COUNT.

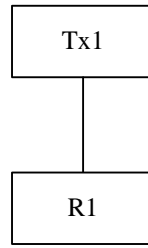


Figure 2.6. DEPTH and DEVICE_COUNT for HDCP Repeater

In Figure 2.7, R1 has three downstream HDCP Receivers connected to it. It reports a DEPTH of one and a DEVICE_COUNT of three.

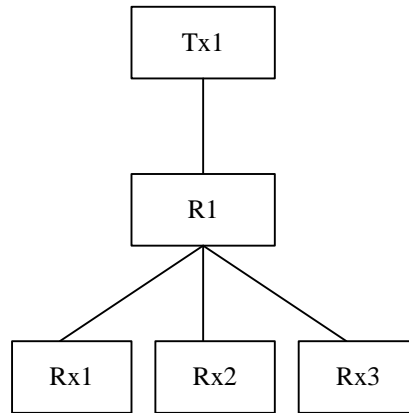


Figure 2.7. DEPTH and DEVICE_COUNT for HDCP Repeater

In Figure 2.8, R1 reports a DEPTH of two and a DEVICE_COUNT of four.

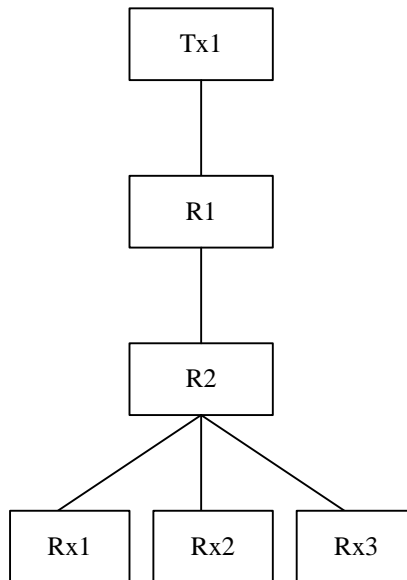
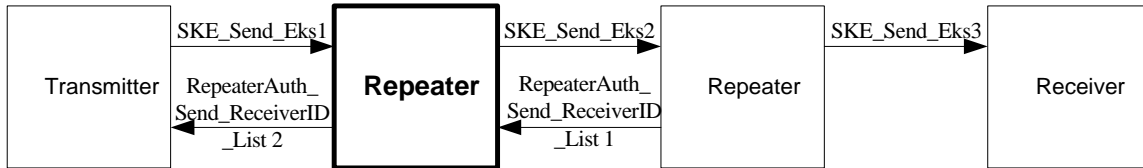


Figure 2.8. DEPTH and DEVICE_COUNT for HDCP Repeater

HDCP Repeaters must be capable of supporting DEVICE_COUNT values less than or equal to 31 and DEPTH values less than or equal to 4. If the computed DEVICE_COUNT for an HDCP Repeater exceeds 31, the error is referred to as MAX_DEVS_EXCEEDED error. The repeater sets MAX_DEVS_EXCEEDED = 'true' in the RepeaterAuth_Send_ReceiverID_List message. If the computed DEPTH for an HDCP Repeater exceeds four, the error is referred to as MAX_CASCADE_EXCEEDED error. The repeater sets MAX_CASCADE_EXCEEDED = 'true' in the RepeaterAuth_Send_ReceiverID_List message. When an HDCP Repeater receives a MAX_DEVS_EXCEEDED or a MAX_CASCADE_EXCEEDED error from a downstream HDCP Repeater, it must propagate the error to the upstream HDCP Transmitter and must not transmit V' and Receiver ID list.

Authentication fails if the topology maximums are exceeded. HDCP Encryption is disabled and the authentication protocol is aborted. The top-level HDCP Transmitter, having already performed SRM integrity check during AKE, proceeds to see if the Receiver ID of any downstream device is found in the current revocation list, and, if present, authentication fails, HDCP Encryption is disabled and authentication protocol is aborted (See Section 2.7 on handling authentication failures).

An HDCP 2.0-compliant repeater device must comply with the timings specified below.



From	To	Max Delay	Conditions and Comments
SKE_Send_Eks1 Session key received from Upstream HDCP Transmitter	SKE_Send_Eks2 k_s generated by HDCP Repeater transmitted downstream	100 ms	Downstream propagation time.
SKE_Send_Eks3 k_s transmitted to all downstream HDCP-protected Interface Ports	RepeaterAuth_Send_ReceiverID_List1 <i>Receiver IDs</i> and topology information transmitted upstream	200 ms	Upstream propagation time when no downstream HDCP Repeaters are attached (no downstream Receiver ID lists to process)
RepeaterAuth_Send_ReceiverID_List 1 Downstream <i>Receiver IDs</i> and topology information received	RepeaterAuth_Send_ReceiverID_List2 <i>Receiver IDs</i> and topology information transmitted upstream	200 ms	Upstream propagation time when one or more HDCP Repeaters are attached. From latest downstream RepeaterAuth_Send_ReceiverID_List message. (downstream Receiver ID lists must be processed)
SKE_Send_Eks1 Upstream HDCP	RepeaterAuth_Send_ReceiverID_List	1.2 seconds	For the Maximum of four repeater levels, 4 * (100 ms + 200 ms)

Transmitter transmits k_s	ist2 Upstream HDCP Transmitter receives RepeaterAuth_Send_ReceiverID_List message		
-----------------------------	--	--	--

Table 2–2. HDCP Repeater Protocol Timing Requirements

Table 2–2 specifies HDCP Repeater timing requirements that bound the worst-case propagation time for the Receiver ID list. A maximum delay of three seconds has been provided to receive the RepeaterAuth_Send_ReceiverID_List message by the upstream transmitter to account for authentication delays due to the presence of downstream receivers that have not been paired with the upstream HDCP Repeater. Note that because each HDCP Repeater does not know the number of downstream HDCP Repeaters, it must use the same three-second timeout used by the upstream HDCP Transmitter for receiving the RepeaterAuth_Send_ReceiverID_List message.

2.6 Link Synchronization

After successful completion of SKE, HDCP Encryption is enabled and encrypted content starts to flow between the HDCP Transmitter and the HDCP Receiver. As explained in Section 3.3, the presence of *Encryption_Indicator* = 1 and *Content_Protection_Scheme* = 2 in audio data packets indicates that HDCP Encryption is enabled and the payload is encrypted for the audio stream. The presence of *Encryption_Indicator* = 1 and *Content_Protection_Scheme* = 2 in the Frame Info Packet indicates that HDCP Encryption is enabled and the payload is encrypted for the video stream. Once encrypted content starts to flow, a periodic Link Synchronization is performed to maintain cipher synchronization between the HDCP Transmitter and the HDCP Receiver.

Audio Link Synchronization is achieved every time an audio control packet with the *audioStreamCtr* field and the *audioInputCtr* field is transmitted. Video Link Synchronization is achieved every time a Frame Info Packet with a *videoStreamCtr* field and a *videoInputCtr* field is transmitted. (See Section 3.3 for details about *audioStreamCtr*, *audioInputCtr*, *videoStreamCtr* and *videoInputCtr*.) The HDCP Receiver updates its *audioInputCtr* corresponding to the audio stream (as indicated by the *audioStreamCtr* value) with the *audioInputCtr* value received from the transmitter. And, the HDCP Receiver updates its *videoInputCtr* corresponding to the video stream (as indicated by the *videoStreamCtr* value) with the *videoInputCtr* value received from the transmitter.

2.7 Authentication Failures

On an authentication failure at the HDCP Transmitter during the authentication protocol, the protocol must be aborted, if HDCP Encryption is enabled, it must be immediately disabled. Authentication must be reattempted at least once by the top-level HDCP Transmitter by the transmission of a new r_{tx} as part of the AKE_Init message. An exception to this rule is in the case of authentication failure due to failure of SRM integrity check or if the *Receiver ID* of an connected downstream HDCP Device is in the revocation list. Authentication need not be reattempted in these cases. The HDCP Repeater initiates re-authentication on its downstream HDCP-protected interface ports only when it receives a re-authentication request i.e. a new r_{tx} value as part of the AKE_Init message, from upstream.

2.8 Key Derivation

Key derivation is illustrated in Figure 2.9.

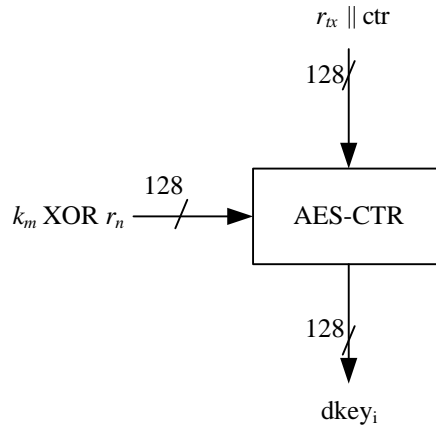


Figure 2.9. Key Derivation

r_{tx} and ctr are in big-endian order. ctr is a 64-bit counter and is initialized to 0 at the beginning of the HDCP Session i.e. after r_{tx} is sent or received. It is incremented by one after every derived key computation. $dkey_i$ is the 128-bit derived key when $ctr = i$. ctr must never be reused during an HDCP Session.

r_n is initialized to 0 during AKE i.e. during the generation of $dkey_0$ and $dkey_1$. It is set to a pseudo-random value during locality check as explained in Section 2.3. The pseudo-random r_n is XORed with the least-significant 64-bits of k_m during generation of $dkey_2$.

2.9 HDCP Transmitter State Diagram

As explained in Section 1.3, the HDCP Transmitter may support simultaneous connections to HDCP Receivers through one or more of its HDCP-protected interface ports. The HDCP Transmitter state diagram is implemented independently on each HDCP-protected interface port. The HDCP Transmitter can be considered to have two separate functions – a main HDCP Transmitter function and several HDCP Transmitter sub-functions. Each sub-function is associated with a specific HDCP-protected interface port on the transmitter and implements the HDCP Transmitter state diagram on the port. The main transmitter function ensures that the constraints on the HDCP System are met. This is explained further in Section 2.9.1.

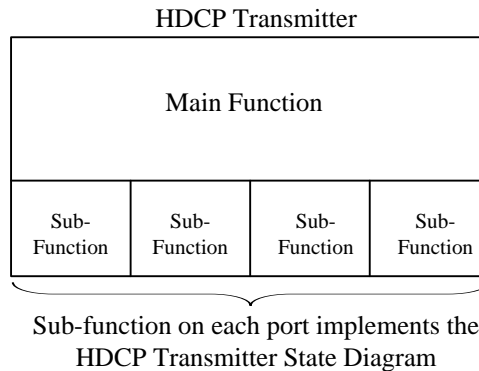
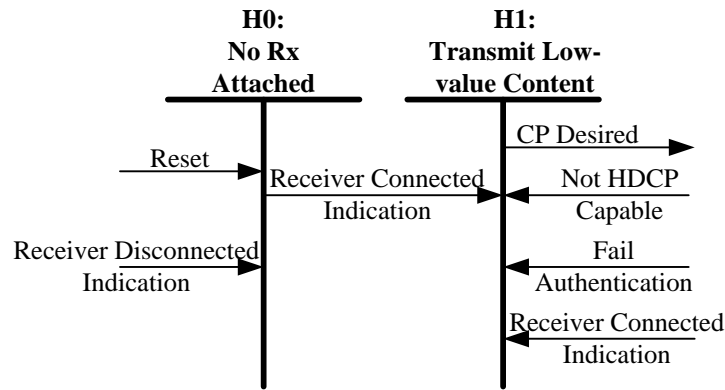


Figure 2.10. HDCP Transmitter Functions

The HDCP Transmitter Link State Diagram and HDCP Transmitter Authentication Protocol State Diagram (Figure 2.11 and Figure 2.12) illustrate the operation states of the authentication protocol for an HDCP Transmitter that is not an HDCP Repeater. For HDCP Repeaters, the downstream (HDCP Transmitter) side is covered in Section 2.11.2.

Transmitter's decision to begin authentication is dependent on events such as detection of an HDCP Receiver, availability of premium content or other implementation dependent details in the transmitter. In the event of authentication failure, an HDCP Receiver must be prepared to process subsequent authentication attempts. The HDCP Transmitter may cease to attempt authentication for transmitter-specific reasons, which include receiving a Receiver Disconnected Indication or after a certain number of authentication re-attempts by the transmitter.

The transmitter must not initiate authentication unless the setup and discovery procedure determines that the receiver is HDCP-capable. This procedure also indicates to the HDCP Transmitter the connect/disconnect status of the HDCP Receiver. For more information of the setup and discovery procedures, please refer to the DiiVA specification.



Note: Transition arrows with no connected state (e.g. Reset) indicate transitions that can occur from multiple states

Figure 2.11. HDCP Transmitter Link State Diagram

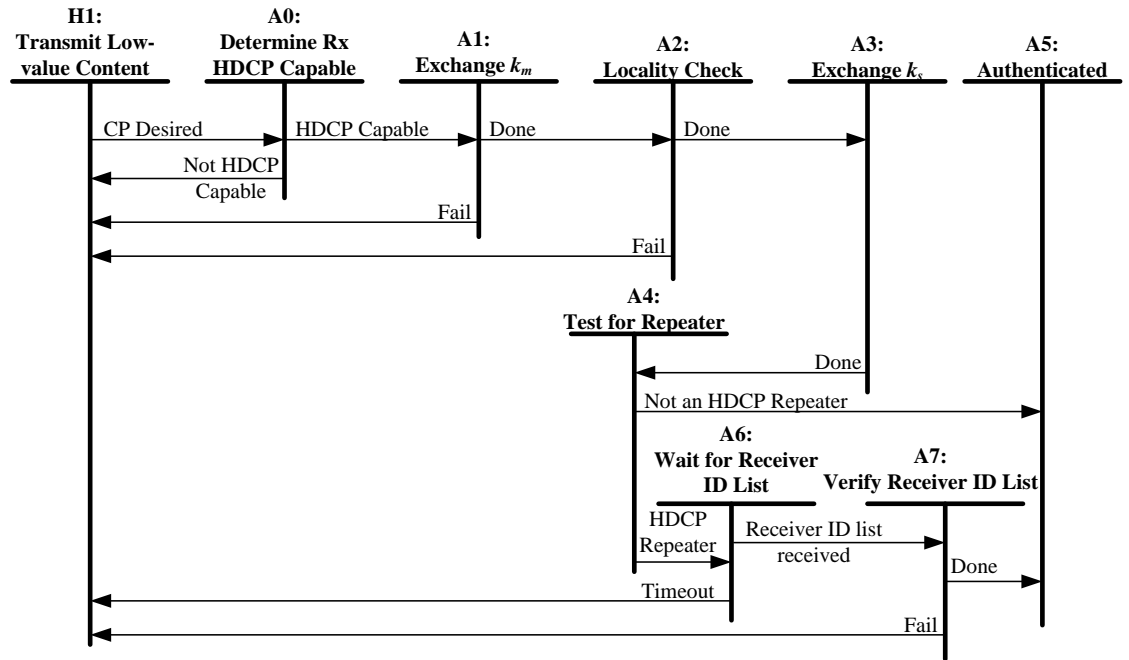


Figure 2.12. HDCP Transmitter Authentication Protocol State Diagram

Transition Any State:H0. Reset conditions at the HDCP Transmitter or disconnect of all HDCP capable receivers cause the HDCP Transmitter to enter the No Receiver Attached state.

Transition H0:H1. The detection of a sink device (through Receiver Connected Indication) indicates to the transmitter that a sink device is connected and ready to display the received content. When the receiver is no longer active, the transmitter is notified through Receiver Disconnected Indication.

State H1: Transmit Low-value Content. In this state the transmitter should begin sending an unencrypted signal with HDCP Encryption disabled. The transmitted signal can be a low value content or informative on-screen display. This will ensure that a valid video signal is displayed to the user before and during authentication. At any time a Receiver Connected Indication received from the connected HDCP Repeater causes the transmitter to transition in to this state.

Transition H1:A0. If content protection is desired by the Upstream Content Control Function, then the HDCP Transmitter should immediately attempt to determine whether the receiver is HDCP capable.

State A0: Determine Rx HDCP Capable. The transmitter determines that the receiver is HDCP capable through the DiiVA device setup and discovery procedures. Since state A0 is reached when content protection is desired by the Upstream Content Control Function, authentication must be started immediately by the transmitter if the receiver is HDCP capable. A valid video screen is displayed to the user with encryption disabled during this time.

Transition A0:H1. If the receiver is not HDCP capable, the transmitter continues to transmit low value content or informative on-screen display.

Transition A0:A1. If the receiver is HDCP capable, the transmitter initiates the authentication protocol.

State A1: Exchange k_m . In this state, the HDCP Transmitter initiates authentication by sending AKE_Init message containing r_{tx} to the HDCP Receiver. It receives AKE_Send_Cert from the receiver containing REPEATER and $cert_{rx}$.

If the HDCP Transmitter does not have k_m stored corresponding to the *Receiver ID*, it generates $E_{k_{pub}}(km)$ and sends $E_{k_{pub}}(km)$ as part of the AKE_No_Stored_km message to the receiver after verification of signature on $cert_{rx}$. It performs integrity check on the SRM and checks to see whether the *Receiver ID* of the connected HDCP Device is in the revocation list. It receives AKE_Send_rrx message containing r_{rx} from the receiver. It computes H, receives AKE_Send_H_prime message from the receiver containing H' within one second after sending AKE_No_Stored_km to the receiver and compares H' against H.

If the HDCP Transmitter has k_m stored corresponding to the *Receiver ID*, it sends AKE_Stored_km message containing $E_{kh}(k_m)$ and m to the receiver, performs integrity check on the SRM, checks to see whether the *Receiver ID* of the connected HDCP Device is in the revocation list and receives r_{rx} as part of AKE_Send_rrx message from the receiver. It computes H, receives AKE_Send_H_prime message from the receiver containing H' within 200 ms after sending AKE_Stored_km to the receiver and compares H' against H.

If the HDCP Transmitter does not have a k_m stored corresponding to the *Receiver ID*, it implements pairing with the HDCP Receiver as explained in Section 2.2.1.

Transition A1:H1. This transition occurs on failure of signature verification on $cert_{rx}$, failure of SRM integrity check, if *Receiver ID* of the connected HDCP Device is in the revocation list or if there is a mismatch between H and H' . This transition also occurs if AKE_Send_H_prime message is not received within one second after sending AKE_No_Stored_km or within 200 ms after sending AKE_Stored_km to the receiver.

Transition A1:A2. The HDCP Transmitter implements locality check after successful completion of AKE and pairing.

State A2: Locality Check. In this state, the HDCP Transmitter initiates locality check by sending LC_Init message containing r_n to the HDCP Receiver, computes L, sends RTT_Challenge message and sets its watchdog timer to 3 ms. On receiving RTT_Response message from the receiver, it compares the 128-bit value received in the RTT_Response message with the most significant 128-bits of L.

Transition A2:H1. This transition occurs on 1024 consecutive locality check failures due to expiration of the watchdog timer at the HDCP Transmitter. A locality check failure due to mismatch of the value contained in the RTT_Response message and the most significant 128-bits of L also causes this transition.

Transition A2:A3. The HDCP Transmitter implements SKE after successful completion of locality check.

State A3: Exchange k_s . The HDCP Transmitter sends encrypted session key, $E_{dkey}(k_s)$, and r_{iv} to the HDCP Receiver as part of the SKE_Send_Eks message. It enables HDCP Encryption 200 ms after sending encrypted session key. HDCP Encryption must be enabled only after successful completion of AKE, locality check and SKE stages.

Transition A3:A4. This transition occurs after completion of SKE.

State A4: Test for Repeater. The HDCP Transmitter evaluates the REPEATER value that was received in State A1.

Transition A4:A5. REPEATER is 'false' (the HDCP Receiver is not an HDCP Repeater).

State A5: Authenticated. At this time, and at no prior time, the HDCP Transmitter has completed the authentication protocol.

A periodic Link Synchronization is performed to maintain cipher synchronization between the HDCP Transmitter and the HDCP Receiver.

Transition A4:A6. REPEATER is 'true' (the HDCP Receiver is an HDCP Repeater).

State A6: Wait for Receiver ID List. The HDCP Transmitter sets up a three-second watchdog timer after sending SKE_Send_Eks.

Transition A6:H1. The watchdog timer expires before the RepeaterAuth_Send_ReceiverID_List is received.

Transition A6:A7. RepeaterAuth_Send_ReceiverID_List message is received.

State A7: Verify Receiver ID List. The watchdog timer is cleared. If both MAX_DEVS_EXCEEDED and MAX_CASCADE_EXCEEDED are not 'true', computes V , and verifies $V == V'$. The *Receiver IDs* from the Receiver ID list are compared against the current revocation list.

Transition A7:H1. This transition is made if $V != V'$ or if any of the *Receiver IDs* in the Receiver ID list are found in the current revocation list. A MAX_CASCADE_EXCEEDED or MAX_DEVS_EXCEEDED error also causes this transition.

Transition A7:A5. This transition occurs if $V == V'$, none of the reported *Receiver IDs* are in the current revocation list, and the downstream topology does not exceed specified maximums.

Note: Since authentication with repeaters is implemented in parallel with the flow of encrypted content and Link Synchronization, the link synchronization process (i.e. State A5) must be implemented asynchronously from the rest of the state diagram. The transition into State A5 must occur from any state for which encryption is currently enabled. Also, the transition from state A5 returns to the appropriate state to allow for undisrupted operation.

The HDCP Transmitter may support simultaneous connections to HDCP Receivers through one or more of its HDCP-protected interface ports. It may share the same session key and r_{iv} across all its HDCP-protected interface ports, as explained in Section 3.6. However, the HDCP Transmitter must ensure that each connected HDCP Receiver receives distinct k_m and r_{tx} values.

2.9.1 Main HDCP Transmitter Function

The HDCP System places the following constraints on the number of HDCP Devices and levels of HDCP Repeaters in the topology.

1. Up to four levels of HDCP Repeaters and as many as 32 total HDCP Devices, including HDCP Repeaters, are allowed to be connected to an HDCP-protected Interface port; and
2. An instance of an Upstream Content Control Function transmits a content stream to the HDCP Transmitter. For every such content stream received and encrypted by the HDCP System, the HDCP Transmitter is allowed to transmit the generated HDCP Content stream to up to four levels of HDCP Repeaters and as many as 32 total HDCP Devices, including HDCP Repeaters.

The first constraint is met by implementing the authentication protocol independently on each HDCP-protected interface port and verifying that the DEPTH and DEVICE_COUNT read from the connected repeater are less than or equal to 4 and 31 respectively (HDCP Transmitter sub-function). To meet the second constraint, the HDCP Transmitter (that is not an HDCP Repeater) performs an additional step after all its HDCP-protected interface ports have reached the terminal states of the authentication protocol i.e. State H0 (unconnected), State H1 (inactive or unauthenticated) and State A5 (authenticated). This is the main HDCP Transmitter function. For each of its HDCP-protected interface ports connected to an HDCP Repeater or HDCP Receiver that have reached the authenticated state, State A5 and that will transmit the content stream received from a specific instance of the Upstream Content Control Function, the HDCP Transmitter computes the total number of HDCP Devices connected to each HDCP-protected interface port by incrementing the DEVICE_COUNT on those ports by one (to account for the connected HDCP Repeater or HDCP Receiver), where the transmitter sets the DEVICE_COUNT to 0 on a port with a connected HDCP Receiver that is not an HDCP Repeater.

Total_Port_Device_Count = DEVICE_COUNT + 1, where DEVICE_COUNT = 0 on a port with a connected HDCP Receiver that is not an HDCP Repeater

It then computes the total number of HDCP Devices connected to the HDCP Transmitter as follows

Total_Transmitter_Device_Count = Total_Port_Device_Count₁ + + Total_Port_Device_Count_n, where n is the total number of HDCP-protected interface ports on the transmitter.

If the computed Total_Transmitter_Device_Count exceeds 32, the top-level HDCP Transmitter disables encryption and aborts the HDCP Session on all its HDCP-protected interface ports. The state diagram (Figure 2.13) and the description below relates to the main HDCP Transmitter function.

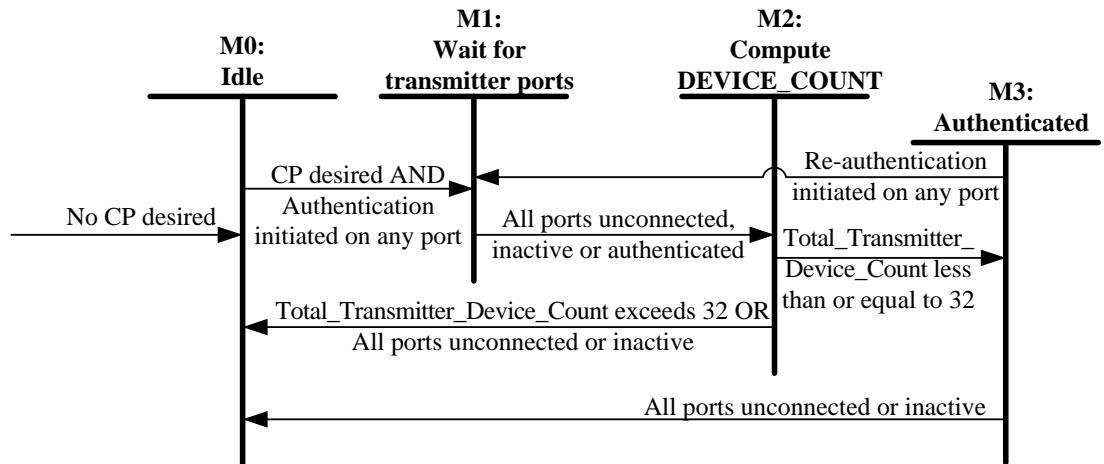


Figure 2.13. Main HDCP Transmitter Function State Diagram

Transition Any State:M0. The HDCP Transmitter transitions in to the Idle state when content protection is not desired by the Upstream Content Control Function.

Transition M0:M1. The transition occurs when content protection is desired by the Upstream Content Control Function and authentication has been initiated by the HDCP Transmitter on any of its HDCP-protected Interface ports by transmission of an AKE_Init message.

State M1: Wait for transmitter ports. In this state the transmitter waits for all its HDCP-protected interface ports to transition to the unconnected (State H0), inactive (State H1) or authenticated state (State A5).

Transition M1:M2. This transition occurs when all ports have transitioned to the unconnected, inactive or authenticated states.

State M2: Compute DEVICE_COUNT. The HDCP Transmitter computes the total number of HDCP Devices connected to it i.e. the Total_Transmitter_Device_Count.

Transition M2:M0. This transition occurs if the computed Total_Transmitter_Device_Count exceeds 32 or all transmitter ports have transitioned to unconnected or inactive state.

Transition M2:M3. This transition occurs if the computed Total_Transmitter_Device_Count for the HDCP Transmitter is less than or equal to 32.

State M3: Authenticated. At this time, and at no time prior, the HDCP Transmitter makes available to the Upstream Content Control Function upon request, information that indicates that the HDCP System is fully engaged and able to deliver HDCP Content, which means (a) HDCP Encryption is operational on each downstream HDCP-protected Interface Port connected to an HDCP Receiver, (b) processing of valid received SRMs, if any, has occurred, as defined in this Specification, and (c) there are no HDCP Receivers on HDCP-protected Interface Ports, or downstream, with *Receiver IDs* in the current revocation list.

Transition M3:M1. This transition occurs when re-authentication has been initiated by the HDCP Transmitter on any of its HDCP-protected Interface ports by transmission of an AKE_Init message.

2.10 HDCP Receiver State Diagram

The operation states of the authentication protocol for an HDCP Receiver that is not an HDCP Repeater are illustrated in Figure 2.14. For HDCP Repeaters, the upstream (HDCP Receiver) side is covered in Section 2.11.3.

The HDCP Receiver must be ready to re-authenticate with the HDCP Transmitter at any point in time. In particular, the only indication to the HDCP Receiver of a re-authentication attempt by the HDCP Transmitter is the reception of an r_{tx} as part of the AKE_Init message from the HDCP Transmitter.

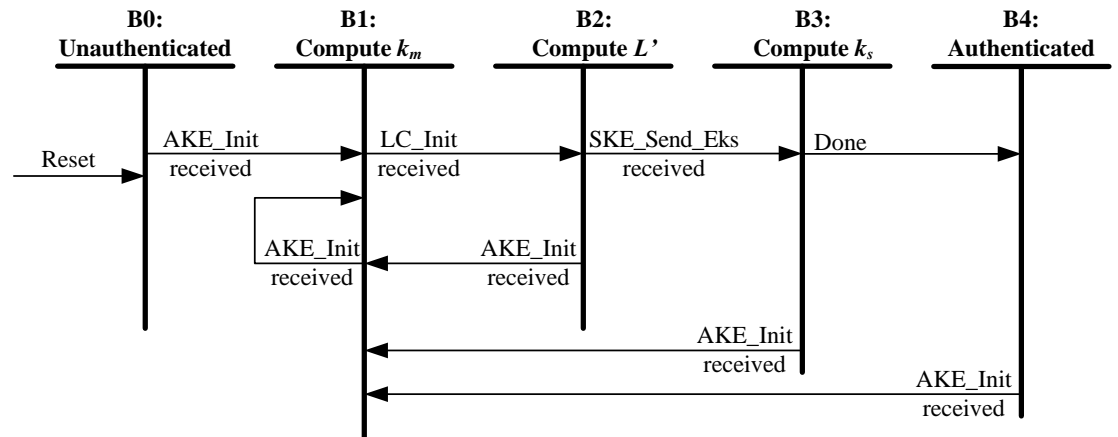


Figure 2.14. HDCP Receiver Authentication Protocol State Diagram

Transition Any State:B0. Reset conditions at the HDCP Receiver cause the HDCP Receiver to enter the unauthenticated state.

State B0: Unauthenticated. The HDCP Receiver is awaiting the reception of r_{tx} from the HDCP Transmitter to trigger the authentication protocol.

Transition B0:B1. r_{tx} is received as part of the AKE_Init message from the HDCP Transmitter.

State B1: Compute k_m . In this state, the HDCP Receiver sends AKE_Send_Cert message in response to AKE_Init, generates and sends r_{rx} as part of AKE_Send_rrx message. If AKE_No_Stored_km is received, it decrypts k_m with $k_{priv_{rx}}$, calculates H' . It sends AKE_Send_H_prime message immediately after computation of H' to ensure that the message is received by the transmitter within the specified one second timeout at the transmitter

If AKE_Stored_km is received, the HDCP Receiver decrypts $E_{k_{ih}}(k_m)$ to derive k_m and calculates H' . It sends AKE_Send_H_prime message immediately after computation of H' to ensure that the message is received by the transmitter within the specified 200 ms timeout at the transmitter

If AKE_No_Stored_km is received, this is an indication to the HDCP Receiver that the HDCP Transmitter does not contain a k_m stored corresponding to its *Receiver ID*. It implements pairing with the HDCP Transmitter as explained in Section 2.2.1.

Transition B1: B1. Should the HDCP Transmitter send an AKE_Init while the HDCP Receiver is in State B1, the HDCP Receiver abandons intermediate results and restarts computation of k_m .

Transition B1: B2. The transition occurs when r_n is received as part of LC_Init message from the transmitter.

State B2: Compute L' . The HDCP Receiver computes L' required during locality check and sends RTT_Response message after receiving the RTT_Challenge message from the transmitter.

Transition B2: B1. Should the HDCP Transmitter send an AKE_Init while the HDCP Receiver is in State B2, the HDCP Receiver abandons intermediate results and restarts computation of k_m .

Transition B2: B3. The transition occurs when SKE_Send_Eks message is received from the transmitter.

State B3: Compute k_s . The HDCP Receiver decrypts $E_{dkey}(k_s)$ to derive k_s .

Transition B3: B1. Should the HDCP Transmitter send an AKE_Init while the HDCP Receiver is in State B3, the HDCP Receiver abandons intermediate results and restarts computation of k_m .

Transition B3: B4. Successful computation of k_s transitions the receiver into the authenticated state.

State B4: Authenticated. The HDCP Receiver has completed the authentication protocol. Periodically, it updates its *audioInputCtr* (or *videoInputCtr*) corresponding to the audio stream indicated by the *audioStreamCtr* value (or the video stream indicated by *videoStreamCtr* value), with the *audioInputCtr* (or *videoInputCtr*) value received from the transmitter.

Transition B4: B1. Should the HDCP Transmitter send an AKE_Init while the HDCP Receiver is in State B4, the HDCP Receiver abandons intermediate results and restarts computation of k_m .

2.11 HDCP Repeater State Diagrams

The HDCP Repeater has one HDCP-protected Interface connection to an upstream HDCP Transmitter and one or more HDCP-protected Interface connections to downstream HDCP Receivers. The state diagram for each downstream connection (Figure 2.16 and Figure 2.17) is substantially the same as that for the host HDCP Transmitter (Section 2.9), with two exceptions.

First, the HDCP Repeater is not required to check for downstream Receiver IDs in a revocation list. Second, the HDCP Repeater initiates authentication downstream when it receives an authentication request from upstream, rather than at detection of an HDCP Receiver on the downstream HDCP-protected Interface Port.

The HDCP Repeater signals the detection of an active downstream HDCP Receiver to the upstream HDCP Transmitter by propagating the Receiver Connected Indication to the upstream HDCP Transmitter. Whenever authentication is initiated by the upstream HDCP Transmitter by sending AKE_Init, the HDCP Repeater immediately initiates authentication on all its downstream HDCP-protected interface ports. Similarly, when re-authentication is attempted by the upstream transmitter by sending a new r_{ix} , the HDCP Repeater immediately initiates re-authentication on all its downstream ports.

The HDCP Repeater must generate unique k_m values for HDCP Devices connected to each of its downstream HDCP-protected interface ports.

If an HDCP Repeater has no active downstream HDCP devices, it must authenticate as an HDCP Receiver with REPEATER set to 'false' if it wishes to receive HDCP Content, but must not pass HDCP Content to downstream devices.

2.11.1 Propagation of Topology Errors and Receiver Connected / Disconnected Indication

MAX_DEVS_EXCEEDED and MAX_CASCADE_EXCEEDED: HDCP Repeaters must be capable of supporting DEVICE_COUNT values less than or equal to 31 and DEPTH values less than or equal to 4. If the computed DEVICE_COUNT for an HDCP Repeater exceeds 31, the error is referred to as MAX_DEVS_EXCEEDED error. The repeater sets MAX_DEVS_EXCEEDED = 'true' in the RepeaterAuth_Send_ReceiverID_List message. If the computed DEPTH for an HDCP Repeater exceeds four, the error is referred to as MAX_CASCADE_EXCEEDED error. The repeater sets MAX_CASCADE_EXCEEDED = 'true' in the RepeaterAuth_Send_ReceiverID_List message. When an HDCP Repeater receives a MAX_DEVS_EXCEEDED or a MAX_CASCADE_EXCEEDED error from a downstream HDCP Repeater, it must propagate the error to the upstream HDCP Transmitter and must not transmit V' and Receiver ID list.

Receiver Disconnected Indication. When an authenticated HDCP Receiver connected to the downstream HDCP Repeater connection is disconnected, the resulting Receiver Disconnected Indication must not be propagated by the repeater to the upstream HDCP Transmitter when HDCP Content is flowing. The disconnected indication must be propagated to the upstream HDCP Transmitter once the flow of HDCP Content stops or if there are no more authenticated HDCP Receivers connected to the HDCP Repeater.

Receiver Connected Indication when HDCP Receiver is Re-connected. When an authenticated HDCP Receiver is disconnected and reconnected to the downstream port of the HDCP Repeater i.e. the downstream port of the repeater detects the same Receiver ID, and there were no intervening re-authentication requests from the upstream HDCP Transmitter during the time the HDCP Receiver was disconnected, the HDCP Repeater need not propagate the Receiver Connected Indication to the upstream HDCP Transmitter. The HDCP Repeater may initiate authentication, complete the authentication protocol with the connected HDCP Receiver and enable HDCP Encryption.

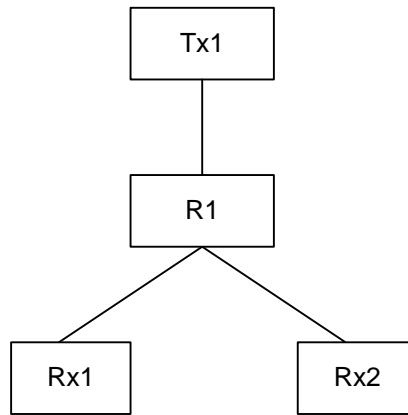
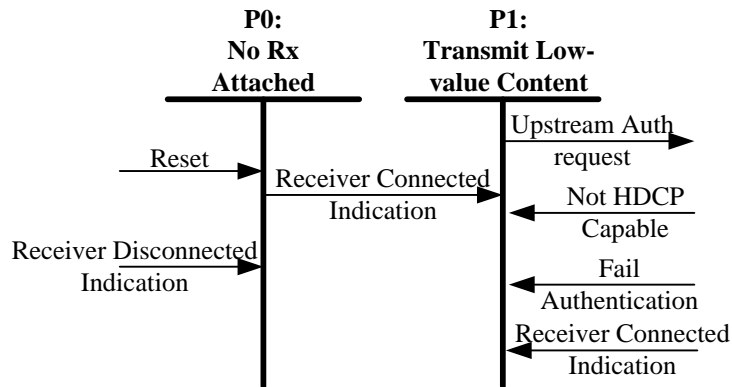


Figure 2.15. HDCP Repeater Reconnect

In Figure 2.15, Rx1 and Rx2 are authenticated HDCP Receivers connected to HDCP Repeater R1. When Rx2 is disconnected and reconnected and there were no intervening re-authentication requests from Tx1, R1 may authenticate Rx2 without propagating the Receiver Connected Indication to Tx1.

2.11.2 HDCP Repeater Downstream State Diagram

In this state diagram and its following description, the downstream (HDCP Transmitter) side refers to the HDCP Transmitter functionality within the HDCP Repeater for its corresponding downstream HDCP-protected Interface Port.



Note: Transition arrows with no connected state (e.g. Reset) indicate transitions that can occur from multiple states

Figure 2.16. HDCP Repeater Downstream Link State Diagram

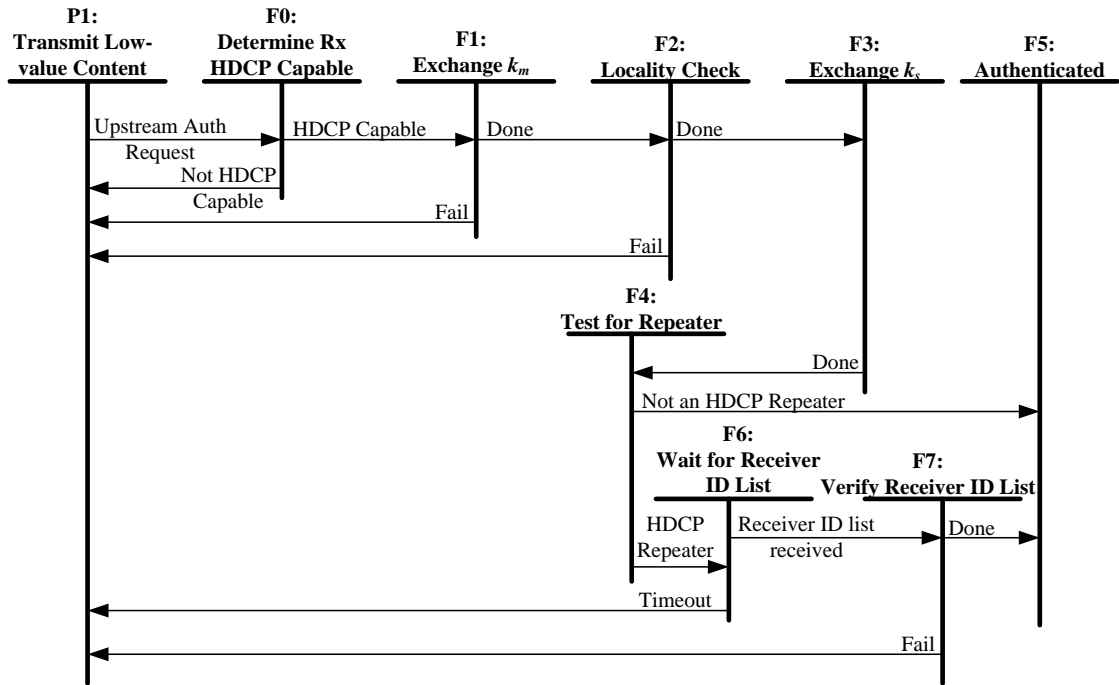


Figure 2.17. HDCP Repeater Downstream Authentication Protocol State Diagram

Transition Any State:P0. Reset conditions at the HDCP Repeater or disconnect of all HDCP capable receivers cause the HDCP Repeater to enter the No Receiver Attached state. A Receiver Disconnected Indication received from the connected downstream HDCP Repeater also causes this transition.

Transition P0:P1. The detection of a sink device (through Receiver Connected Indication) indicates that the receiver is available and active (ready to display received content). When the receiver is no longer active, the downstream (HDCP Transmitter) side is notified through Receiver Disconnected Indication.

State P1: Transmit low-value content. In this state the downstream side should begin sending the unencrypted video signal received from the upstream HDCP Transmitter with HDCP Encryption disabled. At any time a Receiver Connected Indication received from the connected HDCP Repeater causes the downstream side to transition in to this state. From this state, the downstream side initiates authentication only when an Upstream Authentication Request is received i.e. the upstream side receives AKE_Init from the upstream HDCP Transmitter.

Note: As explained in Section 2.11.1, if a previously authenticated HDCP Receiver is re-connected and there were no intervening re-authentication requests from the upstream HDCP Transmitter during the time the HDCP Receiver was disconnected, the downstream side may initiate authentication with the HDCP Receiver without waiting for an Upstream Authentication Request.

Transition P1:F0. Upon an Upstream Authentication Request, the downstream side should immediately attempt to determine whether the receiver is HDCP capable.

State F0: Determine Rx HDCP Capable. The downstream side determines that the receiver is HDCP-capable through the DiiVA device setup and discovery procedures. Since state F0 is reached upon an Upstream Authentication Request, authentication must be started immediately by

the downstream side if the receiver is HDCP capable. A valid video screen is displayed to the user with encryption disabled during this time.

Transition F0:P1. If the receiver is not HDCP capable, the downstream side continues to transmit low value content or informative on-screen display received from the upstream HDCP Transmitter.

Transition F0:F1. If the receiver is HDCP capable, the downstream side initiates the authentication protocol.

State F1: Exchange k_m . In this state, the downstream side initiates authentication by sending AKE_Init message containing r_{tx} to the HDCP Receiver. It receives AKE_Send_Cert from the receiver containing REPEATER and $cert_{rx}$.

If the downstream side does not have k_m stored corresponding to the *Receiver ID*, it generates $E_{k_{pub}}(k_m)$ and sends $E_{k_{pub}}(k_m)$ as part of the AKE_No_Stored_km message to the receiver after verification of signature on $cert_{rx}$. It receives AKE_Send_rrx message containing r_{rx} from the receiver. It computes H, receives AKE_Send_H_prime message from the receiver containing H' within one second after sending AKE_No_Stored_km to the receiver and compares H' against H.

If the downstream side has k_m stored corresponding to the *Receiver ID*, it sends AKE_Stored_km message containing $E_{k_h}(k_m)$ and m to the receiver and receives r_{rx} as part of AKE_Send_rrx message from the receiver. It computes H, receives AKE_Send_H_prime message from the receiver containing H' within 200 ms after sending AKE_Stored_km to the receiver and compares H' against H.

If the downstream side does not have a k_m stored corresponding to the *Receiver ID*, it implements pairing with the HDCP Receiver as explained in Section 2.2.1.

Transition F1:P1. This transition occurs on failure of signature verification on $cert_{rx}$ or if there is a mismatch between H and H' . This transition also occurs if AKE_Send_H_prime message is not received within one second after sending AKE_No_Stored_km or within 200 ms after sending AKE_Stored_km to the receiver.

Transition F1:F2. The downstream side implements locality check after successful completion of AKE and pairing.

State F2: Locality Check. In this state, the downstream side initiates locality check by sending LC_Init message containing r_n to the HDCP Receiver, computes L, sends RTT_Challenge message and sets its watchdog timer to 3 ms. On receiving RTT_Response message from the receiver, it compares the 128-bit value received in the RTT_Response message with the most significant 128-bits of L.

Transition F2:P1. This transition occurs on 1024 consecutive locality check failures due to expiration of the watchdog timer at the downstream side. A locality check failure due to mismatch of the value contained in the RTT_Response message and the most significant 128-bits of L also causes this transition.

Transition F2:F3. The downstream side implements SKE after successful completion of locality check.

State F3: Exchange k_s . The downstream side sends encrypted session key, $E_{dkey}(k_s)$, and r_{iv} to the HDCP Receiver as part of the SKE_Send_Eks message. It enables HDCP Encryption 200 ms after sending encrypted session key. HDCP Encryption must be enabled only after successful completion of AKE, locality check and SKE stages.

Transition F3:F4. This transition occurs after completion of SKE.

State F4: Test for Repeater. The downstream side evaluates the REPEATER value that was received in State F1.

Transition F4:F5. REPEATER is 'false' (the HDCP Receiver is not an HDCP Repeater).

State F5: Authenticated. At this time, and at no prior time, the downstream side has completed the authentication protocol and is fully operational, able to deliver HDCP Content.

A periodic Link Synchronization is performed to maintain cipher synchronization between the downstream side and the HDCP Receiver.

Transition F4:F6. REPEATER is 'true' (the HDCP Receiver is an HDCP Repeater).

State F6: Wait for Receiver ID List. The downstream side sets up a three-second watchdog timer after sending SKE_Send_Eks.

Transition F6:P1. The watchdog timer expires before the RepeaterAuth_Send_ReceiverID_List is received.

Transition F6:F7. RepeaterAuth_Send_ReceiverID_List message is received.

State F7: Verify Receiver ID List. The watchdog timer is cleared. If both MAX_DEVS_EXCEEDED and MAX_CASCADE_EXCEEDED are not 'true', computes V , and verifies $V == V'$. The *Receiver IDs* from this port are added to the Receiver ID list for this HDCP Repeater. The upstream HDCP Transmitter must be informed if topology maximums are exceeded

Transition F7:P1. This transition is made if $V != V'$. A MAX_CASCADE_EXCEEDED or MAX_DEVS_EXCEEDED error also causes this transition.

Transition F7:F5. This transition is made if $V == V'$, the downstream topology does not exceed specified maximums.

Note: Since authentication with repeaters is implemented in parallel with the flow of encrypted content and Link Synchronization, the link synchronization process (i.e. State F5) must be implemented asynchronously from the rest of the state diagram. The transition into State F5 must occur from any state for which encryption is currently enabled. Also, the transition from state F5 returns to the appropriate state to allow for uninterrupted operation.

2.11.3 HDCP Repeater Upstream State Diagram

The HDCP Repeater upstream state diagram, illustrated in Figure 2.18, makes reference to states of the HDCP Repeater downstream state diagram. In this state diagram and its following description, the upstream (HDCP Receiver) side refers to the HDCP Receiver functionality within the HDCP Repeater for its corresponding upstream HDCP-protected Interface Port.

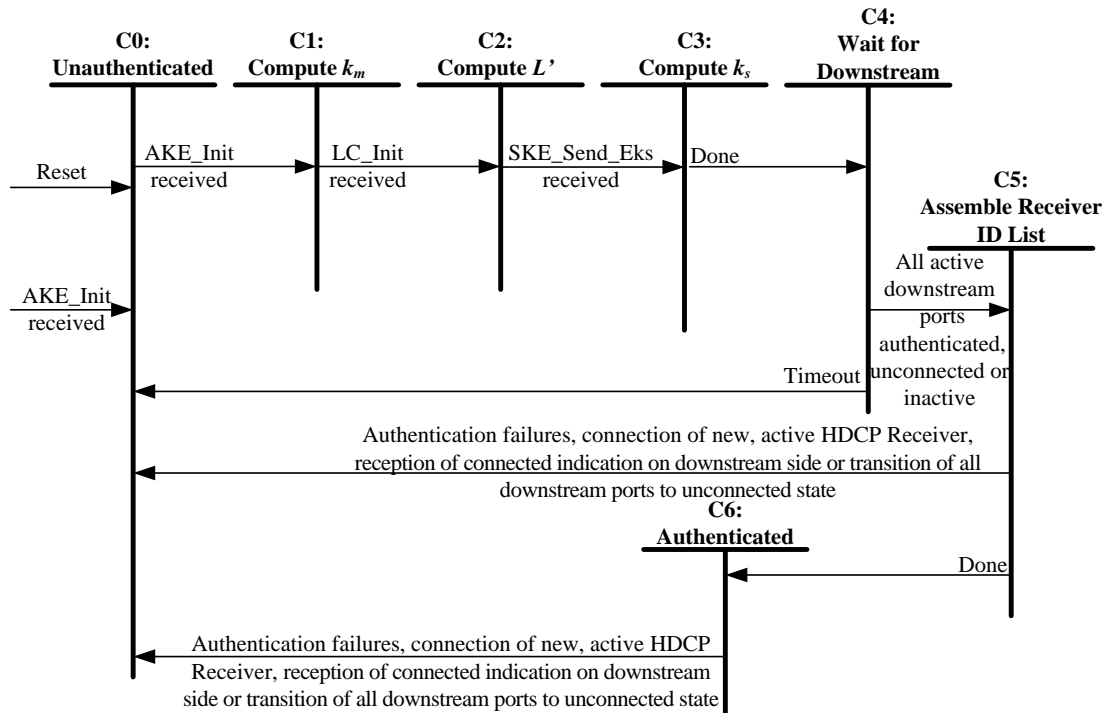


Figure 2.18. HDCP Repeater Upstream Authentication Protocol State Diagram

Transitions Any State:C0. Reset conditions at the HDCP Repeater cause the HDCP Repeater to enter the unauthenticated state. Re-authentication is forced any time AKE_Init is received from the connected HDCP Transmitter, with a transition through the unauthenticated state.

State C0: Unauthenticated. The device is idle, awaiting the reception of r_{tx} from the HDCP Transmitter to trigger the authentication protocol.

When the upstream side becomes unauthenticated due to any downstream HDCP-protected interface port transitioning to the unauthenticated state as a result of authentication failures, connection of a new, active HDCP Receiver on any downstream HDCP-protected interface port that previously did not have an active HDCP Receiver connected or reception of a Receiver Connected Indication on the downstream side from the connected HDCP Repeater, it propagates the Receiver Connected Indication to the upstream HDCP Transmitter. Authentication failures are indicated by Transition F1:P1, Transition F2:P1, Transition F6:P1 and Transition F7:P1.

If a previously authenticated HDCP Receiver connected to the downstream HDCP-protected interface port is re-connected and there were no intervening re-authentication requests from the upstream HDCP Transmitter during the time the HDCP Receiver was disconnected, the upstream side need not transition to the unauthenticated state. The downstream side may authenticate the connected HDCP Receiver, as explained in Section 2.11.1.

When all downstream HDCP-protected interface ports transition to the unconnected state, the upstream becomes unauthenticated and propagates the resulting Receiver Disconnected Indication to the upstream HDCP Transmitter.

Transition C0:C1. r_{tx} is received as part of the AKE_Init message from the HDCP Transmitter.

State C1: Compute k_m . In this state, the upstream (HDCP Receiver) side sends AKE_Send_Cert message in response to AKE_Init, generates and sends r_{rx} as part of AKE_Send_rrx message. If

AKE_No_Stored_km is received, it decrypts k_m with $k_{priv_{rx}}$, calculates H' . It sends AKE_Send_H_prime immediately after computation of H' to ensure that the message is received by the transmitter within the specified one second timeout at the transmitter

If AKE_Stored_km is received, the upstream side decrypts $E_{k_h}(k_m)$ to derive k_m and calculates H' . It sends AKE_Send_H_prime message immediately after computation of H' to ensure that the message is received by the transmitter within the specified 200 ms timeout at the transmitter

If AKE_No_Stored_km is received, this is an indication to the upstream side that the HDCP Transmitter does not contain a k_m stored corresponding to its *Receiver ID*. It implements pairing with the HDCP Transmitter as explained in Section 2.2.1.

Transition C1:C2. The transition occurs when r_n is received as part of LC_Init message from the transmitter.

State C2: Compute L' . The upstream side computes L' required during locality check and sends RTT_Response message after receiving the RTT_Challenge message from the transmitter.

Transition C2: C3. The transition occurs when SKE_Send_Eks message is received from the transmitter.

State C3: Compute k_s . The upstream side decrypts $E_{dkey}(k_s)$ to derive k_s .

Transition C3: C4. Successful computation of k_s causes this transition.

State C4: Wait for Downstream. The upstream state machine waits for all downstream HDCP-protected Interface Ports of the HDCP Repeater to enter the unconnected (State P0), inactive or unauthenticated (State P1), or the authenticated state (State F5).

Transition C4:C0. The watchdog timer expires before all downstream HDCP-protected Interface Ports enter the authenticated, unconnected or inactive state.

Transition C4:C5. All downstream HDCP-protected Interface Ports with connected HDCP Receivers have reached the state of authenticated, unconnected or inactive state.

State C5: Assemble Receiver ID List. The upstream side assembles the list of all connected downstream topology HDCP Devices as the downstream HDCP-protected Interface Ports reach terminal states of the authentication protocol. An HDCP-protected Interface Port that advances to State P0, the unconnected state, or P1, the inactive state, does not add to the list. A downstream HDCP-protected Interface Port that arrives in State F5 that has an HDCP Receiver that is not an HDCP Repeater connected, adds the *Receiver ID* of the connected HDCP Receiver to the list. Downstream HDCP-protected Interface Ports that arrive in State F5 that have an HDCP Repeater connected will cause the Receiver ID list read from the connected HDCP Repeater, plus the *Receiver ID* of the connected HDCP Repeater itself, to be added to the list.

When the Receiver ID list for all downstream HDCP Receivers has been assembled, the upstream side computes DEPTH, DEVICE_COUNT and the upstream V' and sends RepeaterAuth_Send_ReceiverID_List message to the upstream HDCP Transmitter. In the case of a MAX_DEVS_EXCEEDED or a MAX_CASCADE_EXCEEDED error, it does not transmit V' and Receiver ID list. When an HDCP Repeater receives a MAX_DEVS_EXCEEDED or MAX_CASCADE_EXCEEDED error from a downstream HDCP Repeater, it is required to inform the upstream HDCP Transmitter.

Transition C5:C0. All authentication failures on the downstream side, connection of a new, active HDCP Receiver on the downstream HDCP-protected interface port that previously did not have an

active downstream HDCP Receiver connected, reception of a Receiver Connected Indication on the downstream side from the connected HDCP Repeater or transition of all downstream ports to the unconnected state cause this transition. This transition also occurs when topology maximums are exceeded. Authentication failures are indicated by Transition F1:P1, Transition F2:P1, Transition F6:P1 and Transition F7:P1.

If a previously authenticated HDCP Receiver connected to the downstream HDCP-protected interface port is re-connected and there were no intervening re-authentication requests from the upstream HDCP Transmitter during the time the HDCP Receiver was disconnected, the upstream side need not transition to the unauthenticated state. The downstream side may authenticate the connected HDCP Receiver, as explained in Section 2.11.1.

Transition C5:C6. RepeaterAuth_Send_ReceiverID_List message has been sent to the upstream HDCP Transmitter and topology maximums are not exceeded.

State C6: Authenticated. The upstream side has completed the authentication protocol. Periodically, it updates its *audioInputCtr* (or *videoInputCtr*) corresponding to the audio stream indicated by the *audioStreamCtr* value (or the video stream indicated by *videoStreamCtr* value), with the *audioInputCtr* (or *videoInputCtr*) value received from the transmitter.

Transition C6:C0. All authentication failures on the downstream side, connection of a new, active HDCP Receiver on the downstream HDCP-protected interface port that previously did not have an active downstream HDCP Receiver connected, reception of a Receiver Connected Indication on the downstream side from the connected HDCP Repeater or transition of all downstream ports to the unconnected state cause this transition. Authentication failures are indicated by Transition F1:P1, Transition F2:P1, Transition F6:P1 and Transition F7:P1.

If a previously authenticated HDCP Receiver connected to the downstream HDCP-protected interface port is re-connected and there were no intervening re-authentication requests from the upstream HDCP Transmitter during the time the HDCP Receiver was disconnected, the upstream side need not transition to the unauthenticated state. The downstream side may authenticate the connected HDCP Receiver, as explained in Section 2.11.1.

Note: Since authentication with repeaters is implemented in parallel with the flow of encrypted content and Link Synchronization, the link synchronization process (i.e. State C6) must be implemented asynchronously from the rest of the state diagram. The transition into State C6 must occur from any state for which encryption is currently enabled. Also, the transition from state C6 returns to the appropriate state to allow for uninterrupted operation.

2.12 Converters

2.12.1 HDCP 2 – HDCP 1.x Converters

HDCP 2 – HDCP 1.x converters are HDCP Repeaters with an HDCP 2 compliant interface port on the upstream (HDCP Receiver) side and one or more HDCP 1.x compliant interface ports on the downstream (HDCP Transmitter) side.

The HDCP 1.x compliant downstream side implements the state diagram explained in the corresponding HDCP 1.x specification (See Section 1.5).

Note: Locality check is not implemented in the downstream HDCP-protected interface ports.

The HDCP 2 compliant upstream side implements the state diagram as explained in Section 2.11.3 with these modifications.

- **State C5: Assemble Receiver ID List.** The upstream side assembles the list of all connected downstream topology HDCP Devices as the downstream HDCP-protected Interface Ports reach terminal states of the authentication protocol. An HDCP-protected Interface Port that advances to the unconnected state or the inactive state does not add to the list. A downstream HDCP-protected Interface Port that arrives in an authenticated state that has an HDCP Receiver that is not an HDCP Repeater connected, adds the *Bksv* of the connected HDCP Receiver to the Receiver ID list. Downstream HDCP-protected Interface Ports that arrive in an authenticated state that have an HDCP Repeater connected will cause the KSV list read from the connected HDCP Repeater, plus the *Bksv* of the connected HDCP Repeater itself, to be added to the list. KSVs are used in place of *Receiver IDs* and are added to the Receiver ID list in big-endian order

When the Receiver ID list (comprising KSVs of connected downstream HDCP 1.x Receivers, where the KSVs are added to the list in big-endian order) for all downstream HDCP Receivers has been assembled, the upstream side computes DEPTH, DEVICE_COUNT and the upstream V' and sends RepeaterAuth_Send_ReceiverID_List message to the upstream HDCP Transmitter. In the case of a MAX_DEVS_EXCEEDED or a MAX_CASCADE_EXCEEDED error, it does not transmit V' and Receiver ID list. When an HDCP Repeater receives a MAX_DEVS_EXCEEDED or MAX_CASCADE_EXCEEDED error from a downstream HDCP Repeater, it is required to inform the upstream HDCP Transmitter.

2.12.2 HDCP 1.x – HDCP 2 Converters

HDCP 1.x – HDCP 2 converters are HDCP Repeaters with an HDCP 1.x compliant interface port on the upstream (HDCP Receiver) side and one or more HDCP 2 compliant interface ports on the downstream (HDCP Transmitter) side.

The HDCP 1.x compliant upstream side implements the state diagram explained in the corresponding HDCP 1.x specification (See Section 1.5). When any downstream HDCP-protected interface port transitions to the unauthenticated state as a result of authentication failures or connection of a new, active HDCP Receiver, the upstream side becomes unauthenticated.

The HDCP 2 compliant downstream side implements the state diagram as explained in Section 2.11.2 with these modifications.

- **State F7: Verify Receiver ID List.** The watchdog timer is cleared. If both MAX_DEVS_EXCEEDED and MAX_CASCADE_EXCEEDED are not 'true', computes V , and verifies $V == V'$. The *Receiver IDs* from this port are used in place of KSVs and are added to the KSV list for this HDCP Repeater. KSV list is constructed by appending *Receiver IDs* in little-endian order. The upstream HDCP Transmitter must be informed if topology maximums are exceeded.

If authentication with repeaters is implemented in parallel with the flow of encrypted content and Link Synchronization, the link synchronization process (i.e. State F5) must be implemented asynchronously from the rest of the state diagram.

2.13 Session Key Validity

When HDCP Encryption is disabled, the transmitter and receiver ceases to perform HDCP Encryption (Section 3.3) and stops incrementing the *audioInputCtr* and *videoInputCtr*.

If HDCP Encryption was disabled, from its enabled state, due to the detection of Receiver Connected Indication, Receiver Disconnected Indication or authentication failures, the session key expires. The most upstream HDCP Transmitter initiates re-authentication by the transmission of a new r_{tx} . In all other cases, where HDCP Encryption was disabled, from its enabled state, while the link was still active

and authenticated (for e.g., HDCP Encryption may be briefly disabled during transmission of low value content), the session key does not expire. The HDCP Transmitter maintains the encryption parameters (associated with elementary streams) used during the HDCP Session i.e. *audioInputCtr* and *videoInputCtr* values after the last HDCP Encryption operation (after which HDCP Encryption is disabled), *audioStreamCtr*, *videoStreamCtr*, k_s and r_{iv} . When re-enabled, HDCP Encryption is applied seamlessly, without requiring re-authentication, by using the same encryption parameters.

If HDCP Encryption was disabled, from its enabled state, the HDCP Receiver maintains k_s and r_{iv} used during the HDCP Session. If encryption was re-enabled, without intervening re-authentication requests from the transmitter, the HDCP Receiver uses the same k_s and r_{iv} . It updates its *audioInputCtr* (or *videoInputCtr*) corresponding to the audio stream indicated by the *audioStreamCtr* value (or the video stream indicated by the *videoStreamCtr* value) with the *audioInputCtr* (or *videoInputCtr*) value received from the transmitter (see Section 2.6 on Link Synchronization).

2.14 Random Number Generation

Random number generation is required both in the HDCP Transmitter logic and in the HDCP Receiver logic. Counter mode based deterministic random bit generator using AES-128 block cipher specified in NIST SP 800-90 is the recommended random number generator. The minimum entropy requirement for random values that are not used as secret key material (i.e. r_{tx} , r_{rx} , r_{iv} , r_n) is 40 random bits out of 64-bits. This means that a reasonable level of variability or entropy is established if out of 1,000,000 random (r_{tx} , r_{rx} , r_{iv} or r_n) values collected after the first authentication attempt (i.e. after power-up cycles on the HDCP Transmitter or HDCP Receiver logic), the probability of there being any duplicates in this list of 1,000,000 random values is less than 50%.

For randomly generated secret key material (k_m , k_s) the minimum entropy requirement is 128-bits of entropy (i.e. the probability of there being any duplicates in the list of 2^{128} secret values (k_m or k_s) collected after power-up and first authentication attempt on the HDCP Transmitter logic is less than 50%).

A list of possible entropy sources that may be used for generation of random values used as secret key material include

- a true Random Number Generator or analog noise source, even if a poor (biased) one
- a pseudo-random number generator (PRNG), seeded by a true RNG with the required entropy, where the state is stored in non-volatile memory after each use. The state must be kept secret. Flash memory or even disk is usable for this purpose as long as it is secure from tampering.

A list of possible entropy sources that may be used for generation of random values not used as secret key material include

- timers, network statistics, error correction information, radio/cable television signals, disk seek times, etc.
- a reliable (not manipulatable by the user) calendar and time-of-day clock. For example, some broadcast content sources may give reliable date and time information.

3. HDCP Encryption

3.1 Description

Figure 3.1 shows how HDCP fits in to the DiiVA protocol stack. The link consists of two constituent links: Video Link (i.e., a high-speed link transporting the Video content), and Hybrid Link (i.e., a bidirectional high-speed link for the Audio content, control and status).

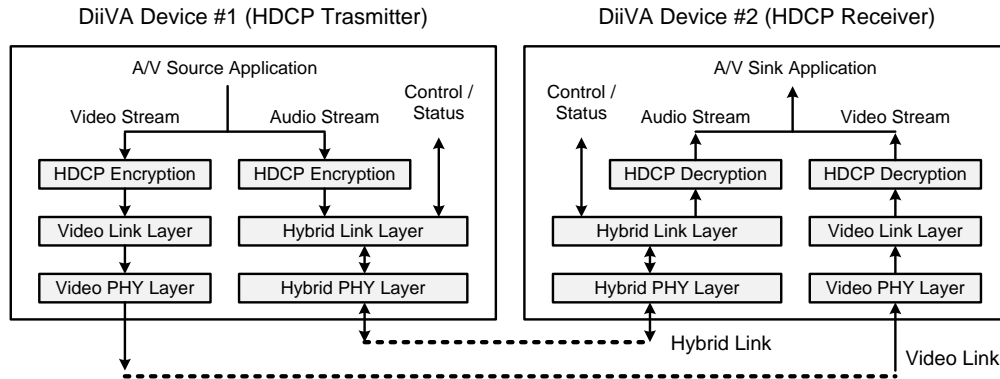


Figure 3.1. Transport Protocol w. HDCP Block Diagram (Informative)

Video in the HDCP Transmitter is assumed to be a stream of uncompressed pixel samples. The audio stream over Hybrid Link is encrypted as specified in Section 3.3.1, while the video stream over Video Link is encrypted as specified in Section 3.3.2. Control and Status messages are also transported over Hybrid Link.

3.2 AV Stream

A DiiVA AV stream consists of two content streams, i.e., an audio data stream and a video data stream. Aside from the content streams, various control/status, timing and formatting information is also transported. Only the content streams are subject to HDCP Encryption.

For the delivery of an audio data stream, the audio control packet and the audio data packet are used. The audio control packet specifies the control information (e.g., the information for audio link synchronization) on the following audio data packets. The audio data packet is used to deliver the audio data. The encryption indicator bit of the audio data packet indicates whether its payload is encrypted or not.

For the delivery of a video data stream, the Frame Info Packet and the video pixel data are used. The Frame Info Packet specifies the control information (e.g., the information for video link synchronization and the encryption indicator) for the following video pixel data. The encryption indicator bit of the Frame Info Packet indicates whether the following video pixel data is encrypted or not.

3.3 HDCP Cipher

DiiVA uses different HDCP Cipher structures for encryption of audio data and video data.

3.3.1 HDCP Cipher for Audio Stream

The HDCP Cipher for audio data consists of a 128-bit AES module that is operated in a Counter (CTR) mode as illustrated in Figure 3.2.

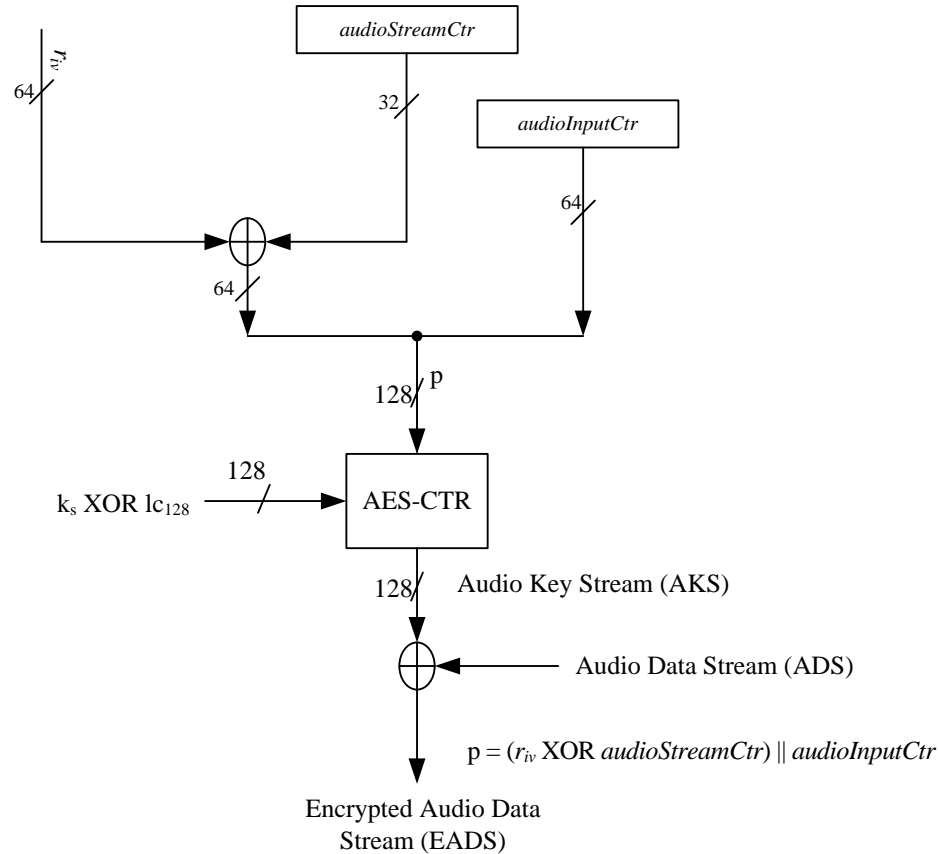


Figure 3.2. HDCP Cipher Structure for Audio Data

k_s is the 128-bit session key which is XORed with lc_{128} .

$p = (r_{iv} \text{ XOR } audioStreamCtr) \parallel audioInputCtr$. All values are in big-endian order.

audioStreamCtr is a 32-bit counter. The HDCP Transmitter assigns a distinct *audioStreamCtr* value for each audio stream so that no two audio streams from the HDCP Transmitter can have the same *audioStreamCtr*. The HDCP Transmitter starts with *audioStreamCtr* value of zero for the first audio stream and increments *audioStreamCtr* by two after assignment to each audio stream. Therefore, the first audio stream is assigned *audioStreamCtr* = 0, the second audio stream is assigned *audioStreamCtr* = 2 and so on. *audioStreamCtr* associated with an audio stream is not incremented during an HDCP Session. *audioStreamCtr* is initialized to zero after SKE and it must not be reset at any other time. It is XORed with the least significant 32-bits of r_{iv} .

audioInputCtr is a 64-bit counter. It is initialized to zero after SKE and must not be reset at any other time. Each audio stream is associated with its own *audioInputCtr*.

HDCP Encryption must be applied to the payload of the audio data packet; the header of the audio data packet must not be encrypted.

During HDCP Encryption, the key stream produced by the AES-CTR module is XORed with the 128-bit (16 Byte) block of audio data to produce the 128-bit encrypted output. *audioInputCtr* associated with an audio stream is incremented by one following encryption of the 128-bit block of audio data for that stream. The value of *audioInputCtr* must never be reused for a given set of encryption parameters, i.e. k_s , r_n , and *audioStreamCtr*.

The 16 Byte encryption block boundary must be aligned with the start of the payload in each audio data packet.

Byte ordering is such that the most-significant byte of the 128-bit key stream produced by the AES-CTR module is XORed with the first byte in time in the 16 Byte payload data block.

One or more audio control packets with a 32-bit *audioStreamCtr* field and a 64-bit *audioInputCtr* field, must be transferred every 100 ms, where the 32-Byte payload format is shown in Table 3.1. The value of *audioStreamCtr* is used for the following audio stream, and the value of *audioInputCtr* is used to encrypt the first 16 Byte block of the following first audio data packet.

Byte #	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	2^*							
1	(Reserved)							
2								
3								
4								
5	<i>audioStreamCtr</i> [23:16]							
6	<i>audioStreamCtr</i> [15:8]							
7	<i>audioStreamCtr</i> [7:0]							
8	<i>audioInputCtr</i> [63:56]							
9	<i>audioInputCtr</i> [55:48]							
10	<i>audioInputCtr</i> [47:40]							
11	<i>audioInputCtr</i> [39:32]							
12	<i>audioInputCtr</i> [31:24]							
13	<i>audioInputCtr</i> [23:16]							
14	<i>audioInputCtr</i> [15:8]							
15	<i>audioInputCtr</i> [7:0]							
16-31	(Reserved)							

Table 3.1. Payload of Audio Control Packet (for Audio Link Synchronization)

* *Content_Protection_Scheme*: 2 means that HDCP 2.0 is used for encryption.

3.3.2 HDCP Cipher for Video Stream

The HDCP Cipher for video data consists of a 128-bit AES module that is operated in a Counter (CTR) mode as illustrated in Figure 3.3.

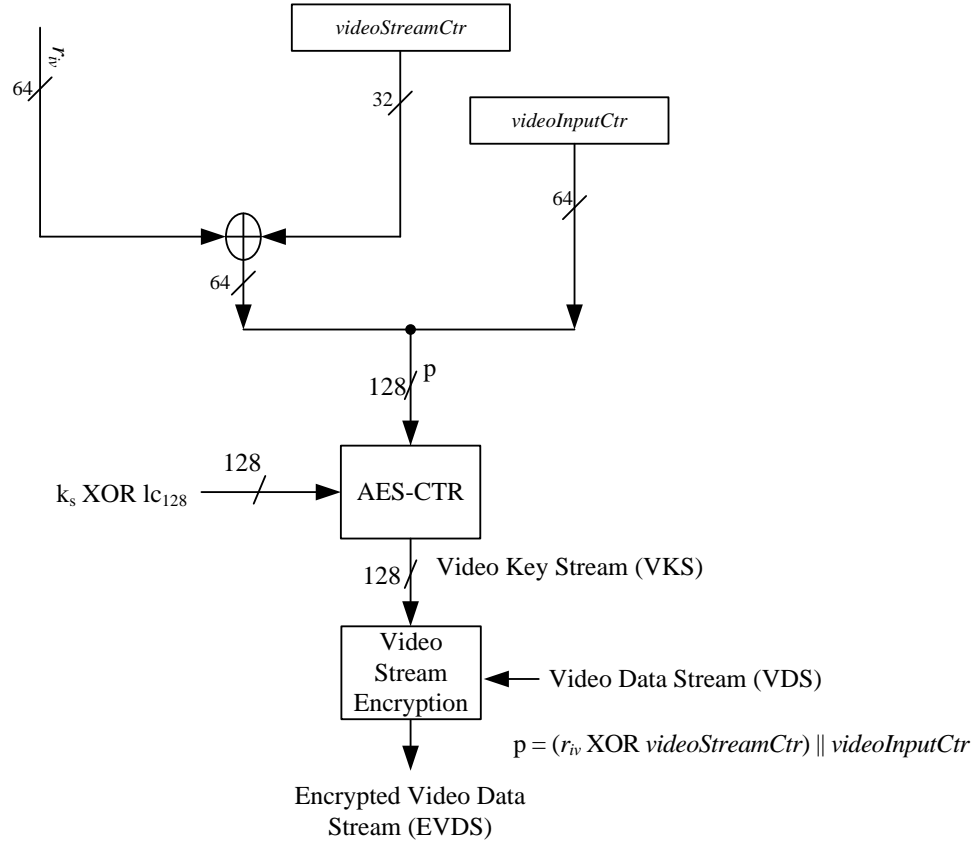


Figure 3.3. HDCP Cipher Structure for Video Data

k_s is the 128-bit session key which is XORed with lc_{128} .

$p = (r_{iv} \text{ XOR } videoStreamCtr) \parallel videoInputCtr$. All values are in big-endian order.

videoStreamCtr is a 32-bit counter. The HDCP Transmitter assigns a distinct *videoStreamCtr* value for each video stream so that no two video streams from the HDCP Transmitter can have the same *videoStreamCtr*. The HDCP Transmitter starts with *videoStreamCtr* value of one for the first video stream and increments *videoStreamCtr* by two after assignment to each video stream. Therefore, the first video stream is assigned *videoStreamCtr* = 1, the second video stream is assigned *videoStreamCtr* = 3 and so on. *videoStreamCtr* associated with an video stream is not incremented during an HDCP Session. *videoStreamCtr* is initialized to one after SKE and it must not be reset at any other time. It is XORed with the least significant 32-bits of r_{iv} .

videoInputCtr is a 64-bit counter. It is initialized to zero after SKE and must not be reset at any other time. Each video stream is associated with its own *videoInputCtr*.

HDCP Encryption must be applied to the video pixel data only.

During HDCP Encryption, the key stream produced by the AES-CTR module is used to encrypt the video data stream. *videoInputCtr* associated with a video stream is incremented by one after the active line finishes. The value of *videoInputCtr* must never be reused for a given set of encryption parameters i.e. k_s , r_{iv} and *videoStreamCtr*.

One Frame Info Packet with a 32-bit *videoStreamCtr* field and a 64-bit *videoInputCtr* field must be transferred every frame (or every field in the interlaced mode), where the 24-Byte payload format is shown in Table 3.2. The value of *videoStreamCtr* is used for the following video stream while the value of *videoInputCtr* is used for the video data in the following first active line.

Byte #	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
0 ~ 3	(specified in the DiiVA specification)								
4	1 [†]							2 [‡]	
5	<i>videoStreamCtr</i> [31:24]								
6	<i>videoStreamCtr</i> [23:16]								
7	<i>videoStreamCtr</i> [15:8]								
8	<i>videoStreamCtr</i> [7:0]								
9	<i>videoInputCtr</i> [63:56]								
10	<i>videoInputCtr</i> [55:48]								
11	<i>videoInputCtr</i> [47:40]								
12	<i>videoInputCtr</i> [39:32]								
13	<i>videoInputCtr</i> [31:24]								
14	<i>videoInputCtr</i> [23:16]								
15	<i>videoInputCtr</i> [15:8]								
16	<i>videoInputCtr</i> [7:0]								
17~23	(Reserved)								

Table 3.2. Payload of Frame Info Packet (for Video Link Synchronization)

In the HDCP Receiver, *videoStreamCtr* and *videoInputCtr* must be updated after a Frame Info Packet is received. And, *videoInputCtr* must increment by 1 after an active line finishes, as shown in Figure 3.4.

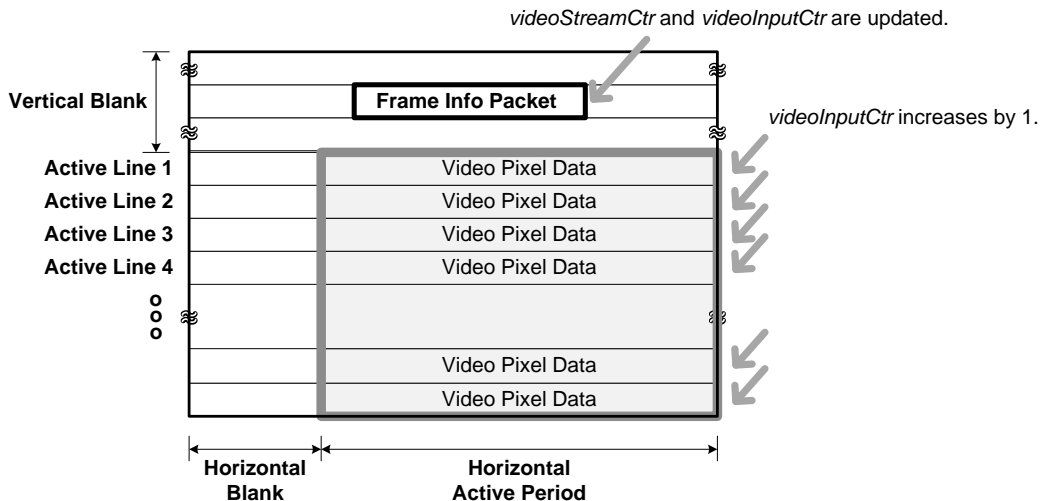


Figure 3.4. Video Link Synchronization Timing in HDCP Receiver

[†] *Encryption_Indicator*: 1 means that the pixel data of the following active lines is encrypted.

[‡] *Content_Protection_Scheme*: 2 means that HDCP 2.0 is used for encryption.

3.3.2.1 Video Stream Encryption

The video stream encryption is composed of block module, output function and pixel data encryption, as shown in Figure 3.5. The block module is same as that of HDCP 1.x except that two sub block modules, F and G, are used, and each sub block module computes the round function B and K two times every clock. The initial inputs to the sub block module F's B registers and K registers are derived from the 128-bit output of the AES-CTR module according to Table 3.3. The initial inputs to the sub block module G are the one's complement of the initial inputs to the sub block module F. The F and G states alternate in providing input to the output function. This alternation together with two rounds per clock ensures that 4 rounds of update are done between successive outputs while a new output is available every clock. The output function is a one stronger one-way function to facilitate the increase to 48 bits while providing a level of security much higher than that of HDCP 1.x. Pixel data encryption is the XOR of the 48-bit output and video pixel data, where the least significant bits are used when the bit widths are different.

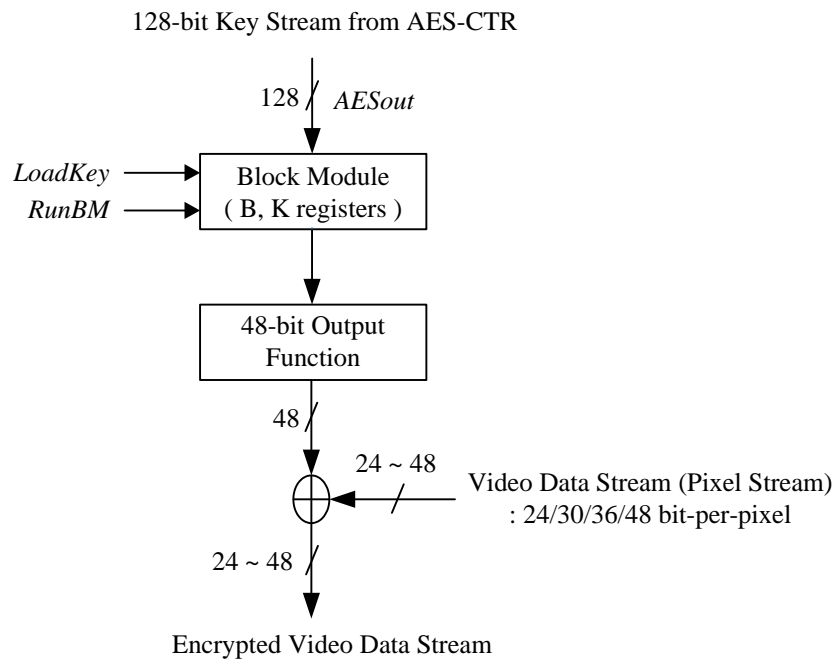


Figure 3.5. Video Stream Encryption

The operation of video stream encryption is as follows. When *LoadKey* is asserted, the 128-bit *AESout* from AES-CTR is loaded to the B and K registers of the block module according to Table 3.3, where “ \oplus ” represents a logical XOR function. Then, the block modules advance their state (i.e., the state is represented by the B and K registers) by 24 steps by asserting *RunBM* for 24 cycles, for a total of 48 rounds. The final state of the sub block module F is provided to the output function to generate a 48-bit output that is used for the first pixel data. For the second pixel data, the sub block module G advances its state by 1 step by asserting *RunBM* for 1 cycle and the result state is provided to the output function to generate the next 48-bit output. Figure 3.6 shows the timing relationship among signals. Examples of Table 3.4 show how to encrypt the 24-bpp ~ 48-bpp pixel data with the 48-bit output function, where the least significant bits of the 48-bit output function are first used.

Sub Block Module	State	Bit Field	Initial Value
F	Bx	[27:20]	$AESout [127:120] \oplus AESout [107:100]$
		[19:0]	$AESout [119:100]$
	By	[27:20]	$AESout [127:120] \oplus AESout [87:80]$
		[19:0]	$AESout [99:80]$
	Bz	[27:20]	$AESout [127:120] \oplus AESout [67:60]$
		[19:0]	$AESout [79:60]$
	Kx	[27:20]	$AESout [127:120] \oplus AESout [47:40]$
		[19:0]	$AESout [59:40]$
	Ky	[27:20]	$AESout [127:120] \oplus AESout [27:20]$
		[19:0]	$AESout [39:20]$
	Kz	[27:20]	$AESout [127:120] \oplus AESout [7:0]$
		[19:0]	$AESout [19:0]$
G	Bx	[27:20]	Complement of ($AESout [127:120] \oplus AESout [107:100]$)
		[19:0]	Complement of ($AESout [119:100]$)
	By	[27:20]	Complement of ($AESout [127:120] \oplus AESout [87:80]$)
		[19:0]	Complement of ($AESout [99:80]$)
	Bz	[27:20]	Complement of ($AESout [127:120] \oplus AESout [67:60]$)
		[19:0]	Complement of ($AESout [79:60]$)
	Kx	[27:20]	Complement of ($AESout [127:120] \oplus AESout [47:40]$)
		[19:0]	Complement of ($AESout [59:40]$)
	Ky	[27:20]	Complement of ($AESout [127:120] \oplus AESout [27:20]$)
		[19:0]	Complement of ($AESout [39:20]$)
	Kz	[27:20]	Complement of ($AESout [127:120] \oplus AESout [7:0]$)
		[19:0]	Complement of ($AESout [19:0]$)

Table 3.3. Initialization of Sub Block Module F and G

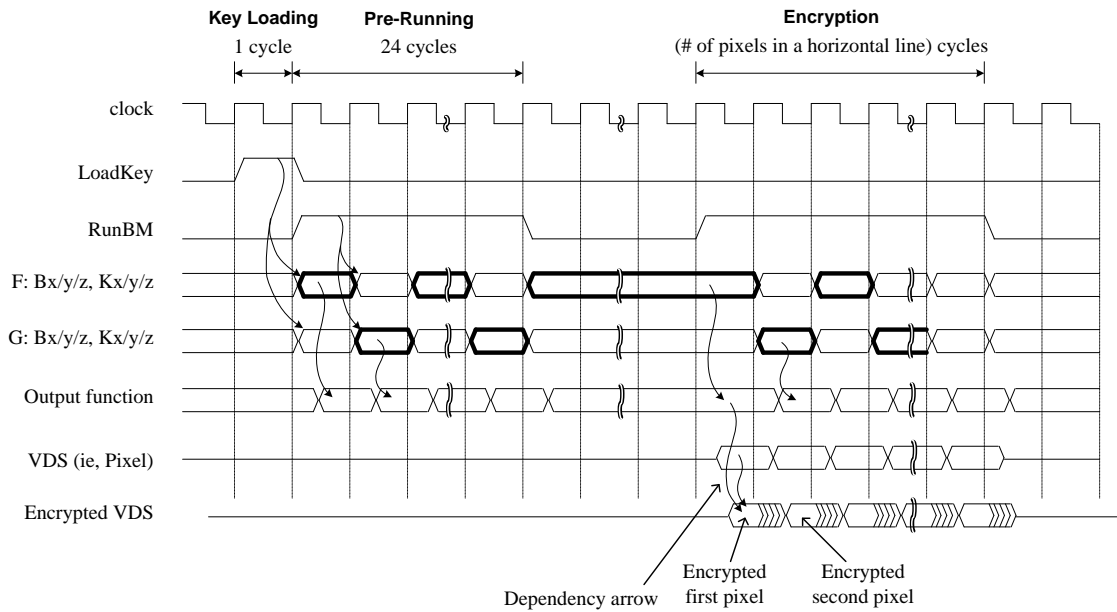


Figure 3.6. Timing Relationship in Video Stream Encryption

Pixel Format	Output Function	Pixel Data
24-bpp RGB (or YCbCr 4:4:4)	[23:16]	B [7:0] (or Cb [7:0])
	[15:8]	G [7:0] (or Y [7:0])
	[7:0]	R [7:0] (or Cr [7:0])
30-bpp RGB (or YCbCr 4:4:4)	[29:20]	B [9:0] (or Cb [9:0])
	[19:10]	G [9:0] (or Y [9:0])
	[9:0]	R [9:0] (or Cr [9:0])
36-bpp RGB (or YCbCr 4:4:4)	[35:24]	B [11:0] (or Cb [11:0])
	[23:12]	G [11:0] (or Y [11:0])
	[11:0]	R [11:0] (or Cr [11:0])
48-bpp RGB (or YCbCr 4:4:4)	[47:32]	B [15:0] (or Cb [15:0])
	[31:16]	G [15:0] (or Y [15:0])
	[15:0]	R [15:0] (or Cr [15:0])
24-bpp YCbCr 4:2:2	[23:12]	Cb [11:0], Cr [11:0]
	[11:0]	Y [23:12]

Table 3.4. Examples of Pixel Data Encryption

3.3.2.2 Block Module

As shown in Figure 3.7, the block module is composed of key expansion, two sub block modules F and G, and state selection. The key expansion is defined in Table 3.3 and the state selection is illustrated in Figure 3.6, where the bold-lined state is provided to the output function. Each sub block module consists of two separate “round function” components. One of these components, *Round Function K*, provides a key stream for the other component, *Round Function B*. Each of these two components operates on a corresponding set of three 28-bit registers. The structure of the sub block module is diagrammed in Figure 3.8. The round function is replicated 2 times prior to updating the K and B registers.

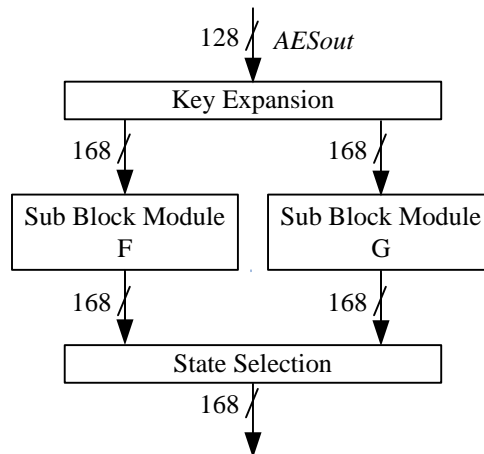


Figure 3.7. Block Module

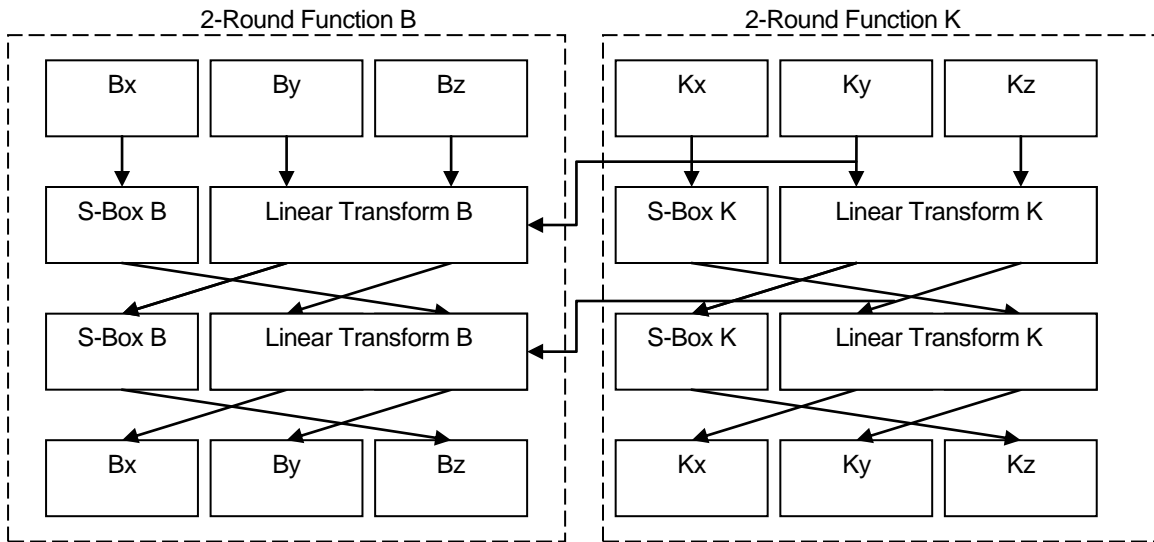


Figure 3.8. Sub Block Module

The S-Boxes for both round functions consist of seven 4 input by 4 output S-boxes. Round function K S-Boxes are labeled SK0 through SK6 and round function B S-Boxes are labeled SB0 through SB6. The I^{th} input to box J is bit $I*7+J$ from the round x register (Bx or Kx), and output I of box J goes to bit $I*7+J$ of register z of the round function (Bz or Kz). Bit 0 is the least significant bit. The S-box permutations of round functions K and B are specified in Table 3.5.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SK0	8	14	5	9	3	0	12	6	1	11	15	2	4	7	10	13
SK1	1	6	4	15	8	3	11	5	10	0	9	12	7	13	14	2
SK2	13	11	8	6	7	4	2	15	1	12	14	0	10	3	9	5
SK3	0	14	11	7	12	3	2	13	15	4	8	1	9	10	5	6
SK4	12	7	15	8	11	14	1	4	6	10	3	5	0	9	13	2
SK5	1	12	7	2	8	3	4	14	11	5	0	15	13	6	10	9
SK6	10	7	6	1	0	14	3	13	12	9	11	2	15	5	4	8
SB0	12	9	3	0	11	5	13	6	2	4	14	7	8	15	1	10
SB1	3	8	14	1	5	2	11	13	10	4	9	7	6	15	12	0
SB2	7	4	1	10	11	13	14	3	12	15	6	0	2	8	9	5
SB3	6	3	1	4	10	12	15	2	5	14	11	8	9	7	0	13
SB4	3	6	15	12	4	1	9	2	5	8	10	7	11	13	0	14
SB5	11	14	6	8	5	2	12	7	1	4	15	3	10	13	9	0
SB6	1	11	7	4	2	5	12	9	13	6	8	15	14	0	3	10

Table 3.5. Block Module S-Box Values

Both linear transformation K and linear transformation B produce 56 output values. These values are the combined outputs from eight diffusion networks that each produces seven outputs. The diffusion network function is specified in Table 3.6. Each diffusion network has seven data inputs labeled $I_0 - I_6$, seven outputs $O_0 - O_6$, plus an additional seven optional key inputs $K_0 - K_6$.

The diffusion networks of round function K are specified in Table 3.7. Note that none of the round function K diffusion networks have the optional key inputs. The diffusion units of round function

B are specified in Table 3.8. Half of these diffusion networks have key inputs that are driven from the Ky register of round function K. A dash in the table indicates that the key input is not present.

Diffusion Network Logic Function	
O₀	$K_0 \oplus I_1 \oplus I_2 \oplus I_3 \oplus I_4 \oplus I_5 \oplus I_6$
O₁	$K_1 \oplus I_0 \oplus I_2 \oplus I_3 \oplus I_4 \oplus I_5 \oplus I_6$
O₂	$K_2 \oplus I_0 \oplus I_1 \oplus I_3 \oplus I_4 \oplus I_5 \oplus I_6$
O₃	$K_3 \oplus I_0 \oplus I_1 \oplus I_2 \oplus I_4 \oplus I_5 \oplus I_6$
O₄	$K_4 \oplus I_0 \oplus I_1 \oplus I_2 \oplus I_3 \oplus I_5 \oplus I_6$
O₅	$K_5 \oplus I_0 \oplus I_1 \oplus I_2 \oplus I_3 \oplus I_4 \oplus I_6$
O₆	$K_6 \oplus I_0 \oplus I_1 \oplus I_2 \oplus I_3 \oplus I_4 \oplus I_5 \oplus I_6$

Table 3.6. Diffusion Network Logic Function

	K1	K2	K3	K4	K5	K6	K7	K8
I₀	Kz0	Kz7	Kz10	Kz13	Kz16	Ky16	Ky20	Ky24
I₁	Kz1	Kz8	Kz11	Kz14	Kz17	Ky17	Ky21	Ky25
I₂	Kz2	Kz9	Kz12	Kz15	Kz18	Ky18	Ky22	Ky26
I₃	Kz3	Ky0	Ky3	Ky6	Ky9	Ky19	Ky23	Ky27
I₄	Kz4	Ky1	Ky4	Ky7	Ky10	Kz19	Kz22	Kz25
I₅	Kz5	Ky2	Ky5	Ky8	Ky11	Kz20	Kz23	Kz26
I₆	Kz6	Ky12	Ky13	Ky14	Ky15	Kz21	Kz24	Kz27
O₀	Kx0	Ky0	Ky1	Ky2	Ky3	Kx1	Kx2	Kx3
O₁	Kx4	Ky4	Ky5	Ky6	Ky7	Kx5	Kx6	Kx7
O₂	Kx8	Ky8	Ky9	Ky10	Ky11	Kx9	Kx10	Kx11
O₃	Kx12	Ky12	Ky13	Ky14	Ky15	Kx13	Kx14	Kx15
O₄	Kx16	Ky16	Ky17	Ky18	Ky19	Kx17	Kx18	Kx19
O₅	Kx20	Ky20	Ky21	Ky22	Ky23	Kx21	Kx22	Kx23
O₆	Kx24	Ky24	Ky25	Ky26	Ky27	Kx25	Kx26	Kx27

Table 3.7. K Round Input and Output Mapping

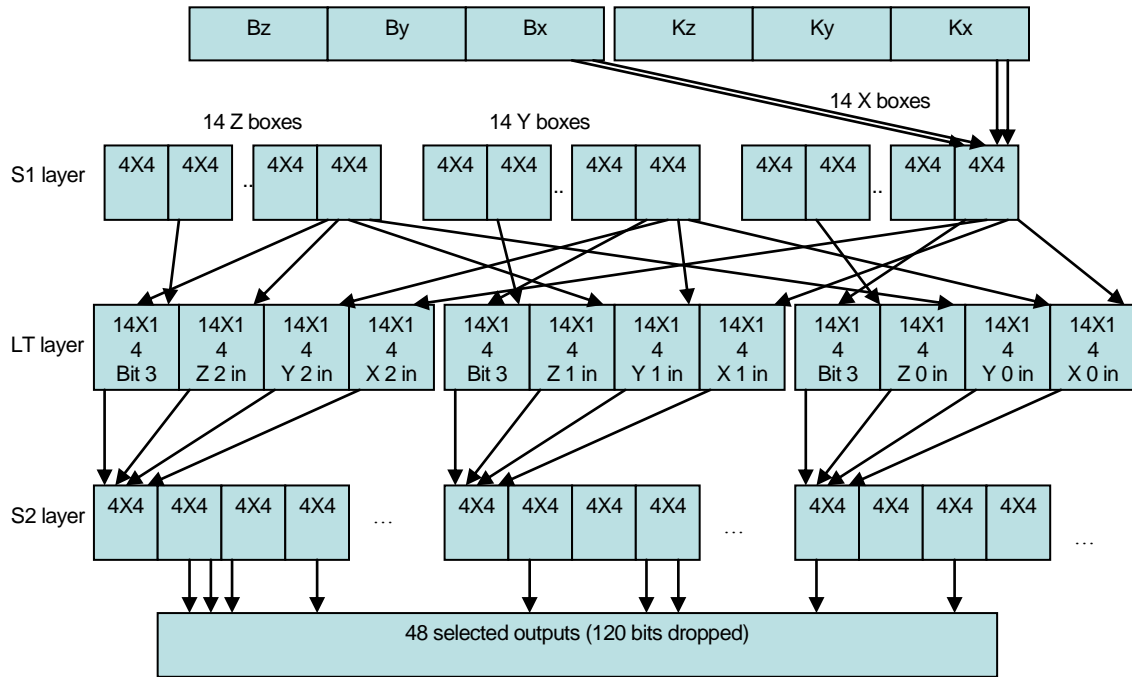
	B1	B2	B3	B4	B5	B6	B7	B8
I₀	Bz0	Bz7	Bz10	Bz13	Bz16	By16	By20	By24
I₁	Bz1	Bz8	Bz11	Bz14	Bz17	By17	By21	By25
I₂	Bz2	Bz9	Bz12	Bz15	Bz18	By18	By22	By26
I₃	Bz3	By0	By3	By6	By9	By19	By23	By27
I₄	Bz4	By1	By4	By7	By10	Bz19	Bz22	Bz25
I₅	Bz5	By2	By5	By8	By11	Bz20	Bz23	Bz26
I₆	Bz6	By12	By13	By14	By15	Bz21	Bz24	Bz27
K₀	Ky0	–	–	–	–	Ky7	Ky14	Ky21
K₁	Ky1	–	–	–	–	Ky8	Ky15	Ky22
K₂	Ky2	–	–	–	–	Ky9	Ky16	Ky23

K₃	Ky3	–	–	–	–	Ky10	Ky17	Ky24
K₄	Ky4	–	–	–	–	Ky11	Ky18	Ky25
K₅	Ky5	–	–	–	–	Ky12	Ky19	Ky26
K₆	Ky6	–	–	–	–	Ky13	Ky20	Ky27
O₀	Bx0	By0	By1	By2	By3	Bx1	Bx2	Bx3
O₁	Bx4	By4	By5	By6	By7	Bx5	Bx6	Bx7
O₂	Bx8	By8	By9	By10	By11	Bx9	Bx10	Bx11
O₃	Bx12	By12	By13	By14	By15	Bx13	Bx14	Bx15
O₄	Bx16	By16	By17	By18	By19	Bx17	Bx18	Bx19
O₅	Bx20	By20	By21	By22	By23	Bx21	Bx22	Bx23
O₆	Bx24	By24	By25	By26	By27	Bx25	Bx26	Bx27

Table 3.8. B Round Input and Output Mapping

3.3.2.3 Output Function

All 168 bits of the K and B registers are used by the output function for the higher security. The output function consists of three layers. The first layer, called S1 layer, contains 42 4X4 S-boxes. The second layer, called LT layer, is comprised of 12 14X14 linear transforms. The final layer, called S2 layer, is another layer of 42 4X4 S-boxes. However, most of S2 layer, and part of LT layer need not be implemented, as the output bits are discarded to create the one-way function from the 168-bit state to the 48-bit encryption mask.



* LT Bit 3 input is S1Box # rotated 7 Bit 3

Figure 3.9. Output Function

3.3.2.3.1 S1 Layer

Table 3.9 indicates how the K and B registers are connected to S1 layer S-box inputs. There are three groups of 14 S-boxes: Z, Y, and X. The Z boxes take inputs from the Bz and Kz registers, Y boxes take By and Ky inputs, and X boxes take Bx and Kx inputs.

S1 Layer		K and B Registers (as Input Source)	
Box	Input bit	Register	Output bit
S1{XYZ} i in 0..13	0	K{xyz}	2*i
S1{XYZ} i in 0..13	1	K{xyz}	2*i + 1
S1{XYZ} i in 0..13	2	B{xyz}	2*i
S1{XYZ} i in 0..13	3	B{xyz}	2*i + 1

Table 3.9. S1 Layer Input Mapping

For example, S1 layer Y box 3 takes input 0 from Ky6, input 1 from Ky7, input 2 from By6, and input 3 from By7 (i.e., the 4-bit input of S1Y3 is By7 || By6 || Ky7 || Ky6).

The 42 S-boxes of S1 layer are defined in Table 3.10.

S1 Box	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
S1X0	10	0	7	11	5	6	2	12	1	15	13	4	8	3	14	9
S1X1	5	15	6	10	11	8	13	1	9	4	0	7	12	2	3	14
S1X2	6	15	0	12	3	4	9	7	8	1	5	10	14	11	2	13
S1X3	14	7	9	12	13	11	0	6	5	2	15	1	10	4	3	8
S1X4	11	12	2	9	7	10	1	6	0	3	15	5	14	13	4	8
S1X5	0	5	3	8	13	14	4	2	10	15	12	1	6	9	11	7
S1X6	9	12	14	2	5	6	8	15	4	3	7	13	11	0	1	10
S1X7	8	15	3	9	14	5	13	6	7	0	10	12	2	11	4	1
S1X8	12	11	15	2	10	1	0	7	3	6	5	9	13	8	14	4
S1X9	3	15	6	1	9	0	12	7	4	2	8	11	10	13	5	14
S1X10	10	1	12	6	13	8	0	3	9	7	5	11	2	14	15	4
S1X11	6	12	13	1	5	11	2	7	10	3	0	14	15	8	9	4
S1X12	4	11	1	2	10	5	13	14	8	6	7	12	3	15	0	9
S1X13	14	3	1	10	9	5	6	0	8	13	2	7	4	11	15	12
S1Y0	0	15	14	5	6	8	11	2	10	9	1	12	3	4	13	7
S1Y1	0	9	5	14	12	2	3	13	6	10	15	4	1	7	8	11
S1Y2	4	13	8	11	10	6	7	0	14	3	1	12	9	15	2	5
S1Y3	0	12	10	9	14	11	1	7	6	15	13	2	3	5	4	8
S1Y4	14	1	9	15	3	12	10	6	7	13	2	4	0	11	5	8
S1Y5	13	10	1	12	6	3	11	5	14	0	4	7	9	15	2	8
S1Y6	9	7	14	13	10	12	4	1	6	8	0	11	3	5	15	2
S1Y7	13	11	3	6	8	4	5	15	7	0	14	9	1	10	2	12
S1Y8	6	15	13	1	11	4	14	2	0	5	3	8	12	10	9	7
S1Y9	11	1	7	12	13	10	2	5	14	8	4	15	3	6	9	0
S1Y10	14	5	9	12	8	6	3	0	4	11	15	2	7	1	10	13
S1Y11	14	3	1	12	4	10	15	9	7	13	2	11	8	6	5	0
S1Y12	1	7	14	4	15	10	0	13	6	11	3	8	5	12	9	2
S1Y13	3	13	5	8	10	6	12	11	0	7	14	4	15	9	1	2
S1Z0	13	3	7	0	8	6	1	10	14	4	2	11	5	9	15	12
S1Z1	11	0	13	10	5	6	8	15	2	14	4	1	9	3	7	12
S1Z2	14	0	8	7	1	12	11	2	3	5	6	9	10	15	13	4
S1Z3	1	2	10	12	13	14	0	7	6	9	3	15	11	4	5	8
S1Z4	12	5	10	6	0	14	13	11	9	3	7	8	15	4	2	1
S1Z5	3	0	8	13	6	11	1	7	15	12	5	10	9	2	14	4
S1Z6	5	8	12	6	10	13	0	11	2	14	9	3	1	7	15	4
S1Z7	11	5	8	14	7	10	2	13	6	15	1	4	0	9	12	3
S1Z8	4	10	3	5	14	13	8	2	7	0	12	9	11	6	1	15
S1Z9	12	10	11	1	7	4	13	8	3	9	5	6	14	2	0	15
S1Z10	8	15	7	10	1	2	11	4	5	3	12	9	6	13	0	14
S1Z11	1	10	7	4	13	0	2	11	14	3	9	15	8	6	5	12
S1Z12	3	13	8	14	6	10	11	4	12	1	7	2	5	15	0	9
S1Z13	15	12	0	7	10	6	3	8	2	1	5	11	4	13	9	14

Table 3.10. S1 Layer S-Box Values

3.3.2.3.2 LT layer

Each output of all 14X14 linear output transforms is the exclusive-or of 7 to 8 inputs, as shown in Table 3.11.

Output	Function
O ₀	I ₁ ⊕ I ₄ ⊕ I ₅ ⊕ I ₆ ⊕ I ₈ ⊕ I ₉ ⊕ I ₁₁
O ₁	I ₀ ⊕ I ₂ ⊕ I ₅ ⊕ I ₆ ⊕ I ₇ ⊕ I ₉ ⊕ I ₁₀ ⊕ I ₁₂
O ₂	I ₁ ⊕ I ₃ ⊕ I ₆ ⊕ I ₇ ⊕ I ₈ ⊕ I ₁₀ ⊕ I ₁₁ ⊕ I ₁₃
O ₃	I ₀ ⊕ I ₂ ⊕ I ₄ ⊕ I ₇ ⊕ I ₈ ⊕ I ₉ ⊕ I ₁₁ ⊕ I ₁₂
O ₄	I ₁ ⊕ I ₃ ⊕ I ₅ ⊕ I ₈ ⊕ I ₉ ⊕ I ₁₀ ⊕ I ₁₂ ⊕ I ₁₃
O ₅	I ₀ ⊕ I ₂ ⊕ I ₄ ⊕ I ₆ ⊕ I ₉ ⊕ I ₁₀ ⊕ I ₁₁ ⊕ I ₁₃
O ₆	I ₁ ⊕ I ₃ ⊕ I ₅ ⊕ I ₇ ⊕ I ₁₀ ⊕ I ₁₁ ⊕ I ₁₂
O ₇	I ₂ ⊕ I ₄ ⊕ I ₆ ⊕ I ₈ ⊕ I ₁₁ ⊕ I ₁₂ ⊕ I ₁₃
O ₈	I ₀ ⊕ I ₃ ⊕ I ₅ ⊕ I ₇ ⊕ I ₉ ⊕ I ₁₂ ⊕ I ₁₃
O ₉	I ₀ ⊕ I ₁ ⊕ I ₄ ⊕ I ₆ ⊕ I ₈ ⊕ I ₁₀ ⊕ I ₁₃
O ₁₀	I ₀ ⊕ I ₁ ⊕ I ₂ ⊕ I ₅ ⊕ I ₇ ⊕ I ₉ ⊕ I ₁₁
O ₁₁	I ₀ ⊕ I ₁ ⊕ I ₂ ⊕ I ₃ ⊕ I ₆ ⊕ I ₈ ⊕ I ₁₀ ⊕ I ₁₂
O ₁₂	I ₁ ⊕ I ₂ ⊕ I ₃ ⊕ I ₄ ⊕ I ₇ ⊕ I ₉ ⊕ I ₁₁ ⊕ I ₁₃
O ₁₃	I ₂ ⊕ I ₃ ⊕ I ₄ ⊕ I ₅ ⊕ I ₈ ⊕ I ₁₀ ⊕ I ₁₂

Table 3.11. LT Layer Logic Function

There are 3 groups of 4 14X14 linear transforms: LTZ3, LTZ2, LTZ1, LTZ0, LTY3, LTY2, LTY1, LTY0, LTX3, LTX2, LTX1, and LTX0. The inputs for the linear transforms are shown in Table 3.12.

LT Layer		S1 Layer (as Input Source)	
Box	Input bit	Box	Output bit
LTX0	j in 0..13	X _j	0
LTX1	j in 0..13	Y _j	0
LTX2	j in 0..13	Z _j	0
LTX3	j in 0..6	X _{j+7}	3
LTX3	j in 7..13	X _{j-7}	3
LTY0	j in 0..13	X _j	1
LTY1	j in 0..13	Y _j	1
LTY2	j in 0..13	Z _j	1
LTY3	j in 0..6	Y _{j+7}	3
LTY3	j in 7..13	Y _{j-7}	3
LTZ0	j in 0..13	X _j	2
LTZ1	j in 0..13	Y _j	2
LTZ2	j in 0..13	Z _j	2
LTZ3	j in 0..6	Z _{j+7}	3
LTZ3	j in 7..13	Z _{j-7}	3

Table 3.12. LT Layer Input Mapping

3.3.2.3.3 S2 Layer

The final layer (i.e., S2 Layer) of 42 4X4 S-boxes are labeled S2Z13 to S2Z0, S2Y13 to S2Y0, and S2X13 to S2X0. The 14 S2Z boxes obtain their inputs from the 4 LTZ boxes, the S2Y boxes from the LTY boxes, and the S2X boxes from the LTX boxes. The mapping is shown in Table 3.13.

S2 Layer		LT Layer	
Box	Input bit	Box	Output bit
S2{XYZ} i in 0..13	0	LT{XYZ}0	I
S2{XYZ} i in 0..13	1	LT{XYZ}1	I
S2{XYZ} i in 0..13	2	LT{XYZ}2	I
S2{XYZ} i in 0..13	3	LT{XYZ}3	I

Table 3.13. S2 Layer Input Mapping

The 42 S-boxes of S2 layer are defined in Table 3.14.

S2 Box	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
S2X0	14	7	11	12	0	9	13	6	8	4	1	10	5	3	2	15
S2X1	9	2	5	12	14	8	3	6	10	13	15	0	7	1	4	11
S2X2	12	5	15	9	11	14	1	2	6	10	8	7	0	3	13	4
S2X3	12	0	6	11	5	3	9	4	7	14	1	2	10	13	15	8
S2X4	9	14	5	8	7	1	2	13	15	3	12	6	4	10	11	0
S2X5	7	8	11	6	0	3	13	10	14	4	1	15	5	9	2	12
S2X6	1	11	14	2	13	4	3	9	15	12	8	7	6	10	5	0
S2X7	3	13	10	0	15	8	12	5	14	1	9	6	4	7	2	11
S2X8	1	11	10	13	8	14	6	3	12	7	5	2	15	4	0	9
S2X9	0	3	7	14	13	6	4	8	15	9	10	5	2	12	1	11
S2X10	8	7	3	9	11	2	13	4	15	0	10	12	5	14	6	1
S2X11	0	6	5	11	7	8	12	1	3	10	15	4	14	13	9	2
S2X12	2	15	11	0	4	1	14	13	9	5	12	3	10	6	7	8
S2X13	6	10	3	4	5	12	9	7	13	1	0	14	8	11	15	2
S2Y0	2	9	1	6	5	3	12	15	14	7	13	8	0	10	11	4
S2Y1	6	3	15	9	5	10	8	7	13	0	4	14	2	12	1	11
S2Y2	4	1	3	10	7	13	12	0	2	15	14	9	8	6	11	5
S2Y3	12	6	11	8	15	3	5	14	2	13	4	1	9	0	10	7
S2Y4	3	4	12	11	14	8	7	1	6	10	0	13	5	15	9	2
S2Y5	10	5	13	14	6	8	3	4	0	9	11	7	15	2	12	1
S2Y6	10	15	3	5	4	9	13	6	7	2	0	12	8	14	11	1
S2Y7	6	1	12	7	13	8	10	4	3	15	9	0	14	2	5	11
S2Y8	1	8	12	11	15	6	0	13	4	14	10	7	3	5	9	2
S2Y9	9	10	5	15	0	13	3	4	7	12	8	6	11	2	14	1
S2Y10	2	9	7	0	4	15	10	5	11	14	13	3	8	1	6	12
S2Y11	8	2	3	5	1	13	15	6	11	12	14	0	7	10	4	9
S2Y12	12	2	10	4	11	7	0	13	3	14	15	9	8	1	5	6
S2Y13	7	4	11	14	9	2	6	13	0	3	5	8	10	12	15	1
S2Z0	15	1	2	11	12	7	9	14	0	6	13	8	5	10	3	4
S2Z1	9	7	3	8	15	10	6	5	2	11	4	13	12	0	1	14
S2Z2	12	0	6	3	2	13	5	10	1	11	15	8	4	14	9	7
S2Z3	0	15	13	3	12	10	2	9	5	8	14	4	6	1	11	7
S2Z4	7	9	8	5	13	3	4	14	12	0	15	10	11	6	2	1
S2Z5	9	10	2	12	4	13	7	11	5	6	8	3	15	0	1	14
S2Z6	12	6	10	5	7	9	4	3	0	11	15	2	13	14	1	8
S2Z7	1	13	7	2	11	0	12	15	4	3	14	9	8	6	5	10
S2Z8	14	9	1	6	5	12	2	15	7	4	11	8	0	10	13	3

S2Z9	14	9	13	4	0	6	3	15	11	12	1	2	7	10	8	5
S2Z10	14	5	3	6	7	9	12	10	2	8	4	13	1	15	11	0
S2Z11	1	7	6	12	2	9	11	5	4	8	10	15	14	3	13	0
S2Z12	9	15	5	2	12	0	6	13	14	4	11	7	3	10	8	1
S2Z13	12	5	1	2	3	6	15	9	7	14	13	8	0	11	10	4

Table 3.14. S2 Layer S-Box Values

Finally, for the 48-bit encryption mask, the 48 bits are selected from the 168 bits of the S2 layer output according to Table 3.15. No more than 2 outputs from any S2 layer box are selected. The logic to implement the 120 discarded outputs of the S2 layer may be optimized out, discarding part or all of S2 layer boxes and the parts of LT layer boxes that feed into them.

Encryption Mask bit	S2 Layer (as Input Source)	
	Box	Output bit
0	S2X1	0
1	S2X1	1
2	S2X2	0
3	S2X2	1
4	S2X3	1
5	S2X3	3
6	S2X4	2
7	S2X4	3
8	S2X5	0
9	S2X5	2
10	S2X8	0
11	S2X8	3
12	S2X11	0
13	S2X11	2
14	S2X12	0
15	S2X12	3
16	S2Y1	0
17	S2Y1	3
18	S2Y2	0
19	S2Y2	1
20	S2Y3	0
21	S2Y3	1
22	S2Y4	0
23	S2Y4	2
24	S2Y5	0
25	S2Y5	2
26	S2Y8	2
27	S2Y8	3
28	S2Y11	0
29	S2Y11	3
30	S2Y12	1
31	S2Y12	2
32	S2Z1	1
33	S2Z1	3
34	S2Z2	1
35	S2Z2	3
36	S2Z3	0
37	S2Z3	2
38	S2Z4	1
39	S2Z4	3
40	S2Z5	0
41	S2Z5	3

42	S2Z8	0
43	S2Z8	2
44	S2Z11	0
45	S2Z11	2
46	S2Z12	0
47	S2Z12	2

Table 3.15. Encryption Mask Mapping

3.4 HDCP Encryption Indication

Any DiiVA audio stream containing HDCP encrypted audio data must include one or more audio control packets with a 32-bit *audioStreamCtr* field and a 64-bit *audioInputCtr* field every 100 ms. Audio data packets with an encrypted audio payload must have a packet header with the following two fields: *Encryption_Indicator* = 1 and *Content_Protection_Scheme* = 2, as specified in the DiiVA specification. The presence of these fields in audio data packets serves to indicate that HDCP Encryption is enabled for audio and the audio data packet payload is encrypted. When HDCP Encryption is disabled, audio control packets with the *audioStreamCtr* field and the *audioInputCtr* field are not required to be delivered. For the proper link synchronization, the audio control packet must be transferred before the first audio data packet with encrypted data.

Any DiiVA video stream containing an HDCP encrypted video pixel data must include one Frame Info Packet with a 32-bit *videoStreamCtr* field and a 64-bit *videoInputCtr* field every frame (or every field in the interlaced mode). A Frame Info Packet following the encrypted video pixel data must have the following two fields: *Encryption_Indicator* = 1 and *Content_Protection_Scheme* = 2, as specified in the DiiVA specification. The presence of these fields in Frame Info Packets serves to indicate that HDCP Encryption is enabled for video and the video pixel data is encrypted. When HDCP Encryption is disabled, Frame Info Packets with the *videoStreamCtr* field and the *videoInputCtr* field are not required to be delivered. For the proper link synchronization, the Frame Info Packet must be transferred before the first video data packet with encrypted pixel data.

3.5 HDCP Cipher Block

The HDCP Cipher Block consists of multiple HDCP Cipher modules to support none or more audio streams and none or more video streams, where each module is an HDCP Cipher for video or audio. The input encryption parameters to each HDCP Cipher module must satisfy a few requirements, i.e., the *streamCtr* value (i.e., *audioStreamCtr* or *videoStreamCtr*) is distinct for each stream (i.e., audio stream or video stream), an *inputCtr* (i.e., *audioInputCtr* or *videoInputCtr*) is associated with each stream, and the same k_s and r_{iv} is used for all streams.

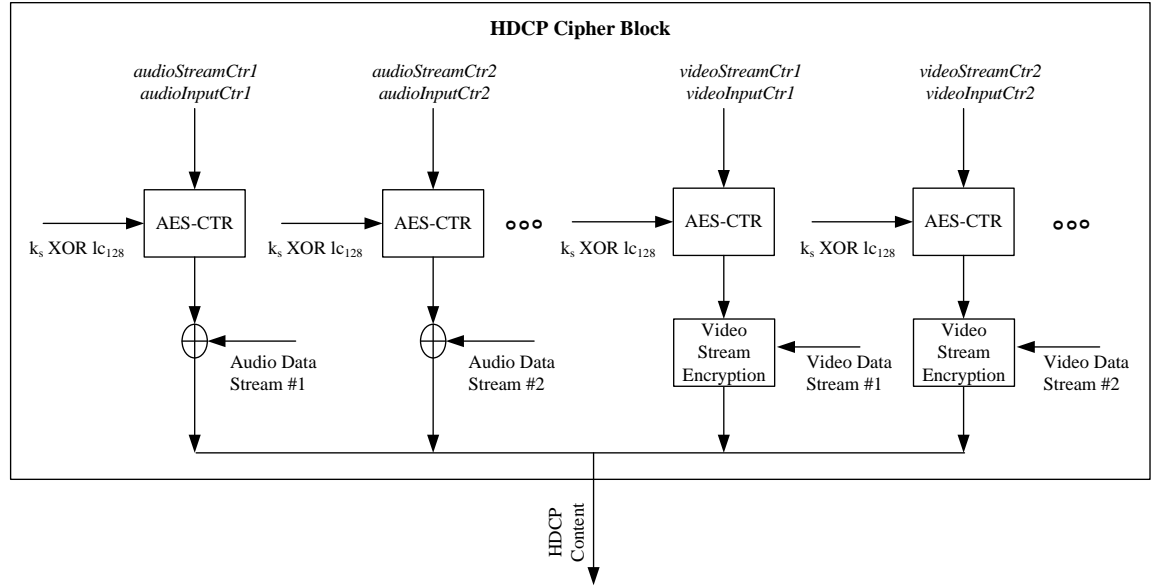


Figure 3.10. HDCP Cipher Block

3.6 Uniqueness of k_s and r_{iv}

HDCP Receivers and HDCP Repeaters with multiple inputs may share the same Public Key Certificates and Private Keys across all inputs. The HDCP Transmitter (including downstream side of HDCP Repeater) must negotiate distinct k_m with each directly connected downstream HDCP Device. While r_{ix} used during each HDCP Session is required to be fresh, transmitters with multiple downstream HDCP links must ensure that each link receives a distinct r_{ix} value.

As illustrated in Figure 3.11, HDCP Transmitters, including downstream side of HDCP Repeaters, with multiple downstream HDCP links may share the same k_s and r_{iv} across those links only if HDCP Content from the same HDCP Cipher Block is transmitted to those links.

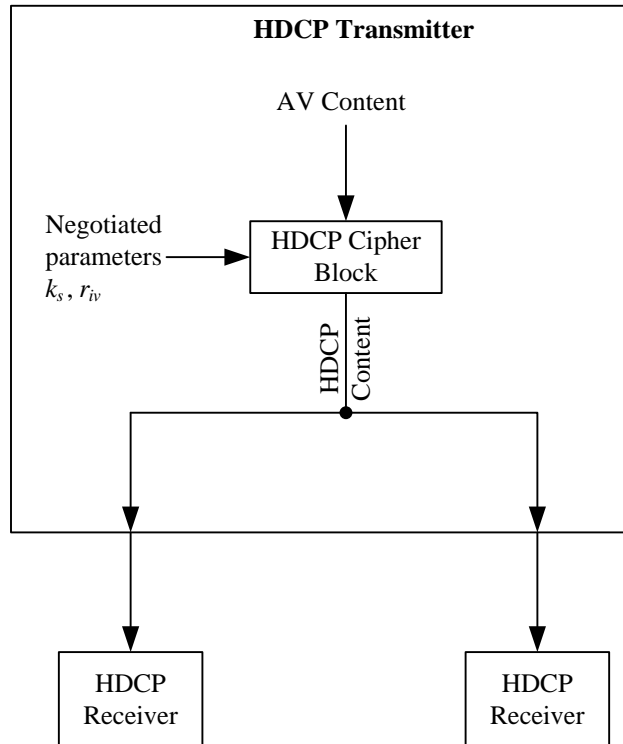


Figure 3.11. k_s and r_{iv} Shared across HDCP Links

As illustrated in Figure 3.12, HDCP Transmitters, including downstream side of HDCP Repeaters, with multiple downstream HDCP links must ensure that each link receives distinct k_s and r_{iv} values if HDCP Content from different HDCP Cipher Blocks is transmitted to those links.

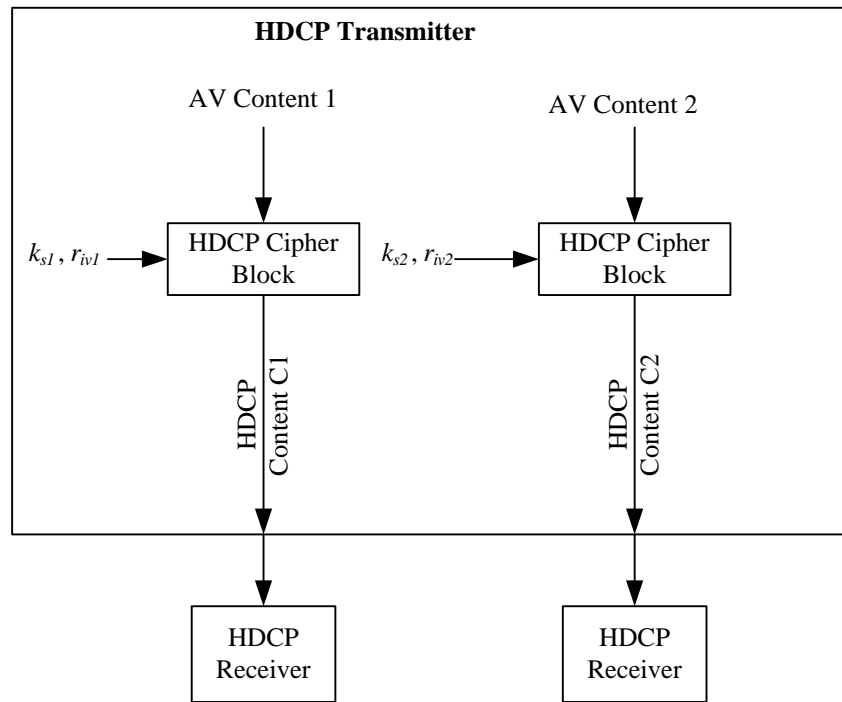


Figure 3.12. Unique k_s and r_{iv} across HDCP Links

4. Authentication Protocol Messages

4.1 Control / Status Stream

Each Control/Status message begins with a `msg_id` field. Valid values of `msg_id` are shown in Table 4.1.

Message Type	msg_id Value
Null message	1
AKE_Init	2
AKE_Send_Cert	3
AKE_No_Stored_km	4
AKE_Stored_km	5
AKE_Send_rrx	6
AKE_Send_H_prime	7
AKE_Send_Pairing_Info	8
LC_Init	9
RTT_Ready	10
RTT_Challenge	11
RTT_Response	12
SKE_Send_Eks	13
RepeaterAuth_Send_ReceiverID_List	14
Reserved	15-31

Table 4.1. Values for msg_id

The DiiVA Control Layer (DCL) message delivery protocol is used to transport messages used for the HDCP Authentication Protocol from the HDCP Transmitter to the HDCP Receiver, and vice versa.

Each message commences with a `msg_id` specifying the message type, followed by parameters specific to each message. Parameter values spanning more than one byte follow the most-significant byte first transmission order.

Note:

- The use of the Null message and Reserved values for `msg_id` are not defined in this specification.

4.2 Message Format

4.2.1 AKE_Init (Transmitter to Receiver)

Syntax	No. of Bytes	Identifier
AKE_Init { <code>msg_id</code> <code>r_{rx}[63..0]</code> }	1 8	uint uint

Table 4.2. AKE_Init Payload

4.2.2 AKE_Send_Cert (Receiver to Transmitter)

The HDCP Receiver sets REPEATER to ‘true’ if it is an HDCP Repeater and ‘false’ if it is an HDCP Receiver that is not an HDCP Repeater. When REPEATER = ‘true’, the HDCP Receiver supports downstream connections as permitted by the Digital Content Protection LLC license.

Syntax	No. of Bytes	Identifier
AKE_Send_Cert { msg_id REPEATER cert _{rx} [4175..0] }	1 1 522	uint bool uint

Table 4.3. AKE_Send_Cert Payload

4.2.3 AKE_No_Stored_km (Transmitter to Receiver)

Syntax	No. of Bytes	Identifier
AKE_No_Stored_km { msg_id E _{kpub} _k _m [1023..0] }	1 128	uint uint

Table 4.4. AKE_No_Stored_km Payload

4.2.4 AKE_Stored_km (Transmitter to Receiver)

Syntax	No. of Bytes	Identifier
AKE_Stored_km { msg_id E _{k_h} _k _m [127..0] m[127..0] }	1 16 16	uint uint uint

Table 4.5. AKE_Stored_km Payload

4.2.5 AKE_Send_rrx (Receiver to Transmitter)

Syntax	No. of Bytes	Identifier
AKE_Send_rrx { msg_id r _{rx} [63..0] }	1 8	uint uint

Table 4.6. AKE_Send_rrx Payload

4.2.6 AKE_Send_H_prime (Receiver to Transmitter)

Syntax	No. of Bytes	Identifier
AK_Send_H_prime { msg_id H [255..0] }	1 32	uint uint

Table 4.7. AKE_Send_H_prime Payload

4.2.7 AKE_Send_Pairing_Info (Receiver to Transmitter)

Syntax	No. of Bytes	Identifier
AKE_Send_Pairing_Info{ msg_id $E_{kh-k_m}[127..0]$ }	1 16	uint uint

Table 4.8. AKE_Send_Pairing_Info Payload

4.2.8 LC_Init (Transmitter to Receiver)

Syntax	No. of Bytes	Identifier
LC_Init { msg_id $r_m[63..0]$ }	1 8	uint uint

Table 4.9. LC_Init Payload

4.2.9 RTT_Ready (Receiver ready for RTT challenge)

Syntax	No. of Bytes	Identifier
RTT_Challenge { msg_id }	1	uint

Table 4.10. RTT_Ready

4.2.10 RTT_Challenge (Transmitter to Receiver)

Syntax	No. of Bytes	Identifier
RTT_Challenge { msg_id $L[127..0]$ }	1 16	uint uint

Table 4.11. RTT_Challenge Payload

4.2.11 RTT_Response (Receiver to Transmitter)

Syntax	No. of Bytes	Identifier
RTT_Response { msg_id $L^*[255..128]$ }	1 16	uint uint

Table 4.12. RTT_Response Payload

4.2.12 SKE_Send_Eks (Transmitter to Receiver)

Syntax	No. of Bytes	Identifier
SKE_Send_Eks{ msg_id $E_{dkey_k_s}[127..0]$ $r_{ivl}[63..0]$ }	1 16 8	uint uint unit

Table 4.13. SKE_Send_Eks Payload

4.2.13 RepeaterAuth_Send_ReceiverID_List (Receiver to Transmitter)

Receiver ID list is constructed by appending *Receiver IDs* in big-endian order.

Receiver ID list = $Receiver\ ID_0 \parallel Receiver\ ID_1 \parallel \dots \parallel Receiver\ ID_{n-1}$, where n is the DEVICE_COUNT.

If the computed DEVICE_COUNT for an HDCP Repeater exceeds 31, the repeater sets MAX_DEVS_EXCEEDED = 'true'. If the computed DEPTH for an HDCP Repeater exceeds four, the repeater sets MAX_CASCADE_EXCEEDED = 'true'. If topology maximums are not exceeded, MAX_DEVS_EXCEEDED = 'false' and MAX_CASCADE_EXCEEDED = 'false'

Syntax	No. of Bytes	Identifier
RepeaterAuth_Send_ReceiverID_List{ msg_id MAX_DEVS_EXCEEDED MAX_CASCADE_EXCEEDED if (MAX_DEVS_EXCEEDED != 1 && MAX_CASCADE_EXCEEDED != 1) { DEVICE_COUNT DEPTH V [255..0] for (j=0; j< DEVICE_COUNT; j++) { $Receiver_ID_j[39..0]$ } } }	1 1 1 1 1 32 5	uint bool bool uint uint uint uint

Table 4.14. RepeaterAuth_Send_ReceiverID_List Payload

5. Renewability

It is contemplated that an authorized participant in the authentication protocol may become compromised so as to expose the RSA private keys it possesses for misuse by unauthorized parties. In consideration of this, each HDCP Receiver is issued a unique Receiver ID which is contained in $cert_{rx}$. Through a process defined in the HDCP Adopter's License, the Digital Content Protection LLC may determine that an HDCP Receiver's RSA private key, $kpriv_{rx}$, has been compromised. If so, it places the corresponding Receiver ID on a revocation list that the HDCP Transmitter checks during authentication.

The HDCP Transmitter is required to manage system renewability messages (SRMs) carrying the Receiver ID revocation list. The validity of an SRM is established by verifying the integrity of its signature with the Digital Content Protection LLC public key, which is specified by the Digital Content Protection LLC.

For interoperability with HDCP 1.x, KSVs of revoked HDCP 1.x devices will be included in the HDCP 2 SRM, in addition to the HDCP 1.x SRM. Similarly, Receiver IDs of revoked HDCP 2 devices will be included in the HDCP 1.x SRM, in addition to the HDCP 2 SRM.

The SRMs are delivered with content and must be checked when available. The Receiver IDs must immediately be checked against the SRM when a new version of the SRM is received. Additionally, devices compliant with HDCP 2.0 and higher must be capable of storing at least 5kB of the SRM in their non-volatile memory. The process by which a device compliant with HDCP 2.0 or higher updates the SRM stored in its non-volatile storage when presented with a newer SRM version is explained in Section 5.2.

5.1 SRM Size and Scalability

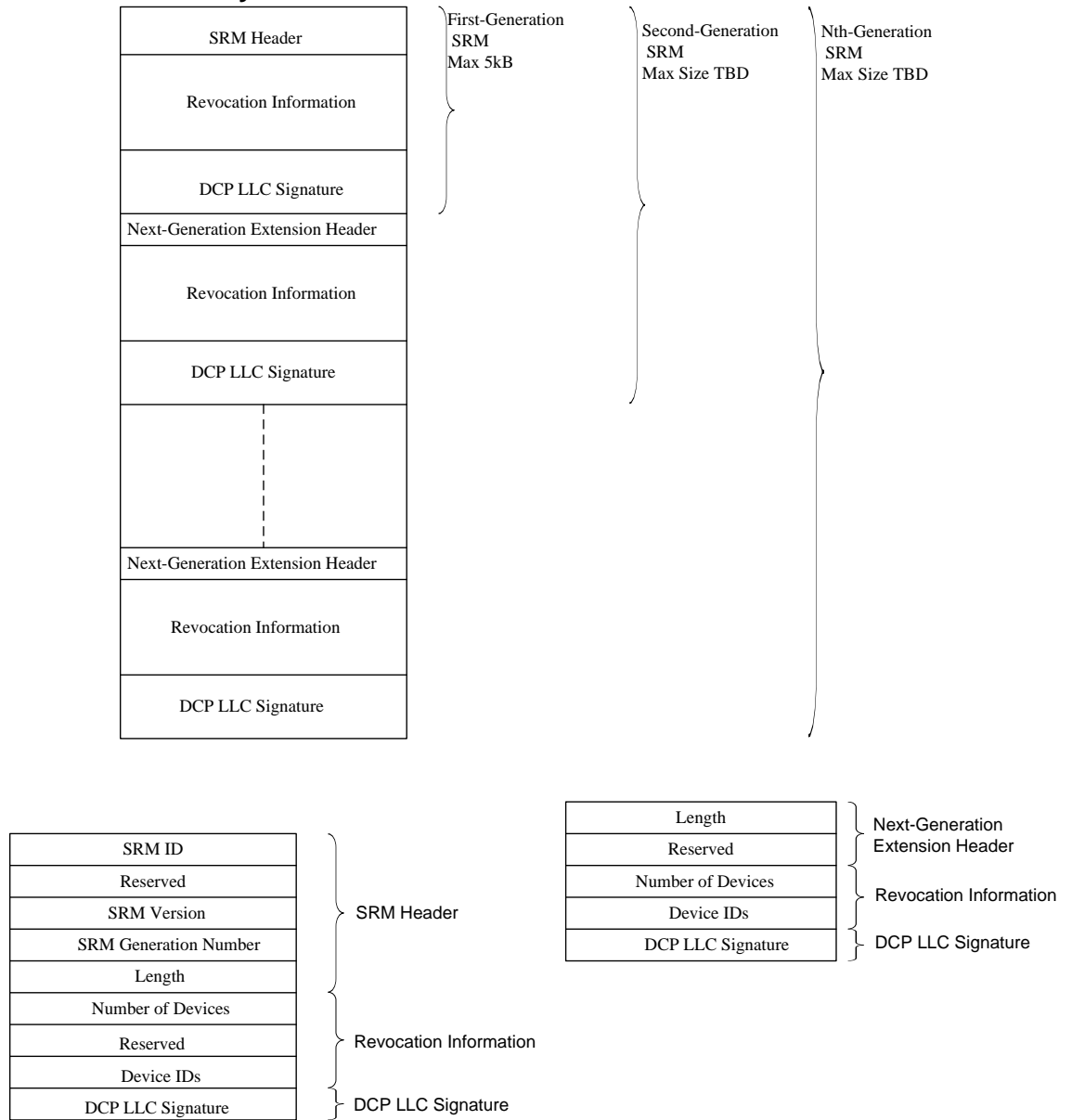


Figure 5.1. SRM Generational Format

As illustrated in Figure 5.1, the size of the First-Generation HDCP SRM will be limited to a maximum of 5kB. The actual size of the First-Generation SRM is 5116 bytes. For scalability of the SRM, the SRM format supports next-generation extensions. By supporting generations of SRMs, an HDCP SRM can, if required in future, grow beyond the 5kB limit to accommodate more Receiver IDs. Next-generation extensions are appended to the current-generation SRM in order to ensure backward compatibility with devices that support only previous-generation SRMs.

Table 5.1 gives the format of the HDCP 2 SRM. All values are stored in big endian format.

Name	Size (bits)	Function
SRM ID	4	A value of 0x9 signifies that the message is for HDCP 2. All other

		values are reserved. SRMs with values other than 0x9 must be ignored.
HDCP2 Indicator	4	A value of 0x1 signifies that the message is for HDCP2
Reserved	8	Reserved for future definition. Must be 0x00
SRM Version	16	Sequentially increasing unique SRM numbers. Higher numbered SRMs are more recent
SRM Generation Number	8	Indicates the generation of the SRM. The generation number starts at 1 and increases sequentially
Length	24	Length in bytes and includes the combined size of this field (three bytes) and all following fields contained in the first-generation SRM i.e. size of this field, Number of Devices field, Reserved (22 bits) field, Device IDs field and Digital Content Protection LLC signature field (384 bytes) in the first-generation SRM
Number of Devices	10	Specifies the number (N1) of Receiver IDs / KSVs contained in the first-generation SRM
Reserved	22	Reserved for future definition. All bits set to 0
Device IDs	40 * N1 Max size for this field is 37760 (4720 bytes)	40-bit Receiver IDs / KSVs
DCP LLC Signature	3072	A cryptographic signature calculated over all preceding fields of the SRM. RSASSA-PKCS1-v1_5 is the signature scheme used as defined by PKCS #1 V2.1: RSA Cryptography Standard. SHA-256 is the underlying hash function

Table 5.1. System Renewability Message Format

Each subsequent next-generation extensions to the first-generation SRM will have the following fields.

Name	Size (bits)	Function
Length	16	Length in bytes and includes the combined size of this field (two bytes) and all following fields contained in this next-generation extension i.e. size of this field, Number of Devices field, Reserved (6 bits) field, Device IDs field and Digital Content Protection LLC signature field (384 bytes) in this next-generation SRM
Reserved	6	Reserved for future definition. All bits set to 0
Number of Devices	10	Specifies the number (N2) of Receiver IDs / KSVs contained in this next generation extension
Device IDs	40 * N2	40-bit Receiver IDs / KSVs
DCP LLC Signature	3072	A cryptographic signature calculated over all preceding fields of the SRM. RSASSA-PKCS1-v1_5 is the signature scheme used as defined by PKCS #1 V2.1: RSA Cryptography Standard. SHA-256 is the underlying hash function

Table 5.2. Next-generation extension format

5.2 Updating SRMs

The stored HDCP SRM must be updated when a newer version of the SRM is delivered with the content. The procedure for updating an SRM is as follows:

1. Verify that the version number of the new SRM is greater than the version number of the SRM currently stored in the device's non-volatile storage
2. If the version number of the new SRM is greater (implying that it is a more recent version), verify the signature on the new SRM

On successful signature verification, replace the current SRM in the device's non-volatile storage with the new SRM. If, for instance, the device supports only second-generation SRMs and the new SRM is a third-generation SRM, the device is not required to store the third-generation extension. Devices compliant with HDCP 2.0 or higher must be capable of storing at least 5kB (actual size is 5116 bytes) of the SRM (First-Generation SRM).

Appendix A. Confidentiality and Integrity of Values

Table A.1 identifies the requirements of confidentiality and integrity for values within the protocol. A *confidential* value must never be revealed. The *integrity* of many values in the system is protected by fail-safe mechanisms of the protocol. Values that are not protected in this manner require active measures beyond the protocol to ensure integrity. Such values are noted in the table as requiring integrity.

Value	Confidentiality Required [±] ?	Integrity Required [±] ?
lc_{128}	Yes	Yes
$kpub_{dcp}$	No	Yes
$cert_{rx}$	No	No
$kpub_{rx}$	No	Yes
Receiver ID	No	Yes
$kpriv_{rx}$	Yes	Yes
r_{rx}	No	Yes*
r_{iv}	No	Yes*
REPEATER	No	Yes
r_{rx}	No	Yes**
k_m	Yes	Yes*
k_d	Yes	Yes*
$dkey_i$	Yes	Yes*
H	Yes	Yes
H'	No	No
m	No	No
k_h	Yes	Yes

[±] According to the robustness rules in the HDCP Adopter's License

* Only within the transmitter

** Only within the receiver

r_n	No	Yes*
L	Yes	Yes
L'	No	No
k_s	Yes	Yes*
V	Yes	Yes
V'	No	No
Receiver ID list	No	Yes
DEPTH	No	Yes
DEVICE_COUNT	No	Yes
MAX_DEVS_EXCEEDED	No	Yes
MAX_CASCADE_EXCEEDED	No	Yes
<i>audioInputCtr</i>	No	Yes*
<i>audioStreamCtr</i>	No	Yes*
<i>videoInputCtr</i>	No	Yes*
<i>videoStreamCtr</i>	No	Yes*
p	No	Yes*

Table A.1. Confidentiality and Integrity of Values

Appendix B. DCP LLC Public Key

Table B.1 gives the production DCP LLC public key.

Parameter	Value (hexadecimal)	
Modulus n	B0E9 AA45 F129 BA0A 1CBE 1757 28EB 2B4E	
	8FD0 C06A AD79 980F 8D43 8D47 04B8 2BF4	
	1521 5619 0140 013B D091 9062 9E89 C227	
	8ECF B6DB CE3F 7210 5093 8C23 2983 7B80	
	64A7 59E8 6167 4CBC D858 B8F1 D4F8 2C37	
	9816 260E 4EF9 4EEE 24DE CCD1 4B4B C506	
	7AFB 4965 E6C0 0083 481E 8E42 2A53 A0F5	
	3729 2B5A F973 C59A A1B5 B574 7C06 DC7B	
	7CDC 6C6E 826B 4988 D41B 25E0 EED1 79BD	
	3985 FA4F 25EC 7019 23C1 B9A6 D97E 3EDA	
	48A9 58E3 1814 1E9F 307F 4CA8 AE53 2266	
	2BBE 24CB 4766 FC83 CF5C 2D1E 3AAB AB06	
	BE05 AA1A 9B2D B7A6 54F3 632B 97BF 93BE	
	C1AF 2139 490C E931 90CC C2BB 3C02 C4E2	
	BDBD 2F84 639B D2DD 783E 90C6 C5AC 1677	
	2E69 6C77 FDED 8A4D 6A8C A3A9 256C 21FD	
	B294 0C84 AA07 2926 46F7 9B3A 1987 E09F	
	EB30 A8F5 64EB 07F1 E9DB F9AF 2C8B 697E	
	2E67 393F F3A6 E5CD DA24 9BA2 7872 F0A2	
	27C3 E025 B4A1 046A 5980 27B5 DAB4 B453	
	973B 2899 ACF4 9627 0F7F 300C 4AAF CB9E	
	D871 2824 3EBC 3515 BE13 EBAF 4301 BD61	
	2454 349F 733E B510 9FC9 FC80 E84D E332	
	968F 8810 2325 F3D3 3E6E 6DBB DC29 66EB	
	Public Exponent e	03

Table B.1. DCP LLC Public Key

Appendix C. Bibliography (Informative)

These documents are not normatively referenced in this specification, but may provide useful supplementary information.

Appendix D. Test Vectors

D.1. Facsimile Keys

Note: The facsimile keys provided must be used ONLY for test purposes.

All values are provided in big-endian order.

Table D.1 provides facsimile key information for transmitter T1.

	Value in Hex
Global Constant lc_{128}	93 ce 5a 56 a0 a1 f4 f7 3c 65 8a 1b d2 ae f0 f7

Table D.1

Table D.2 provides the facsimile public parameters associated with the DCP LLC key $k_{pub_{dcp}}$. These parameters are used only for test purposes. They are not used in production devices or SRMs.

	Value in Hex
Modulus n	A2 C7 55 57 54 CB AA A7 7A 27 92 C3 1A 6D C2 31 CF 12 C2 24 BF 89 72 46 A4 8D 20 83 B2 DD 04 DA 7E 01 A9 19 EF 7E 8C 47 54 C8 59 72 5C 89 60 62 9F 39 D0 E4 80 CA A8 D4 1E 91 E3 0E 2C 77 55 6D 58 A8 9E 3E F2 DA 78 3E BA D1 05 37 07 F2 88 74 0C BC FB 68 A4 7A 27 AD 63 A5 1F 67 F1 45 85 16 49 8A E6 34 1C 6E 80 F5 FF 13 72 85 5D C1 DE 5F 01 86 55 86 71 E8 10 33 14 70 2A 5F 15 7B 5C 65 3C 46 3A 17 79 ED 54 6A A6 C9 DF EB 2A 81 2A 80 2A 46 A2 06 DB FD D5 F3 CF 74 BB 66 56 48 D7 7C 6A 03 14 1E 55 56 E4 B6 FA 38 2B 5D FB 87 9F 9E 78 21 87 C0 0C 63 3E 8D 0F E2 A7 19 10 9B 15 E1 11 87 49 33 49 B8 66 32 28 7C 87 F5 D2 2E C5 F3 66 2F 79 EF 40 5A D4 14 85 74 5F 06 43 50 CD DE 84 E7 3C 7D 8E 8A 49 CC 5A CF 73 A1 8A 13 FF 37 13 3D AD 57 D8 51 22 D6 32 1F C0 68 4C A0 5B DD 5F 78 C8 9F 2D 3A A2 B8 1E 4A E4 08 55 64 05 E6 94 FB EB 03 6A 0A BE 83 18 94 D4 B6 C3 F2 58 9C

	7A 24 DD D1 3A B7 3A B0 BB E5 D1 28 AB AD 24 54 72 0E 76 D2 89 32 EA 46 D3 78 D0 A9 67 78 C1 2D 18 B0 33 DE DB 27 CC B0 7C C9 A4 BD DF 2B 64 10 32 44 06 81 21 B3 BA CF 33 85 49 1E 86 4C BD F2 3D 34 EF D6 23 7A 9F 2C DA 84 F0 83 83 71 7D DA 6E 44 96 CD 1D 05 DE 30 F6 1E 2F 9C 99 9C 60 07
Public Exponent e	03

Table D.2

Table D.3 and Table D.4 provide the facsimile certificates (*cert_{rx}*) for receivers R1 and R2.

As provided in Table 2.1 of High-bandwidth Digital Content Protection System, Revision 2.0, Interface Independent Adaptation specification, the certificate format consists of 40-bit Receiver ID, followed by 1048-bit Receiver Public Key, 16-bit Reserved and 3072-bit Signature fields. All values are stored in big-endian format.

For example, in Table D.3, 0x745bb8bd04 is the Receiver ID which is followed by Receiver Public Key, Reserved and Signature fields.

	Value (Sequence of Hexadecimal bytes) for R1
Certificate (<i>cert_{rx}</i>)	74 5b b8 bd 04 bc 83 c7 95 78 f9 0c 91 4b 89 38 05 5a a4 ac 1f a8 03 93 82 79 75 af 66 22 de 43 80 8d cd 5d 90 b8 3c b3 d8 9e b0 0d 09 44 f4 3f 5f ab b9 c4 c9 96 ef 78 b5 8f 69 77 b4 7d 08 14 9c 81 a0 8f 04 1f a0 88 e1 20 c7 34 4a 49 35 65 99 cf 53 19 f0 c6 81 76 05 5c b9 de dd ab 3d b0 92 a1 23 4f 0c 71 30 42 78 f6 55 ae bd 36 25 8e 25 0d 4e 5e 8e 77 6a 60 e3 c1 e9 ee cd 2b 9e 18 63 97 d4 e6 75 01 00 01 00 00 1d 0a 61 ea ab f8 a8 2b 02 69 a1 34 fd 91 ac 2b f2 8f 34 8b d4 84 fa 62 bc 01 4a 4a a2 b2 14 bf b5 f4 df ac 80 93 0d 13 ec 9c e5 d8 34 70 51 9a 66 80 eb be cc 7e 45 f0 e6 39 63 84 c9 b9 8e 8c af 9c a9 d4 0e eb 9a 57 2a 17 41 ca 97 f3 19 96 b5 5d 0f 30 a3 84 e5 73 a2 ed 05 69 7a 22 ce 84 1f 3e 39 9e 28 76 c9 bc 89 5b 70 b1 7b f4 ed b6 74 12 ab 48 29 64 ce 6c 60 04 eb a9 7a a2 15 a6 58 9a ad 32 c7 53 39 e5 fe f0 37 a7 a0 c5 ff ec d9 b0 05 bb 25 13 a0 a4 c7 0b 2a 5d c6 8f 51 11 cb 36 ed 5c 17 7e 22 20 c3 eb 40 8c 67 bb 1c d2 47 b0 e0 bd e7 4c cd 5d d5 23 12 f8 3b 1d 91 3b f3 c7 60 ea 90 24 48 e5 92 21 6c f6 d9 5e 76

8d 2b 86 a6 7c 16 ae a8 36 08 a0 37 14 1a d7 03 e1 40 31 ca 6c 95 e0 10 b0 43 cf b7 e0 30 05 b9 ac b7 08 68 cd 7e 11 47 2a 03 3b eb 74 c8 19 62 8b 2f 11 91 b6 06 4f e0 2a 44 20 43 29 13 1f dd d0 4a 11 6c 0e 83 bf 22 62 3b eb ec d7 76 28 ba 64 88 42 c8 73 a7 9e 4a 69 3a b2 0c 4b 3a d9 50 db 7c 51 ee 15 e0 6b 2c 63 a6 91 57 dd bf 17 47 23 ad 15 cb b9 91 18 0b 51 8f f9 1c 51 67 c1 0b 78 f5 d9 55 dc 48 e4 c0 83 a5 df 75 e2 dc 88 d2 c6 dd df 1f 37 90 35 f6 fd da e0 04 32 69 c1 af d9 f9 11 c5 aa 74 58 32 1c 71 aa a7 14 fb 23 17 22
--

Table D.3

	Value (Sequence of Hexadecimal bytes) for R2
Certificate (<i>cert_{rx}</i>)	8b a4 47 42 fb c9 1b 82 e2 76 7f 90 4f e9 12 33 7c 21 1f 7b 25 da 76 de ae 59 70 f7 c2 e7 e0 4a cf bd 5b ba 1c 36 4e e3 78 4c 92 6a 3c d8 c1 e9 51 a9 35 eb d8 e8 d5 3e 3b 1d 00 c1 16 16 d0 58 eb 2a 4b a0 76 9c d0 e4 b2 23 dc aa 37 07 e5 85 1a aa 13 55 01 4e ed 88 ca 3f fb c5 58 46 91 ec 35 99 08 1c a1 22 64 e8 3c 2e 70 df a9 10 14 81 46 a2 38 08 ef 1b d2 46 ee 38 0d 6d 92 d3 f2 02 e7 e4 29 ad 0d 01 00 01 00 00 91 18 81 a5 cd ab 78 50 ad 1d 3b 77 be 51 32 9f 04 e6 3e f7 01 39 f2 59 98 75 9d 29 12 33 39 b4 80 91 9d 6a ff 0d 5c 59 22 43 77 fc ed c2 40 9d e2 d1 4b ff 02 78 36 d3 ad cb a6 d3 d3 9d cc ff cb 3c a3 cb fd df cf e2 85 a8 bd a2 f6 60 06 b2 9b 53 c4 d6 22 bd 65 3c 6f 40 01 7c 2c 78 89 31 70 47 56 88 f5 56 33 f2 0a 91 27 b1 68 5f 84 98 1d 37 bd 69 11 6d 60 ca 01 44 be fa 92 1f ec 15 be 37 68 d1 dc cc 66 7c c4 8b 78 51 d9 81 df aa e2 70 2f 02 59 10 64 b2 93 6d 09 23 a9 7d 0a db 8a 34 53 ca e2 6a 6d 39 fb 25 5e 38 86 eb 4d a1 c1 ea bd ac 1d 14 46 ac 58 86 55 ec 40 9f dc 4f 80 f2 68 0c 81 a3 df 01 a0 62 44 9e 20 42 89 88 24 b2 6a 40 11 4b 96 33 ba 0d ae 49 98 4b 24 16 5f ff 85 86 4a 09 cd ce 30 f2 fa ff 74 28 40 97 a5 56 29 74 53 a2 34 e4 ee e0 45 b6 d8 a7 9b a0 1a 00 2d ff 8d 2f ed 70 15 c5 e0 11 bb c8 ef 5b 2c b3 12 0f be 88 7c 98 44 3c 65 45 bc 20 ac 07 e2 4c 74 2a b4 b1 0e 47 2a d6 20 19 ce 75 18 45 28 90 4f 84 42 81 37 ed 1d 0b 48 f7 53 e3 92 f2 eb df 7a 91 df e8 db b1 c4 fd fd c1 ad 4e cc be 11 e2 76 9b 78 2b b8 f4 0e 9d 05 d6 08 d0 76 2c e8 4d ee 3d 31 da c4 f7 01 12 8f 5d 94 e6 cb 15 fe 53 42 b2

	51 8c 5d c7 64 de 14 8f af c1 af 36
--	-------------------------------------

Table D.4

Table D.5 and Table D.6 provide the private keys for receivers R1 and R2.

	Value in Hex for R1
P	dc 1a 02 b8 36 ed 3a e8 74 74 cd 72 28 4a ee 31 90 e4 d0 6a f9 f6 f8 d3 50 29 c2 84 97 98 10 5d ea 7b 88 fd 36 c5 04 99 ad ab 27 0a 5a 2a f9 18 7b 7d b0 c3 cb e3 5a c2 9a 10 f7 c9 9a 18 3e b5
q	db 42 e9 42 e3 2a 78 c9 6f 2b 7b 74 d6 9b ae b9 3d f4 e7 35 90 1c c4 5a b4 22 8c 3c 08 9b a5 29 64 57 29 b2 c4 80 f9 ee c6 94 30 3e d2 33 9f bb 6a 43 03 89 14 9b 8f 20 b8 60 1f 7f 30 3b 20 c1
d mod (p-1)	73 d1 a4 18 b7 9e 81 df 0c 58 e2 3a ee 04 ef ee 59 26 6e 9d bc 47 3f 8c 42 a4 96 dd 1a c0 43 ec 87 94 d5 f3 18 bc f7 bc be 6c 4f b0 dc dd bc 12 2b f9 69 e8 be 03 37 21 2b dd 3d e6 72 15 cb f9
d mod (q-1)	09 1d e6 1f 0e dd 04 3a b3 f1 a5 e7 7c c8 ea 61 ef 6e 90 72 8c b4 75 81 a3 fd cf c0 eb 46 b5 7e 5c 1a b7 b4 24 31 8c b2 dd f4 e9 70 a3 42 dc 40 69 b1 b1 a2 f0 85 6b 55 1b f5 7b 39 c9 a2 9b c1
q ⁻¹ mod p	89 58 a5 a3 63 d9 a9 ee 0e 7e a1 c0 56 2d 59 fc f8 66 1c 26 48 21 9d e0 61 e4 a8 06 97 64 c7 01 77 47 11 8e a2 81 d2 00 dd 5a 1b 8f 7a 1b 2c 68 56 39 cf cd d3 6a ff 73 81 1d 91 3d 48 b4 43 4c

Table D.5

	Value in Hex for R2
p	ff 7d a0 6d 7d c4 eb 8e 60 e2 0b fd b9 00 11 58 55 28 37 b9 28 7a d4 ec c8 49 e3 37 63 37 8f 8d c2 22 75 00 d0 4b c0 a5 a4 97 ad 35 5b 69 2b 17 9f 7d 84 04 5b 61 7d 40 3c a5 ca f9 e7 51 17 e7
q	c9 82 22 32 71 88 06 bc a8 97 58 74 7c cd af 9e 9d 71 eb db c6 7c 24 91 8b da cf f5 6b a1 8e b5 09 87 ca 11 d2 70 f9 81 c7 dd aa a9 0c 1b 16 e7 c3 93 0b 35 80 ca 77 92 a3 f1 8c 6d d7 39 e4 eb
d mod (p-1)	42 5c e0 51 f0 6c 38 ff 57 9c ff 9e 5c f2 6e 8e f2 37 ab 19 b6 31 09 a3 a3 76 c5 c5 3a 49 51 49 72 16 bf 2b 81 ef 5b 4f eb 4b d6 9a d8 6e 9d d9 d9 fc a1 50 fc 67 7b 40 37 40 9d 53 82 49 27 1b
d mod (q-1)	5b 70 74 ea 25 00 8f e6 0e 2e d7 51 cc cc 5d 54 01 a8 0f 5a 24 80 72 eb a4 e5 ff 16 23 e8 24 e4 db d5 45 89 be cf cb 38 ec 24 17 6c 2c 75 22 78 bb 13 bf b3 60 a4 ff 8b 88 5f 74 d4 e7 24 7b 4f
q ⁻¹ mod p	e8 0a 4a 20 24 17 0f ef 3b cb ee 39 49 4a 1f 50 35 e4 d9 4b 5b 2c 2a af f8 e4 1b 17 04 bf ca 7b fd b2 1d d6 1a bf 61 c4 46 7c 8d ce 74 39 7e 52 3a 6e 8a 3b a4 bf 07 da 86 07 eb 17

	bc 83 c7 95 78 f9 0c 91 4b 89 38 05 5a a4 ac 1f a8 03 93 82 79 75 af 66 22 de 43 80 8d cd 5d 90 b8 3c b3 d8 9e b0 0d 09 44 f4 3f 5f ab b9 c4 c9 96 ef 78 b5 8f 69 77 b4 7d 08 14 9c 81 a0 8f 04 1f a0 88 e1 20 c7 34 4a 49 35 65 99 cf 53 19 f0 c6 81 76 05 5c b9 de dd ab 3d b0 92 a1 23 4f 0c 71 30 42 78 f6 55 ae bd 36 25 8e 25 0d 4e 5e 8e 77 6a 60 e3 c1 e9 ee cd 2b 9e 18 63 97 d4 e6 75 e: 01 00 01	c9 1b 82 e2 76 7f 90 4f e9 12 33 7c 21 1f 7b 25 da 76 de ae 59 70 f7 c2 e7 e0 4a cf bd 5b ba 1c 36 4e e3 78 4c 92 6a 3c d8 c1 e9 51 a9 35 eb d8 e8 d5 3e 3b 1d 00 c1 16 16 d0 58 eb 2a 4b a0 76 9c d0 e4 b2 23 dc aa 37 07 e5 85 1a aa 13 55 01 4e ed 88 ca 3f fb c5 58 46 91 ec 35 99 08 1c a1 22 64 e8 3c 2e 70 df a9 10 14 81 46 a2 38 08 ef 1b d2 46 ee 38 0d 6d 92 d3 f2 02 e7 e4 29 ad 0d e: 01 00 01
k_m	68 bc c5 1b a9 db 1b d0 fa f1 5e 9a d8 a5 af b9	ca 9f 83 95 70 d0 d0 f9 cf e4 eb 54 7e 09 fa 3b
$E_{k_{pub}}(km)$	Seed: 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F 10 11 12 13 14 15 16 17 18 19 1A 1B 1C 1D 1E 1F lhash: e3 b0 c4 42 98 fc 1c 14 9a fb f4 c8 99 6f b9 24 27 ae 41 e4 64 9b 93 4c a4 95 99 1b 78 52 b8 55 $E_{k_{pub}}(km)$: 75 d1 07 f6 9b 7f 1e bd 84 2a 33 e2 89 03 75 b1 27 3c c2 f1 da f8 76 94 9b e0 5e 35 a4 b3 32 a0 b5 ea 75 ef 6f 3a d8 31 3a dd	Seed: 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F 10 11 12 13 14 15 16 17 18 19 1A 1B 1C 1D 1E 1F lhash: e3 b0 c4 42 98 fc 1c 14 9a fb f4 c8 99 6f b9 24 27 ae 41 e4 64 9b 93 4c a4 95 99 1b 78 52 b8 55 $E_{k_{pub}}(km)$: 78 73 6b 24 d6 26 fd 11 36 b5 55 5a a8 be 46 9e 69 a1 ef 19 de d2 43 33 7b e7 e8 88 e2 8e d1 6f 95 b3 56 b7 a0 ac 62 26 57 03 69 03 f9 5c 8b 1d 6a d5 ab f9 8f 7a 71 51 d6 73 22 9a cd 51 7a

	c5 9b de a3 bb 00 39 29 48 93 76 2a e9 e1 b5 17 0c 64 6b d4 12 8f 9b e1 07 b5 a7 9e d6 fd 6e 28 c8 5b d0 c4 01 e7 69 f4 70 ab b8 91 2a 31 4b 86 fd 96 80 20 19 7b 73 ad 7e 78 ae e1 71 07 07 50 2d 3f 43 ff d4 50 4e d7 70 fe cf f2 25 82 ba 43 9e 61 d6 f5 02 84	72 29 3f d3 fe fb bf f0 74 89 09 cb c9 cd 57 bb 4a 83 94 01 f1 9e 1f 97 e1 50 84 5c d8 b5 b0 e1 ab f1 15 19 63 29 4f 37 3b a1 ec 14 40 bf db 33 bb 46 da f8 3c a4 73 7e ba 97 2a 18 57 6b d6 f8 58
r_{rx}	3b a0 be de 0c 46 a9 91	e1 7a b0 fd 0f 54 40 52
$dkey_0$	89 9e a9 7a 52 a8 1a 15 a3 d0 08 74 b0 67 7d f4	83 02 a3 c7 57 2c c6 69 f7 0a e7 3f 84 bf 05 65
$dkey_1$	9a 80 a3 a3 1a dd 35 55 24 77 1e 66 8d 8f 5d 2d	8f eb 20 67 68 b0 36 8b c9 15 85 62 8f 5c 34 5b
k_d	89 9e a9 7a 52 a8 1a 15 a3 d0 08 74 b0 67 7d f4 9a 80 a3 a3 1a dd 35 55 24 77 1e 66 8d 8f 5d 2d	83 02 a3 c7 57 2c c6 69 f7 0a e7 3f 84 bf 05 65 8f eb 20 67 68 b0 36 8b c9 15 85 62 8f 5c 34 5b
H	c3 c0 39 2d c8 66 a2 c3 98 07 b4 bc 3c bb 7a d0 e6 1f 49 d5 e7 04 7e 9a ea 8c ac f9 d7 c8 cd 89	ee 6f 40 74 eb 1b d0 7b 35 15 b0 f8 28 6a b5 66 96 e9 39 2b d7 62 be d4 6a 92 d8 d0 a4 18 4d 42
H'	c3 c0 39 2d c8 66 a2 c3 98 07 b4 bc 3c bb 7a d0 e6 1f 49 d5 e7 04 7e 9a ea 8c ac f9 d7 c8 cd 89	ee 6f 40 74 eb 1b d0 7b 35 15 b0 f8 28 6a b5 66 96 e9 39 2b d7 62 be d4 6a 92 d8 d0 a4 18 4d 42
Pairing		
$E_{kh}(k_m)$	Hash of private = SHA256 hash on concatenation of p, q, d mod (p-1), d mod (q-1), q^{-1} mod p i.e. SHA- 256(p q d mod (p-1) d mod (q-	Hash of private = SHA256 hash on concatenation of p, q, d mod (p-1), d mod (q- 1), q^{-1} mod p i.e. SHA-256(p q d mod (p-1) d mod (q- 1) q^{-1} mod p):

	$1) q^{-1} \text{ mod } p) :$ 5d 7f 16 2f e1 33 c7 0c 44 b7 f2 95 0d 4b 32 05 34 c6 63 5c 41 11 dc cf c4 24 e1 e5 0c 42 73 7c $k_h :$ 34 c6 63 5c 41 11 dc cf c4 24 e1 e5 0c 42 73 7c $E_{kh}(k_m) :$ ce 82 f8 36 56 cb bb af 40 ba 83 17 8c d3 a4 a6	36 85 b9 ee 44 60 49 13 95 e8 05 f0 43 ee 3e 25 ef 5d d8 39 05 34 ae 90 79 89 00 db 83 86 3f d2 $k_h :$ ef 5d d8 39 05 34 ae 90 79 89 00 db 83 86 3f d2 $E_{kh}(k_m) :$ 2e ec e5 58 e7 8f 1a 96 d3 bd 40 14 a6 7e 29 3a
m	18 fa e4 20 6a fb 51 49 00 00 00 00 00 00 00 00	f9 f1 30 a8 2d 5b e5 c3 00 00 00 00 00 00 00
Locality Check		
r_n	32 75 3e a8 78 a6 38 1c	a0 fe 9b b8 20 60 58 ca
L	1b 57 26 de b5 65 1c 77 31 70 d0 09 4a 14 eb 0d 1f 1c ab a9 fe 84 fd d4 eb 17 52 e3 e8 d0 d6 36	19 16 b1 59 73 be e3 67 f0 56 50 51 44 0f 53 a2 df 53 8d ce e2 58 1f 65 f3 bf 03 0e 68 14 e0 e4
L'	1b 57 26 de b5 65 1c 77 31 70 d0 09 4a 14 eb 0d 1f 1c ab a9 fe 84 fd d4 eb 17 52 e3 e8 d0 d6 36	19 16 b1 59 73 be e3 67 f0 56 50 51 44 0f 53 a2 df 53 8d ce e2 58 1f 65 f3 bf 03 0e 68 14 e0 e4
Session Key Exchange		
k_s	f3 df 1d d9 57 96 12 3f 98 97 89 b4 21 e1 2d e1	f3 df 1d d9 57 96 12 3f 98 97 89 b4 21 e1 2d e1
r_{iv}	40 2b 6b 43 c5 e8 86 d8	9a 6d 11 00 a9 b7 6f 64
dkey ₂	38 4d eb f3 5d b2 3b 70 dd 68 5d 03 ea 05 6f 75	56 04 d8 41 07 27 f6 5d 70 90 2d 00 e5 b4 29 97
$E_{dkey}(k_s)$	cb 92 f6 2a 0a 24 29 4f 7e 5f 6a 69 c7 a2 eb 05	a5 db c5 98 50 b1 e4 62 09 7d 14 49 cb 01 44 24
Authentication with Repeaters		
Receiver ID_0	35 79 6a 17 2e	N/A as R2 is not an

<i>Receiver ID₁</i>	47 8e 71 e2 0f	HDPC Repeater
<i>Receiver ID₂</i>	74 e8 53 97 a6	
Receiver ID list	35 79 6a 17 2e 47 8e 71 e2 0f 74 e8 53 97 a6	
DEPTH	0x01	
DEVICE_COUNT	0x03	
MAX_DEVS_EXCEEDED	0x00	
MAX_CASCADE_EXCEEDED	0x00	
V	cc d0 09 37 72 d3 c0 cc 4e 9b 8f da 04 1c 6b 66 0b 86 31 47 55 28 9e 9f 75 4f 28 5d 28 6f 32 cf	
V'	cc d0 09 37 72 d3 c0 cc 4e 9b 8f da 04 1c 6b 66 0b 86 31 47 55 28 9e 9f 75 4f 28 5d 28 6f 32 cf	

Table D.8

D.3. Audio Stream Encryption

Provided below is the input audio stream to be encrypted at T1.

Audio Stream #1: Audio Data (Plaintext to be encrypted)

```
00 00 01 00 01 1b 3c 5b b8 00 00 00 01 b5 85 44 3b 98 00 00 00 00
01 b2 44 54 47 31 41 fe 00 00 01 01 62 af 5f e7 e5 22 b8 a3 be ab
cf be ab f3 f1 73 0a 3f 9a 6e 62 b0 f8 d5 55 c2 8f e5 c9 ae 75 d0
dc 40 bf 40 bf a4 21 2e 9b c8 ba 1b 91 94 c5 38 9d 1b 42 51 85 30
a4 14 c2 b9 16 35 20 4d 21 70 9a 93 5b 4d 84 a5 65 a6 7b 54 f2 1b
46 36 1b 95 09 4e c3 68 6e a1 28 d3 90 ed 42 52 d9 b6 aa 12 85 16
d1 6b ba aa 9a e9 2a 8b 45 f5 d9 34 6f 55 34 5b 45 90 d3 e0 a0 82
c8 18 db 17 aa b5 35 38 64 b9 0a e9 a8 fc 1e 9f 47 02 80 1a d7 d0
d4 2f 50 37 44 da e8 55 e0 f0 25 3b ba 28 e0 86 7f e5 45 48 91 79
f0 45 5e 7b 3b ba 37 e6 16 ad ba 8c aa df 02 de 8b 79 e4 eb ae 65
fa a0 99 f8 81 aa 6d ca d8 db f3 b6 f7 9a 35 4d 18 34 66 d2 d0 ab
b3 3b 93 77 50 00 00 00 01 02 62 56 eb ea e7 3f c9 8b 93 55 c3 ae
ff 72 6e 8a 37 e7 dd 39 e2 6f 7f d5 55 46 fc e4 d4 b3 32 37 e6 2d
f5 0d 1b 2b 50 cc d8 da da 9a e7 04 dd 77 8d 54 6f 92 30 6b da a6
fc b5 be b1 a3 d2 c5 83 16 c1 ad ae fd 12 24 48 a1 28 02 30 57 08
c1 53 f3 ee 7a 13 89 fd f4 57 53 65 b6 db 4d d6 9b d2 4d 34 f9 07
33 f0 e6 7e cb 68 47 02 80 1b 69 33 b8 d8 4e 5b 5d 9b 5a a3 a7 8d
55 b7 b2 ea 92 7a 2c b5 25 af 3d aa a4 e3 6c b6 91 36 08 e1 a7 c2
f1 28 5f 25 2e 2a 92 05 14 14 c0 c6 5e 28 e6 80 6d 83 e0 97 93 20
c8 a8 aa e6 a4 54 56 f5 74 28 fe 3d d0 4e f9 04 6c 2c e8 d8 11 bf
3a 6f 51 5a 31 6a 98 23 54 d6 c9 5a 38 60 c5 a3 5b 64 d1 d1 8b 46
8c da 1a 3c 6a 9a e6 a9 a9 93 41 33 0a b6 75 6e 9b 23 25 6b 6a 41
38 70 26 0e a6 18 b2 1b a6 12 74 51 d2 8f 4f 00 00 00 01 03 72 56
ce 6d ee ef 7f f7 77 5d ff 77 73 73 be 87 1b f0 d8 b9 2f 76 be e7
c3 20 c8 a8 85 5c d4 19 14 f1 32 26 5d 34 78 0d 8e c1 47 02 80 1c
b0 ef 57 4d 1e c6 08 9b 5d 77 31 11 51 51 55 75 de 14 8a ef 75 e9
50 1d ba 88 51 0b 44 28 85 a4 d0 dc 07 83 43 e3 c8 cf 8f 9b d5 d4
82 00 57 08 01 5d 36 db 75 b2 66 68 9e a1 49 99 14 d3 65 a6 db 6e
8c 8e ea 9a 12 38 4e 36 9a 69 b1 aa a4 8c c3 6d ee a6 c7 55 55 ad
94 19 55 68 54 82 c8 6d 55 42 50 aa fa ed b6 a2 6f 85 fc 1a d8 3a
f3 6d 8b cf a8 36 fc fd 18 31 46 0d f9 8b 7d 2b 41 ba d6 ad 9d aa
6a 69 69 dd 95 54 c2 6f 81 8a e0 18 ac 5d 42 8d 03 34 9e 05 5a 21
b4 03 b8 07 74 51 df d2 d2 62 e0 da 73 45 22 e7 ba 73 41 32 26 45
45 5d 73 e5 45 45 45 50 47 02 80 1d a3 fe 19 15 22 45 0a 3b e5 45
55 5a f0 00 00 00 01 04 72 ad 73 e3 55 e7 fa aa 45 39 fa aa a9 df
d5 55 45 1f fe a9 12 2f 3f d5 15 22 8a 3b fa 24 48 91 46 f8 fa b5
8a d6 35 ad f9 bb 7d 0b 79 fd 11 55 54 3a ff 95 15 15 15 46 f0 ca
d7 2b 6b 67 6f cc 1b e9 1a e6 da aa 64 82 58 16 10 96 05 84 13 bf
13 e1 cd 45 ad 70 c6 d2 df 99 a3 7e a3 6b 5b 85 40 a4 10 02 0c aa
7d f7 53 47 47 49
```

Audio Stream #2: Audio Data (Plaintext to be encrypted)

```
00 00 00 01 00 02 13 51 4b 80 00 00 00 01 b5 86 5f fb 98 00 00 00
00 01 b2 44 54 47 31 41 fe 00 00 01 01 5a 37 f1 26 b6 a6 cb 5b 6b
66 cd a3 5e
```

The encrypted audio stream generated at transmitter T1 for receiver R2 is provided below.

Audio Stream #1: Encrypted Audio Data

audioStreamCtr = 0, audioInputCtr = 0 (in Audio Control Packet)

21 8b 92 a3 28 c9 84 36 17 46 4e d8 68 7a 67 b0 eb 66 72 30 24 5b
70 2a 25 86 ab 4a 7a 9a 3a 4f 4a f2 92 c3 49 2b f8 7e 1b 9a 71 b0
0a 74 07 3e 74 77 61 9a 22 d8 c9 d0 51 2e 81 02 0c 1a 34 78 04 80
2a 54 7c ee 69 cf 39 26 8d 8f 13 26 b0 98 b5 bf ce 1e 0f 5b e1 a2
d1 b0 9e d8 42 a6 cc 4f 76 16 d3 5c 15 e1 29 72 7c 47 bb 8a 4e 11
a1 12 07 65 5c 34 42 51 a2 19 89 60 06 75 b6 1b e5 17 2a 6e 10 d8
ff 45 37 d0 a0 cc ae 2d b2 0e fa 43 22 4d fb 60 f9 48 4e b2 49 93
f7 c3 50 e9 2e f1 9c d3 92 30 87 25 0e 66 ef ec 63 16 2a ca 0d 9b
39 60 ee ec 39 76 60 65 48 b8 cc 03 27 d5 4d d0 d5 82 a4 23 78 58
23 ed db 94 89 80 81 22 22 c9 4e dc 6a 18 04 80 68 f9 57 77 65 9f
f7 e9 66 c9 24 80 9f d4 5a 23 36 5e ae 1d 58 32 96 a0 d9 1e 68 73
64 65 ff ff 58 ce 4e 16 05 bf 97 5e 6a 47 e5 ee 50 4e 59 dc 3f e6
b6 cc 10 2e f0 01 b3 0b 42 ad 78 26 d1 13 ff 39 e3 43 d8 cf fa 6c
fe 93 f3 89 df 71 bc 96 34 7f b8 68 ad ce 31 87 ae 9c f6 26 e9 63
63 ed d2 a2 db 06 01 e2 05 fd 1f 74 19 0b 80 a0 22 af 6a 50 5c 7c
3e 28 bc 59 f0 0e dc 60 30 30 e5 65 62 0f d5 f0 6c ad cf 6f 88 81
c2 54 4b 42 6f d1 8a ba ce 30 eb 7e 9a 03 af 59 60 5a 2e 45 13 22
d0 ed 04 59 22 4b 17 cc 50 d8 c5 e4 36 c4 e4 34 68 75 7f 88 b6 de
64 0d d3 b0 94 84 a7 a8 71 bd 9b 1b 98 99 7d 3e 1e 31 d3 a9 8a 0f
5b 54 2d bc d7 2d 17 8b 50 0b c3 42 be 15 54 2b 3c 07 f2 95 3a a2
55 36 ed 7b af 1b 8a d4 0d dc 3a 52 63 cc 31 dd 75 d2 a9 e0 49 f3
bd c5 a3 de 27 b8 15 41 4e f0 06 2d a6 35 a8 f9 73 6b b2 0b c8 01
cc 96 a0 f2 36 40 68 14 8e 27 de 9d 01 13 98 37 cc 1c 7b 2e ef 9f
2c 26 a6 6b c8 3b cb 31 3b 4e 05 79 15 15 94 ce 31 bd 78 9c 69 b5
9d 4b 28 28 98 08 18 8f b6 80 35 71 07 6f bd 53 52 4a 0b 39 bb 7e
13 37 9d cd 0c fe a0 52 f4 35 99 b4 63 30 62 a5 0a 45 d1 14 b8 16
8d 5c c5 68 c2 8d 8a ba 6d e9 f4 74 17 24 9a e4 11 74 f9 8d 6e 58
09 15 22 83 0e 8f 97 40 c2 da 47 8e f4 df d5 91 a8 fc b7 87 36 2c
b9 70 b0 ab 49 07 e3 36 13 46 46 0c 66 b1 ec 39 98 4f 4d 7a b0 98
ea 19 fb 38 81 17 51 d8 43 58 4a d2 f6 d8 58 e3 dd 76 0b 1a 56 a4
52 f6 8a 54 ce d7 d6 26 db 05 e5 45 5c e1 a8 41 e8 96 89 16 73 5c
26 56 95 b7 d9 6c b1 ad f5 5e cc 7e b5 b5 2c 8c 2a e1 31 fb 45 c4
1c d4 32 b2 35 bb 2f 4a d7 a6 7f 9c 3d ef 93 4a 6a d4 8f 84 82 fe
d4 0c 47 b6 bd c0 74 fe 44 af 96 23 63 10 a8 8c 53 bf 24 7a 81 ca
70 87 f6 a9 51 71 bc 07 62 3f 57 3f b8 5a 00 fc 4b fe e7 31 25 79
29 b0 58 46 0a 4c 96 91 94 c0 3e c9 9f 93 ae e3 3c 54 e1 e9 65 f9
6b d4 f7 14 c2 cb 22 a6 1b 3f 0e 96 bb 43 75 50 fe 34 a4 74 4b a6
9b 3a 77 2a 30 bf 51 98 83 96 fe 64 b4 07 0a 63 f7 bc 15 6a 4c 3b
c9 21 9c ff 8e f3 3f fc b3 6d bd 54 31 bf bf 78 87 fa 98 e8 18 9f
2c 8c e2 39 a9 6f f1 9a b2 3e 98 9f 7d f7 73 80 f2 ee a0 d0 23 10

(align-purpose blank)

Audio Stream #2: Encrypted Audio Data

audioStreamCtr = 0, audioInputCtr = 775 (in Audio Control Packet)

c9 b5 25 ed 9a 83 37 3d b7 87 3f d8 3a 78 50 00 d1 5d d5 48 f7 59
2e bd e9 7e 10 c9 ff a0 68 5f 62 9b 69 08 89 ec f0 c7 31 be 36 c0
1e 83 0c d6 43 33 e6 ce 9e 13

D.4. Video Stream Encryption

Table D.9 gives the block module states during T1 - R2 encryption, where *videoStreamCtr* = 1 and *videoInputCtr* = 0 (in Frame Info Packet). Table D.9 has the values after each sequence is completed, where the prefix (ie, F: and G:) indicates which Block Module is related, e.g., F:Kx denotes the Kx registers in Block Module F and F:a2a07a2f24b9 in Output Function implies that the value is derived from the registers of Block Module F.

Sequence	F:Kx	F:Ky	F:Kz	F:Bx	F:By	F:Bz	Output Function
	G:Kx	G:Ky	G:Kz	G:Bx	G:By	G:Bz	
LoadKey	93d97b2	0cdaf2d	c519ee4	ca4c1eb	510b170	b953498	F:a2a07a2f24b9
	6c2684d	f3250d2	3ae611b	35b3e14	ae4e8f	46acb67	
PreRun 1	399b766	5b8ca30	1270cdd	0ba36c5	20e7e2d	480ff9e	G:863164ca3cf6
	4915888	2cfb018	22938a5	cb76b19	fd3a68f	1129caa	
PreRun	5f71a2b	f0091d7	a9202e7	acb9254	0fff0f3	20e3805	F:c4faece7d442
	8c18658	ff6861d	43efb18	f36fd94	aa6be5f	4dec608	
...
PreRun 23	24d07db	f4e93cb	4fb22e4	c864da3	d54b69d	df89fed	G:e788743db499
	f2546bc	fa924ea	ad21524	e12698b	5f14c7b	363349d	
PreRun 24	0ad16ed	9ae3c1f	5856abf	cfe8962	e015e25	1649763	F:79c47ad79eb5
	f84cc4d	8ae8981	af4f538	0452b9a	ca2ad21	bcf4ce6	
Line 1, Pixel 1	3984205	c3cbe63	17fc255	3ed79cf	28a3229	f380e00	G:eca9c21bf7ee
	a7712aa	225882a	940cce4	188ff9e	287551d	4035011	
Line 1, Pixel 2	c4c529e	4144ce6	63de0d2	957f407	b3d0f28	c23b69c	F:0c3804d57df4
	b9bebfb	ce59f8b	9856a94	08dd5f1	5ae4911	ed045a9	
Line 1, Pixel 3	a02c802	2d9c9c8	2f2cd51	77d3421	1d0cf4d	771b711	G:faf8b2323f6f
	277453e	83ae2da	f5bcd37	47310cd	d00fe88	30e5a59	
Line 1, Pixel 4	706d088	48cb4fd	df7ddd	2fc92f6	97fd8eb	8995974	F:c7e783d26cf7
	08f1cc2	543f19d	7c91859	7090dbc	1ed93e8	901de0e	
Line 1, Pixel 5	377f0b9	ea6aea0	b6eef41	9330e36	f59312c	a981b72	G:7c3681c25229
	bd8b370	be0ceed	2fe259d	26d6faf	f2bf3c6	0cbb9f	
Line 1, Pixel 6	ff69cae	0ff475e	e890e5a	860bb47	05b4b05	ab2c4e6	F:6f3dd14e874b
	7b905d3	f496845	5b7ae27	ba0b3a0	03fa795	050e91d	
Line 1, Pixel 7	788bd4e	f40a130	9734e85	532a317	b51505d	bc19ed	G:63ed1b873b73
	c328c36	9072cac	eccba7	7db7280	95c2040	cb2c87b	
Line 1, Pixel 8	c0d385c	7b7a15f	ecd40e3	c496dac	531f835	52d6b3d	F:0066d413dcec
	16b9c44	adc9bbc	dfea041	b31bbbb	c7ce49c	2906426	
...
LoadKey	f67f39b	4060f2d	ad3c2c0	19da674	fecfe93	5552938	F:c272671504c1
	0980c64	bf9f0d2	52c3d3f	e62598b	013016c	aaad6c7	
PreRun 1	55cdf10	94988cf	3b81731	51cc744	a214ce0	626a0f9	G:5a31a62f6ce7
	25b30fe	d0dc7f3	2a42f49	c3eced	7fc90ce	3da6b8f	
PreRun 2	d199f34	9b98788	d2adc68	2da9690	f1834ec	5956727	F:04aa36a94036
	7dd4f14	68d240c	c9d82ef	a88ddd5	4321367	3a24098	
...
PreRun 23	e4869dc	c23281a	197a918	24863f2	e947222	e2a0071	G:a83ebbed62c3
	bc56651	bab01c3	eb814ee	690cfd6	576cd1c	47e837e	
PreRun 24	85fc9ba	6d84fa0	2d52695	32a6340	cd08a1e	20d75e1	F:1f1ea4c93d96
	9c49095	72cb763	21a3f96	b5ad7e5	3234f53	dc344c6	
Line 2, Pixel 1	212b562	1440a4f	8460815	4ff7c51	4539854	6cf8d8c	G:b0ae2850f8c6
	2581891	bf5e501	4637751	3bae04f	5961a14	6bb67c0	
Line 2, Pixel 2	f9fb0e7	876d6a2	283b555	3031926	00a91f3	f435128	F:54a2f2d6f333
	7305298	3074b2b	768fde5	70b84a0	4512d9f	cd6a88b	
Line 2, Pixel 3	f6f2c42	5ad4445	3f5f7ec	ef61eb3	c6f8ca4	aa63760	G:e63feb79cacf
	9d1d32b	55745f4	502a4c4	ad481d8	9258498	cb78fca	
Line 2, Pixel 4	b2064b0	88d0104	cdd7d63	561c1a4	5656aba	df7509b	F:a41c825c2b13
	e86c96a	74bede3	5eba1a4	4a3d38a	57c5b5e	0fe0380	
Line 2, Pixel 5	953926d	913b9b4	0be165f	9373270	9a08d31	833d1f7	G:acc832abe621
	ba02ce8	09a1c03	2e746bb	cb42abe	0de56a0	f87934c	
Line 2, Pixel 6	9f1de03	f59e0a4	3fbffa4	7ab4348	d2cdcc0	58f0d78	F:298aa84f7d46
	d5e4220	cf64ca9	b3405b0	075d16c	89858ef	fe2ff37	
Line 2, Pixel 7	8f7653d	c0ed2a9	09d8ae1	686bd6d	38c5da5	2d8363f	G:435c0dc687d6

	ac53805	420e671	89313	fcbb6f7	c9280c6	30b41b8	
Line 2, Pixel 8	6c87bd7	8597169	111a8c3	f30daae	cbccfd6	1b22eed	F:9ea248c8e15f
	ef12180	90d62cc	43001a8	e9901ae	3a9272f	34e26df	
...

Table D.9

Table D.10 gives the intermediate values of the output function calculation, where the block module states are given in Table D.9.

In the table, the following notation is used for the box group:

$$L1X = L1X13 \ || \ \dots \ || \ L1X2 \ || \ L1X1 \ || \ L1X0$$

$$L1Y = L1Y13 \ || \ \dots \ || \ L1Y2 \ || \ L1Y1 \ || \ L1Y0$$

$$L1Z = L1Z13 \ || \ \dots \ || \ L1Z2 \ || \ L1Z1 \ || \ L1Z0$$

$$LTX = LTX3 \ || \ LTX2 \ || \ LTX1 \ || \ LTX0$$

$$LTY = LTY3 \ || \ LTY2 \ || \ LTY1 \ || \ LTY0$$

$$LTZ = LTZ3 \ || \ LTZ2 \ || \ LTZ1 \ || \ LTZ0$$

$$L2X = L2X13 \ || \ \dots \ L2X2 \ || \ L2X1 \ || \ L2X0$$

$$L2Y = L2Y13 \ || \ \dots \ L2Y2 \ || \ L2Y1 \ || \ L2Y0$$

$$L2Z = L2Z13 \ || \ \dots \ L2Z2 \ || \ L2Z1 \ || \ L2Z0$$

XXX_i = The input value of the box group XXX

XXX_o = The output value of the box group XXX

And, the prefix (ie, F: and G:) indicates which Block Module is related, e.g., F:PreRun1 implies that the value of Output Function is derived from the registers (ie, Bx/y/z and Kx/y/z) in Block Module F and the column shows the values of the registers and the intermediate values of Block Module F.

Symbols	F: LoadKey	G: PreRun 1	F: PreRun 2	G: PreRun 3	F: PreRun 4
Kx	93d97b2	4915888	5f71a2b	afb759e	3671814
Ky	0cdaf2d	2cfb018	f0091d7	cae607e	7a858cc
Kz	c519ee4	22938a5	a9202e7	10dad89	26e49d4
Bx	ca4c1eb	cb76b19	acb9254	a6f70d9	35f13d7
By	510b170	fd3a68f	0fff0f3	0971a3c	809e88f
Bz	b953498	1129caa	20e3805	9b5d9a8	85b2078
L1X_i	e18b71e117eb8e	d0ad4d59ac24a4	99f39f852a4663	aa7bef5f11e5b6	0f56df052cc55c
L1Y_i	443431ae374e31	cef43fab4881ec	33cccced01fd1f	30a67e16881ff2	9322a4d9a0b0fc
L1Z_i	bc95452d72b690	06062987e0aa99	2a21ca0c823257	858c75e6b5a8a1	8256be18217d90
L1X_o	fbab7b4c563a9e	b40e9853ce9305	d64624763fd9db	277b545a5c3472	e9b0d4863ea488
L1Y_o	afc8cfeffc6e2ef	f908c7eb676d83	84873c25d18f97	812359b4e7c5be	74194ba84e24b3
L1Z_o	b5327d877afbed	fb1bb06bec36e4	077fecb1fac86a	2ae68dc0ae3343	280b6152857fed
LTX_i	8febb6d450772a	713be48c5562cd	3f01ce019de0bf	a02010d5e59eaa	37d459db40da20
LTY_i	d7fee7ec77ff1d	8db76ee87e6454	5d49eb31a156f1	570fc3d32cfc4b	a42e64e866e878
LTZ_i	3f0d36b6fee2f1	e5b20b78ef14b1	7a3df2a5597dda	60cd9209f5bb6	4ea029fc8d2354
LTX_o	0c034051b2adec	193623d6df53b2	7b52dfb3f14581	f836049e449566	be56dd85b34d5f
LTY_o	985fee2a4c832e	24ca4321d13d66	69451b1660d1ae	9e9d9dbb542679	17bdfdf5db96350
LTZ_o	3ead1a38aa41b6	b853cd5ad60e32	0ed6ab5d516429	1c62db40aca2da	7cd665d10168b6
L2X_i	5417a933103524	4328f31a77ee1e	48efa7fe4c4a47	eba9830512c93c	c2dfade70d7b1b
L2Y_i	e46cd3447a19f8	51972b03dc03d0	0fa087785c113e	b46b9ec79758cd	764e3defe58e8e
L2Z_i	2488adf0f1a1de	e4fdb2461f2c14	7243cac2dc1e0f	504cbc716f9430	589ec8149d4f1e
L2X_o	c464a70289be50	505fbbd8adfd22	5991a3b50458e6	f3f0fd3485aac5	8bd1a4297a472a
L2Y_o	fbf82bd4406f6e	22c5576525cac2	76e27d4785619b	8bf3c9e691322a	d016f551c82bdb
L2Z_o	1c421aace9e003	ac0f21b4a1d47c	6e8b77d766c773	692120f671828f	3c98af59e38e7d
Output	a2a07a2f24b9	863164ca3cf6	8c65162ff38e	410679787c78	9e4d4eab9d2b

Symbols	G: PreRun 5	F: PreRun 6	G: PreRun 7	F: PreRun 8	G: PreRun 9
Kx	cd342ff	9a3b6f7	f61c258	44537ca	9bd1d18
Ky	592cf83	4de2538	7606f87	3b33c19	055b593
Kz	0b7ba03	7b9e2c0	aafb445	91c741c	366ec11
Bx	a86b7a2	de7ff4d	03cdf24	001dc80	2ebda1c
By	0d632ee	40b75f5	4d3e657	7d350ab	ae144c6
Bz	6bfe41c	3f59585	3c03927	688aa5b	47442b5
LIX_i	b8b14b9c4ebb3b	e5ea4fefdef753	331ec1f4ce1960	101015c7d3b022	29ebbdcb5b905e0
LIY_i	11e54a3c3be8cb	5031be4e55cf64	53d60cda7b645f	4fe70f473089ad	88d9156351e14b
LIZ_i	48afdfeb6204c3	1fef65b646b044	2ee2332fa6185d	6981b09b9845bc	435e5272388d45
LIX_o	78e1990bd41aa4	f595944a94878b	a2cfab156471da	34caf12f991667	169bb82613e43a
LIY_o	d756d363c44e1c	61c5f98f3c3536	6463bca0541a27	a250b781ce63f4	066b145d314dcc
LIZ_o	ac9e2fc31a1190	c95edd406dfe58	005715845d2369	31ef64f3c9dc15	ae0043dcd96f56
LTX_i	ccd896eed0a768	d751b1a5dbbe25	0778f3518a45ce	e0734db2d1a379	12781b61bd2e32
LTY_i	4b127505712846	a05c42c89ae045	081c40eba1f729	6516ec0cc7a6c7	8e2310d70816db
LTZ_i	25ed580faf6831	3bbafbeb957594	2204d72e4c4c7a	7864fad24eda47	e9852ef673d04c
LTX_o	c334a2f175d0c4	adb739215471d	71da547b1804a9	67515730c4c731	58e8ad62fd31bb
LTY_o	7e8be6a29caf01	6094adb0542a93	e3bb1dd023fc93	ba367fdb329ec5	0021a27c8493fc
LTZ_o	2c1bc7f66b9f89	2ac4b96ce6a1c8	3a2570e73384c7	1ab7bf40684f7e	6d992da730a683
L2X_i	894242bb42cf6e	84a5dd0ac7db8f	68af041eb81cc5	0c853f8c5f0867	1968e376bf96d1
L2Y_i	5cfd986e240e1	18d0525687485d	dd9104fc85eeb7	e1bfd4f744ed2d	27407111539564
L2Z_i	47f59b34647ee5	32c0e7f18e3468	06afc4b300e779	4459d7e5f59d1a	1ea3d87e8448f1
L2X_o	d573da6705a432	d4f2c4385dd7af	99f108d5ff0079	6a32e9e630c636	a5cf1d53f0e117
L2Y_o	28911e3dccc419	43a2dc8d01f2aa	c1c99fb808abef	f20c2fb66ea6fa	bd12481f8bddd85
L2Z_o	3d09c8277d9917	25ee8fa6523260	c6a0759597ba56	3c98af59e38e7d	58a6a7f15dc1e1
Output	c1983eb17873	ed556c7a33ee	8f5c2c2efbc3	9e4d4eab9d2b	0da398566f35
Symbols	F: PreRun 10	G: PreRun 11	F: PreRun 12	G: PreRun 13	F: PreRun 14
Kx	271005e	742c8b8	13ab569	1a595e7	beb0259
Ky	262c1e1	46fab35	c82fbf5	386f861	e2c3f19
Kz	01bb481	e5dd725	4ec7097	9ffc62f	290c647
Bx	15d712c	18bc415	af5d325	ef114bd	0f9d77b
By	7065f3a	dd5387f	37b7301	d1f3ac2	a436363
Bz	edabaf9	215ccd3	53b3816	4a74d97	43436e8
LIX_i	0657c54c0419f2	17908ef0602764	89cf66e71d1a65	c9ee152551bed7	23fea7c44e5dad
LIY_i	4e124a74cd3e89	d4d6772ea34fdd	3c6c8e7f2f3315	c724de3fa8d209	ba423c4b3f492d
LIZ_i	c8c5abaf98ec85	3a1575f1d3c61d	543ebc1f80255b	61bb7f70d6867f	422d403c5ad893
LIX_o	edb3a1eb0771e7	3e3a4e194b97d5	86f4c04f5d75d6	469ff136ec122c	124f8725d4bb03
LIY_o	a939d3fa9b9269	9f63523f4fe574	85f7e9f2189b98	fd186962475809	4349cc8bc8e354
LIZ_o	4c825914c95a26	77a28d3826bb09	66406b54fcac6b	3df98fd52d6bf8	a87d74e1b743e0
LTX_i	85d43987ee5d5d	b4ab18ddb5a8df	a5501a176b887e	6273dd6e464f88	5830e74511a56d
LTY_i	f3b4407a75aedb	b183cbc776bd14	3f5f32b3b11849	0baa92e8b416e6	f03eab6413158d
LTZ_i	68cb2690a0b09b	9a5b11069fd327	7a0baf67a01eff	2efd9dbcae3671	45a4f9aacacd70
LTX_o	5fd211570b4f06	1780f692a73e98	a5815aa59a921b	7cba1d70326d27	4da4a57afd367f
LTY_o	d26c7a389efd7f	0b6c3bfde7606b	06a08b0238c1ee	220133caf3ced2	41d32299a0f6ab
LTZ_o	868f6df78835a2	a78625a8741efa	25851545cd1ee8	f5f92c152d5754	6b341dbd61c95b
L2X_i	4a3b9d88ac2f16	117d7cbcc37204	87863c4ae17071	58998d6694add7	3961fa2fb7975d
L2Y_i	b91d65c37bb1ff	3202e6e95ef6df	006009f3f49132	24b176b3456632	7d037038d85837
L2Z_i	d72769d4b444dc	e1915abf975058	07933e1db61608	8f8b596dab8b86	2a9287ed05da7f
L2X_o	5cbc94ef14642d	af1e8f66584f90	dd3def82e4c67	c9a0f4c3471316	45c7b5a0fde283
L2Y_o	8e2136e54d11b4	ea87e052897cc4	7cf29eb51ed191	bb094005685c91	d180417726329f
L2Z_o	bd6a34673dc205	af856b986eaca0	cd864dde34f590	714d64ce8a5829	1b83bf5e931f54
Output	e9a4c6d79152	c4cb6072df8d	cd32bd97dccc2	6af94213c24d	4f5c20bb67f8

Table D.10

Table D.11 gives the encrypted 24-bpp RGB video stream during T1 - R2 encryption, where the block module states are given in Table D.9. When YCbCr4:4:4 is used, replace R with Cr, G with Y, and B with Cb. Table D.11 has the values while each sequence is being executed.

Sequence	Output Function	24-bpp RGB Raw Pixel	24-bpp RGB Encrypted Pixel
Line 1, Pixel 1	F:79c47ad79eb5	B,G,R: 24,01,c5	f39f70
Line 1, Pixel 2	G:eca9c21bf7ee	B,G,R: 81,0d,aa	9afa44
Line 1, Pixel 3	F:0c3804d57df4	B,G,R: 09,76,e5	dc0b11
Line 1, Pixel 4	G:faf8b2323f6f	B,G,R: 63,3d,77	510218
Line 1, Pixel 5	F:c7e783d26cf7	B,G,R: 0d,ed,12	df81e5
Line 1, Pixel 6	G:7c3681c25229	B,G,R: 8d,8c,8f	4fdea6
Line 1, Pixel 7	F:6f3dd14e874b	B,G,R: 65,f9,f2	2b7eb9
Line 1, Pixel 8	G:63ed1b873b73	B,G,R: 12,c6,ce	95fdbd

Table D.11

Table D.12 gives the encrypted 30-bpp RGB video stream during T1 - R2 encryption, where the block module states are given in Table D.9. When YCbCr4:4:4 is used, replace R with Cr, G with Y, and B with Cb. Table D.12 has the values while each sequence is being executed.

Sequence	Output Function	30-bpp RGB Raw Pixel	30-bpp RGB Encrypted Pixel
Line 1, Pixel 1	F:79c47ad79eb5	B,G,R: 124,301,0c5	289b9a70
Line 1, Pixel 2	G:eca9c21bf7ee	B,G,R: 281,10d,2aa	2a0fc144
Line 1, Pixel 3	F:0c3804d57df4	B,G,R: 209,176,3e5	2440a611
Line 1, Pixel 4	G:faf8b2323f6f	B,G,R: 263,13d,277	1406c918
Line 1, Pixel 5	F:c7e783d26cf7	B,G,R: 30d,3ed,212	330ddae5
Line 1, Pixel 6	G:7c3681c25229	B,G,R: 18d,38c,38f	191c61a6
Line 1, Pixel 7	F:6f3dd14e874b	B,G,R: 065,1f9,1f2	171962b9
Line 1, Pixel 8	G:63ed1b873b73	B,G,R: 212,0c6,2ce	3aa421bd

Table D.12

Table D.13 gives the encrypted 24-bpp YCbCr4:2:2 video stream during T1 - R2 encryption, where the block module states are given in Table D.9. Table D.13 has the values while each sequence is being executed.

Sequence	Output Function	24-bpp YCbCr422 Raw Pixel ={Cb,Y} or {Cr,Y}	24-bpp YCbCr422 Encrypted Pixel
Line 1, Pixel 1	F:79c47ad79eb5	Cb,Y: 301,4c5	e78a70
Line 1, Pixel 2	G:eca9c21bf7ee	Cr,Y: d0d,2aa	cb2544
Line 1, Pixel 3	F:0c3804d57df4	Cb,Y: 176,7e5	c21a11
Line 1, Pixel 4	G:faf8b2323f6f	Cr,Y: d3d,277	e1ed18
Line 1, Pixel 5	F:c7e783d26cf7	Cb,Y: 7ed,612	acbae5
Line 1, Pixel 6	G:7c3681c25229	Cr,Y: 78c,b8f	ba99a6
Line 1, Pixel 7	F:6f3dd14e874b	Cb,Y: 9f9,9f2	d11eb9
Line 1, Pixel 8	G:63ed1b873b73	Cr,Y: 4c6,6ce	cb5dbd

Table D.13