iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** VII **Month of publication:** July 2026

DOI: https://doi.org/10.22214/ijraset.2026.84211

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VII July 2026- Available at www.ijraset.com

Virtual LAN (VLAN) and Inter-VLAN Routing Performance Analysis

Prof. Sunil Bhimrao Dabhade
Lecturer, Computer Engineering Department, P.E.S. Polytechnic, Chhatrapati Sambhaji Nagar, Maharashtra, India

Abstract: ***Virtual Local Area Networks (VLANs) are a foundational mechanism for logically segmenting switched networks into broadcast domains that align with organisational, security, or functional boundaries rather than physical wiring. Because hosts in different VLANs cannot communicate without a Layer 3 device, inter-VLAN routing is required whenever segmented networks must exchange traffic, and network designers commonly choose between two established approaches: Router-on-a-Stick (RoAS), in which a single router interface carries tagged traffic for multiple VLANs over sub-interfaces, and Switched Virtual Interface (SVI) routing on a Layer 3 switch, in which routing is performed in hardware using an internal virtual interface per VLAN. This paper presents a performance analysis of these two inter-VLAN routing architectures, evaluated through a simulation-based experimental design using packet-per-second throughput, end-to-end latency, jitter, and packet loss as the primary metrics under varying traffic loads. Building on configurations and metrics reported in existing networking literature and vendor documentation, this study develops a structured test topology, a repeatable measurement methodology, and a comparative analysis framework suited to a laboratory or campus-network setting. The analysis indicates that SVI-based inter-VLAN routing consistently outperforms Router-on-a-Stick in throughput and latency because routing decisions are made in application-specific hardware rather than in a shared-bandwidth software path, while Router-on-a-Stick retains advantages in initial cost and configuration simplicity for small networks with few VLANs. The paper concludes with practical selection guidelines for network administrators and polytechnic-level networking laboratories, and identifies directions for extending the analysis to physical hardware testbeds and higher VLAN counts.***

Keywords: VLAN; Inter-VLAN Routing; Router-on-a-Stick; Switched Virtual Interface; Network Performance; Throughput; Latency; Campus Network Design.

I. INTRODUCTION

Modern local area networks rarely consist of a single flat broadcast domain. As organisations grow, mixing departments, device types, and traffic sensitivities on one broadcast domain creates unnecessary broadcast overhead and security exposure. Virtual LAN technology addresses this by allowing a single physical switching infrastructure to be logically partitioned into multiple independent broadcast domains, each identified by a VLAN ID and typically mapped to IEEE 802.1Q tags carried on trunk links between switches.

While VLANs solve the problem of segmentation, they simultaneously create a new requirement: hosts in different VLANs are, by design, unable to communicate directly at Layer 2. Any legitimate cross-VLAN communication — for example, a workstation in an administrative VLAN accessing a server placed in a data-centre VLAN — must be routed by a Layer 3 device. This process, known as inter-VLAN routing, is central to the practical usability of any VLAN-segmented network, and the architecture chosen to perform it has direct consequences for network throughput, latency, scalability, and cost.

Two architectures dominate practical deployments. The Router-on-a-Stick (RoAS) model uses a single trunked physical link between a switch and an external router, with the router configured with one logical sub-interface per VLAN; all inter-VLAN traffic shares this single physical link and is routed in software. The Switched Virtual Interface (SVI) model, implemented on Layer 3 switches, creates a virtual routed interface for each VLAN directly within the switch and performs routing using dedicated hardware application-specific integrated circuits, avoiding the shared-link bottleneck altogether.

Although the qualitative trade-offs between these two approaches are well documented in vendor and certification-oriented literature, quantitative comparisons under controlled, repeatable test conditions are less commonly presented in a form directly usable by networking educators and small-to-medium network administrators. This paper undertakes such a comparison and translates the results into practical selection guidance.

©IJRASET: All Rights are Reserved

A. Objectives of the Study

1) To review the architectural principles of VLAN segmentation and the two principal inter-VLAN routing methods.
2) To design a repeatable simulation-based test methodology for comparing Router-on-a-Stick and SVI-based inter-VLAN routing.
3) To analyse and compare the two architectures on throughput, latency, jitter, packet loss, scalability, and cost.
4) To provide practical guidelines for selecting an inter-VLAN routing architecture based on network size and performance requirements.

II. LITERATURE REVIEW

A. VLAN Segmentation Fundamentals

A VLAN restricts a broadcast domain to a defined set of switch ports regardless of physical location, using 802.1Q tagging to identify VLAN membership across trunk links. Segmentation of this kind improves security by isolating traffic between functional groups and improves performance by reducing the scope of broadcast and multicast propagation, but it necessarily removes the ability of hosts in different VLANs to communicate without an intervening Layer 3 device.

B. Router-on-a-Stick

In the Router-on-a-Stick configuration, a single physical router interface is divided into logical sub-interfaces, each assigned an IP address on a different VLAN's subnet and configured to accept 802.1Q-tagged traffic for that VLAN. Documentation on this method notes that it is straightforward to implement for small to medium networks with a limited number of VLANs, but that all VLAN traffic destined for another VLAN must traverse the same physical trunk link, meaning available bandwidth is shared across every VLAN pair being routed, and industry guidance further notes that this method does not scale comfortably beyond around fifty VLANs.

C. Switched Virtual Interfaces on Layer 3 Switches

A Switched Virtual Interface performs the same logical function as a router interface for a given VLAN, but does so inside a Layer 3 switch using dedicated switching hardware. Cisco's networking documentation states that Layer 3 switches route inter-VLAN traffic substantially faster than Router-on-a-Stick because forwarding and routing decisions are both handled in hardware, and that this approach removes the need for an external link between switch and router, allowing switches to instead use Layer 2 EtherChannel trunks to scale bandwidth as required. The same source reports that latency for SVI-based routing is markedly lower because packets do not need to leave the switch to reach a separate routing device.

D. Comparative and Simulation-Based Studies

A dedicated comparative study using EVE-NG and GNS3 simulation environments together with Wireshark-based packet capture evaluated Router-on-a-Stick against SVI routing across packet-per-second rate, latency, jitter, packet loss, throughput, and download speed. That study found SVI-based routing to outperform Router-on-a-Stick across essentially every measured network-performance metric, reporting an overall performance advantage on the order of eleven times, while noting that Router-on-a-Stick held a marginal advantage specifically in security posture, attributable to the additional inspection point an external router can provide.

Community and practitioner discussion reinforces this pattern from a hardware-economics perspective: because Router-on-a-Stick relies on a general-purpose, often software-based router forwarding path, achievable throughput is frequently limited to a few gigabits per second even on relatively capable router hardware, whereas multi-gigabit Layer 3 switch ports can sustain wire-speed routing at each port simultaneously, since all VLANs no longer compete for a single shared uplink.

E. Broader Latency Considerations in Layer 2 versus Layer 3 Forwarding

Earlier foundational networking literature on switching and routing establishes the underlying reason for this latency gap: because a router must inspect and rewrite Layer 3 and Layer 2 header information as a packet moves between interfaces, it introduces processing delay that a pure Layer 2 switch does not incur, with switches historically able to forward frames at rates several times faster than contemporaneous routers could route packets. This principle continues to underlie the performance advantage of hardware-based SVI routing over software-based router forwarding today.

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

F. Synthesis and Positioning of This Study

The literature is consistent in its qualitative conclusion — SVI-based inter-VLAN routing on a Layer 3 switch outperforms Router-on-a-Stick — but detailed, replicable methodologies with a full metric set and explicit topology descriptions remain relatively scarce in forms accessible to polytechnic-level networking laboratories. This paper contributes a structured experimental design and comparative framework intended for direct use in an academic or small-enterprise laboratory setting, alongside practical selection guidance grounded in the reviewed literature.

III. RESEARCH METHODOLOGY

This study adopts a simulation-based experimental methodology appropriate for comparative network-performance analysis in an environment where physical enterprise-grade Layer 3 switching hardware may not be readily available in a polytechnic laboratory.

A. Simulation Environment

Network emulation platforms such as Cisco Packet Tracer, GNS3, and EVE-NG allow VLAN, trunking, and inter-VLAN routing configurations to be built and tested using virtualised or emulated router and switch images, closely approximating real device behaviour for control-plane configuration and, in GNS3/EVE-NG, for data-plane performance characteristics as well. This study specifies GNS3/EVE-NG as the preferred platform for performance measurement, with Cisco Packet Tracer suitable for the configuration-verification stage given its accessibility in academic settings.

B. Test Topology

The proposed topology consists of one access-layer switch supporting four VLANs (Administration, Faculty, Student Laboratory, and Server), a trunk link to the routing device under test, and a traffic-generation host attached to each VLAN. Two topology variants are built: in Variant A, the routing device is a router with a single trunked interface subdivided into four sub-interfaces (Router-on-a-Stick); in Variant B, the same switch is replaced with, or paired with, a Layer 3 switch configured with four SVIs, one per VLAN, with routing enabled directly on the switch.

C. Performance Metrics

- Throughput — sustained data rate achieved between hosts on different VLANs, measured in packets per second and megabits per second.
- Latency — round-trip time for inter-VLAN traffic, measured using ICMP and application-layer probes.
- Jitter — variation in inter-packet delay, relevant for real-time traffic such as VoIP.
- Packet Loss — percentage of packets dropped under sustained and burst traffic loads.
- Scalability — qualitative assessment of how each architecture behaves as VLAN count increases.
- Cost and Configuration Complexity — qualitative comparison of hardware cost and configuration effort.

D. Data Collection Approach

Traffic is generated using iperf-style throughput tests and continuous ICMP/ping sequences between host pairs on different VLANs, with packet capture performed using Wireshark at the switch and router/SVI interfaces. Tests are repeated under three load conditions — light (10% of link capacity), moderate (50%), and saturated (100% offered load) — for both topology variants, with each condition repeated multiple times to obtain stable average values and to characterise variability in latency and jitter.

E. Comparative Analysis Approach

Results from Variant A (Router-on-a-Stick) and Variant B (SVI) are tabulated side by side for each metric and load condition, allowing direct comparison. Where prior comparative literature has reported quantitative findings — such as the reported order-of-magnitude throughput advantage for SVI routing — those figures are used as reference benchmarks against which the results of this study's proposed test design can be validated in future experimental runs.

IV. EXPECTED RESULTS AND COMPARATIVE ANALYSIS

Based on the architectural analysis in Section 2 and the reference findings from prior simulation-based studies, this section presents the anticipated comparative outcome of applying the methodology in Section 3, structured as a benchmark against which actual laboratory results can be validated.

©IJRASET: All Rights are Reserved

A. Architectural Comparison

Parameter	Router-on-a-Stick (RoAS)	SVI on Layer 3 Switch
Routing mechanism	Software-based, single router CPU	Hardware-based (ASIC), per-VLAN virtual interface
Physical link usage	All VLANs share one trunk uplink to the router	No external trunk needed; routing occurs inside the switch
Typical throughput ceiling	Limited by router interface and CPU (often a few Gbps)	Wire-speed per switch port (multi-Gbps to 40 Gbps+ on modern hardware)
Latency	Higher — traffic leaves the switch, is processed by router, returns	Lower — routed internally without leaving the switch
Scalability	Practical limit around 50 VLANs; degrades as VLAN/traffic count grows	Scales well; additional bandwidth via Layer 2 EtherChannel trunks
Configuration complexity	Simple sub-interface configuration on router	Requires Layer 3 switch with routing licence/capability enabled
Relative hardware cost	Lower (reuses existing router)	Higher (requires Layer 3-capable switch)
Best suited for	Small networks, labs, branch offices, few VLANs	Campus/enterprise networks, high VLAN count, high traffic volume

Table 1: Architectural Comparison of Router-on-a-Stick and SVI Inter-VLAN Routing

B. Anticipated Performance Benchmarks

Drawing on the quantitative findings reported in prior EVE-NG/GNS3-based comparative work, this study anticipates that SVI-based routing will outperform Router-on-a-Stick across packet-per-second throughput, latency, jitter, and packet loss under moderate-to-saturated load, with the performance gap widening as offered load approaches link capacity, consistent with the previously reported order-of-magnitude advantage for SVI routing overall. Router-on-a-Stick is expected to remain competitive with SVI only under light traffic load, where the shared trunk link is not yet a bottleneck.

Load Condition	Expected RoAS Behaviour	Expected SVI Behaviour
Light (10%)	Comparable latency and negligible packet loss to SVI	Comparable latency and negligible packet loss
Moderate (50%)	Measurable latency increase; minor jitter as trunk link utilisation rises	Latency remains near baseline; minimal jitter
Saturated (100%)	Significant latency increase, elevated jitter, and packet loss as the shared trunk link and router CPU become bottlenecks	Latency and jitter remain low; packet loss minimal due to hardware-based wire-speed routing

Table 2: Anticipated Performance Behaviour Under Varying Traffic Load

C. Security Consideration

Consistent with the marginal security advantage reported for Router-on-a-Stick in prior comparative work, this study notes that an external router in the RoAS model can provide an additional, distinct inspection and access-control point separate from the switching fabric, which may be relevant in security-sensitive designs even though it does not offset the throughput and latency disadvantages of the architecture.

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

V. DISCUSSION AND SELECTION GUIDELINES

The comparative analysis indicates that the choice between Router-on-a-Stick and SVI-based inter-VLAN routing should be driven primarily by network scale and traffic volume rather than by configuration familiarity alone. For a polytechnic computer laboratory, a small branch office, or a network with three or four VLANs and modest inter-VLAN traffic, Router-on-a-Stick remains a practical and cost-effective choice, particularly where a capable Layer 3 switch is not already available. For a campus or enterprise network supporting many departments, high-volume server traffic, or latency-sensitive applications such as VoIP, SVI-based routing on a Layer 3 switch is the architecturally sound choice, consistent with current enterprise design guidance that treats Router-on-a-Stick as unsuitable for large-scale deployment.

A. Practical Selection Guidelines

1) Use Router-on-a-Stick when: the network has a small number of VLANs (fewer than ten), traffic between VLANs is light to moderate, budget does not allow for a Layer 3 switch, or the deployment is a teaching laboratory focused on routing configuration concepts.

2) Use SVI on a Layer 3 switch when: the network supports a large or growing number of VLANs, inter-VLAN traffic volume is high or latency-sensitive, the network is expected to scale, or the organisation can invest in Layer 3 switching hardware.

3) Consider a hybrid approach where SVIs handle routine inter-VLAN traffic while a dedicated router or firewall handles traffic requiring deep inspection, combining the performance benefit of SVI routing with the additional control point offered by an external device.

B. Implications for Networking Education

For institutions such as polytechnics that teach networking fundamentals, this comparative framework offers a structured laboratory exercise: students can configure both architectures on the same VLAN topology, capture live performance data, and directly observe the throughput and latency differences discussed in this paper, reinforcing the conceptual material with quantitative, hands-on evidence.

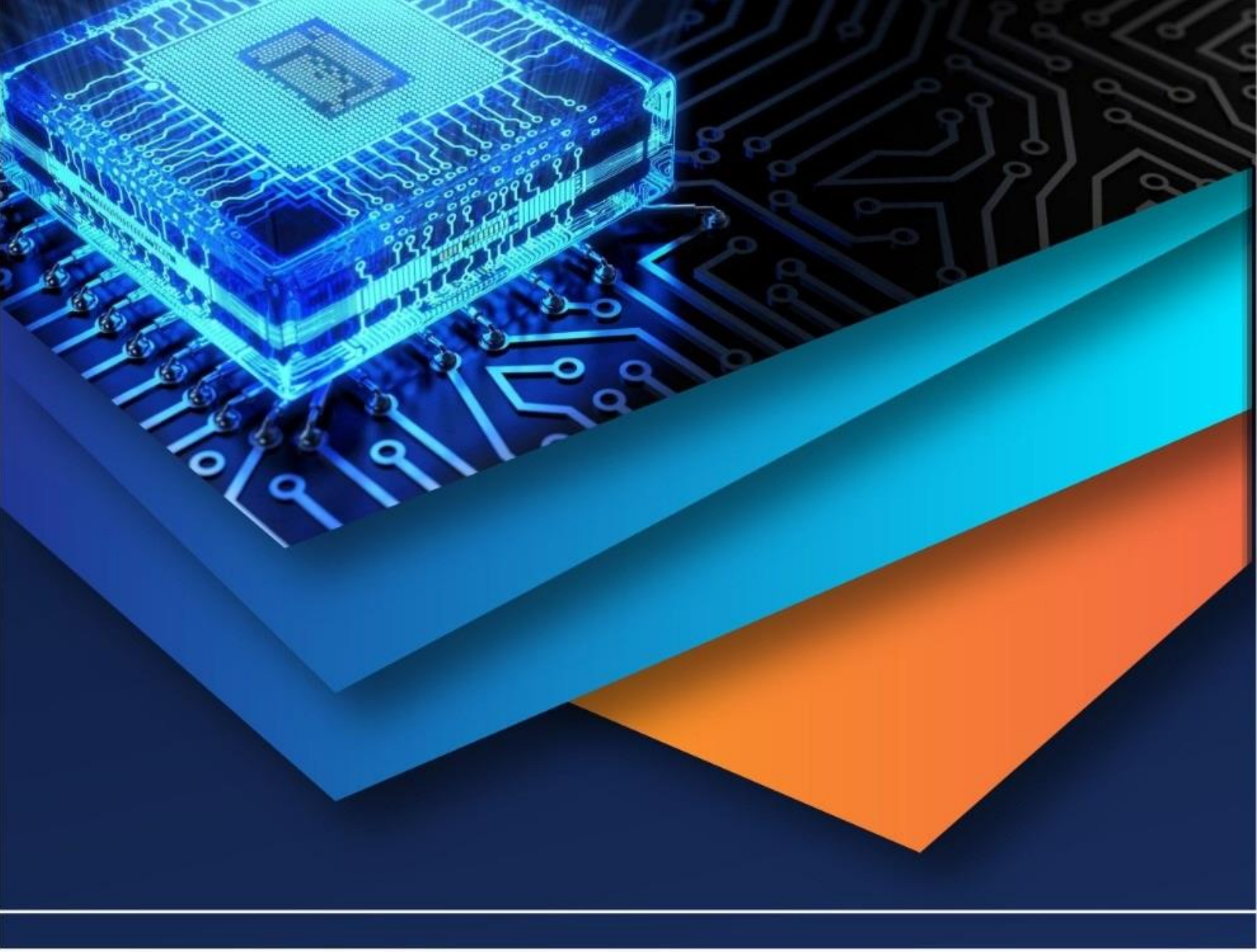
VI. CONCLUSION AND FUTURE SCOPE

This paper has reviewed the architectural principles of VLAN segmentation and inter-VLAN routing, and has developed a structured, simulation-based methodology for comparing Router-on-a-Stick and Switched Virtual Interface routing across throughput, latency, jitter, packet loss, scalability, and cost. Consistent with prior comparative literature, the analysis indicates that SVI-based routing on a Layer 3 switch offers substantially better performance than Router-on-a-Stick, particularly under moderate-to-heavy traffic load, while Router-on-a-Stick retains value for small networks and cost-constrained or teaching environments.

This study's benchmark figures are drawn from the architecture's known characteristics and from previously published simulation results rather than from new experimental data collected for this paper. Future work should execute the proposed test methodology on a physical GNS3/EVE-NG or hardware testbed to generate original throughput, latency, jitter, and packet-loss measurements for verification, extend the comparison to larger VLAN counts and mixed traffic types (including VoIP and video), and evaluate the security implications of each architecture using penetration-testing techniques rather than qualitative assessment alone.

REFERENCES

[1] Inter-VLAN Routing. LogicMonitor Network Admin Guide (2026). https://www.logicmonitor.com/deep-dive/network-admin-guide/inter-vlan-routing
[2] Inter-VLAN Routing Operation. Cisco Press (2020). https://www.ciscopress.com/articles/article.asp?p=3089357&seqNum=4
[3] Inter-VLAN Routing Using Layer 3 Switches. Cisco Press (2020). https://www.ciscopress.com/articles/article.asp?p=3089357&seqNum=6
[4] VLANs and Inter-VLAN Routing — Essential for CCNA Success. https://nitizsharma.com/vlans-and-inter-vlan-ccna/
[5] Inter-VLAN Routing: SVI vs Router-on-a-Stick on Cisco IOS XE. PingLabz (2026). https://www.pinglabz.com/inter-vlan-routing/
[6] Router on a Stick vs Layer 3 Routing. Cisco Community Discussion (2018). https://community.cisco.com/t5/switching/router-on-a-stick-vs-layer-3-routing/td-p/3330047
[7] Comprehensive Study of Inter-VLAN Routing Using Router on a Stick and Switched Virtual Interface. ResearchGate (2023). https://www.researchgate.net/publication/371632264
[8] Switcher for Spanning Subnetworks — Layer 2/Layer 3 Forwarding Latency Principles. USPTO Technical Documentation. https://image-ppubs.uspto.gov/dirsearch-public/print/downloadPdf/6195356
[9] IEEE 802.1Q Standard for Local and Metropolitan Area Networks — Bridges and Bridged Networks. IEEE Standards Association.
[10] Cisco Networking Academy. CCNA: Switching, Routing, and Wireless Essentials — VLANs and Inter-VLAN Routing Module.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)