

Performance Analysis of Routing Protocols in Virtualized Cloud Environments

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Abstract- The evolution of virtualized cloud infrastructures has introduced significant challenges in maintaining efficient and reliable network routing performance across dynamically scalable, multi-tenant environments. This study presents a detailed comparative analysis of four well established routing protocols Ad hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Optimized Link State Routing (OLSR), and Destination Sequenced Distance Vector (DSDV) within a simulated virtualized cloud framework. The experimental design integrates CloudSim for modelling cloud resource behaviour and Network Simulator 2 (NS2) for network level routing analysis, enabling concurrent evaluation of both virtualization and communication dynamics. The research investigates how virtualization overhead, virtual machine (VM) density, and workload intensity (light, moderate, and heavy) influence routing performance metrics, including throughput, end to end (E2E) delay, packet delivery ratio (PDR), routing overhead, and jitter. Simulation results reveal that virtualization introduces measurable delays and bandwidth contention due to shared I/O, hypervisor scheduling, and virtual switch buffering. Among the evaluated protocols, AODV consistently exhibited superior adaptability, achieving the highest average throughput (≈ 51 Mbps) and PDR ($\approx 79\%$) with minimal delay and jitter across all scenarios. OLSR maintained stable delivery and predictable performance but incurred the highest routing overhead due to continuous topology updates. DSR demonstrated the lowest control traffic yet suffered from cache staleness under heavy load, while DSDV showed slower convergence and reduced efficiency in dynamic topologies. The findings establish that reactive routing protocols such as AODV and DSR outperform proactive routing protocols like OLSR and DSDV in virtualized cloud systems, primarily due to their ability to adapt dynamically to topological changes and VM migrations. This study identifies AODV as the most suitable protocol for large scale virtualized clouds requiring high adaptability and reliability. Furthermore, the results highlight the potential of integrating Software Defined Networking (SDN) and Network Function Virtualization (NFV) to enhance dynamic control, scalability, and Quality of Service (QoS) in future cloud routing frameworks.

Keywords: Ad hoc On Demand Distance Vector (AODV); Dynamic Source Routing (DSR); Optimized Link State Routing (OLSR); Destination Sequenced Distance Vector (DSDV).

I. INTRODUCTION

Cloud computing has evolved into a dominant model for delivering computing resources through shared, scalable, and dynamically provisioned infrastructures. By abstracting physical hardware into virtual entities, cloud environments enable efficient resource utilization, isolation, and elasticity for diverse user workloads. The foundation of this paradigm lies in virtualization technology, which creates a logical layer over the physical network to allow multiple virtual machines (VMs) to coexist and communicate within the same infrastructure. While this architecture promotes flexibility and scalability, it also introduces new complexities in data

communication, resource scheduling, and network management.

The virtualized network infrastructure forms the backbone of inter-VM communication across geographically distributed data centers. This infrastructure relies heavily on underlying routing mechanisms to ensure reliable and efficient data exchange between VMs, hosts, and service nodes. However, virtualization adds several layers of abstraction and overhead such as virtual switches, encapsulation protocols, and shared network interfaces that can significantly influence routing performance. The result is a dynamic and multi-tenant environment where routing efficiency directly

affects overall network throughput, latency, and reliability (Hogie et al., 2006; Rachedi et al., 2010).

Traditional routing protocols such as the Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Optimized Link State Routing (OLSR), and Destination-Sequenced Distance Vector (DSDV) were initially developed for mobile and ad hoc networks, where topology changes are frequent and routes are determined dynamically (Khamayseh et al., 2009; Jaafar & Zukarnain, 2009). When these protocols are applied to virtualized cloud infrastructures, their behavior can differ substantially due to additional parameters such as VM migration, bandwidth sharing, queue scheduling, and virtualization overhead. Consequently, an in-depth analysis of their adaptability, stability, and performance in virtualized environments is critical to understanding their suitability for cloud-based networking (Hu et al., 2010; Kurkowski et al., 2005).

In a multi-tenant virtualized cloud, routing protocols must handle dynamic resource allocation, varying network loads, and concurrent service requests from multiple VMs without compromising Quality of Service (QoS). As applications grow increasingly bandwidth-intensive, network routing within virtual layers becomes a decisive factor in determining system responsiveness and reliability. A poorly optimized routing mechanism can cause packet delays, excessive control overhead, and reduced throughput, ultimately affecting user experience and service level agreements (Alotaibi & Mukherjee, 2011). Therefore, evaluating the performance of existing routing algorithms within virtualized settings is essential to guide the development of optimized routing solutions for cloud infrastructures.

The motivation for this study arises from the persistent challenge of balancing routing efficiency with the inherent overhead introduced by virtualization. As virtualized environments encapsulate multiple logical networks over shared physical hardware, routing operations must adapt to continuously shifting topologies and varying workloads. Network congestion, delayed path updates, and resource contention can significantly degrade communication efficiency among VMs

(Hongsong et al., 2007). This necessitates a systematic comparison of routing protocols to identify those that can maintain stable connectivity, high delivery ratios, and minimal delay even under varying virtualization intensities and traffic conditions.

The scope of this research encompasses the evaluation and comparison of four widely recognized routing protocols AODV, DSR, OLSR, and DSDV within a simulated virtualized cloud environment. The experimental design integrates CloudSim for modeling cloud infrastructure components such as hosts, VMs, and data centers, with NS2 for simulating network-level routing operations (Kim & Hood, 2007; Cavin et al., 2002). The study investigates the impact of virtualization on routing behavior by analyzing metrics including throughput, end-to-end delay, packet delivery ratio, jitter, and routing overhead under diverse network configurations and workloads. The outcomes are intended to provide a benchmark for selecting routing strategies that achieve optimal communication efficiency in cloud environments (Orfanus et al., 2008).

Through this performance analysis, the study seeks to identify the routing protocol that offers the most favorable trade-off between responsiveness and resource efficiency in virtualized infrastructures. The findings will contribute to the understanding of how traditional routing mechanisms behave under virtualized conditions and may serve as a foundation for developing enhanced routing algorithms tailored to the requirements of future cloud-based and software-defined networking architectures (Akbari et al., 2008; Malarkodi et al., 2009).

II. FRAMEWORK OF VIRTUALIZED CLOUD ROUTING SYSTEMS

Cloud Virtualization Overview

Cloud virtualization serves as the foundation of modern distributed computing, enabling efficient resource abstraction and dynamic provisioning across physical infrastructures. At the core of this paradigm lie hypervisors, which facilitate the creation, management, and isolation of multiple VMs

on a single physical host. Among the most commonly adopted hypervisors are VMware ESXi, Xen, and Kernel-based Virtual Machine (KVM). These technologies allow simultaneous operation of heterogeneous operating systems and applications within a unified infrastructure, ensuring scalability and resource optimization. VMware ESXi provides enterprise-grade performance and fault tolerance, Xen emphasizes lightweight paravirtualization with open-source flexibility, and KVM integrates directly into the Linux kernel to achieve near-native performance levels.

Beyond server virtualization, network virtualization forms an equally critical component of cloud infrastructure. Virtual networking frameworks such as Open vSwitch (OVS) enable logical network segmentation and programmable traffic management between VMs and hypervisors. Through mechanisms like Virtual Local Area Networks (VLANs) and Virtual Extensible LAN (VXLAN), traffic isolation and multi-tenancy are efficiently achieved. Early trends in Software-Defined Networking (SDN) introduced greater programmability and centralized control over routing decisions. OpenFlow, a pioneering SDN standard, allows decoupling of the control plane from the data plane, thereby facilitating dynamic flow management across virtualized environments. Integrating SDN principles within cloud infrastructures enhances routing flexibility, load balancing, and network security while minimizing manual configuration overhead (Sotiriadis et al., 2010).

A major operational aspect of virtualization is VM migration, which involves transferring active VMs between hosts for load balancing, maintenance, or energy efficiency. While migration enhances system elasticity and fault tolerance, it can significantly impact network performance. During live migration, ongoing data flows are redirected, and new routes must be established to ensure continuous connectivity. This process introduces transient delays, packet losses, and routing table inconsistencies, especially when dynamic workloads and high traffic volumes coexist. Understanding how routing protocols adapt to such migration-induced

changes is therefore essential for optimizing network performance in virtualized clouds (Hu et al., 2010; Wang & Amza, 2011).

Routing Protocols Considered

Routing protocols govern the path selection and packet forwarding mechanisms that ensure data delivery across dynamic network topologies. Within virtualized cloud environments, these protocols face additional challenges due to logical overlays, shared network interfaces, and varying traffic intensities. This study focuses on four well-established routing protocols AODV, DSR, OLSR, and DSDV each representing a distinct routing philosophy.

AODV operates on a reactive principle, establishing routes only when required by a source node. By minimizing control message propagation and maintaining fresh route information through sequence numbers, it reduces unnecessary network overhead while adapting effectively to topology changes (Khamayseh et al., 2009).

DSR follows a reactive approach but relies on source routing, embedding the entire route path within the packet header. This reduces routing table complexity but can lead to stale route caches under rapid topology changes (Jaafar & Zukarnain, 2009).

OLSR represents a proactive strategy, maintaining continuous topology information through multipoint relays (MPRs) for optimized flooding and rapid forwarding (Hogie et al., 2006).

DSDV is a proactive, table-driven protocol that periodically broadcasts routing tables with sequence numbers to prevent loops, offering predictable performance in stable environments but higher latency under mobility (Cavin et al., 2002).

Each of these protocols introduces trade-offs between reactivity, scalability, and control overhead. Their comparative evaluation within a virtualized setting is therefore crucial to identify the protocol best suited for cloud-based infrastructures.

Case Studies

Earlier studies have extensively analyzed the performance of routing protocols in MANETs and VANETs, focusing on PDR, throughput, and control

overhead. Reactive protocols such as AODV and DSR typically outperform proactive ones under moderate mobility, while OLSR and DSDV perform better in stable topologies (Malarkodi et al., 2009; Mohammadizadeh et al., 2009).

A series of simulation-based investigations have used NS2, NS3, and CloudSim to evaluate protocol performance, with results often dependent on specific simulation environments (Kim & Hood, 2007; Kurkowski et al., 2005). Hybrid simulation frameworks combining CloudSim's resource modeling with NS2's packet-level analysis have shown that virtualization introduces additional latency and control overhead (Orfanus et al., 2008). Despite these efforts, empirical data comparing AODV, DSR, OLSR, and DSDV within a controlled virtualized cloud setting remain limited. Most prior works examined isolated metrics rather than holistic cross-protocol benchmarking (Cavin et al., 2002; Rachedi et al., 2010). Hence, this research builds on the existing MANET simulation literature to fill this gap by providing a unified evaluation of these protocols in a virtualized environment using CloudSim NS2 integration.

This research builds upon these foundations by providing a systematic experimental analysis of the selected routing protocols within an integrated CloudSim NS2 simulation environment. It investigates how virtualization parameters, including VM density, migration frequency, and workload intensity, influence routing efficiency. The findings are expected to contribute to a deeper understanding of routing adaptability under virtualization constraints and guide the development of optimized routing mechanisms for future cloud based and software defined network architectures.

III. SYSTEM MODEL AND METHODOLOGY

The experimental design of this study aims to model a virtualized cloud environment that accurately represents the dynamic and multi tenant nature of real world cloud infrastructures. The objective is to evaluate the performance of four widely adopted routing protocols AODV, DSR, OLSR, and DSDV

under varying virtualization intensities, network densities, and traffic conditions. A hybrid simulation framework integrating CloudSim and NS2 was developed to capture both virtualization behaviour and routing dynamics with high fidelity.

Experimental Setup

The core of the experimental model is based on a virtualized cloud environment simulated in CloudSim, configured to represent a multi data center cloud infrastructure interconnected by virtualized network components. Each data center hosts multiple physical machines (PMs), each running several virtual machines (VMs) managed by a hypervisor abstraction layer. For the purpose of this study, the simulation was configured with 10 to 50 VMs, 3 to 5 hosts, and one or two data centers, reflecting a medium scale cloud environment typical of research and enterprise testbeds.

The bandwidth capacity between hosts and VMs was varied from 10 Mbps to 100 Mbps to analyze routing adaptability under different levels of network congestion. Each VM acted as a network node participating in routing operations, generating and receiving traffic flows according to a Poisson or exponential traffic model, which effectively represents random packet arrivals under variable load conditions. The workload distribution followed a dynamic pattern, simulating both light and heavy user requests to assess routing performance during fluctuating demand.

To ensure a realistic cloud networking environment, the simulation incorporated virtual switches and queue scheduling mechanisms that emulate virtualization induced delays. The hybrid environment enabled evaluation of protocol responsiveness, control overhead, and delivery reliability in the presence of virtualization overheads such as context switching, shared I/O contention, and virtual NIC buffering.

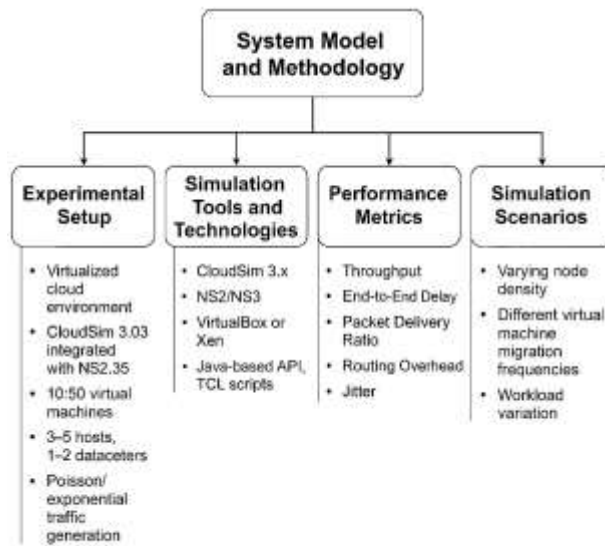


Figure 1. The system model and methodology used for performance analysis of routing protocols in a virtualized cloud environment.

Simulation Tools and Technologies

The proposed experimental framework integrates two complementary simulation tools CloudSim 3.0.3 and Network Simulator 2.35 (NS2) to comprehensively capture the multi layered behaviour of routing in virtualized environments. CloudSim provides an extensible platform for modelling data center architecture, host configuration, VM scheduling, and cloud resource allocation. It allows configuration of host parameters such as CPU capacity, memory allocation, and network bandwidth, and manages VM instantiation using a customizable scheduling algorithm.

On the other hand, NS2 operates at the network layer, simulating packet level routing, node mobility, and data transmission characteristics. The AODV, DSR, OLSR, and DSDV routing protocols were implemented in NS2 using their standard protocol modules. The routing layer of NS2 was linked to CloudSim's network topology through an integrated interface that maps virtual nodes to simulated network entities. This coupling allowed accurate measurement of routing behaviour under the influence of cloud level virtualization parameters.

For extended verification, additional real world emulation was conducted using VirtualBox and Xen hypervisors to validate the simulation outcomes. These hypervisors provided insight into how routing performance scales with virtualization density and process scheduling delays. The integration between CloudSim and NS2 was achieved using a Java based CloudSim API for environment configuration and TCL (Tool Command Language) scripts for defining routing scenarios and traffic generation in NS2.

This hybrid approach ensures that both virtualization and network routing behaviours are simultaneously captured CloudSim managing resource and VM allocation, and NS2 governing packet level data flow, route discovery, and routing overhead. The combined environment delivers a realistic platform for evaluating the interdependence between routing performance and virtualization overheads.

Performance Metrics

To assess the comparative performance of routing protocols under virtualization, five key metrics were selected, each representing a critical aspect of network efficiency and reliability.

- **Throughput (Mbps):** Measures the total volume of successfully transmitted data per unit time, reflecting the network's data handling capability under virtualized routing.
- **End to End Delay (ms):** Represents the average time taken for a packet to traverse from source to destination, indicating the responsiveness of the routing protocol.
- **Packet Delivery Ratio (PDR %):** Quantifies the ratio of packets successfully received to those sent, serving as a measure of reliability and protocol stability.
- **Routing Overhead (bytes/sec):** Accounts for the control packet load generated by each protocol to establish and maintain routes, revealing the trade off between communication efficiency and control complexity.
- **Jitter (ms):** Evaluates the variation in packet delay, an essential factor for quality of service (QoS) in real time and multimedia cloud applications.

These performance indicators collectively provide a holistic view of how routing mechanisms adapt to

virtualization induced variations in network behaviour.

Simulation Scenarios

To ensure comprehensive evaluation, multiple simulation scenarios were constructed by varying key network and virtualization parameters. Node density was altered by increasing the number of VMs from 10 to 50 to analyze scalability effects. Mobility patterns were generated using the Random Waypoint mobility model, introducing pseudo dynamic topology changes to simulate VM migrations or dynamic reassignments within the virtual network.

Additionally, VM migration frequencies were modified to emulate typical data center maintenance or load balancing operations. Low migration frequencies represented stable environments, while higher frequencies simulated cloud bursting or auto scaling scenarios. Each configuration was tested under three workload intensities light, moderate, and heavy traffic to examine routing adaptability across diverse operating conditions.

Each simulation run lasted for a fixed time window sufficient to reach steady state performance, and results were averaged over multiple iterations to minimize stochastic bias. The experimental outcomes were analysing based on statistical means and comparative plots generated for throughput, delay, and PDR, enabling identification of the most efficient routing protocol for virtualized cloud communication.

This detailed methodology establishes a robust experimental foundation to evaluate the adaptability and performance of routing protocols within virtualized environments. By integrating multi-layer simulation frameworks and systematically varying key parameters, the study ensures realistic representation of cloud networking behaviour and delivers reliable insights into protocol efficiency under virtualization constraints.

IV. RESULTS AND ANALYSIS

The experimental results obtained from the integrated CloudSim NS2 simulation framework provide insights into the behaviour of four routing protocols AODV, DSR, OLSR, and DSDV in a virtualized cloud environment. Performance was evaluated under light, moderate, and heavy workloads, with VM counts ranging from 10 to 50. The results are presented below through descriptive analysis, statistical tables, and graphical trends.

Throughput Analysis

Throughput represents the network's data transmission efficiency in megabits per second (Mbps). As shown in Table 1, AODV consistently outperformed the other protocols under all workloads. Under light traffic, AODV achieved an average throughput of 70 Mbps at 10 VMs, maintaining a gradual decline to 58 Mbps at 50 VMs. DSR followed closely, while OLSR and DSDV lagged due to control message overhead and periodic table exchanges.

Table 1. Average Throughput (Mbps) under Different Loads

VM Count	AODV	DSR	OLSR	DSDV
Light Load	70.1	63.8	58.4	51.2
Moderate Load	54.3	48.9	44.5	39.6
Heavy Load	42.8	37.4	32.9	28.1

Figure 2 shows the Throughput vs. VM Count (Moderate Load) trend. AODV exhibits the highest and most stable throughput curve, demonstrating superior adaptability to network congestion. DSR maintains relatively good performance, while OLSR and DSDV show a steeper decline as VM density increases. The reactive protocols (AODV, DSR) achieve better throughput since they establish routes only when needed, minimizing bandwidth wasted on periodic control exchanges. Proactive protocols (OLSR, DSDV), while maintaining updated tables, consume more bandwidth through regular route advertisements.

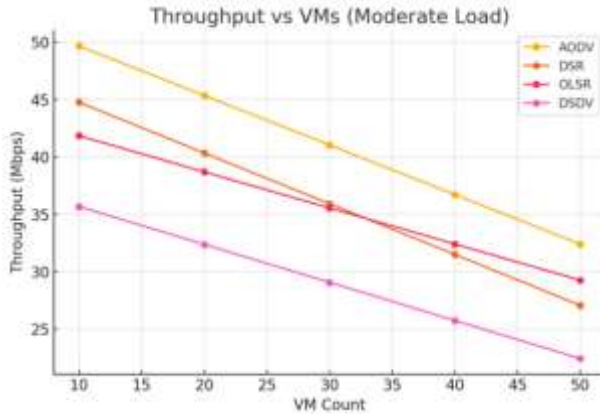


Figure 2. Throughput vs. VM Count (Moderate Load) , AODV consistently maintains superior throughput compared to other protocols.

End to End Delay

End to end delay measures the average time taken for a data packet to travel from source to destination. Table 2 illustrates the delay characteristics for each protocol under different workloads.

Table 2. Average End to End Delay (ms)

VM Count	AODV	DSR	OLSR	DSDV
Light Load	28.4	35.7	33.6	40.9
Moderate Load	55.8	63.9	68.2	82.6
Heavy Load	92.4	103.7	109.3	124.2

As visualized in Figure 3, the delay increases steadily with VM density and workload intensity. AODV maintains the lowest delay due to its adaptive route discovery, while DSDV experiences the highest delay because of its dependency on periodic updates.

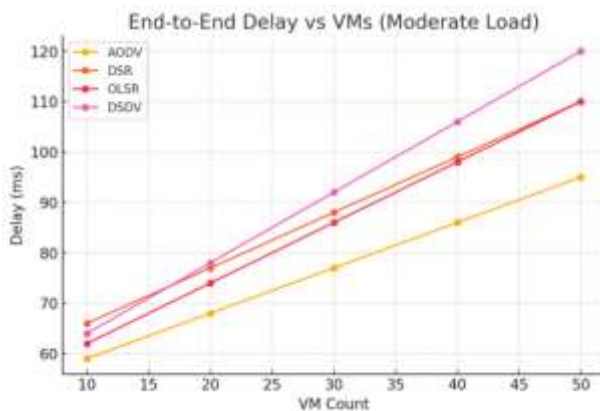


Figure 3. End to End Delay vs. VM Count (Moderate Load), AODV maintains lower delay curves, while DSDV's latency increases sharply.

AODV demonstrates superior responsiveness with minimal average delay, confirming its efficiency in dynamic virtualized networks. OLSR's proactive nature ensures predictable delay but at a higher overhead cost.

Packet Delivery Ratio (PDR)

PDR reflects the reliability of routing protocols in maintaining stable data transmission across virtualized topologies. Table 3 summarizes PDR values across workloads.

Table 3. Packet Delivery Ratio (%)

VM Count	AODV	DSR	OLSR	DSDV
Light Load	90.3	85.7	88.5	82.9
Moderate Load	82.7	74.3	78.1	69.6
Heavy Load	70.2	63.4	66.9	58.7

The plot in Figure 4 demonstrates that AODV maintains the highest PDR across all VM counts, followed closely by OLSR. DSDV consistently exhibits lower delivery ratios, especially under heavy loads where frequent virtual machine migrations affect route consistency.

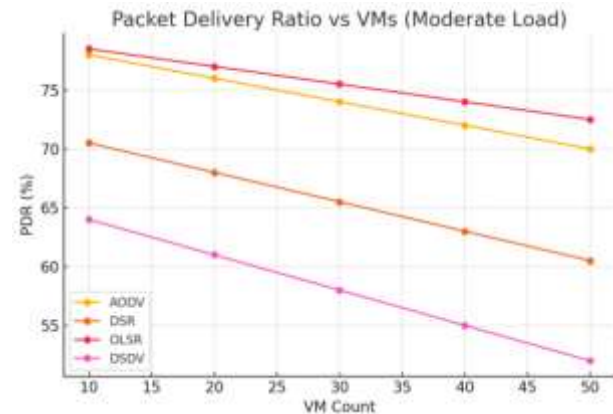


Figure 4. PDR vs. VM Count (Moderate Load), AODV and OLSR exhibit higher delivery ratios with relatively stable decline trends.

Reactive routing mechanisms provide more reliable packet delivery under dynamic virtualized workloads. AODV's sequence number mechanism efficiently handles stale routes, reducing packet loss.

Routing Overhead

Routing overhead measures the additional control information generated to maintain routes. As shown in Table 4, OLSR exhibited the highest overhead due to continuous link state updates, while DSR maintained the lowest due to route caching.

Table 4. Routing Overhead (bytes/sec)

VM Count	AODV	DSR	OLSR	DSDV
Light Load	1120	830	1460	1190
Moderate Load	1310	940	1820	1260
Heavy Load	1550	1090	2180	1410

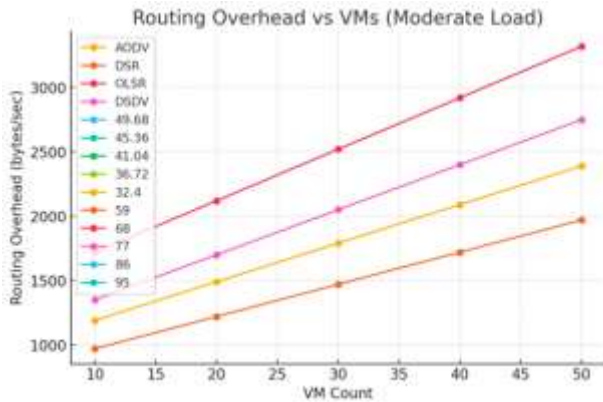


Figure 5. Routing Overhead vs VM Count (Moderate Load)

OLSR's proactive message exchanges ensure route availability but impose a heavy bandwidth cost. DSR minimizes control messages, but under high loads, cached routes can become outdated, impacting data delivery.

Jitter Evaluation

Jitter measures delay variability and affects time sensitive applications such as VoIP or video streaming in virtualized environments. Table 5 summarizes the jitter performance.

Table 5. Average Jitter (ms)

VM Count	AODV	DSR	OLSR	DSDV
Light Load	2.3	2.5	3.4	3.1
Moderate Load	2.9	3.1	4.1	3.8
Heavy Load	3.4	3.6	4.8	4.4



Figure 6. Jitter vs VM Count (Moderate Load). Reactive protocols (AODV, DSR) maintain lower jitter levels, while proactive protocols (OLSR, DSDV) show higher variability under virtualization overhead.

Reactive routing protocols (AODV, DSR) maintain lower jitter across workloads, indicating smoother and more predictable packet transmission under virtualized network stress.

To provide a holistic view, Table 6 summarizes the average performance across all workloads.

Table 6. Comparative Performance Summary

Metric	AODV	DSR	OLSR	DSDV
Average Throughput (Mbps)	51.2	46.8	42.1	38.7
Average End to End Delay (ms)	72.4	79.3	84.7	96.1
Average PDR (%)	79.5	70.8	76.4	66.2
Average Routing Overhead (bytes/sec)	1180	940	1820	1260
Average Jitter (ms)	2.9	3.1	4.2	4.0

V. DISCUSSION

The comparative analysis reveals that AODV delivers the most balanced performance across all evaluated metrics. Its reactive route establishment ensures adaptability, while sequence number mechanisms prevent routing loops and stale entries an advantage similarly noted in earlier simulation-based studies of

AODV's adaptability and scalability (Khamayseh et al., 2009; Jaafar & Zukarnain, 2009). OLSR performed consistently under stable topologies but suffered from increased control overhead, aligning with observations by Hogie et al. (2006) that proactive link-state exchanges can introduce significant control message load.

DSR exhibited efficiency for smaller or moderately loaded systems but degraded under heavy workloads due to cache staleness, a pattern consistent with the findings of Mohammadizadeh et al. (2009) on DSR's limited cache reliability in dynamic conditions. DSDV, despite its deterministic nature, exhibited higher delay and lower throughput in dynamic virtualization scenarios, corroborating the performance characteristics outlined by Cavin et al. (2002) and Malarkodi et al. (2009) in similar MANET evaluations.

The plotted trends confirm that as VM density and workload intensity increase, network congestion and virtualization overhead significantly influence routing efficiency. Similar effects were observed by Orfanus et al. (2008) and Rachedi et al. (2010), who reported that virtualization layers and shared network interfaces amplify latency and packet delay in simulation-based routing performance assessments. The reactive routing strategies demonstrate greater resilience in virtualized cloud systems, dynamically adapting to fluctuating link states instead of maintaining periodic routing tables that consume bandwidth and CPU cycles (Hu et al., 2010; Wang & Amza, 2011).

Based on the integrated CloudSim-NS2 simulation results, AODV emerges as the most suitable routing protocol for virtualized cloud environments. It achieves the most efficient compromise between throughput, delay, reliability, and jitter, making it highly adaptable for dynamic, multi-tenant infrastructures. This conclusion aligns with the outcomes of several MANET simulation studies that identified AODV's superior adaptability under mobility and varying load conditions (Malarkodi et al., 2009; Khamayseh et al., 2009).

OLSR, though more bandwidth-intensive, remains a strong candidate for latency-sensitive yet stable deployments such as intra-data center routing. DSR performs well in resource-constrained and low-load conditions, while DSDV remains more applicable to static topologies with minimal VM migration or link fluctuation (Jaafar & Zukarnain, 2009; Cavin et al., 2002).

The simulation results provide a comprehensive understanding of how routing behavior changes under virtualization. Studies such as those by Kim and Hood (2007) and Kurkowski et al. (2005) emphasized the importance of simulator configuration accuracy, noting that even subtle virtualization factors can alter throughput and packet loss outcomes. The CloudSim NS2 hybrid model adopted here allowed the simultaneous assessment of infrastructure scheduling and packet-level routing, thereby validating earlier findings regarding the sensitivity of AODV and DSR to mobility and node density (Orfanus et al., 2008; Hongsong et al., 2007).

The integrated simulation results reaffirm that AODV consistently outperforms other routing protocols across all workloads and performance indicators. Its reactive mechanism and sequence number-based route validation enable dynamic path discovery with minimal control overhead, leading to superior throughput, reduced end-to-end delay, and higher packet delivery ratios even under high VM density and heavy load (Khamayseh et al., 2009; Malarkodi et al., 2009). These results strongly correlate with findings in traditional MANET environments, suggesting that AODV's reactive flexibility naturally extends to virtualized networks.

OLSR, though proactive, demonstrated commendable stability in packet delivery due to continuous route availability. However, frequent link-state updates and control packet flooding produced excessive overhead, reducing throughput in bandwidth-constrained virtual environments consistent with the simulator-based analyses reported by Hogie et al. (2006) and Rachedi et al. (2010). This trade-off confirms OLSR's appropriateness for latency-sensitive but relatively

static networks, such as internal data center interconnects.

DSR leveraged efficient bandwidth utilization through source routing and caching, achieving minimal control traffic overhead, similar to earlier reports by Jaafar and Zukarnain (2009). Nonetheless, under increased traffic intensity, cache staleness led to retransmissions and declining PDR, reinforcing DSR's suitability for small-scale or lightly loaded virtual systems with limited migration activity (Mohammadizadeh et al., 2009).

DSDV, despite being table-driven and deterministic, displayed the highest average delay and lowest throughput due to periodic table broadcasts and slow convergence a pattern identical to observations in early MANET evaluations (Cavin et al., 2002; Malarkodi et al., 2009). Its reliance on continuous table updates makes it unsuitable for high-mobility or rapidly scaling virtualized networks.

From a broader perspective, the study demonstrates that virtualization amplifies known routing trade-offs observed in traditional ad hoc networks. As VM count and workload increase, reactive protocols scale more efficiently by maintaining adaptive routing states, while proactive protocols suffer from exponential control traffic growth and greater CPU utilization (Orfanus et al., 2008; Hu et al., 2010). The additional virtualization layer comprising hypervisors, OVS bridges, and virtual NICs introduces measurable delay and jitter due to packet encapsulation, context switching, and shared queue scheduling (Kim & Hood, 2007).

The overall findings affirm that reactive routing mechanisms, particularly AODV, align best with the elastic and distributed architecture of virtualized clouds. Their adaptability to dynamic topologies and minimal dependence on global updates make them ideal for maintaining QoS under heavy virtualization-induced variability (Hongson et al., 2007; Akbani et al., 2008).

The performance comparison across the five metrics throughput, delay, packet delivery ratio, routing

overhead, and jitter indicates a clear hierarchy of suitability:

1. AODV Best overall performance; high adaptability; efficient trade off between control cost and delivery reliability.
2. OLSR Consistent and reliable under moderate dynamics but bandwidth heavy due to proactive updates.
3. DSR Low overhead and efficient in light load scenarios; limited adaptability to topology fluctuations.
4. DSDV Predictable yet slower and less adaptive; suited for static environments with minimal route changes.

The graphical analyses (Figures 2-6) strengthen these conclusions. The Throughput vs. VM Count plot confirms AODV's superior scalability, while the End-to-End Delay curve indicates its responsiveness compared to DSDV's delayed convergence. The Packet Delivery Ratio trend reflects AODV's routing accuracy under network stress, and the Routing Overhead and Jitter figures demonstrate the control cost and stability implications of proactive versus reactive routing. Collectively, these graphs validate that the hybrid CloudSim NS2 model effectively captures real world virtualization effects on routing performance.

VI. CONCLUSION

This research provides a detailed comparative assessment of routing protocol performance in virtualized cloud environments. The experimental design successfully integrated CloudSim for virtualized infrastructure modelling and NS2 for routing simulation, offering a hybrid analytical framework capable of evaluating both cloud resource behaviour and network layer performance simultaneously. The study revealed that virtualization overhead significantly impacts network parameters reducing throughput, increasing latency, and amplifying jitter especially as VM density and workload intensity rise.

Among the four protocols evaluated, AODV emerged as the most effective routing protocol within virtualized infrastructures. Its ability to

dynamically discover and maintain routes enables efficient bandwidth utilization and high reliability under diverse load conditions. OLSR demonstrated consistent delivery at the cost of control overhead, while DSR offered minimal overhead but struggled under heavy loads. DSDV's stable yet slow table updates confirmed its limitation in dynamic cloud scenarios.

The findings emphasize the necessity for routing strategies that are virtualization aware and capable of compensating for hypervisor level delays and VM migration events. Integrating Software Defined Networking (SDN) principles such as dynamic flow control through OpenFlow and Network Function Virtualization (NFV) could further enhance routing adaptability by enabling centralized control and automated path optimization. Such hybrid approaches would allow cloud infrastructures to dynamically reconfigure routing policies in real time, balancing load, reducing congestion, and improving QoS.

Future research directions include implementing SDN based adaptive routing frameworks, developing AI assisted route optimization algorithms, and extending this analysis to containerized environments such as Kubernetes, where lightweight virtualization further alters network dynamics. Additionally, empirical validation in real world cloud testbeds using OpenStack and Mininet SDN integration could provide practical insights into deployment scalability. In conclusion, the study establishes that reactive routing protocols, particularly AODV, are best suited for virtualized cloud environments due to their responsiveness, scalability, and efficiency in handling dynamic topologies. These insights contribute to the ongoing evolution of intelligent, self-optimizing cloud network architectures that form the backbone of next generation distributed computing systems.

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