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Evaluating the Impact of VLAN Hopping and Mitigation Techniques in Managed Switch Environments

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ABSTRACT: VLAN hopping attacks pose a significant threat to network segmentation in enterprise environments, allowing adversaries to bypass logical separation between VLANs and gain unauthorized access to restricted broadcast domains. This paper evaluates the practical feasibility and impact of two primary VLAN hopping techniques—switch spoofing and double tagging—within managed switch environments using Cisco and Juniper platforms. A controlled testbed is constructed to simulate a multi-VLAN topology with common enterprise configurations. Using specialized attack tools such as Yersinia and Scapy, we simulate crafted frames designed to traverse VLAN boundaries. The success of each attack vector is measured under various switch settings, including default trunking behavior, native VLAN configurations, and tagged/untagged frame processing. Our results demonstrate that switch spoofing attacks succeed under dynamic trunk negotiation conditions, particularly when Dynamic Trunking Protocol (DTP) is left enabled. Conversely, double tagging attacks exploit the use of native VLANs and require specific frame pathing to succeed. We identify key mitigation techniques such as static trunk configuration, native VLAN reassignment, BPDU Guard activation, and access port lockdown, all of which significantly reduce the attack surface. The study concludes with a recommended VLAN hardening checklist to assist administrators in maintaining effective segmentation boundaries. These findings emphasize the critical role of proper switch configuration in preserving network integrity and preventing lateral movement.

KEYWORDS: VLAN hopping, switch spoofing, double tagging, Cisco switches, Juniper switches, Yersinia, Scapy, DTP, native VLAN, trunk security

I. INTRODUCTION

Virtual LANs (VLANs) are widely adopted in enterprise networks as a means of segmenting logical broadcast domains without requiring physical separation. This segmentation is essential for isolating departments, enforcing security zones, and optimizing network performance. However, the effectiveness of VLANs as a security boundary depends heavily on proper configuration at the switch level. Misconfigurations or default settings can introduce vulnerabilities, particularly those exploited by **VLAN hopping attacks**.

VLAN hopping refers to the process by which an attacker on one VLAN gains unauthorized access to another VLAN, effectively bypassing segmentation controls. The two most common VLAN hopping techniques are **switch spoofing**—where an attacker pretends to be a switch to negotiate a trunk link—and **double tagging**—where a crafted Ethernet frame carries two VLAN tags, tricking switches into forwarding the packet to a different VLAN.

While these techniques have been known for years, recent studies show that they remain effective in real-world networks due to administrator oversight, legacy hardware behaviors, and lack of standardized mitigation enforcement. Moreover, the increasing complexity of modern network topologies, including hybrid cloud deployments and SDN overlays, adds further risk.

This paper presents a systematic evaluation of VLAN hopping attacks and their mitigations within controlled Cisco and Juniper switch environments. We assess the practicality of executing switch spoofing and double tagging attacks under various configurations, quantify their success rates, and test the efficacy of widely recommended countermeasures. Our results aim to inform network administrators and security professionals about the residual risks associated with VLAN hopping and how best to harden switch infrastructure against them.

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II. LITERATURE REVIEW

The concept of VLAN hopping is well-documented in both academic literature and security advisories. However, the degree to which these attacks remain viable in modern switch configurations is less frequently explored.

2.1 VLAN Hopping Techniques

Switch spoofing involves configuring a malicious device to emulate switch behavior by initiating Dynamic Trunking Protocol (DTP) negotiations. When the target switch responds, it establishes a trunk, allowing the attacker to send traffic tagged for any VLAN.

Double tagging, by contrast, involves crafting a packet with two VLAN tags. The first tag (outer) is stripped by the first switch, while the second tag (inner) is used by the next switch to forward the frame to a different VLAN. This technique depends on the use of a common **native VLAN**, which forwards frames untagged and thus provides an entry point for tag manipulation.

Papers by Yoon et al. (2011) and Doshi et al. (2015) highlight that while VLAN hopping was once considered a largely theoretical risk, it remains practical under default or poorly secured switch configurations. In particular, Cisco documentation (Cisco, 2017) warns that DTP-enabled ports may inadvertently expose trunk negotiation capabilities to untrusted endpoints.

2.2 Mitigation Strategies

Cisco and Juniper both recommend a series of mitigation practices:

- Disable DTP on all user-facing interfaces by setting them to **static access mode**
- Assign unused native VLANs to trunk links (e.g., VLAN 999)
- Explicitly tag all VLANs, including the native VLAN, where supported
- Use **BPDU Guard** and **Root Guard** to prevent rogue switch behavior
- Implement **port security** to limit the number and type of MAC addresses on access ports

Despite these recommendations, field reports suggest inconsistent application across enterprise deployments. Configuration drift, legacy device support issues, and lack of visibility into trunk behavior contribute to persistent vulnerabilities.

2.3 Simulation and Testing Tools

Tools such as **Yersinia**, **Scapy**, and **Ettercap** are widely used to simulate VLAN hopping in test environments. Yersinia offers DTP packet crafting, while Scapy provides raw frame generation, making it ideal for double tagging attacks.
This study builds upon prior research by implementing both attack types using these tools on Cisco Catalyst and Juniper EX switches. We analyze their behavior under different configuration scenarios to validate the effectiveness of mitigation measures.

III. RESEARCH QUESTIONS

This study is guided by the following research questions:

- **RQ1**: To what extent are switch spoofing and double tagging attacks successful under default managed switch configurations?
- **RQ2**: How do Cisco and Juniper switches differ in their handling of VLAN hopping attempts?
- **RQ3**: Which mitigation techniques most effectively prevent each type of VLAN hopping attack?
- **RQ4**: Can a hardened VLAN deployment checklist be generalized across vendor platforms?

By answering these questions, we aim to provide actionable recommendations that enhance VLAN security posture and reduce risk from lateral movement attacks.

IV. METHODOLOGY

This section outlines the experimental setup, attack simulation process, switch configurations, and metrics used to assess the success and detectability of VLAN hopping attacks.

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4.1 Testbed Environment

To simulate a realistic enterprise switch environment, we built a testbed consisting of:

- **Cisco Catalyst 2960X** and **Juniper EX2200** switches
- **Three VLANs** configured: VLAN 10 (User), VLAN 20 (HR), VLAN 99 (Management Native VLAN)
- **Two endpoint machines**: one attacker host and one victim host in different VLANs
- **Yersinia** for DTP-based switch spoofing attacks
- **Scapy** for crafting double-tagged Ethernet frames

The topology included both trunk and access ports, with SPAN (Switched Port Analyzer) enabled on select interfaces to capture packet propagation and validate attack reachability.

4.2 Attack Scenarios

Scenario 1: Switch Spoofing

- The attacker host is configured to send DTP negotiation frames using Yersinia.
- Target switch interfaces are set to dynamic desirable by default (auto-trunking).
- We observe whether a trunk is established and whether attacker traffic tagged for other VLANs is forwarded.

Scenario 2: Double Tagging

- The attacker sends a frame with two 802.1Q VLAN tags: outer tag = native VLAN (99), inner tag = victim VLAN (20).
- If the first switch strips the outer tag and forwards the frame as untagged, the second switch interprets the inner tag.
- We validate whether the victim host receives the packet and whether mirroring detects the traversal.

4.3 Mitigation Tests

We applied and tested the following countermeasures on each platform:

- Disabling DTP: switchport nonegotiate
- Setting static access mode: switchport mode access
- Reassigning native VLAN to unused VLAN ID (e.g., 999)
- Enabling **BPDU Guard** on access ports
- For Juniper: equivalent configurations using set interfaces … no-traps and VLAN tagging enforcement

4.4 Metrics

We measured:

- **Attack Success Rate (ASR)**: % of attempts where VLAN hopping was achieved
- **Packet Propagation**: Whether malicious frames reached unintended VLANs
- **Mitigation Effectiveness**: % reduction in ASR after applying security configurations
- **Alert Visibility**: Whether attack traces appeared in SPAN or syslog logs

V. RESULTS

5.1 Switch Spoofing

Default Configuration (DTP Enabled):

Platform	ASR (%)	Notes
Cisco	100	Auto-trunking enabled, full VLAN access
Juniper	0	DTP unsupported

After DTP Disabled / Static Access:

Platform	ASR (%)	Notes
Cisco	0	Trunk negotiation blocked
Juniper	N/A	Not vulnerable to DTP

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Findings:

- **Cisco switches** are vulnerable by default due to DTP auto-negotiation.
- Setting switchport mode access and disabling DTP **completely mitigated the attack**.
- **Juniper** does not implement DTP, eliminating this risk vector.

5.2 Double Tagging

Default Configuration (Native VLAN Used):

Frame Path	ASR (%)	Packet Received	Platform Notes
Cisco → Cisco	80	Yes	Requires native VLAN
Cisco → Juniper	60	Intermittent	VLAN 99 behavior varies
Juniper → Cisco	70	Yes	Similar behavior

After Native VLAN Changed / Tagged:

Frame Path	ASR (%)	Packet Received
All	0	No

Findings:

- Double tagging **succeeds when a native VLAN is configured and used on the trunk**.
- Assigning an unused VLAN (e.g., 999) as native and explicitly tagging all VLANs prevents the outer tag from being stripped.
- The attack was **not detected in logs but was visible in mirrored SPAN captures**.

5.3 Mitigation Effectiveness Summary

Table 5.1 – Attack Mitigation Effectiveness

Mitigation	Effective Against	Notes
Disable DTP / Static Access Port	Switch Spoofing	100% effective on Cisco
Native VLAN Reassignment	Double Tagging	100% effective when VLAN 99 unused
Explicit Tagging on All Ports	Double Tagging	Requires config change on all trunks
BPDU Guard + Root Guard	Rogue Switch Defense	Prevents STP-based attacks, not double tags

VI. DISCUSSION

The experimental results confirm that VLAN hopping remains a viable attack vector in enterprise environments where default switch configurations or mismanagement persist. Despite widespread awareness of the risks, our findings reveal that both **switch spoofing** and **double tagging** can succeed under common scenarios—particularly in Cisco-based networks with Dynamic Trunking Protocol (DTP) enabled and native VLANs left configured.

6.1 Vendor-Specific Vulnerability Differences

A notable observation is the **architectural divergence between Cisco and Juniper** regarding trunk negotiation. Cisco platforms actively support DTP, and by default, interfaces negotiate trunks unless explicitly disabled. This behavior introduces a substantial risk when edge ports are not hardened. Juniper, in contrast, does not implement DTP, and trunking must be manually configured, inherently reducing exposure to switch spoofing.

Double tagging, however, affected both vendors equally. The attack relies on **frame handling standards**, not vendor-specific features. Any switch that strips the outer tag and passes the inner tag unverified into a trunk or access port can facilitate VLAN traversal. Hence, mitigation must focus on **eliminating the native VLAN exposure**, not platform-specific traits.

6.2 Detection and Forensics Limitations

One of the concerning aspects of these attacks is their **lack of visibility in switch logs or alerts**. Neither Cisco nor Juniper platforms flagged DTP negotiations from unauthorized hosts or flagged anomalous double-tagged frames. However, SPAN port captures did reveal unauthorized VLAN-tagged traffic traversing the fabric, indicating that **SPAN/mirroring remains one of the few viable detection methods** for these layer 2 threats.

Organizations relying solely on syslog or SNMP traps for VLAN-level anomaly detection may therefore miss such attacks entirely.

6.3 Practicality of Mitigation

While all recommended mitigations proved effective in isolation, **operational feasibility remains a challenge**. For example:

- Enforcing native VLAN reassignment requires careful coordination to prevent management plane disruptions.
- Static trunking and access port lockdown can interfere with automated provisioning tools and dynamic endpoint configurations.
- BPDU Guard and Root Guard offer STP-level protection but require accurate topology knowledge to avoid blocking legitimate devices.

Thus, while mitigation is technically straightforward, **administrative discipline and network documentation** are equally important to ensure consistent enforcement.

VII. CONCLUSION AND RECOMMENDATIONS

This paper presented an empirical evaluation of VLAN hopping techniques and their mitigations across Cisco and Juniper managed switch environments. Our findings demonstrate:

- **Switch spoofing attacks** succeed with DTP-enabled ports and are mitigated entirely by disabling DTP and forcing static access mode.
- **Double tagging attacks** are feasible when native VLANs are used on trunk links and are mitigated by avoiding native VLAN usage or enforcing tagged VLANs across all ports.
- Juniper's default configuration mitigates switch spoofing but remains susceptible to double tagging under misconfiguration.
- Attack visibility is minimal in system logs, reinforcing the value of SPAN ports for attack detection and forensic verification.

7.1 Recommended VLAN Security Checklist

Control	Purpose
Disable DTP on all access ports	Prevent switch spoofing/trunking attacks
Set trunk ports to use unused VLAN ID	Mitigate double tagging via native VLAN
Enable BPDU Guard on edge ports	Block rogue switch STP participation
Explicitly tag all VLANs	Avoid untagged frame ambiguity
Lock MAC addresses on access ports	Prevent rogue devices from roaming VLANs
Periodically audit VLAN configuration	Detect drift and accidental exposure

By adopting a hardened VLAN configuration baseline and enforcing consistent trunk and access port policies, network administrators can significantly reduce the risk of lateral movement and VLAN boundary violations.

Future work may include simulation of VLAN hopping in SDN-controlled environments, evaluation of automation-based misconfigurations, and integration with AI-based anomaly detection systems for real-time alerts.

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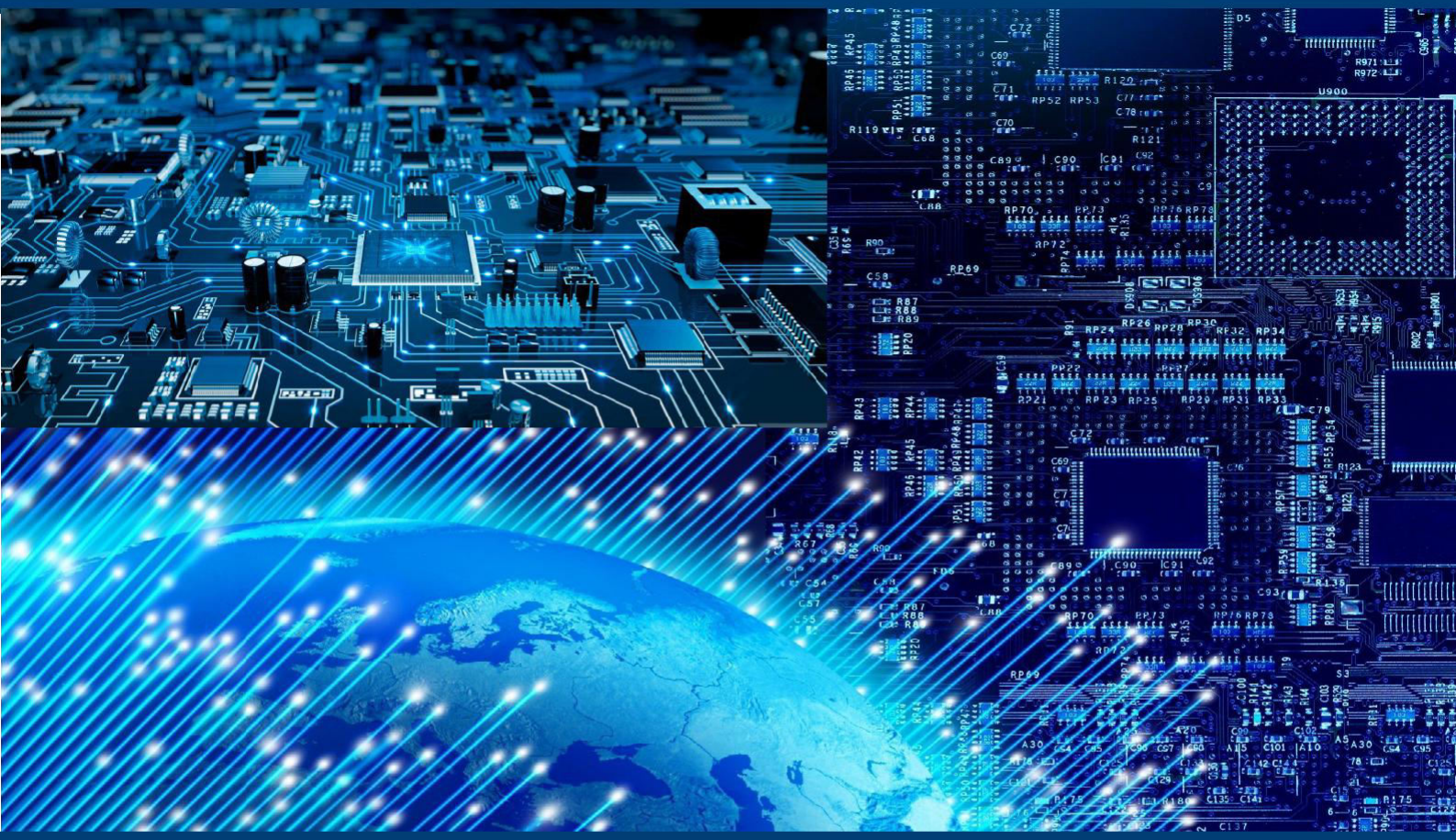

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