Network redundancy interoperability specification

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1. Introduction

To provide a system that is hardened against a number of common network failures, this document intends to set concepts that will afford a ProA AVB device the ability to endure such failures.

This specification follows the concept of duplicating the network infrastructure into two independent networks. By connecting endpoints to both networks, seamless redundancy can be achieved.

This document does not specify a particular implementation, but rather defines the general requirements that implementations must adhere to in order to achieve interoperability.

2. References

Name	*Reference*
802.1Q	IEEE 802.1Q-2014 “IEEE Standard for Local and metropolitan area networks – Bridges and Bridged Networks”
AVDECC	IEEE 1722.1-2013, “IEEE Standard for Device Discovery, Connection Management, and Control Protocol for IEEE 1722™ Based Devices”.
AVTP	IEEE 1722-2016, “IEEE Standard for a Transport Protocol for Time-Sensitive Applications in Bridges Local Area Networks”.
gPTP	IEEE 802.1AS-2011 “IEEE Standard for Local and metropolitan area networks – Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks”

3. Glossary

Term	*Meaning*
ACMP	AVDECC connection management protocol as described in [AVDECC, Clause 8].
ADP	AVDECC discovery protocol as described in [AVDECC, Clause 6].
AECP	AVDECC enumeration and control protocol as described in [AVDECC, Clause 9].

AVB_INTERFACE	An AVB capable network interface as described in [AVDECC, Clause 3].
AVB_INTERFACE_INDEX	An AVB interface index as described in [AVDECC, Clause 7.2.6].
AVDECC entity	A logical object within an end station, that implements the requirements of [AVDECC, Clause 5.3].
BAD_ARGUMENTS	A status code as described in [AVDECC, Clause 7.4].
CLOCK_SOURCE	A clock source descriptor as described in [AVDECC, Clause 7.2.9].
CONFIGURATION	A configuration descriptor as described in [AVDECC, Clause 7.2.2].
Controller	An AVDECC Controller.
INCOMPATIBLE_REQUEST	A status code as described in [AVDECC, Clause 8.2.1.6].
MAAP	Mac address acquisition protocol as described in [AVTP, Annex B].
MRP	Multiple Registration Protocol as described in [802.1Q, Clause 10].
MSRP	Multiple Stream Registration Protocol as described in [802.1Q, Clause 35].
MSRP_ACCUMULATED_LATENCY	Multiple stream reservation protocol accumulated latency as described in [AVDECC, clause 7.4.15]
MVRP	Multiple VLAN registration protocol as described in [802.1Q, Clause 11.2].
PAAD	A professional audio device with Ethernet AVB functionality.
Primary AVB_INTERFACE	The AVB_INTERFACE descriptor of the R-PAAD-CFG, which descriptor index is 0.
Primary Ethernet port	The Ethernet port of the R-PAAD which is identified by the manufacturer as being primary.
Primary Network	The network to which the Primary Ethernet port of each R-PAAD is connected.
Primary STREAM_INPUT	A STREAM_INPUT which is bound to the Primary AVB_INTERFACE.
Primary STREAM_OUTPUT	A STREAM_OUTPUT which is bound to the Primary AVB_INTERFACE.
Redundant pair	The composition of a primary STREAM_INPUT/OUTPUT and its associated secondary STREAM_INPUT/OUTPUT. Two different STREAM_INPUT/OUTPUTs are said to be associated when both are referencing each other in their “redundant_streams” field.

R-PAAD	A PAAD that implements redundancy as defined in this specification.
R-PAAD-AE	The AVDECC entity under consideration inside the R-PAAD.
R-PAAD-CFG	The CONFIGURATION under consideration inside the R-PAAD-AE.
REGISTER_UNSOLICITED_NOTIFICATION	The Register unsolicited notification command as described in [AVDECC, clause 7.4.37]
Secondary AVB_INTERFACE	The AVB_INTERFACE descriptor of the R-PAAD-CFG, which descriptor index is 1.
Secondary Ethernet port	The Ethernet port of the R-PAAD which is identified by the manufacturer as being secondary.
Secondary Network	The network to which the Secondary Ethernet port of each R-PAAD is connected.
Secondary STREAM_INPUT	A STREAM_INPUT which is bound to the Secondary AVB_INTERFACE.
Secondary STREAM_OUTPUT	A STREAM_OUTPUT which is bound to the Secondary AVB_INTERFACE.
STREAM_ID	A Stream ID as described in [802.1Q, Clause 35.2.2.8.2].
STREAM_INPUT	A stream input descriptor as described in [AVDECC, Clause 7.2.6].
STREAM_OUTPUT	A stream output descriptor as described in [AVDECC, Clause 7.2.6].

4. Scope

The intent of this specification is to define a mechanism that is capable of recovering seamlessly from the loss of connectivity in either the primary or secondary network (e.g. a broken cable or power loss of a bridge).

5. Fundamental Concepts

5.1. R-PAAD-AE and R-PAAD-CFG

The present specification considers one AVDECC entity and one CONFIGURATION within an R-PAAD. If the physical device contains more elements, it is seen as several independent R-PAADs by this specification.

The AVDECC entity under consideration in the R-PAAD is called the R-PAAD-AE.

The CONFIGURATION under consideration in the R-PAAD-AE is called the R-PAAD-CFG.

5.2. Primary Ethernet Port and Secondary Ethernet Port

In an R-PAAD, the present specification considers one given pair of Ethernet ports that the manufacturer has identified as being used for redundancy. Within this pair, one port has been somehow identified as primary by the manufacturer: this is the primary Ethernet port. The other one has been somehow identified as secondary: this is the secondary Ethernet port..

5.3. Primary Network and Secondary Network

The design goals of this specification will be achieved only if the user is connecting the Primary Ethernet port of each R-PAAD to a given physical network and the Secondary Ethernet port of each R-PAAD to another physical network.

The network to which the Primary Ethernet port of each R-PAAD is connected is called the Primary network.

The network to which the Secondary Ethernet port of each R-PAAD is connected is called the Secondary network.

5.4. Primary Interface and Secondary interface

The Primary AVB_INTERFACE of an R-PAAD-CFG is the AVB_INTERFACE which descriptor index is 0.

The Secondary AVB_INTERFACE of an R-PAAD-CFG is the AVB_INTERFACE which descriptor index is 1.

Note: this definition provides a straight-forward mapping between the primary and secondary Ethernet ports and the primary and secondary AVB_INTERFACEs. It allows a Controller to issue a warning to the user when it detects mixed Ethernet ports (primary/secondary) being connected to the same physical network.

5.5. Primary Stream and Secondary Stream

According to [AVDECC], each STREAM_INPUT and each STREAM_OUTPUT is statically bound to a given AVB_INTERFACE. This is achieved through the use of the AVB_INTERFACE_INDEX field.

The present specification defines a Primary STREAM_INPUT/OUTPUT as being a STREAM_INPUT/OUTPUT which is bound to the Primary AVB_INTERFACE of an R-PAAD-CFG. In other words, it is a STREAM_INPUT/OUTPUT which AVB_INTERFACE_INDEX is 0.

The present specification defines a Secondary STREAM_INPUT/OUTPUT as being a STREAM_INPUT/OUTPUT which is bound to the Secondary AVB_INTERFACE of an R-PAAD-CFG. In other words, it is a STREAM_INPUT/OUTPUT which AVB_INTERFACE_INDEX is 1.

Note: this definition matches the intuitive idea that all primary streams are created and transmitted on the primary network while all secondary streams are created and transmitted on the secondary network.

5.6. Redundant Pair

[Annex A] defines an extension to the STREAM_INPUT/OUTPUT descriptor that allows an entity to associate STREAM_INPUTs (respectively STREAM_OUTPUTs) together in a set called a “redundant set”.

The present specification defines a redundant pair as being the composition of a Primary STREAM_INPUT/OUTPUT and a Secondary STREAM_INPUT/OUTPUT that are in the same redundant set.

6. Requirements

6.1. General

- The R-PAAD shall have at least two AVB-capable Ethernet ports.
- The R-PAAD shall not forward traffic from the Primary Ethernet port to the Secondary Ethernet port, and vice versa (it shall not act as a bridge between these two ports).
- The R-PAAD shall have at least one AVDECC entity.
- The interface of the R-PAAD that is represented by the Primary AVB_INTERFACE shall not use the same MAC address as the interface that is represented by the Secondary AVB_INTERFACE.

6.2. AVDECC

6.2.1. AEM

6.2.1.1. AVB_INTERFACE descriptor [AVDECC, Clause 7.2.6]

- The R-PAAD-CFG shall have at least two AVB_INTERFACEs.
- The Primary AVB_INTERFACE shall be internally connected to the Primary Ethernet port.
- The Secondary AVB_INTERFACE shall be internally connected to the Secondary Ethernet port.

6.2.1.2. STREAM_INPUT/STREAM_OUTPUT descriptor [AVDECC, Clause 7.2.6] [Annex A]

- Each Primary STREAM_INPUT/OUTPUT shall have a set of associated redundant STREAM_INPUT/OUTPUTs as described in [Annex A]. Within this set, there shall be exactly one Secondary STREAM_INPUT/OUTPUT.
- Each Secondary STREAM_INPUT/OUTPUT shall have a set of associated redundant STREAM_INPUT/OUTPUTs as described in [Annex A]. Within this set, there shall be exactly one Primary STREAM_INPUT/OUTPUT.

6.2.1.3. CLOCK_SOURCE descriptor [AVDECC, Clause 7.2.9]

- If either the primary or the secondary STREAM_INPUT of a redundant pair requires a clock source descriptor, both the primary and the secondary streams must have an associated clock source descriptor.
- The R-PAAD-AE shall ensure that the recovered clock signal is sourced from an active stream regardless of if the primary or secondary clock source is selected.

6.2.1.4. AUDIO_MAP descriptor [AVDECC, Clause 7.2.19]

- For each audio mapping referencing either the primary or secondary STREAM_INPUT/OUTPUT of a pair, there shall exist a related mapping referring to the other stream of the pair, with the same “stream_channel”, “cluster_offset” and “cluster_channel” fields.

6.2.2. ADP

- The R-PAAD-AE shall run independent ADP state machines on the Primary and Secondary AVB_INTERACE.
- The R-PAAD-AE shall advertise the same ENTITY_ID and same entity model on the Primary and Secondary AVB_INTERFACE.
- The R-PAAD-AE shall ensure that the AEM_INTERFACE_INDEX_VALID flag is set and the interface_index is correctly populated.

6.2.3. AECP

6.2.3.1. ACQUIRE_ENTITY [AVDECC, Clause 7.4.1]

- The R-PAAD-AE shall ensure that the acquisition/release of the primary or the secondary STREAM_INPUT/OUTPUT descriptor of a pair results in the acquisition/release of both descriptors within that pair.
- If needed, an unsolicited notification is sent to indicate an asynchronous change in the acquired state of the descriptors.

6.2.3.2. LOCK_ENTITY [AVDECC, Clause 7.4.2]

- The R-PAAD-AE shall ensure that locking/unlocking the primary or the secondary STREAM_INPUT/OUTPUT descriptor of a redundant pair results in the locking/unlocking of both descriptors within that pair.
- If needed, an unsolicited notification is sent to indicate an asynchronous change in the locked state of the descriptors.

6.2.3.3. SET_STREAM_FORMAT [AVDECC, Clause 7.4.9]

- The R-PAAD-AE shall ensure that changing the format of the primary or the secondary STREAM_INPUT/OUTPUT of a pair results in a change to the stream format of both streams within that pair.
- The R-PAAD-AE shall ensure that a stream format change will succeed on both streams of a redundant pair before changing the stream format of either stream within that pair.
- In the event of an error the R-PAAD-AE must ensure that no change has been made to either the primary or the secondary stream.
- If needed, an unsolicited notification is sent to indicate an asynchronous change in stream format.

6.2.3.4. SET_STREAM_INFO [AVDECC, Clause 7.4.15]

- The R-PAAD-AE shall ensure that changing the msrp_accumulated_latency of the primary or the secondary STREAM_OUTPUT of a redundant pair results in a change to the msrp_accumulated_latency of both streams within that pair.
- If needed, an unsolicited notification is sent to indicate an asynchronous change in msrp_accumulated_latency.

6.2.3.5. SET_CLOCK_SOURCE [AVDECC, clause 7.4.23]

- The R-PAAD-AE shall ensure that setting the clock source associated with the primary STREAM_INPUT has the same effect as setting the clock source associated with the secondary STREAM_INPUT – and vice versa.

6.2.3.6. GET_CLOCK_SOURCE [AVDECC, clause 7.4.24]

- When the R-PAAD-AE is using the clock source associated with a primary or secondary STREAM_INPUT it can return the clock source associated with either the primary or secondary STREAM_INPUT.

6.2.3.7. REGISTER_UNSOLICITED_NOTIFICATION [AVDECC, Clause 7.4.37]

- The R-PAAD-AE shall register controllers on a per AVB_INTERFACE basis. Unsolicited notifications shall only be sent to the interface where the REGISTER_UNSOLICITED_NOTIFICATION command was received.

6.2.3.8. ADD_AUDIO_MAPPINGS [AVDECC, Clause 7.4.45]

- The R-PAAD-AE shall ensure that the addition of any mapping referencing either the primary or secondary STREAM_INPUT/OUTPUT shall automatically result in the addition of a related mapping referring to the other stream of the pair, with the same “stream_channel”, “cluster_offset” and “cluster_channel” fields.
- If two conflicting mappings are present in the same ADD_AUDIO_MAPPINGS command, then no mappings shall be applied and the response shall be returned with the status code set to BAD_ARGUMENTS.
- If needed, an unsolicited notification is sent to indicate an asynchronous change in audio mappings.

6.2.3.9. REMOVE_AUDIO_MAPPINGS [AVDECC, Clause 7.4.46]

- The R-PAAD-AE shall ensure that the removal of any mapping referencing either the primary or secondary STREAM_INPUT/OUTPUT shall automatically result in the removal of a related mapping referring to the other stream of the pair, with the same “stream_channel”, “cluster_offset” and “cluster_channel” fields.
- If needed, an unsolicited notification is sent to indicate an asynchronous change in audio mappings.

6.2.4. ACMP

- The R-PAAD-AE shall treat all ACMP commands, except the CONNECT_TX_COMMAND (cf. below), the same way, no matter whether they arrive on the Primary or Secondary AVB_INTERFACE.
- The R-PAAD-AE shall send an ACMP response only to the Primary (resp. Secondary) AVB_INTERFACE if the command was received on the Primary (resp. Secondary) AVB_INTERFACE.

- The R-PAAD-AE shall send CONNECT_TX_COMMAND/DISCONNECT_TX_COMMAND only on the Primary (resp. Secondary) AVB_INTERFACE if the STREAM_INPUT that is being connected/disconnected is a Primary (resp. Secondary) STREAM_INPUT.
- The R-PAAD-AE shall not process successfully an incoming CONNECT_TX_COMMAND if it was received on the Primary (resp. Secondary) AVB_INTERFACE and the STREAM_OUTPUT that is being connected is a Secondary (resp. Primary) STREAM_OUTPUT. The R-PAAD-AE can either silently discard this incoming command, or explicitly refuse it by responding with the INCOMPATIBLE_REQUEST status code.

6.3. AVTP

6.3.1. MAAP

- The R-PAAD shall run independent MAAP state machines on the interface represented by the Primary AVB_INTERFACE and the interface represented by the Secondary AVB_INTERFACE.

6.4. gPTP

- The R-PAAD shall implement an independent gPTP end station on the interface represented by the Primary AVB_INTERFACE and the interface represented by the Secondary AVB_INTERFACE.
- The R-PAAD shall not implement a gPTP bridge between the interfaces represented by the Primary and Secondary AVB_INTERFACEs.

6.5. MRP

6.5.1. MSRP

- The R-PAAD shall run an independent set of MSRP state machines on the interface represented by the Primary AVB_INTERFACE and the interface represented by the Secondary AVB_INTERFACE.
- The R-PAAD shall not implement an MSRP bridge between the interfaces represented by the Primary and Secondary AVB_INTERFACEs.
- A Secondary STREAM_OUTPUT shall not use the same STREAM_ID as its associated Primary STREAM_OUTPUT.

6.5.2. MVRP

- The R-PAAD shall run an independent set of MVRP state machines on the interface represented by the Primary AVB_INTERFACE and the interface represented by the Secondary AVB_INTERFACE.
- The R-PAAD shall not implement an MVRP bridge between the interfaces represented by the Primary and Secondary AVB_INTERFACEs.

Annex A (Normative) STREAM_INPUT/OUTPUT Descriptor Extension

Avnu defines an extension to the 1722.1 STREAM_INPUT/OUTPUT descriptor.

A set of STREAM_INPUT/OUTPUT descriptors are said to have a redundant association when each of them is referencing all of the others in its “redundant_streams” field.

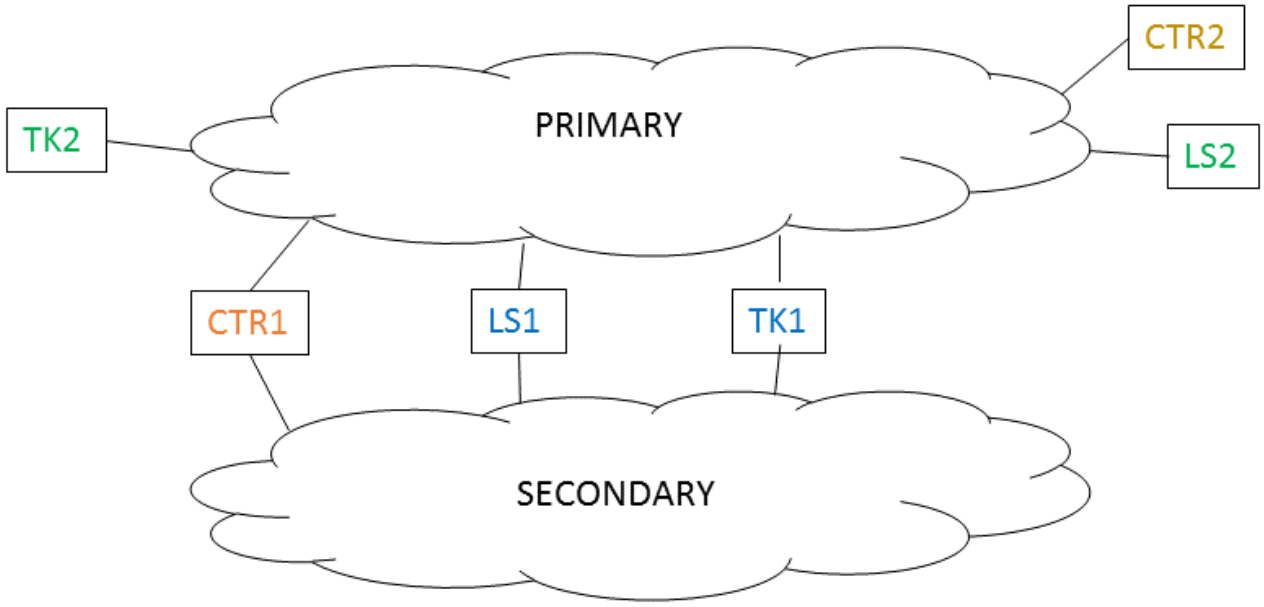
The new format is as follows, and can be used by any AVDECC entity for any STREAM_INPUT/OUTPUT.

1722.1 - 7.2.6 STREAM_INPUT and STREAM_OUTPUT Descriptor

Offset (Octets)	Length (Octets)	Name	Description
0	2	descriptor_type	The type of the descriptor. Always set to STREAM_INPUT or STREAM_OUTPUT.
2	2	descriptor_index	The index of the descriptor. This is the index of the Stream.
4	64	object_name	64-octet UTF-8 string containing a Stream name.
68	2	localized_description	The localized string reference pointing to the localized Stream name. See 7.3.6.
70	2	clock_domain_index	The descriptor_index of the Clock Domain providing the media clock for the Stream. See 7.2.9.
72	2	stream_flags	Flags describing capabilities or features of the Stream. See Table 7.9.
74	8	current_format	The Stream format of the current format, as defined in 7.3.2.
82	2	formats_offset	The offset from the start of the descriptor for the first octet of the formats. This field is 136 for this version of AEM.
84	2	number_of_formats	The number of formats supported by this audio Stream. The value of this field is referred to as N. The maximum value for this field is 47 for this version of AEM.
86	8	backup_talker_entity_id_0	The primary backup AVDECC Talker’s Entity ID.
94	2	backup_talker_unique_id_0	The primary backup AVDECC Talker’s Unique ID.
96	8	backup_talker_entity_id_1	The secondary backup AVDECC Talker’s Entity ID.
104	2	backup_talker_unique_id_1	The secondary backup AVDECC Talker’s Unique ID.
106	8	backup_talker_entity_id_2	The tertiary backup AVDECC Talker’s Entity ID.
114	2	backup_talker_unique_id_2	The tertiary backup AVDECC Talker’s Unique ID.
116	8	backedup_talker_entity_id	The Entity ID of the AVDECC Talker that this Stream is backing up.
124	2	backedup_talker_unique_id	The Unique ID of the AVDECC Talker that this Stream is backing up.
126	2	avb_interface_index	The descriptor_index of the AVB_INTERFACE from which this Stream is sourced or to which it is sinked.
128	4	buffer_length	The length in nanoseconds of the MAC’s ingress or

			egress buffer as defined in Figure 5.4 of IEEE Std 1722-2011. For a STREAM_INPUT this is the MAC's ingress buffer size, and for a STREAM_OUTPUT this is the MAC's egress buffer size. This is the length of the buffer between the IEEE Std 1722-2011 reference plane and the MAC.
132	2	redundant_offset	The offset from the start of the descriptor for the first octet of the redundant_streams array. This field is 136+8*N for this version of AEM.
134	2	number_of_redundant_streams	The number of redundant streams supported by this Stream. The value of this field is referred to as R. The maximum value for this field is 8 for this version of AEM.
136	8*N	formats	Array of Stream formats of the supported formats, as defined in 7.3.2.
136+8*N	2*R	redundant_streams	Array of redundant STREAM_INPUT STREAM_OUTPUT descriptor indices. The present document doesn't specify any order for the elements of this array.

Annex B (Informative) Workflow Example



In this example, we have the following elements:

- A primary network, composed of AVB switches and Ethernet cables
- A secondary network, composed of AVB switches and Ethernet cables.
- A Controller CTR1 connected to both networks with two Ethernet interfaces.
- A second, independent, Controller CTR2 connected to the primary network only, with a single Ethernet interface.
- An AVB Talker TK1 and an AVB Listener LS1, connected to both networks with two AVB interfaces.
- An AVB Talker TK2 and an AVB Listener LS2, connected to the Primary network only, with one AVB interface.

Deployment clarifications:

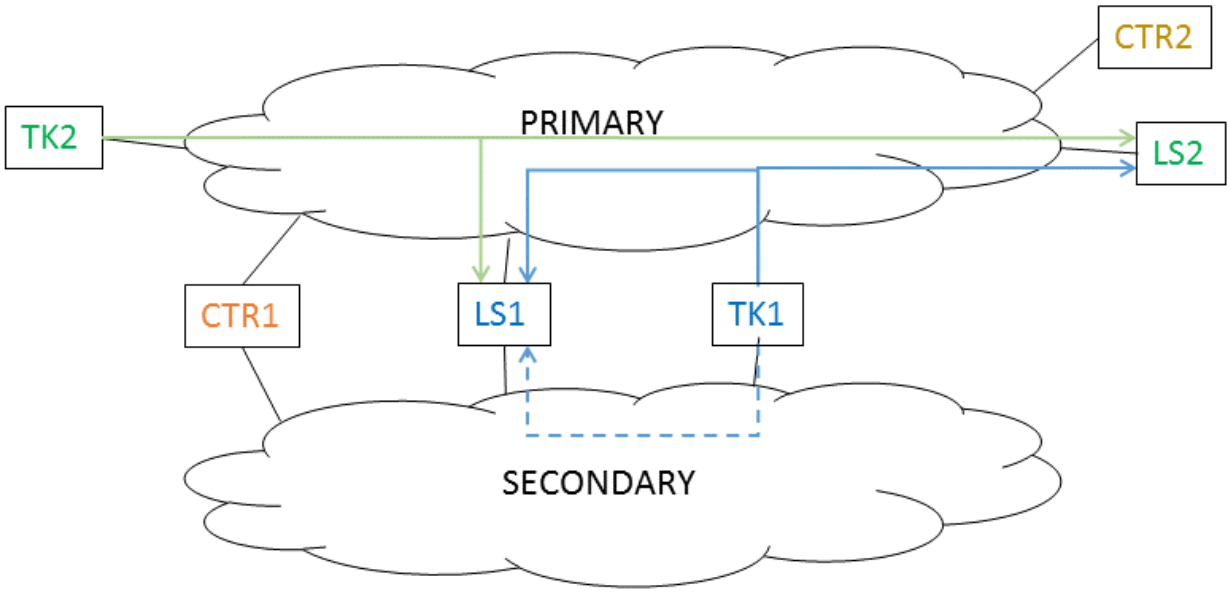
- The primary and secondary networks are not connected by any network links.
- Non-redundant end stations and controllers can be used without disturbing the normal operations of the redundant system. These devices are connected to the Primary network.

B.1 Configuration Phase

During the configuration phase, a Controller is used to configure all the end stations and connect both primary and secondary streams. During this configuration phase, we suppose that there is no failure in the system.

Supposing there is a failure in the Primary or the Secondary infrastructure, the user must fix it before starting the operational phase.

Below is a typical example of stream connections that could be achieved during this phase:



Description:

- TK1 has two AVB interfaces: on the Primary network it is streaming audio to LS1 and LS2 (solid blue line). On the Secondary network it is streaming the same audio to LS1 only (dashed blue line).
- TK2 has only one AVB interface that is connected to the Primary network. It is streaming audio to LS1 and LS2 (solid green line).

B.2 Operational phase

Once all the connections have been successfully established, the system is operational. The listeners are rendering the audio streams they receive and are in a mode where they can endure a failure of a single network.

Note: there is no specific action from the user to make a listener go into the operational phase. As soon as the listener has its two redundant sinks connected, it renders one or the other, depending what is available.

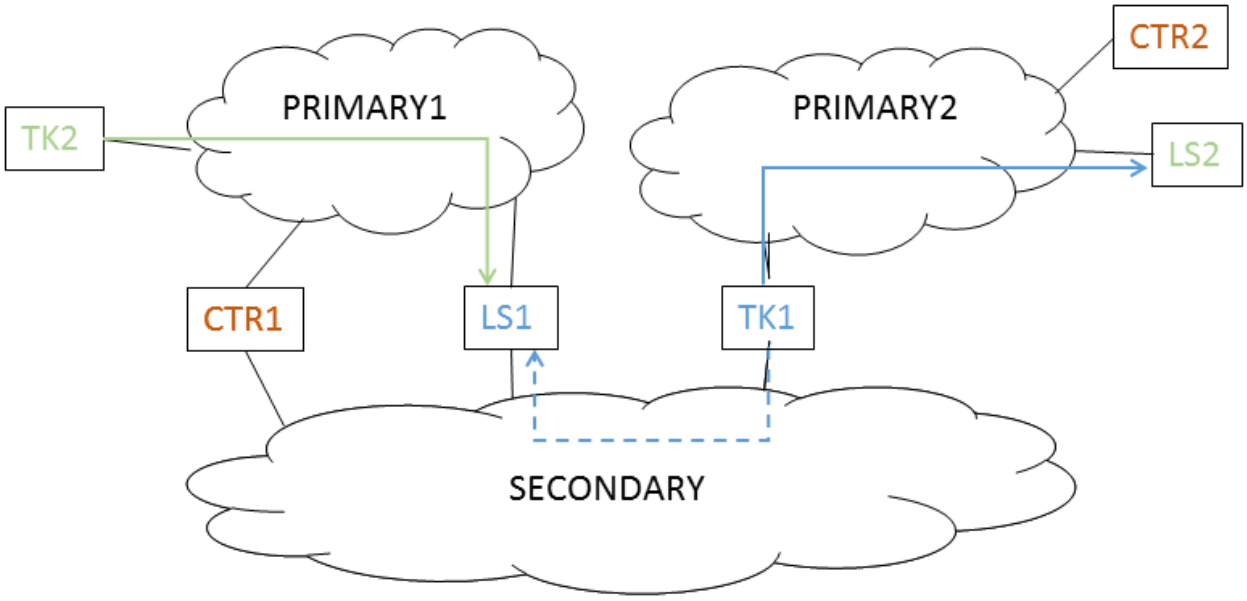
The redundant talker TK1 sends the same stream content, at the same rate, on both primary and secondary AVB interface.

The redundant listener LS1 continuously receives the same stream content, at the same rate, from both the primary and secondary interfaces. The model for the listener is as follows (implementation can be different as long as the external behavior is the same): the listener has 2 audio buffers, one for each interface, that are filled in parallel with the received packets. In normal operations (no failure), both buffers contain exactly the same data, and the listener can choose to play audio from the first buffer or the second one. At any time, if one of the two buffers become empty because of a failure on one network, the listener switches to the other buffer and continues playing audio seamlessly.

B.3 Failure During the Operational phase

The failure modes covered by this specification are limited to the loss of connectivity in either the primary or secondary network (e.g. a broken cable or power loss of a bridge).

Let's consider the following failure, where the primary network is split into two disjoint networks. Let's name them PRIMARY1 and PRIMARY2:



Observations:

- LS1 no longer receives the Primary stream from TK1, but it still receives the Secondary stream, so the failure doesn't result in a loss of audio. The stream from TK2 is intact as the failure didn't occur on the path TK2->LS1.
- LS2 no longer receives the stream from TK2. As there was no Secondary stream, this signal is lost. LS2 still receives the stream from TK1 as the failure didn't occur on the path TK1->LS2.
- CTR1 can no longer reach TK1 on PRIMARY1, but it can still reach it on SECONDARY.
- CTR1 can no longer reach LS2, but CTR2 can still reach LS2 via PRIMARY2.