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Tech Notes

Understanding EtherChannel Load Balancing and Redundancy on Catalyst Switches

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Contents

Introduction

Fast EtherChannel allows multiple physical Fast Ethernet links to combine into one logical channel. This allows load sharing of traffic among the links in the channel as well as redundancy in the event that one or more links in the channel should fail. Fast EtherChannel can be used to interconnect LAN switches, routers, servers, and clients via unshielded twisted-pair (UTP) wiring or single mode and multimode fiber. This document refers to Fast EtherChannel, Gigabit EtherChannel, port channel, channel and port group with a single term, EtherChannel. The information in the document applies to all

of these EtherChannels.

This document presents the concept of load balancing and redundancy on Cisco Catalyst switches with the use of the EtherChannel. This document also covers the Port Aggregation Protocol (PAgP) and trunking support over EtherChannel. This document does not cover how to configure EtherChannel on Catalyst switches. For details on how to configure EtherChannel on Catalyst switches, refer to the documents in the Related Information section.

Prerequisites

Requirements

There are no specific requirements for this document.

Components Used

This document is not restricted to specific software and hardware versions.

Conventions

For more information on document conventions, refer to the Cisco Technical Tips Conventions.

Load Balancing: How to Determine the Link Across Which to Send Traffic

This section explains the load balance of packets over an EtherChannel group for each switch platform.

Catalyst 6500/6000 Series

To distribute frames across the links in a channel, EtherChannel reduces part of the binary pattern that the addresses in the frame form to a numerical value that selects one of the links in the channel. EtherChannel frame distribution uses a Cisco-proprietary hashing algorithm. The algorithm is deterministic; if you use the same addresses and session information, you always hash to the same port in the channel. This method prevents out-of-order packet delivery.

In Catalyst 6500/6000 switches that run Catalyst OS (CatOS), EtherChannel aggregates the bandwidth of up to eight compatibly configured ports into a single logical link. With software releases 6.2(1) and earlier, the six- and nine-slot Catalyst 6500 series switches support a maximum of 128 EtherChannels. In software release 6.2(2) and later releases, the spanning tree feature handles the port ID. Therefore, the maximum number of EtherChannels with support is 126 for a six- or nine-slot chassis and 63 for a 13-slot chassis. All Ethernet ports on all modules, which include those on a standby Supervisor Engine, support EtherChannel with no requirement that ports be contiguous or on the same module. All ports in each EtherChannel must be the same speed. You can base the load-balance policy (frame distribution) on a MAC address (Layer 2 [L2]), an IP address (Layer 3 [L3]), or a port number (Layer 4 [L4]). You can activate these policies, respectively, if you issue the **set port channel all distribution {ip | mac| session | ip-vlan-session} [source | destination | both]** command. The **session** keyword has support on the Supervisor Engine 2 and Supervisor Engine 720. The **ip-vlan-session** keyword only has support on the the Supervisor Engine 720. Use this keyword to specify the frame distribution method, with use of

the IP address, VLAN, and L4 traffic.

If a packet does not belong to a category selection, the next-lower level category is considered. If the hardware cannot support the frame distribution method that you have selected, a "Feature not supported" error message displays.

The Cisco-proprietary hash algorithm computes a value in the range 0–7. With this value as a basis, a particular port in the EtherChannel is chosen. The port setup includes a mask which indicates which values the port accepts for transmission. With the maximum number of ports in a single EtherChannel, which is eight ports, each port accepts only one value. If you have four ports in the EtherChannel, each port accepts two values, and so on. This table lists the ratios of the values that each port accepts, which depends on the number of ports in the EtherChannel:

Number of Ports in the EtherChannel	Load Balancing
8	1:1:1:1:1:1:1:1
7	2:1:1:1:1:1:1
6	2:2:1:1:1:1
5	2:2:2:1:1
4	2:2:2:2
3	3:3:2
2	4:4

Note: This table only lists the number of values (which the hash algorithm calculates) that a particular port accepts. You cannot control the port that a particular flow uses. You can only influence the load balance with a frame distribution method that results in the greatest variety.

Hence, in essence, you can only achieve perfect load balancing, even with random addresses, if you have two, four, or eight ports in the port channel.

To check the frame distribution policy, issue the **show port channel** *mod/port* **info** command. If you start with version 6.1(x) and later, you can determine the port for use in the port channel to forward traffic, with the frame distribution policy as the basis. The command for this determination is **show channel hash** *channel-id* {*src_ip_addr* | *dest_ip_addr* | *src_mac_addr* | *dest_mac_addr* | *src_port* | *dest_port*} [*dest_ip_addr* | *dest_mac_addr* | *dest_port*] .

Here are examples:

1.
```
Console> (enable) show channel hash 865 10.10.10.1 10.10.10.2
Selected channel port: 1/1
```

2.
```
Console> (enable) show channel hash 865 00-02-fc-26-24-94
00-d0-c0-d7-2d-d4

!--- Note: This command should be on one line.

Selected channel port: 1/2
```

Catalyst 6500/6000 switches that run Cisco IOS® System Software support a maximum of 64 EtherChannels. You can form an EtherChannel with up to eight compatibly configured LAN ports on any module in a Catalyst 6500/6000 series switch. All LAN ports in each EtherChannel must be the same speed, and you must configure all the ports as either L2 or L3 LAN ports.

EtherChannel load balancing can use MAC addresses, IP addresses, or L4 port numbers with a Policy Feature Card 2 (PFC2) and either source mode, destination mode, or both. The mode you select applies to all EtherChannels that you configure on the switch. Use the option that provides the greatest variety in your configuration. For example, if the traffic on a channel only goes to a single MAC address, use of the destination MAC address results in the choice of the same link in the channel each time. Use of source addresses or IP addresses can result in a better load balance. To configure the load balancing, issue the **port-channel load-balance {src-mac | dst-mac | src-dst-mac | src-ip | dst-ip | src-dst-ip | src-port | dst-port | src-dst-port}** global configuration command.

Issue the **show etherchannel load-balance** command to check the frame distribution policy. You can determine which interface in the EtherChannel forwards traffic, with the frame distribution policy as a basis. To make this determination, issue the **remote login switch** command to log in remotely to the Switch Processor (SP) console. Then, issue the **test etherchannel load-balance interface port-channel** *number* **{ip | l4port | mac}** [*source_ip_add | source_mac_add | source_l4_port*] [*dest_ip_add | dest_mac_add | dest_l4_port*] command.

Here are examples:

1.
```
6509# remote login switch
      Trying Switch ...
      Entering CONSOLE for Switch
      Type "^C^C^C" to end this session

      6509-sp# test etherchannel load-balance interface port-channel 1
      ip 10.10.10.2 10.10.10.1

      !--- Note: This command should be on one line.

      Would select Gi6/1 of Po1

       6509-sp#
```

2.
```
6509# remote login switch
      Trying Switch ...
      Entering CONSOLE for Switch
      Type "^C^C^C" to end this session

      6509-sp# test etherchannel load-balance interface port-channel 1 mac
      00d0.c0d7.2dd4 0002.fc26.2494

      !--- Note: This command should be on one line.

      Would select Gi6/1 of Po1

       6509-sp#
```

Catalyst 5500/5000 Series

A Catalyst 5500/5000 series switch allows from two to four links to be present per Fast EtherChannel. A

connection across a Fast EtherChannel is determined by source/destination address pairs. An XOR mathematical operation is performed on the last two bits of the source MAC address and the destination MAC address. This operation yields one of four results: (0 0), (0 1), (1 0), or (1 1). Each of these values points to a link in the Fast EtherChannel bundle. In the case of a two-port Fast EtherChannel, only a single bit is used in the XOR operation. This scenario yields two possible results, each pointing to a link in the bundle. Circumstances can occur where one address in the source/destination pair is a constant. For example, the destination may be a server or, even more likely, a router. In that case, you still see statistical load balancing because the source address is always different. In Cisco IOS Software Release 3.1.1 and later, spanning tree is supported. As far as spanning tree is concerned, a Fast EtherChannel looks like a single bridge port, and bridge protocol data units (BPDUs) are sent down on only one of the links. A Fast EtherChannel that is in blocking mode blocks all ports on that EtherChannel connection.

EtherChannel distributes frames across the links in a channel based on the low-order bits of the source and destination MAC addresses of each frame. The frame distribution method is not configurable.

Catalyst 4500/4000 Series

In the Catalyst 4500/4000 series switches with CatOS (Supervisor Engine I and II), you can form an EtherChannel with up to eight compatibly configured Fast Ethernet or Gigabit Ethernet ports on the switch. The exact EtherChannel formation depends on the hardware. Because the spanning tree feature handles the port ID, the maximum number of channels is 126 for a six-slot chassis. In addition, you can configure an EtherChannel using ports from multiple modules as of CatOS release 5.x and later. All ports in an EtherChannel must be the same speed.

EtherChannel distributes frames across the links in a channel based on the low-order bits of the source and destination MAC addresses of each frame. The frame distribution method is not configurable.

A Catalyst 4500/4000 series switch with Cisco IOS Software (Supervisor Engine II+ and later) supports a maximum of 64 EtherChannels. You can form an EtherChannel with up to eight compatibly configured Ethernet interfaces on any module and across modules. All interfaces in each EtherChannel must be the same speed, and you must configure all the interfaces as either L2 or L3 interfaces.

EtherChannel balances the traffic load across the links in a channel by reducing part of the binary pattern formed from the addresses in the frame to a numerical value that selects one of the links in the channel. EtherChannel load balancing can use MAC addresses, IP addresses, or L4 port numbers and either source mode, destination mode, or both. Use the option that provides the greatest variety in your configuration. For example, if the traffic on a channel only goes to a single MAC address, use of the destination MAC address results in the choice of the same link in the channel each time. Use of source or IP addresses can result in a better load balance. To configure load balancing, issue the **port-channel load-balance {src-mac | dst-mac | src-dst-mac | src-ip | dst-ip | src-dst-ip | src-port | dst-port | src-dst-port}** global configuration command.

Catalyst 2900XL/3500XL Series

A Catalyst 2900XL that runs a Cisco IOS Software release earlier than Cisco IOS Software Release 11.2 (8)SA3 chooses a link in the channel based on the link on which the destination MAC address was last heard. The software dynamically reallocates this address to another link in the channel if the link on which the address was learned is busier than the others. You can configure a Catalyst 2900XL that runs Cisco IOS Software Release 11.2(8)SA3 or later and a Catalyst 3500XL that runs Cisco IOS Software Release 11.2(8)SA6 or later to choose a link to be sent across the Fast EtherChannel; the switch chooses

the link on the basis of the destination or source MAC address of the frame. The default is to use the source MAC address. This default means that all packets that the switch receives on a non-Fast EtherChannel port with the same MAC source address that have a destination of the MAC addresses on the other side of the channel take the same link in the channel. Use source-based forward when many stations that attach to the Catalyst 2900XL/3500XL send to a few stations, such as a single router, on the other side of the Fast EtherChannel. The use of source-based forward in this situation evenly distributes traffic across all links in the channel. Also, the Catalyst 2900XL/3500XL switches maintain a notion of a "default" port on which to transmit traffic, such as Spanning Tree Protocol (STP), multicasts, and unknown unicasts.

Catalyst 3750/3560

The Catalyst 3750/3560 series switch can support up to eight compatibly configured Ethernet interfaces in an EtherChannel. The EtherChannel provides full-duplex bandwidth up to 800 Mbps (Fast EtherChannel) or 8 Gbps (Gigabit EtherChannel) between your switch and another switch or host. With Cisco IOS Software Release 12.2(20)SE and earlier, the number of EtherChannels has a limit of 12. With Cisco IOS Software Release 12.2(25)SE and later, the number of EtherChannels has a limit of 48.

EtherChannel balances the traffic load across the links in a channel through the reduction of part of the binary pattern that the addresses in the frame form to a numerical value that selects one of the links in the channel. EtherChannel load balancing can use MAC addresses or IP addresses, source or destination addresses, or both source and destination addresses. The mode applies to all EtherChannels configured on the switch. You configure the load balancing and forwarding method with use of the **port-channel load-balance {dst-ip | dst-mac | src-dst-ip | src-dst-mac | src-ip | src-mac}** global configuration command.

You can find out which interface will be used in the EtherChannel to forward traffic based on the load balancing method. The command for this determination is **test etherchannel load-balance interface port-channel** *number* **{ip | mac}** [*source_ip_add | source_mac_add*] [*dest_ip_add | dest_mac_add*].

Catalyst 2950/2955/3550

The Catalyst 2950/2955 series switch can support up to eight compatibly configured Ethernet interfaces in an EtherChannel. The EtherChannel can provide full-duplex bandwidth up to 800 Mbps (Fast EtherChannel) or 2 Gbps (Gigabit EtherChannel) between your switch and another switch or host. The number of EtherChannels has the limit of six with eight ports per EtherChannel.

The Catalyst 3550 series switches support both L2 and L3 EtherChannel, with up to eight compatibly configured Ethernet interfaces. The EtherChannel provides full-duplex bandwidth up to 800 Mbps (Fast EtherChannel) or 8 Gbps (Gigabit EtherChannel) between your switch and another switch or host. The limit of the number of EtherChannels is the number of ports of the same type.

For the 2950/2955/3550 series switch, EtherChannel balances the traffic load across the links in a channel by randomly associating a newly learned MAC address with one of the links in the channel. EtherChannel load balancing can use either source-MAC or destination-MAC address forwarding.

With source-MAC address forwarding, when packets are forwarded to an EtherChannel, the packets are distributed across the ports in the channel based on the source-MAC address of the incoming packet. Therefore, to provide load balancing, packets from different hosts use different ports in the channel, but packets from same host use the same port in the channel. With destination-MAC address forwarding,

when packets are forwarded to an EtherChannel, the packets are distributed across the ports in the channel based on the destination host MAC address of the incoming packet. Therefore, packets to the same destination are forwarded over the same port, and packets to a different destination are sent on a different port in the channel.

For the 3550 series switch, when source-MAC address forwarding is used, load distribution based on the source and destination IP address is also enabled for routed IP traffic. All routed IP traffic chooses a port based on the source and destination IP address. Packets between two IP hosts always use the same port in the channel, and traffic between any other pair of hosts can use a different port in the channel.

To configure the load-balance and forward method, issue the **port-channel load-balance {dst-mac | src-mac}** global configuration command.

Catalyst 1900/2820

With the enablement of PAgP, the two possible methods of link determination are preserve order and maximize load balancing between the links on the Fast EtherChannel. The What Is PAgP and Where Do You Use It? section of this document describes PAgP. The default is to maximize load balancing. PAgP is used to negotiate the configured method with the device at the other side of the channel. If preserve order is configured, the device at the other side is instructed to use source-based transmissions so that the Catalyst 1900/2820 always receives packets with the same source MAC address on the same link in the channel. This is the link that the Catalyst 1900/2820 always uses to send traffic to this MAC address. If maximize load balancing is configured, PAgP tells the other side that it can distribute traffic arbitrarily, and unicast traffic is transmitted by the Catalyst 1900/2820 on the link where the source address was last seen. This provides the maximum possible load-balancing configuration. When Fast EtherChannel is configured with PAgP disabled, the switch cannot negotiate with the partner about the switch learning capability. Whether the switch preserves frame ordering depends on whether the Fast EtherChannel partner performs source-based distribution. The Catalyst 1900/2820s also elect an active port. The active port is used for flooded traffic such as unknown unicast, unregistered multicast, and broadcast packets. If the port-channel mode is on (PAgP disabled), the active port is the link with the highest priority value. If the mode is desirable or auto (PAgP enabled), the active port is selected based on the priority of the links on the switch that has the higher Ethernet address. When two ports on the switch with the higher Ethernet address have the same priority, the port with the lower "ifIndex" is selected.

Catalyst 2948G-L3/4908G-L3 and Catalyst 8500

When one link fails, all traffic that previously used that link now uses the link next to it. For example, if Link 1 fails in a bundle, traffic that previously used Link 1 before the failure now uses Link 2.

Matrix of Load Balancing Methods

This matrix consolidates the load balancing methods that this document describes:

Platform	Address Used in XOR	Source-Based?	Destination-Based?	Source-Destination-Based?	Load Balancing Method—Configurable/Fixed?
6500/6000	L2, L3, or L4	Yes	Yes	Yes	Configurable

	addresses				
5500/5000	L2 address only	—	—	Yes	Cannot change the method
4500/4000	L2, L3, or L4 addresses	Yes	Yes	Yes	Configurable
2900XL/3500XL	L2 address only	Yes	Yes	—	Configurable
3750/3560	L2 or L3 address only	Yes	Yes	Yes	Configurable
2950/2955/3550	L2 address only[1]	Yes	Yes	—[1]	Configurable
1900/2820	These platforms use a special method of load balancing. See the Catalyst 1900/2820 section for details.				
8500	L3 address only	—	—	Yes	Cannot change the method

[1] For the 3550 series switch, when source-MAC address forwarding is used, load distribution based on the source and destination IP address is also enabled for routed IP traffic. All routed IP traffic chooses a port based on the source and destination IP address.

What Is PAgP and Where Do You Use It?

PAgP aids in the automatic creation of EtherChannel links. PAgP packets are sent between EtherChannel-capable ports in order to negotiate the formation of a channel. Some restrictions have been deliberately introduced into PAgP. The restrictions are:

- PAgP does not form a bundle on ports that are configured for dynamic VLANs. PAgP requires that all ports in the channel belong to the same VLAN or are configured as trunk ports. When a bundle already exists and a VLAN of a port is modified, all ports in the bundle are modified to match that VLAN.

- PAgP does not group ports that operate at different speeds or port duplex. If speed and duplex change when a bundle exists, PAgP changes the port speed and duplex for all ports in the bundle.

- PAgP modes are off, auto, desirable, and on. Only the combinations auto-desirable, desirable-desirable, and on-on allow the formation of a channel. If a device on one side of the channel does not support PAgP, such as a router, the device on the other side must have PAgP set to on.

PAgP is currently supported on the Catalyst 4500/4000, 5500/5000, 6500/6000, Catalyst

2940/2950/2955/3550/3560/3750, and Catalyst 1900/2820 switches. The Catalyst 2900XL/3500XL, Catalyst 2948G-L3/4908G-L3, and Catalyst 8500 switches do not support PAgP protocol.

ISL/802.1Q Trunking Support on EtherChannel

You can configure EtherChannel connections with or without Inter-Switch Link Protocol (ISL)/IEEE 802.1Q trunking. After the formation of a channel, the configuration of any port in the channel as a trunk applies the configuration to all ports in the channel. Identically configured trunk ports can be configured as an EtherChannel. You must have all ISL or all 802.1Q; you cannot mix the two. ISL/802.1Q encapsulation, if enabled, takes place independently of the source/destination load-balancing mechanism of Fast EtherChannel. The VLAN ID has no influence on the link that a packet takes. ISL/802.1Q simply enables that trunk to belong to multiple VLANs. If trunking is not enabled, all ports associated with the Fast EtherChannel must belong to the same VLAN.

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Related Information

- **Configuring EtherChannel** on Catalyst 6000 Switches That Run CatOS
- **Understanding and Designing Networks Using Fast EtherChannel Technology**
- **Configuring EtherChannels** on Catalyst 6500/6000 Switches That Run Cisco IOS Software
- **Configuring Fast EtherChannel and Gigabit EtherChannel** on Catalyst 5000 Switches
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- **Understanding and Configuring EtherChannel** on Catalyst 4000 Switches That Run Cisco IOS Software
- *Creating EtherChannel Port Groups* **section of Configuring the Switch Ports** on Catalyst 2900XL/3500XL Switches
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