Leader

Leader Electronics Corporation Technical Information Series Vol.04

IP Conversion of Broadcasting 1 ⋮ Overview

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01　Background

Overview about IP transmission

Overview

Until now, in broadcast stations, from video production to transmissions, SDI (Serial Digital Interface) has been operated mainly, which is an industry specific standard. But in recent years, resolution (2K→4K/8K), bit depth (8bit→10bit/12bit), and frame rate (60p→120p) have been improved. In other words, as the image quality has been improved, it need to process more and more amount of data. As a result, some problems have become apparent such as the number of BNC cables and transmission distance.

Therefore, IP (Internet Protocol) technology are attracted attention. The cables for IP are light comparing to BNC cable so we can extend the transmission distance, and possibly reduce the cost in the future because the IP technology is making progress dramatically. In addition, with PTP, the Black Burst signals (BB) is no longer necessary and we can construct more flexible systems, so it has become widely used in broadcasting industry.

Comparing SDI with IP

Transmission Speed

In 1990, SD-SDI (270Mbsp) was defined. At that time, the Ethernet transmission speed was about 10Mbps which is significantly insufficient for broadcasting. Therefore, in Broadcast stations, SDI, which is the only standards using coaxial cables, has been applied for a long times. However the transmission by coaxial cables is coming up to the limit because the videos have gradually evolved to 1080i (1.5Gbps), 1080p (3Gbps), 4K/30p (6Gbps), 4K/60p (12Gbps). And we should predict that 8K is become prevalent in the future. On the other hand, the Ethernet has grown rapidly in contrast to SDI, with 1 Gbps in 2000, 100 Gbps in 2010, and 400 Gbps as of 2019, and more in the future.

Cost

SDI requires dedicated instruments due to industrial unique standards. And equipment are required update every time developed new formats. However the costs tend to be expensive due to its small market. On the other hand, IP is expected to dramatic cost down because we can use highly versatile instruments such as switching hubs.

Multiplex

In SDI, one signal is transmitted by one cable. Against that, in IP, multiple signals can be transmitted by one cable. For example, when we use 100 Gbps network, more than 60 HD-SDI (1.5 Gbps) signals can be transmitted by one cable. It can also be supported format expansion such as 4K and 8K. In addition to video signals, control signals, synchronization signals,

intercoms, and all shooting data can be transmitted via IP, making it possible to reduce the number of cables and equipment.

Bidirectional

Bidirectional communication is available in IP unlike unidirectional communication in SDI with fixed inputs and outputs. Therefore, we are only required to connect each equipment to switching hub, it makes possible to construct high flexible systems.

Connection Image

For SDI, each equipment is connected in processing in order. To synchronize each equipment, they require the external sync signal.
Since SDI is unidirectional communication, basically we only connect each equipment to output images without any special settings.
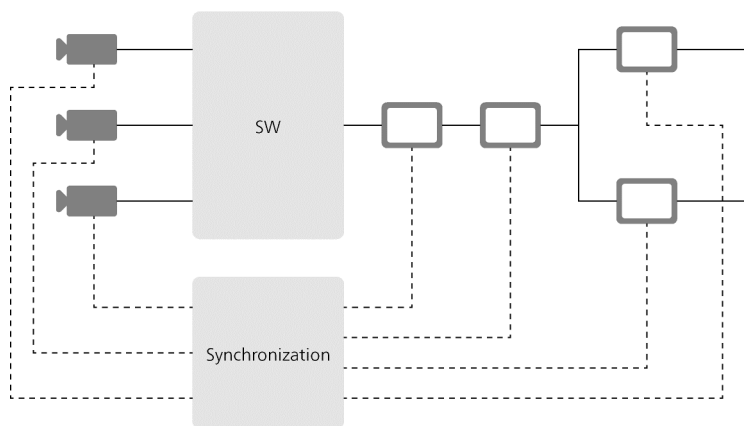
Figure | Connection image for SDI

On the other hand, IP is simply constructed with only connecting switching hub to each equipment. Furthermore, using PTP, which is synchronized protocol for IP, it is also not required the external sync signal.
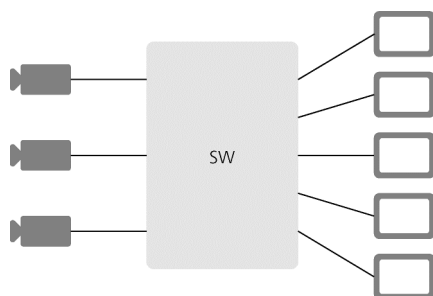Since IP is bidirectional communication, we have to construct the setting for each equipment to output images.

Figure | Connection image for IP

02 The Technologies Supporting IP transmission

The technologies and the standards for IP transmission

Connections

In SDI, we use BNC connector and BNC cables for video signals transmissions. In IP, we mainly use the port and fiber-optic cables called SFP. In this section, we will explain the connections using fiber-optic cable.

SFP

SFP is an abbreviation for Small Form-factor Pluggable. We usually connect the SFP port to the fiber-optic cable through the SFP transceiver. The SFP transceivers can convert the electrical signals from the equipment side and the optical signals from the cable side mutually.
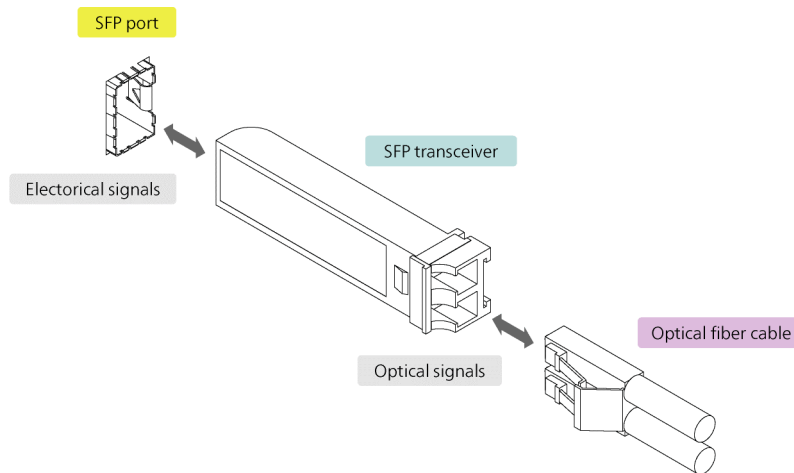

Figure | SFP connection

SFP transceivers has several types several types as below classified by the network transmission speed. Here, available SFP transceiver type could be different by the equipment even if its appearance are similar, so we have to take care for that when selecting them. In addition, transmission speed of the SFP receiving ports are required to be same as that of SFP transmission port.

SFP port	SFP transceiver	Transmission speed
SFP	SFP	1Gbps
	SFP+	10Gbps
	SFP28	25Gbps
QSFP	QSFP+	40Gbps
	QSFP28	100Gbps

Fiber-optic

In optical communication, the cable which transmits the signals is called fiber-optic. A fiber-optic consists of two parts. One is "core" through which signals transmit, the other is "clad" which confines signals inside the core. Optical signals are transmitted by total reflection at the interface between core and clads. Fiber-optic cables can transmit a large amount of data at high speed over long distances. However we need to take care to handle fiber-optic cables because the core and clad are usually made of glass.

Fiber-optic cables are roughly categorized MMF(Multi Mode Fiber) and SMF(Single Mode Fiber). Here, "Mode" refers to the way that optical signals are transmitted.

MMFs have a large core diameter of 50 μm or 62.5 μm and can transmit optical signals in multiple modes. But they could also degrade the signal and lose data. They are cheaper than SMF, but are not suitable for long-distance communication. For example, in the case of 10GBASE-SR standard (10Gbps, MMF), the transmission distance is up to 300m.
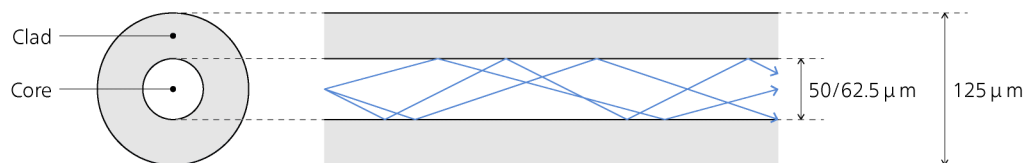

Figure | MMF

SMF has a small core diameter of 9.2 μm, and signal attenuation and deterioration are suppressed by transmitting optical signals in only one mode. It is more expensive than MMF, but it is suitable for long-distance communication. For example, in the case of 10GBASE-LR standard (10Gbps, SMF), the transmission distance is up to 10km.
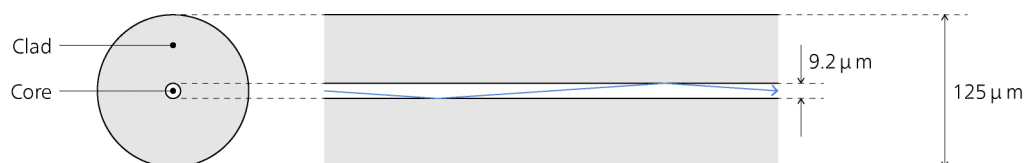

Figure | SMF

Packetization for SDI Signals

In this section, we will explain the standards when packetize uncompressed SDI signals. See more details, separate volume "Content edition".

Overview

In 2012, SMPTE ST 2022-6 was stipulated as the standard of packetization for uncompressed SDI signals. SMPTE ST 2022-6 is the system that is packetized the entire SDI signal. And it supports up to 3G-SDI.
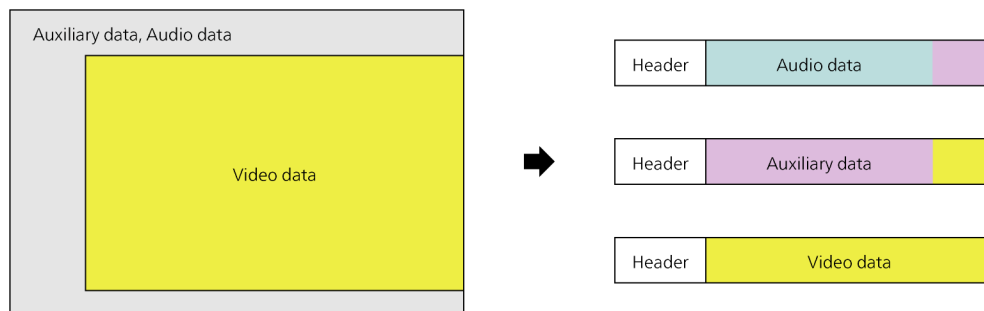
Figure | Image of SMPTE ST 2022-6

In this standard, the data of video, audio, and auxiliary are mixed in one packet. So it was not efficient for receiving individual factor signal. Therefore, from 2017 to 2018, SMPTE ST 2110-20, which packetizes video data, SMPTE ST 2110-30,   which is packetizes audio data, and SMPTE ST 2110-40, which is the standard packetized auxiliary data, were stipulated.
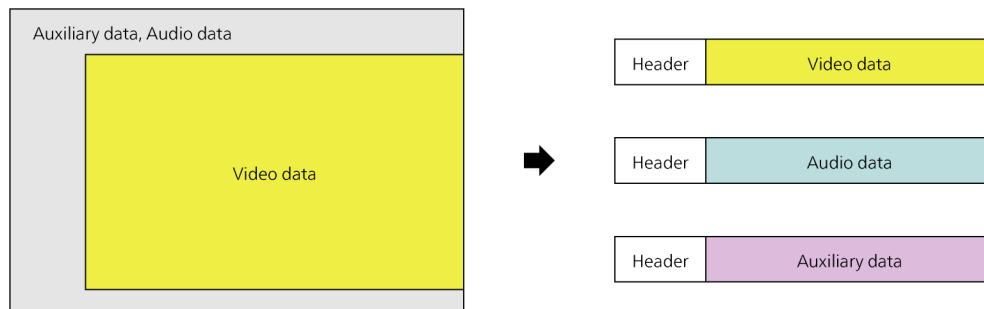
Figure | Image of SMPTE ST 2110

Moreover, SMPTE ST 2110 can synchronize with high accuracy by using PTP, which is the synchronization protocol stipulated in SMPTE ST 2059.

Standards

SMPTE ST 2022

SMPTE ST 2022 consists of seven standards from 2022-1 to 2022-7.In this section, we will explain from 2022-5 to 2022-7. These are related to uncompressed SDI signals.

Standard	Name	Overview
SMPTE ST 2022-5	Forward Error Correction for Transport of High Bit Rate Media Signals over IP Networks (HBRMT)	forward error correction for 2022-6
SMPTE ST 2022-6	Transport of High Bit Rate Media Signals over IP Networks (HBRMT)	Packetization forthe entire SDI signal
SMPTE ST 2022-7	Seamless Protection Switching of SMPTE ST 2022 IP Datagrams	Seamless signal switching for redundant transmission lines

SMPTE ST 2110

SMPTE ST 2110 consists of six standards from 2022-10 to 2022-40.And these generic name is "Professional Media Over Managed IP Networks".
SMPTE ST 2110 is not included the specification for error correction and signal switching. But we can use SMPTE ST 2022-7.

Standard	Name	Overview
SMPTE ST 2110-10	System Timing and Definitions	Timings and rules for the entire systems
SMPTE ST 2110-20	Uncompressed Active Video	Packetization for the video data
SMPTE ST 2110-21	Traffic Shaping and Delivery Timing for Video	Transmission timings for video data
SMPTE ST 2110-30	PCM Digital Audio	Packetization for AES67 format audio data
SMPTE ST 2110-31	AES3 Transparent Transport	Packetization for AES3 format audio data
SMPTE ST 2110-40	SMPTE ST 291-1 Ancillary Data	Packetization for auxiliary data

PTP

In this section, we will explain PTP (Precision Time Protocol), which is the protocol for synchronizing on IP networks. See more details, separate volume "synchronization edition (under editing)".

Overview

PTP is the protocol that substitutes for external sync signal (Black Burst). PTP synchronizes of video or audio by accurately adjusting the time of the equipment on the network. PTP used in various situations, not only the broadcasting industry but also the telecom and the financial industry.

NTP (Network Time Protocol) is the time synchronization protocol, too. Until now, NTP had been used widely. However, the accuracy of NTP is 1 millisecond, while the accuracy of PTP is about 1 microsecond. So PTP makes it possible to synchronize more accurate than NTP.
For your information, the broadcasts require the synchronization accuracy 200 nanoseconds to 300 nanoseconds.

Standards

IEEE 1588

This is a fundamental standards for PTP, and there are two. "v1" was specified in 2002, and "v2" as specified in 2008. But v1 and v2 are not compatible.

Standard name	Name	Overview
IEEE 1588-2002 (v1)	IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems	Adopted by Dante (network audio standard)
IEEE 1588-2008 (v2)	IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems	Adopted by SMPTE ST 2022-6,SMPTE ST 2110, and AES67

SMPTE ST 2059

This is a PTP standard adapted for broadcast equipment.

Standard name	Name	Overview
SMPTE ST 2059-1	Generation and Alignment of Interface Signals to the SMPTE Epoch	How to calculate for video and audio phase starting from the SMPTE epoch.
SMPTE ST 2059-2	SMPTE Profile for Use of IEEE-1588 Precision Time Protocol in Professional Broadcast Applications	SMPTE profile when used IEEE 1588 in broadcast.
SMPTE EG 2059-10	Introduction to the New Synchronization System	Introduction and usage examples for PTP

Control

In this section, we will explain the standards for controlling networks. See more details, separate volume "Control edition (under editing)".

Overview

Above as packetization for SDI signals and the PTP are conversions of conventional SDI signals to IP On the other hand, the control is a peculiar element of the IP conversion. In this section, we will explain that IS-04 and IS-05 in　NMOS(Networked Media Open Specifications), which is established by AMWA(Advanced Media Workflow Association).
AMWA refers the international organization which standardize control systems. NMOS refers the standard control standards.

Standard

IS-04 (Discovery and Registration)

This standard is for discovery and registration of the equipment on networks.
The following API (Application Programming Interface) is provided.

・NodeAPI
・QueryAPI
・RegistrationAPI

IS-05 (Device Connection Management)

This standard is for management for connection between devices.
The following API (Application Programming Interface) is provided.

・ConnectionAPI

# 03   Basic Knowledge about Communication

About basic knowledge of communication required for IP transmission

IP

IP is an abbreviation for Internet Protocol, which is a mechanism for subdividing the data you want to send into a constant size packets and transmitting them over a network.
Subdividing into packets makes it avoid to occupy the network for long times and minimize retransmission due to error occasion.
On the receiving side, you can obtain original data by restoring the packet data.

Subdividing into packets   Transmission   Restoring the packet data
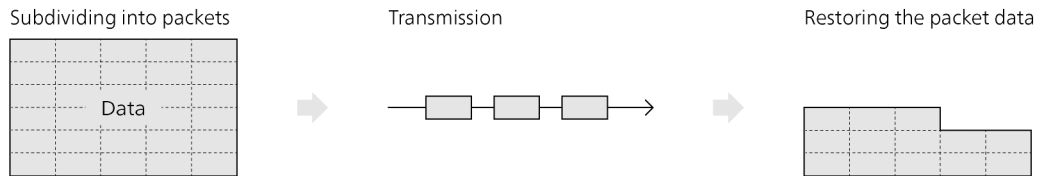
On the other hand, IP is said low reliable protocol. Because IP packets are not arrived in receiver side in the right order or are lost the data during transmitting. To prevent them, TCP/IP formats, which are combined IP with TCP (Transmission Control Protocol), are used widely.
(However, in broadcast field, UDP is used instead of TCP.)

Transmission   Reception

Protocol

Protocol means "Rule". And The "P" in "IP" is an abbreviation for protocol. Therefore the case of "IP", it indicates "the rules when using internets".
Protocol has various types besides IP. And they are defined by organizations such as IETF (Internet Engineering Task Force).
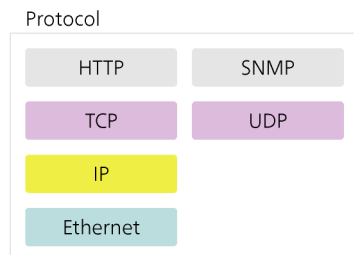
Protocol

Figure | One example of the protocol

Packet

In communicating mainly by IP, packets refer to the data subdivided into a certain size. The packet consists of IP header and data. The IP header has various information related to the data.

For example, in the case of an IP packets, they indicate the data with an IP header attached. The IP header has various information the IP address, etc.
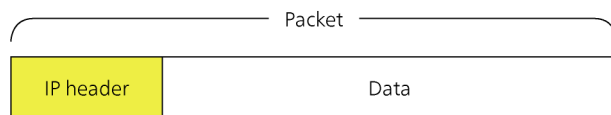
IP header	Data

Packet

Figure | Packet

In the case of a TCP, the segment indicates the data with a TCP header attached. But, they are also called packet. So in this document, we will call them packet.
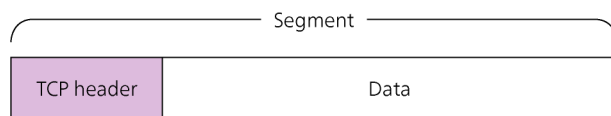
TCP header	Data

Segment

Figure | Segment

In the case of a UDP, the datagram indicates the data with a UDP header attached. But, they are also called packet. So in this document, we will call them packet.
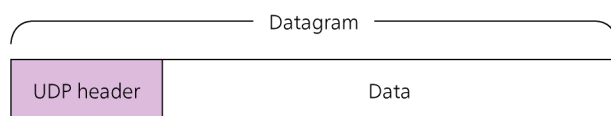
UDP header	Data

Datagram

Figure | Datagram

As a supplementary explanation, in the case of an Ethernet, the frame indicates the data with an Ethernet header and the FCS (Frame Check Sequence) attached. This FCS indicates the attached data to detect errors.
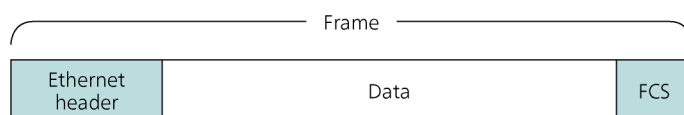
Ethernet header	Data	FCS

Frame

Figure | Flame

Encapsulation

One packet consists of the header and the data. We reckon them as one data, and attach another header. This is called encapsulation.

For example, the TCP packets consist of the TCP header and the data. And we reckon them as one data, and attach the IP header.

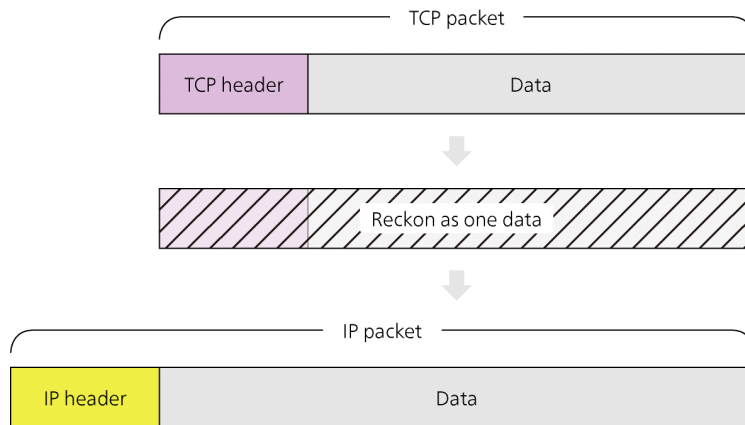Furthermore, removing the header from the packet and retrieving the data is called decapsulation.

Figure | Encapsulation

OSI Reference Model / TCP / IP Model

The following is a standardized communication mechanism for connecting various network devices to each other. OSI reference model are classified the functions required for communication into seven layers. They are almost not used actually, despite important concept to know the communication mechanism. On the other hand, TCP/IP model consisted of four layers are used widely.

They has different contents. But both models have the layerized function, each layer is independent. The transmitting side sends data from the upper layer to the lower layer, and the receiving side passes the data received in the lower layer to upper layer. With this, communications are established.

OSI Reference Model	TCP / IP Model	Main Protocol
7th layer Application layer	4th layer Application layer	HTTP, SNMP, FTP, RTP, and so forth
6th layer Presentation layer		
5th layer Session layer		
4th layer Transport layer	3rd layer Transport layer	TCP, UDP, and so forth
3rd layer Network layer	2nd layer Internet layer	IP, and so forth
2nd layer Data link layer	1st layer Network internet layer	Ethernet, and so forth
1st layer Physical layer		

Figure | OSI reference model / TCP / IP model

※   There are various theories about supporting OSI reference model ,TCP/IP model supports, and the protocol accompanying each layers. In this section, we described one example.

In the below, we will explain the flow of data sending and receiving by using OSI reference model. As an example, taking RTP (Real-time Transport Protocol), which is the protocol used for broadcast. And we will use UDP, IP, and Ethernet as communications protocol.

At first, we will explain the data sending.
The RTP header is added to the sending data, and they are passed to the transport layer (L4).

RTP header	Data

In the transport layer "L4", the UDP header is added, and they are passed to the network layer "L3". (Encapsulation)

UDP header	RTP header	Data

In the network layer "L3", the IP header is added, and they are passed to the data link layer "L2".

| IP header	UDP header	RTP header	Data
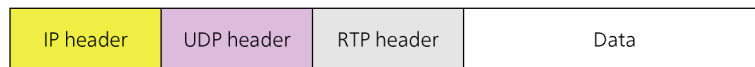
In the data link layer (L2), an Ethernet header and FCS are added, and they are passed to the physical layer (L1) and converted to "0" and "1" data for transmission.

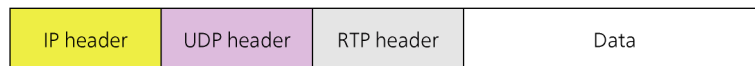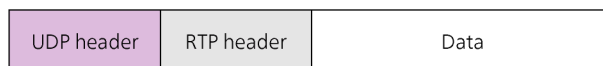| Ethernet header	IP header	UDP header	RTP header	Data	FCS
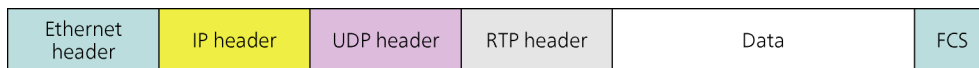
At next, we will describe the data receiving.
The "0" and "1" data received at the physical layer (L1) are restored to the Ethernet frame format and passed to the data link layer (L2).

Ethernet header	IP header	UDP header	RTP header	Data	FCS
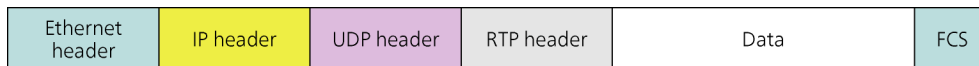
At the data link layer (L2), the Ethernet header and FCS are removed and passed to the network layer (L3). (Decapsulation)

IP header	UDP header	RTP header	Data

At the network layer (L3), the IP header is removed and passed to the transport layer (L4).

UDP header	RTP header	Data

At the transport layer (L4), the UDP header is removed and passed to the application layer.

RTP header	Data

You can see the data by removing the RTP header at the application layer.

Data

IP Address

IP Address is the abbreviation of Internet Protocol Address. This is a unique identification number assigned each instrument connected to the internet or the LAN.

IP Address consists 32 bits, and they are shown as the formats from "0.0.0.0" to "255.255.255.255".These are called IPv4, and the total numbers of them are about 4.3 billion. But the depletion of IP addresses has already become a problem. So the transition to IPv6 is progressing.

IPv4	192	.	168	.	0	.	1
	11000000		10101000		00000000		00000001
	8 bit		8 bit		8 bit		8 bit

IPv6 consists 128 bits, they are shown from "0:0:0:0:0:0:0:0" to "FFFF: FFFF: FFFF: FFFF: FFFF: FFFF: FFFF: FFFF". IPv4 and IPv6 are not compatible. So we are required So we are required IPv6 supports for   network equipment.

IPv6	1234 : 5678 : 90AB : CDEF : 1234 : 5678 : 90AB : CDEF
	16 bit 16 bit 16 bit 16 bit 16 bit 16 bit 16 bit 16 bit

MAC Address

MAC address is an abbreviation for Media Access Control Address. They are unique identification number and is assigned each equipment connected to the network. In principle, once assigned, these are not changed. They consists of a total of 48 bits and are shown from "00:00:00:00:00:00" to "FF: FF: FF: FF: FF: FF". The first 24 bits are called OUI (Organizationally Unique Identifier), which is a unique number representing the manufacturer name. The latter 24 bits are the numbers assigned by the manufacturer for each product.

The total number of MAC addresses are about 70 trillion, and it is said that there is no concern about depletion at this time.

00:09:0D:12:34:56

8 bit   8 bit   8 bit   8 bit   8 bit   8 bit

The unique number for representing manufacturer names   The number assigned to each product

L2 Switch (Switching Hub, Ethernet Switch)

"L2" in L2 Switch refers second layer of OSI reference model, which is   the data link layer. L2 Switch is an equipment which operates on this data link layer. This judges destinations according to MAC address and send the data to equipment only required.
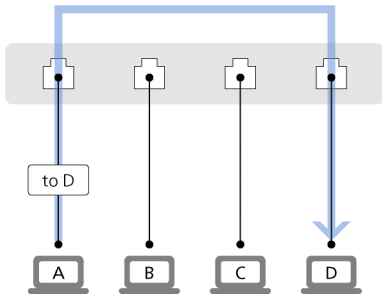

Figure | L2 Switch

Moreover L3 Switch is an equipment which operates on network layer, which is third layer of OSI reference model. This judges destinations according to IP address and send the data.

Furthermore the equipment which operates the physical layer, which is first layer of OSI reference model, are refered the repeater Hub. It sends the received data to all equipment. If received data is not for myself, the data are discarded. Currently, repeater hubs are not used so well.
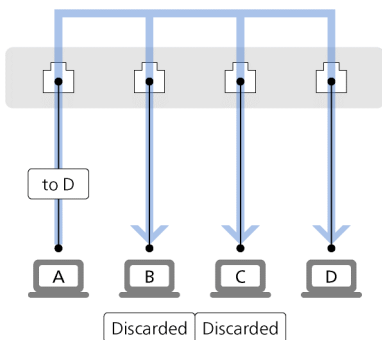

Figure | Repeater Hub

About structure of the documents

"Vol.4 IP Conversion of Broadcasting" has four parts in total. This documents is "Overview edition". Please take a look at the followings as well.

・IP Conversion of Broadcasting 1   Overview   Background, Technologies that support
   IP transmission, Basic knowledge about communication   * This document
・IP Conversion of Broadcasting 2   Contents   About SMPTE ST 2110   * Under editing
・IP Conversion of Broadcasting 3   Synchronization   About PTP   * Under editing
・IP Conversion of Broadcasting 4   Control   About NMOS   * Under editing