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*Original article*

# Design and Implementation of an EtherChannel Redundant Switched Network Using PAgP and LACP Protocols with Load-Balancing Verification

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**Abstract**
A company needs a dependable and quick computer network. Nevertheless, network infrastructure is a major issue that affects the network's bandwidth, yet it is frequently overlooked. EtherChannel technology can be used to resolve bandwidth problems. Using Cisco's EtherChannel technology, the study specifically examines the use of Port Aggregation Protocol (PAgP) and Link Aggregation Control Protocol (LACP) to build redundant switched networks. The study confirms the efficiency of load balancing across aggregated links by implementing PAgP and LACP in Layer 2 trunk configurations between distribution and access layer switches. The findings demonstrate how EtherChannel ensures optimal utilization by distributing traffic evenly across several links, improving network performance, fault tolerance, and reliability. The study concludes with a comparison of PAgP and LACP, highlighting the benefits of each in various network environments and outlining potential directions for further research on load balancing and network scalability.
**Keywords**. EtherChannel, Port Aggregation, Load-balance, PAgP Protocol, LACP Protocol.

## Introduction

A network will frequently span several switches. Switches are usually connected via trunk ports. Using a single physical port for the trunk connection has two problems. Firstly, the port is a single point of failure. Consequently, the trunk connection is lost if the port goes down. Second, the port acts as a traffic bottleneck. Increased bandwidth through load balancing and fault tolerance are two obvious advantages of adding redundancy to the trunk connection. To address this problem, Cisco implemented port aggregation known as EtherChannel, which, for trunk connections, will give other switches more bandwidth and redundancy. [1] The issue with multiple-port EtherChannel is that load balancing will overload one link while there is very little traffic on other links. Additionally, it is a strategy to distribute traffic among several links to maximize the use of the link. As a result, it lessens congestion, boosts network efficiency and reliability, and minimizes packet loss and delay [3].

Several studies show how to implement Ethernet channels in networks and evaluate the impact of utilizing PAgP and LACP to boost bandwidth. Using EtherChannel technology, the study's author looked at PAgP and LACP. The parameters that are measured are packet loss, delay, jitter, and throughput on file-sharing/FTP and video streams. The results on delay show that PAgP performs 12% better than LACP. The PAgP protocol performs 2.3 percent better than the LACP protocol in the FTP service jitter test. Furthermore, the PAgP protocol achieves a lower packet loss percentage (0.18 percent for the PAgP protocol and 0.232 percent for the LACP protocol) in the FTP packet loss test, outperforming the LACP protocol. The average FTP throughput test result for the PAgP protocol is 83.8 Mbps, while the LACP protocol produces test results of 77.68 Mbps. In terms of video stream delay, jitter, and throughput, the LACP protocol performs better than the PAgP protocol by 2.2 percent, 23 percent, and 0.5 percent [2].

One more paper is to be proposed. A comprehensive model for load balancing, appropriate for every type of network, is what was proposed. The load is distributed regularly, which forms the basis of the model. The relationships and data sharing between devices will be in check. EtherChannel as a consequence. produces the addresses by decreasing a portion of the binary pattern. One is chosen by the frame by generating a numerical value between each link. Dispersing frames is the aim of the selections. via a channel by altering the particular URL. Cisco has a proprietary hashing algorithm. The results show that the proposed solution avoids overload and the link that simultaneously results in packet loss. Because there is a gap in another link, reduce the packet. Delays reduce traffic and increase output. reliability and network efficiency [3].

Another study uses PAgP and LACP protocols to test Network Load Balancing EtherChannel technology. By using the PAgP protocol, network performance as determined by throughput, delay, and jitter can be improved [4].

The FTP protocol on a VLAN network was used to measure various scenarios to determine the values of the quality-of-service parameters, namely, throughput, delay, and packet loss. The GLBP and PAGP protocol combination increases throughput and delay values in both normal and failover scenarios; however, its packet loss value is slightly lower than that of other combinations in a number of scenarios. [5]. This paper's primary goal is to implement a redundant switched network in Cisco Packet Tracer using EtherChannel


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between the distribution and access layer switches, configure it using LACP (link aggregation control protocol) and PAgP (port aggregation protocol) in Layer 2 with trunk configuration, and confirm load balance.

## Methods

### *Network Topology*

In this system, we've concentrated on two of the three layers that make up the network topology. The distribution layer which connects the campus networks' access and core layers (DistA and DistB) through distribution switches, has two primary features: scalable and redundant high-speed links to the core and access layers and scalable and redundant high-speed links to the core and access layers. Each layer has characteristics that provide both physical and logical network functions at the appropriate point in the campus network [6][7]. End users are connected to the network through the access layer. Layer 2 (VLAN) connectivity between users is typically offered by access switches [6]. This layer's devices are sometimes referred to as building access switches with the names Access A and Access B.

As shown below in the (Figure 1), two parallel Gigabit EthernetChannel (Gig/01 and Gig/02) have been designed between two distribution switches to form EtherChannel (Port-Channel 1), and two parallel Fast EthernetChannel between DistA (Fa0/21 and Fa0/22) and Access A (Fa0/1 and Fa0/2) to form Port-Channel 3. On the other side, two parallel connections have been made from DistB (Fa0/23 and Fa0/24) to Access B (Fa0/1 and Fa0/2) to form Port-Channel 3.

The Ethernet family of technologies offers physical and data-link specifications for managing access to a shared network medium, which offers full-duplex bandwidth of up to 800 Mbps between your switch and another switch or host for Fast EtherChannel on a switch with 24 Fast Ethernet ports, has become the most popular technology in LAN networking [1]. Up to 8 Gbps (8 ports of 1 Gbps) can be configured for Gigabit EtherChannel, depending on how many Gigabit Ethernet interfaces are supported [8].

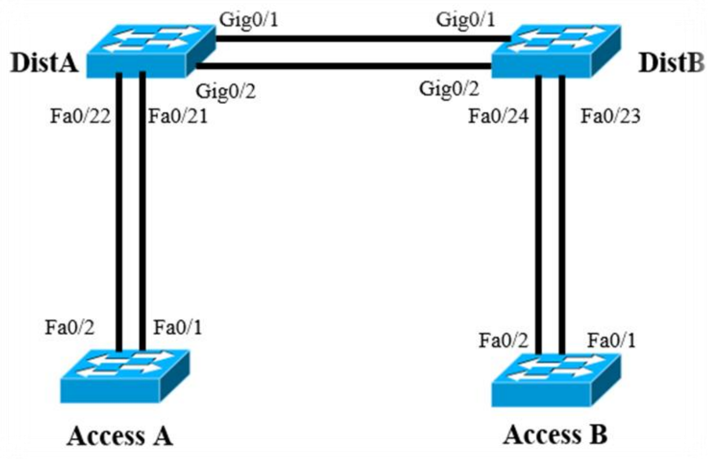


***Figure 1. This is a figure showing EtherChannel Topology***

The port-channel does the following tasks: first. By dividing the band among the working links in that channel, it used to increase the aggregate bandwidth on the link. Second. maintaining the bandwidth to achieve optimal utilization while distributing the load evenly among the various links. Third. Provide high fail tolerance. The MAC address table won't be affected if one link fails because traffic will go directly to other links in the same channel group [3].

Cisco Packet Tracer 82 was used to implement the design. Hostnames, VLANs, trunk parameters, and EtherChannel settings were set up on each switch. To create an EtherChannel, there are three ways: manual (on)-no negotiation protocol. Both ends must be configured as "on," also PAgP (Port Aggregation Protocol) – Cisco proprietary, and LACP (Link Aggregation Control Protocol)-IEEE standard (802.3ad).

PAgP is only used in Cisco environments, while LACP is the industry standard, making it the better choice when dealing with multi-vendor setups [9]. By using PAgP and LACP, the switch learns the identity of partners capable of supporting PAgP and the capabilities of each port. It then dynamically groups similarly configured ports into a single logical link (channel or aggregate port). Similarly, configured ports are grouped based on hardware, administrative, and port parameter constraints. For example, PAgP groups the ports with the same speed, duplex mode, native VLAN, VLAN range, and trunking status and type. After grouping the links into an EtherChannel, PAgP adds the group to the spanning tree as a single switch port [8]. In the system we've designed between distribution applied PAgP, the simplicity and compatibility of PAgP in a Cisco-only network is the main justification for its use in this situation. Additionally, in a consistent Cisco environment, the protocol guarantees simpler management and troubleshooting.

LACP has been used for the connection between DistA and Access A, as well as between DistB and Access B, because it ensures compatibility with equipment from different manufacturers and is commonly used in


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multi-vendor environments. LACP can be used to demonstrate adherence to industry standards in order to build scalable and vendor-independent networks.
To assign the trunk VLAN (Virtual Local Area Network), which is defined between access switches and end devices and named as VLAN 10 (Sales), 20 (HR), and 30 (Marketing) between each two PCs with ports Fa/03 and Fa/04 for VLAN 10, Fa/04 and Fa/05 for VLAN 20, in addition to Fa/06 and Fa/07 for VLAN 30, for Cisco devices, trunking is one form that any interface can work with. That interface can be used to carry one or more VLANs between two switches. The difference between any trunk interface and the access interface. that it can be used to handle traffic only for one VLAN, and it's not allowed for other VLANs to use it. Those multi-VLANs that are used through a trunk need an identity to distinguish them; for that reason, a tag is used for each VLAN to give it a special identity between the different switches that it goes through. The access interface does not need to use this tag because it has to carry just one VLAN, and this VLAN has to be assigned by the switch itself [2].

***EtherChannel Configuration with Used PAgP and LACP***
After assigning the group channel and ensuring that each switch has a distinct number of ports, configure port-channel 1 with PAgP on DistA using (desirable mode) and on the other side, DistB using (auto mode). This will enable the EtherChannel to function automatically and facilitate interface negotiations. port-channel 2 between DistA and Access have been assigned PAgP with desirable mode for DistA and auto mode for Access. Finally, port-channel 3 between DistB and Access B has been assigned active mode and passive mode by using the command (show etherchannel port), as shown below in (Table 1).

***Table 1. This is a table showing EtherChannel and each port that uses PAgP and LACP***

| Switch | Port-Channel | Member Port | Port State | Protocol | EC State |
|---|---|---|---|---|---|
| DistA | Po1 | Gi0/1 | Port-channel | PAgP | Desirable-S1 |
| DistA | Po1 | Gi0/2 | Port-channel | PAgP | Desirable-S1 |
| DistA | Po2 | Fa0/21 | Port-channel | PAgP | Desirable-S1 |
| DistA | Po2 | Fa0/22 | Port-channel | PAgP | Desirable-S1 |
| DistA | Po3 | Fa0/23 | Port-channel | LACP | Active |
| DistA | Po3 | Fa0/24 | Port-channel | LACP | Active |
| DistB | Po1 | Gi0/1 | Port-channel | PAgP | Desirable-S1 |
| DistB | Po1 | Gi0/2 | Port-channel | PAgP | Desirable-S1 |
| DistB | Po2 | Fa0/21 | Port-channel | PAgP | Desirable-S1 |
| DistB | Po2 | Fa0/22 | Port-channel | PAgP | Desirable-S1 |
| DistB | Po3 | Fa0/23 | Port-channel | LACP | Active |
| DistB | Po3 | Fa0/24 | Port-channel | LACP | Active |
| AccessA | Po2 | Fa0/1 | Port-channel | PAgP | Auto |
| AccessA | Po2 | Fa0/2 | Port-channel | PAgP | Auto |
| AccessB | Po3 | Fa0/1 | Port-channel | LACP | Passive |
| AccessB | Po3 | Fa0/2 | Port-channel | LACP | Passive |

***Configure the port-channel as a VLAN trunk***
As shown below in (Table 2), assigning the VLAN on all switches and end devices to configure VLAN using the switchport mode access command requires that the port be assigned to a single user only. VLAN gives the end user or access layer VLAN connectivity. The port is provided. A static VLAN membership using the switchport access VLAN command [7].

***Table 2. This is a table showing VLAN names and their assigned***

| VLAN ID | VLAN Name | Status | Ports Assigned |
|---|---|---|---|
| 10 | Sales | active | Fa0/3, Fa0/4 |
| 20 | HR | active | Fa0/5, Fa0/6 |
| 30 | Marketing | active | Fa0/7, Fa0/8 |

The quantity of links between switches can increase rapidly when VLANs are added to a network. Trunking is a more effective way to use cabling and physical interfaces [7]. Following that, the trunk method 802.1Q trunking was used. It is enabled by switchport mode trunk to all switches and uplink interfaces. The trunk is also assigned the auto duplex and speed between interface ports. To ensure that each port-channel is operating, use the command show interface trunk. As shown below in (Tables 3 and 4), by using the command (show interface status) will show all the information about each interface status included the


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VLAN of each interface and its trunk speed and duplex method, In addition to that, using command (show interface trunk) it verifies that the logical port-channel interfaces are in trunking mode, which permits the configured VLANs to pass through the link.

***Table 3. This is a table showing the trunk status for the distribution switch***

| Switch | Port | Status | VLAN | Duplex | Speed | Type |
|---|---|---|---|---|---|---|
| DistA | Po1 | connected | trunk | auto | auto | 10/100BaseTX |
| DistA | Po2 | connected | trunk | auto | auto | 10/100BaseTX |
| DistA | Fa0/1 | connected | 1 | auto | 10/100BaseTX | 10/100BaseTX |
| DistA | Fa0/2 | connected | 1 | auto | 10/100BaseTX | 10/100BaseTX |
| DistA | Fa0/23 | connected | trunk | auto | auto | 10/100BaseTX |
| DistA | Gig0/1 | connected | trunk | auto | auto | 10/100BaseTX |
| DistA | Gig0/2 | connected | trunk | auto | auto | 10/100BaseTX |
| DistB | Po1 | connected | trunk | auto | auto | 10/100BaseTX |
| DistB | Po3 | connected | trunk | auto | auto | 10/100BaseTX |
| DistB | Fa0/1 | connected | 1 | auto | 10/100BaseTX | 10/100BaseTX |
| DistB | Fa0/2 | connected | trunk | auto | 10/100BaseTX | 10/100BaseTX |
| DistB | Fa0/23 | connected | trunk | auto | auto | 10/100BaseTX |
| DistB | Gig0/1 | connected | trunk | auto | auto | 10/100BaseTX |
| DistB | Gig0/2 | connected | trunk | auto | auto | 10/100BaseTX |

***Table 4. This is a table showing the trunk status for the access switch***

| Switch | Port | Status | VLAN | Duplex | Speed | Type |
|---|---|---|---|---|---|---|
| DistA | Po1 | connected | trunk | auto | auto | 10/100BaseTX |
| DistA | Po2 | connected | trunk | auto | auto | 10/100BaseTX |
| DistA | Fa0/1 | connected | 1 | auto | 10/100BaseTX | 10/100BaseTX |
| DistA | Fa0/2 | connected | 1 | auto | 10/100BaseTX | 10/100BaseTX |
| DistA | Fa0/23 | connected | trunk | auto | auto | 10/100BaseTX |
| DistA | Gig0/1 | connected | trunk | auto | auto | 10/100BaseTX |
| DistA | Gig0/2 | connected | trunk | auto | auto | 10/100BaseTX |
| DistB | Po1 | connected | trunk | auto | auto | 10/100BaseTX |
| DistB | Po3 | connected | trunk | auto | auto | 10/100BaseTX |
| DistB | Fa0/1 | connected | 1 | auto | 10/100BaseTX | 10/100BaseTX |
| DistB | Fa0/2 | connected | trunk | auto | 10/100BaseTX | 10/100BaseTX |
| DistB | Fa0/23 | connected | trunk | auto | auto | 10/100BaseTX |
| DistB | Gig0/1 | connected | trunk | auto | auto | 10/100BaseTX |
| DistB | Gig0/2 | connected | trunk | auto | auto | 10/100BaseTX |
| AccessA | Po2 | connected | trunk | auto | auto | 10/100BaseTX |
| AccessA | Fa0/1 | connected | trunk | auto | 10/100BaseTX | 10/100BaseTX |
| AccessA | Fa0/2 | connected | trunk | auto | 10/100BaseTX | 10/100BaseTX |
| AccessA | Fa0/3 | connected | 10 | auto | 10/100BaseTX | 10/100BaseTX |
| AccessA | Fa0/4 | connected | 10 | auto | 10/100BaseTX | 10/100BaseTX |
| AccessA | Fa0/5 | connected | 20 | auto | 10/100BaseTX | 10/100BaseTX |
| AccessA | Fa0/6 | connected | 20 | auto | 10/100BaseTX | 10/100BaseTX |
| AccessA | Fa0/22 | connected | trunk | auto | auto | 10/100BaseTX |
| AccessA | Fa0/23 | connected | trunk | auto | auto | 10/100BaseTX |
| AccessB | Po3 | connected | trunk | auto | auto | 10/100BaseTX |
| AccessB | Fa0/1 | connected | trunk | auto | 10/100BaseTX | 10/100BaseTX |
| AccessB | Fa0/2 | connected | trunk | auto | 10/100BaseTX | 10/100BaseTX |
| AccessB | Fa0/3 | connected | 10 | auto | 10/100BaseTX | 10/100BaseTX |
| AccessB | Fa0/4 | connected | 10 | auto | 10/100BaseTX | 10/100BaseTX |
| AccessB | Fa0/7 | connected | 30 | auto | 10/100BaseTX | 10/100BaseTX |
| AccessB | Fa0/8 | connected | 30 | auto | 10/100BaseTX | 10/100BaseTX |
| AccessB | Fa0/23 | connected | trunk | auto | auto | 10/100BaseTX |
| AccessB | Fa0/24 | connected | trunk | auto | auto | 10/100BaseTX |


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### *Load-balance in EtherChannel*

As we explained above, EtherChannel combines multiple physical channels to create a single logical channel. Links enabling bandwidth and traffic load sharing between links and addition. A redundancy in case one or more links fail. The EtherChannel is utilized to connect single-mode and multimode fiber cables to LAN devices [3]. EtherChannel divides up the traffic among the channel's active links. Cisco uses a proprietary algorithm known as the hash algorithm load-balance to choose each link. algorithm that determines the destination of each traffic based on its source. Destination port number, IP address, or MAC address [3].
By using the command (show etherchannel load-balance) to check if the load-balance method is source and destination MAC address, this method is a typical and useful default for Layer 2 frames. It guarantees that every packet sent over the same physical link is part of a single conversation, which is identified by the source and destination MAC addresses. This distributes traffic among the bundled links for overall bandwidth utilization while preventing out-of-order packet delivery, which is essential for TCP-based applications.

## Results

In Figure 2, the final network topology is depicted with the distribution and access layers fully connected via EtherChannel.

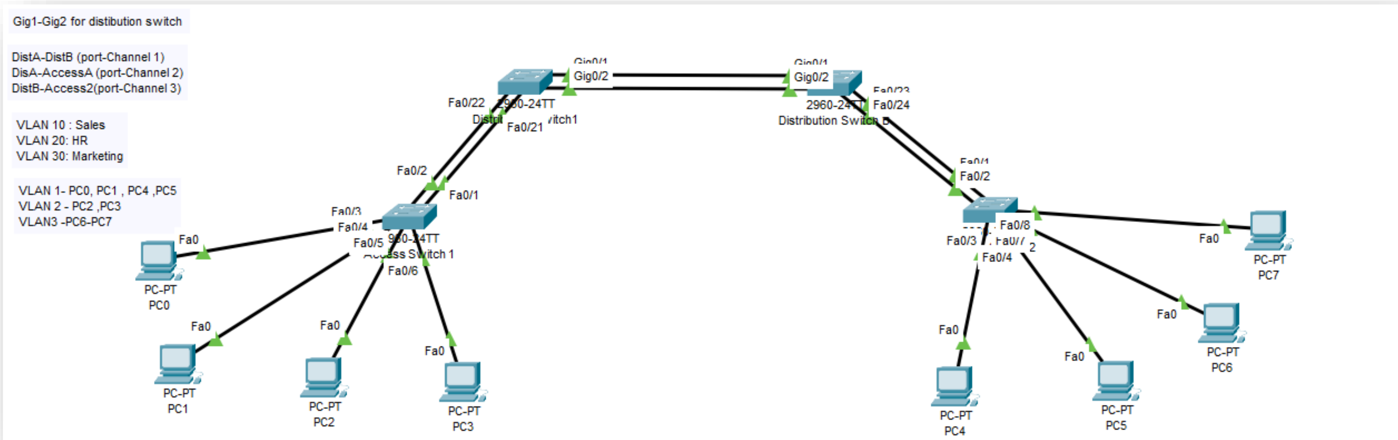


***Figure 2. This is a figure showing Network Topology***

The command (show etherchannel summary) was used on every switch to perform the verifications shown below in (Table 5). The EtherChannels are operating at Layer 2; all port-channels are active and forwarding traffic. member interfaces are successfully bundled and synchronized, and both aggregation protocols functioned properly: PAgP was successfully negotiated between Cisco-only distribution switches and access switches. All configured port-channels reached the SU (Switching Up) state. Standards-based aggregation behavior was confirmed by the accurate establishment of LACP on access layer connections. There were no suspended individuals or mismatched ports found, indicating that all bundled interfaces had the correct speed, duplex, VLAN, and trunk parameter alignment.

***Table 5. This is a table showing the trunk status for the access switch***

| Group | Port-Channel | Protocol | Ports |
|---|---|---|---|
| 1 | Po1(SU) | PAgP | Gig0/1(P), Gig0/2(P) |
| 2 | Po2(SU) | PAgP | Fa0/1(P), Fa0/2(P) |
| 3 | Po3(SU) | LACP | Fa0/1(P), Fa0/2(P) |
| 2 | Po2(SU) | PAgP | Fa0/21(P), Fa0/22(P) |
| 3 | Po3(SU) | LACP | Fa0/23(P), Fa0/24(P) |
| 3 | Po3(SU) | LACP | Fa0/1(P), Fa0/2(P) |

The commands (show interfaces trunk) and (show interface status) were used to confirm the functionality of trunking. The findings, which are shown in previous (Tables 3 and 4) show that: VLANs 10 (Sales), 20 (HR), and 30 (Marketing) were successfully propagated across all trunk links; all port-channel interfaces were operating in 802.1Q trunk mode access interfaces were correctly assigned to their respective VLANs end-to-end connectivity tests between hosts within the same VLAN but across different access switches confirmed that VLAN traffic was correct and without packet loss.
As shown below (Table 6), this detailed table provides an overview of the main findings from network topology. The port-channel table lists EtherChannel links along with member ports, bandwidth, and load-balancing information. The defined VLANs, their functions, and PC assignments are listed in the VLAN table.


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This table shows how Cisco Catalyst 2960 switches operate: Gigabit bundles can reach 8 Gbps, and Fast EtherChannel bundles can reach 800 Mbps. There were two active physical links in each EtherChannel, and traffic was distributed roughly 50/50 among the bundled links. This behavior verifies that the hashing-based load-balancing algorithm is operating correctly and that the available bandwidth is being used efficiently. The source-destination MAC address hashing algorithm was confirmed to be active by using the command (show etherchannel load-balance) to validate the load-balancing mechanism. This algorithm distributes various traffic flows among available links while ensuring that frames that are part of the same conversation follow a consistent physical path.

The findings verify that stable Layer-2 connectivity with efficient VLAN trunking, seamless redundancy, and increased aggregate bandwidth was successfully achieved by the EtherChannel implementation using PAgP and LACP. Despite the simulation limitations of Packet Tracer, load-balancing behavior was verified using interface counters and traffic flow analysis, showing effective traffic distribution across bundled links.

***Table 6. This is a table showing bandwidth and load-balance for EtherChannel***

| Port-Channel | Link Description | Member Ports (distribution) | Port Speed per Link | Total Bandwidth (full duplex) | LoadBalancing Algorithm | Load Distribution |
|---|---|---|---|---|---|---|
| 1 | DistA – DistB (distribution) | Gig0/1, Gig0/2 | 1 Gbps | 2×1 Gbps = 2 Gbps | srcdst-mac | 50 % per link |
| 2 | DistA – AccessA (access switch 1) | Fa0/21, Fa0/22 | 100 Mbps | 2×100 Mbps = 200 Mbps | srcdst-mac | 50 % per link |
| 3 | DistB – Access2 (access switch 2) | Fa0/23, Fa0/24 | 100 Mbps | 2×100 Mbps = 200 Mbps | srcdst-mac | 50 % per link |

## Discussion

This study describes an EtherChannel configuration that combines several physical links into a single logical interface between access and distribution switches. This method lessens the need for spanning-tree blocking, boosts available bandwidth, and offers redundancy. In our topology, port-channels 2 and 3 combined two Fast-Ethernet links, each providing 200 Mbps of bandwidth to the access layers, while port-channel 1 combined two 1 Gbps uplinks between distribution switches to produce 2 Gbps of full-duplex bandwidth. The final configuration verified that stable port-channel interfaces were formed by both PAgP and LACP setups. Verification of load balancing revealed that traffic was dispersed equally among the bundled links. With only two active links per port-channel, Cisco's EtherChannel implementation uses a hash function that chooses an active port based on source or destination MAC addresses. This algorithm produced a roughly 50/50 traffic split, maximizing utilization of each link.

Our findings also highlight EtherChannel's resilience: traffic is automatically redistributed among the remaining members in less than a second in the event of a link failure, ensuring service continuity. We tested two aggregation protocols. While LACP (Link Aggregation. The standard that is widely supported by vendors, PAgP (Port Aggregation Protocol), is Cisco-proprietary and only functions between Cisco devices. PAgP offered easy configuration and smooth operation in our Cisco-only distribution layer. LACP was applied to the access links to show standards compliance and to show how devices from different vendors could be integrated. Our experiments showed similar throughput and redundancy because both protocols use the same hashing mechanism and negotiate the same physical links. There are a few restrictions to be aware of. Instead of measuring latency jitter or packet-loss metrics on real hardware, the study relied on Cisco Packet Tracer simulations. Larger bundles should be tested because they may show uneven load distribution. Only two links per port-channel were aggregated. Future research could compare various hashing algorithms, assess EtherChannel performance under various traffic profiles, and investigate multi-vendor interoperability using LACP. The applicability of this design would be further strengthened by looking into cutting-edge features like multi-chassis EtherChannel or stacking technologies and evaluating the security implications.

## Conclusion

EtherChannel greatly improves bandwidth reliability and failover capabilities on redundant switched networks. Thanks to Cisco's hash-based load-balancing, the network delivered 2 Gbps and 200 Mbps of full-duplex capacity, respectively, by combining two gigabit links between distribution switches and two fast-Ethernet links to each access switch. The design's goal of removing single points of failure while maintaining VLAN segmentation via trunked port-channels was accomplished. Overall, the project shows that EtherChannel can offer enterprise LANs cost-effective scalability and resilience when properly configured. PAgP proved well-suited to Cisco-only segments, while LACP offers flexibility for multi-vendor environments.


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***Conflicts of Interest***
Regarding this work, the authors declare that they have no conflicts of interest.

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