SOFTWARE-DEFINED MOBILE NETWORK

Exploring the performance of an innovative paradigm that integrates Software-Defined Networking with mobile communication systems

INTRODUCTION

Rapid evolution of networking technologies

Advancements in networking technologies have enabled the development of new paradigms like Software-Defined Networking (SDN) and its application in mobile networks.

Emergence of Software-Defined Mobile Networks (SDMN)

SDMN leverages SDN principles to bring programmability, flexibility, and centralized control to mobile network environments.

Research objectives

Explore and analyze SDMN through simulation and emulation, evaluate performance metrics, and provide insights into the benefits and challenges of SDMN.

This research aims to contribute to the understanding of Software-Defined Mobile Networks by investigating their benefits and challenges

SIGNIFICANCE OF SDMN

Dynamic Mobility Management

SDMN enables seamless connectivity and reduced handover latency, ensuring uninterrupted user experiences during mobility.

Traffic Optimization

SDMN's dynamic flow control and congestion management capabilities optimize network bandwidth utilization, prioritizing critical traffic flows.

Improved Quality of Service (QoS)

SDMN leverages SDN principles to provide fine-grained control over network parameters, enhancing QoS for various applications and services.

Scalability and Adaptability

The centralized control and programmability of SDMN architectures enable scalable and adaptable mobile networks, accommodating growing user demands and emerging use cases.

TOOLS AND TECHNOLOGIES

Mininet-WiFi
Network emulator with wireless and mobility capabilities for creating virtualized network topologies

ONOS
Open-source SDN controller for managing and dynamically configuring network flow rules

NS3
Discrete-event network simulator for simulating wireless scenarios and calculating propagation loss metrics

Iperf
Network testing tool for measuring throughput and diagnosing network performance

Wireshark
Network traffic analysis tool for evaluating packet loss and handover performance

TCPDump
Packet capture and analysis tool for evaluating network traffic

Python & Matplotlib
Scripting and data analysis tools for test automation and visualizing performance metrics

METHODOLOGY - EXPERIMENTAL SETUP

Traditional Network Architecture

A network setup without SDN capabilities, where traffic was handled locally by Layer 2/3 switches with static configurations.

Software-Defined Network (SDN) Architecture

An SDN architecture where the ONOS controller dynamically managed traffic using OpenFlow-enabled switches, allowing for centralized traffic management and real-time flow rule adjustments.

Virtualized Testbed Configuration

The experiments were carried out in a virtualized testbed environment using Mininet-WiFi, ONOS, NS3, and custom Python scripts for data analysis and visualization.

KEY SCENARIOS AND METRICS

- ## Latency Analysis

  Measure the average round-trip time (RTT) of packets under low and high traffic conditions, using the metric of Latency (ms) = Σ RTTi / n

- ## Throughput and Congestion Management

  Evaluate the network's ability to manage multiple traffic flows and prioritize specific flows dynamically, using the metric of Throughput (Mbps) = Data Transferred (Mbits) / Time (s)

- ## Mobility and Handover Performance

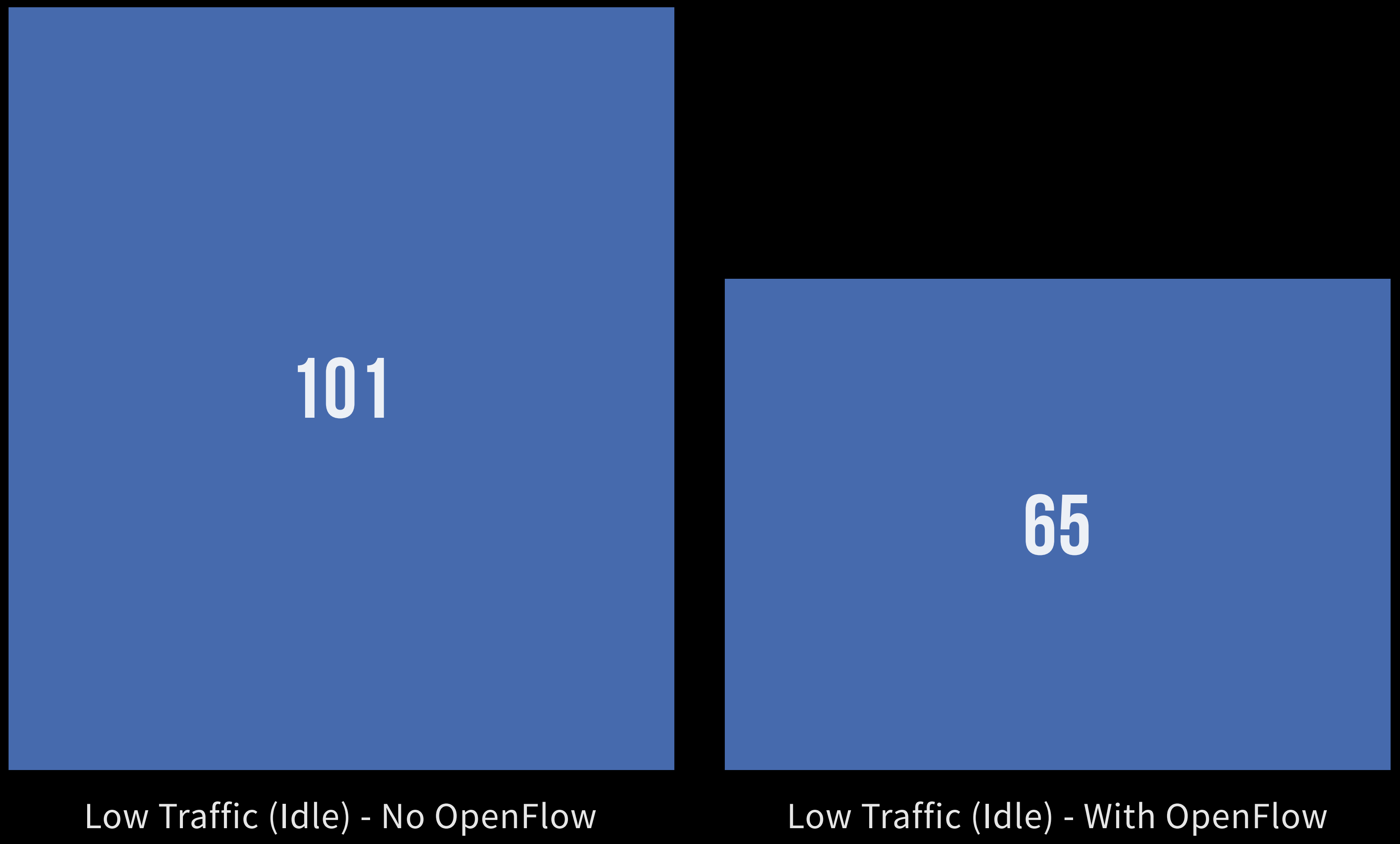
  Analyze packet loss and latency during handover scenarios in a mobile network, using the metrics of Packet Loss Ratio (%) and Handover Latency (ms)

- ## Packet Loss Analysis

  Evaluate the impact of distance on packet loss in a wireless network, using the metrics of Free Space Path Loss (dB) and Log-Normal Shadowing Model

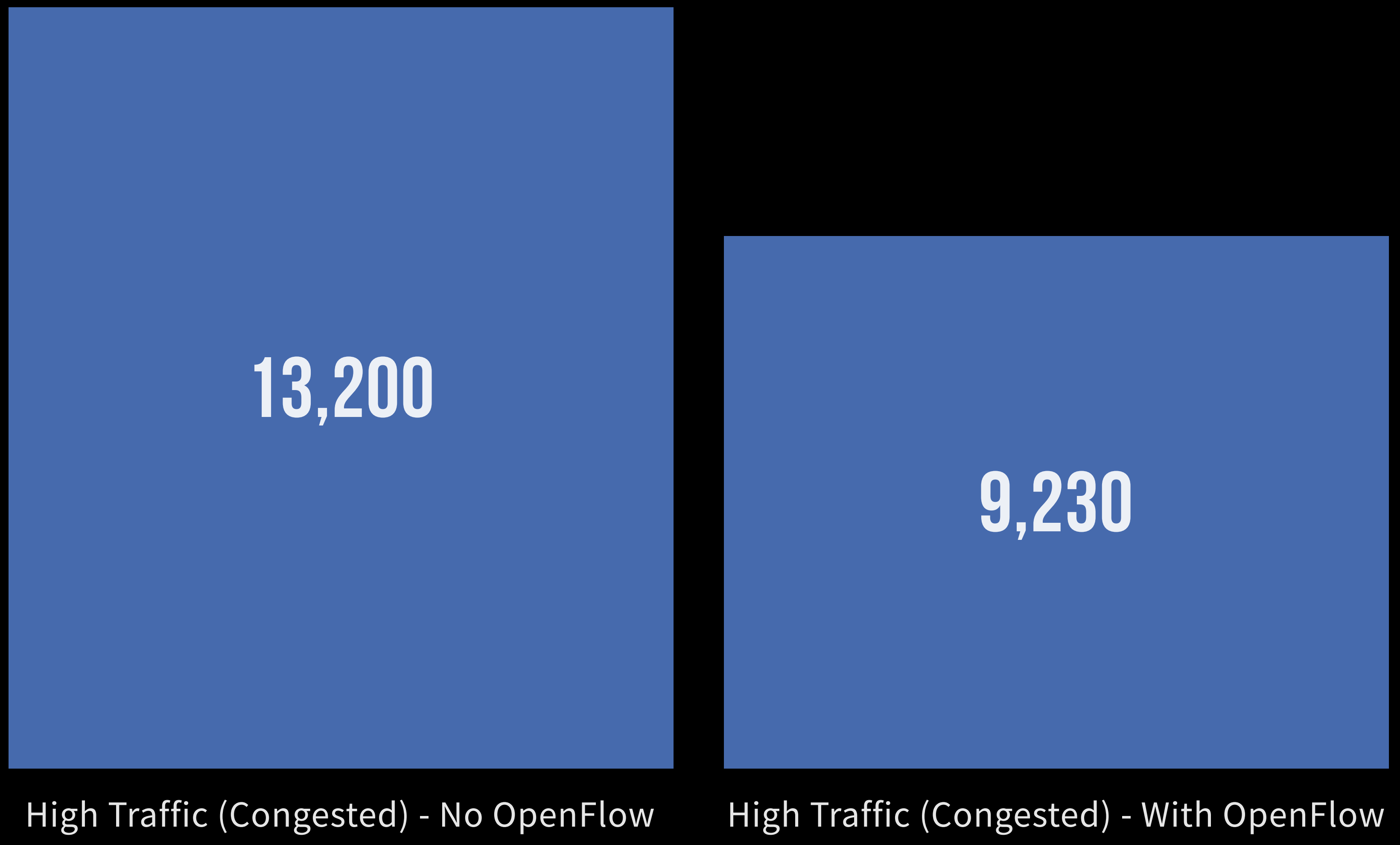
RESULTS - LATENCY ANALYSIS (LOW TRAFFIC)

Comparison of RTT under low traffic conditions with and without OpenFlow (in microseconds)



RESULTS - LATENCY ANALYSIS (HIGH TRAFFIC)

Comparison of RTT under high traffic conditions with and without OpenFlow (in microseconds)



RESULTS - MOBILITY AND HANDOVER PERFORMANCE

The next slide highlights key metrics on handover latency and packet loss reduction in a cellular network, comparing traditional backhaul and OpenFlow-enabled SDN approaches.

RESULTS - MOBILITY AND HANDOVER PERFORMANCE

Metric	Traditional	OpenFlow	Improvement
Handover Latency (s)	0.058	0.04	~ 31%
Handover Success Rate (%)	100.0	100.0	No change
Throughput (Mbps)	0.0389	0.0371	~ 4.6% (Reduction)
Packet Loss	2.0	1.0	~ 50%

RESULTS - PACKET LOSS ANALYSIS

The next slide outlines a study that evaluated the impact of distance on packet loss in a wireless network using the Log-Normal Shadowing Model. The study simulated realistic signal attenuation and analyzed the relationship between signal strength, distance, and packet loss.

RESULTS - PACKET LOSS ANALYSIS

Distance (m)	FSPL (dB)	Theoretical Signal Strength (dBm)	Simulated Signal Strength (dBm)	Packet Loss (%)
50	74	-66.02	-65.0	32.1
100	80.04	-72.04	-74.0	36.98
200	86.06	-78.06	-83.0	74.41
300	89.58	-81.58	-88.0	81.55
400	92.08	-84.08	-92.0	100.0

CONCLUSION

Improved Latency

SDN-enabled networks demonstrated up to 30% reduction in round-trip time (RTT) under high traffic conditions compared to traditional networks, through dynamic flow optimization.

Seamless Mobility and Handover

SDN-based handover mechanisms reduced latency by 31% and halved packet loss during transitions between base stations, providing seamless connectivity.

Enhanced Throughput and Congestion Management

ONOS controller was able to prioritize specific traffic flows, ensuring better bandwidth allocation and fairness under network congestion.

Mitigated Packet Loss

The study revealed that SDN-enabled networks can effectively manage packet loss caused by signal strength degradation, a critical factor for modern applications.

The key findings of this research project emphasize the importance of centralized control and programmability offered by Software-Defined Mobile Networks. The SDMN approach demonstrated significant improvements in latency, throughput, handover performance, and packet loss mitigation compared to traditional mobile network architectures, making it a crucial enabler for modern applications that require robust and flexible mobile communications systems.

FUTURE WORK

- **Scalability Testing**
  Evaluate the performance of Software-Defined Mobile Networks (SDMN) under high traffic loads by simulating and analyzing larger network topologies with more base stations, access points, and mobile stations.

- **Energy Efficiency**
  Investigate techniques to optimize power usage in SDMN, particularly during handovers and in idle states, to improve the overall energy efficiency of the network.

- **Integration of Network Slicing**
  Explore SDMN's ability to implement network slicing, which can allocate dedicated resources to different traffic types, such as IoT devices, video calls, and online gaming, to enhance flexibility and enable tailored quality of service.

- **Real-World Deployments**
  Transition from simulated environments to real-world implementations, leveraging tools like OpenDaylight or ONOS with physical base stations and routers, to validate SDMN's performance and practical viability in actual network infrastructures.

- **Additional Metrics**
  Include additional performance metrics, such as jitter, reliability, and end-to-end delay, to provide a more comprehensive evaluation of SDMN's capabilities and offer deeper insights into the overall quality and reliability of the SDMN-based network.