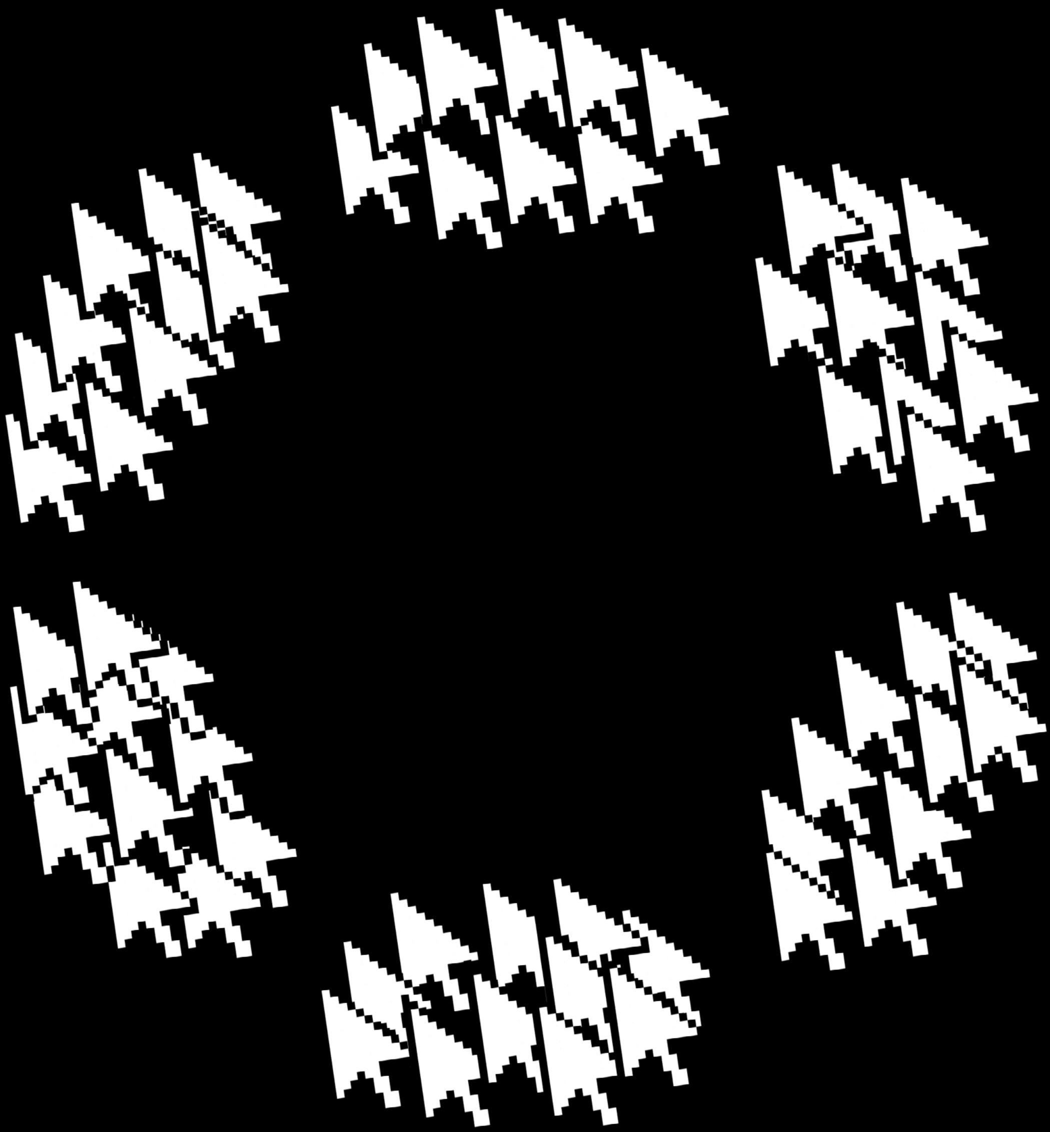
Proof of performance: 140k TPS showcases Polkadot's real-world scalability

The Spammening stress tests reveal Polkadot's true capabilities under extreme real-world conditions, establishing a new industry standard for testing blockchain performance.



PREPARED BY
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Polkadot

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Executive summary

The next chapter in blockchain adoption hinges on real-world performance. Polkadot's breakthrough results set new standards for what's possible.

A comprehensive stress test of Polkadot's performance capabilities on a live, globally decentralized network represents a milestone not only for its results but also as a benchmarking blueprint for Web3. Conducted between November and December 2024, this groundbreaking experiment, called the "Spammening," moved beyond theoretical benchmarks to evaluate how Polkadot's infrastructure handles extreme transaction loads in a live environment with real economic stakes.

Key takeaways

1. **Exceptional scalability**
   Even at minimal core utilization, Polkadot demonstrated industry-leading throughput of over 143,343 TPS on its sister network, Kusama, suggesting massive headroom for future growth. Based on this performance, projections suggest a network throughput exceeding 623k TPS.

2. **Rock-solid stability**
   The network maintained consistent performance under extreme loads, with block times and finality remaining stable throughout the stress test.

3. **Benchmarking blueprint**
   In an industry where performance metrics are often theoretical, Polkadot's stress test delivered the only number that truly matters to builders: real, achievable TPS on a live network. Moving beyond idealized testnet conditions, Polkadot set a new standard for real-world blockchain performance testing.

"What we witnessed during the Spammening was just a glimpse of what's possible. In 2025, Polkadot will double its cores to 200 and we only used 23 cores in this first Spammening!."

— Robert Klotzner, Lead Developer, Parity Technologies

This report details the full methodology, results, and implications of these tests, offering crucial insights for developers, enterprises, and stakeholders across the blockchain ecosystem.

143,343 batch TPS at 23% capacity

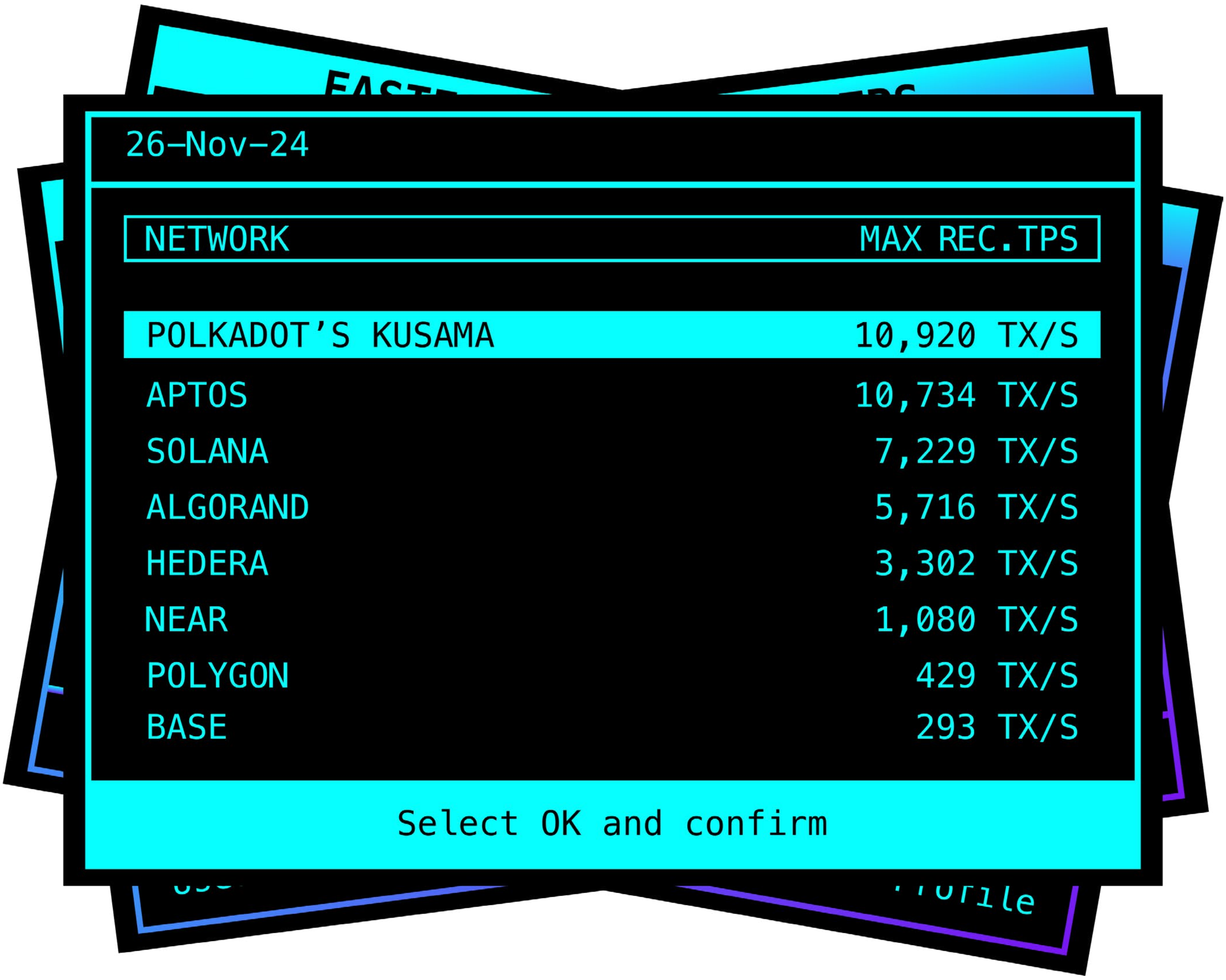
Max batch TPS achieved on 23 out of 100 available cores on Polkadot's Kusama network.

10,920 non-batch TPS at 15% capacity

Max non-batch TPS achieved on 15 out of 100 available cores on Polkadot's Kusama network.

623,230 Max TPS at 100%

If the system utilized all 100 cores, max theoretical throughput would exceed 623k TPS.



Introduction

Real blockchain performance isn't about theoretical benchmarks—it's about resilience under real-world pressure. The Spammening tests pushed Polkadot's Kusama network to reveal its true capabilities.

Blockchain networks are built to perform, but what truly defines their potential is how they handle the unpredictable. While metrics like transactions per second (TPS) often dominate discussions, they rarely capture the complexities of live networks, where validator performance, network latency, and economic incentives significantly impact actual throughput. Despite live network testing being the truest method of determining TPS, metrics are typically measured on testnets with near-perfect conditions, heavily skewing results. While other networks shy away from stress-testing real networks, Polkadot bucked this trend, setting a new standard for TPS: in-the-wild testing on live networks.

Polkadot's multichain architecture is made to scale, but it is also difficult to evaluate its true performance simply. Traditional evaluations often focus on the Polkadot Chain (aka relay chain) alone, which is not meant to directly handle transactions at all, therefore overlooking the crucial impact of Polkadot's L1 rollups (formerly known as parachains) that form the backbone of Polkadot's flexible scalability.

Polkadot 2.0's upgrade introduced many new features like Asynchronous Backing, which optimizes rollup pipelining, halving block times from 12s to 6s; Agile Coretime, which enables dynamic resource allocation to rollups; and Elastic Scaling, which allows rollups to further triple their throughput and reduce block confirmation latency threefold.

These capabilities are currently live on Kusama, Polkadot's sister network. The Kusama mainnet operates as a live, fully functional blockchain with real economic value that mirrors Polkadot's architecture and codebase. As well as serving as a playground to validate Polkadot-bound projects in a live environment, Kusama is an established project in its own right, home to many independent and commercial projects. It currently holds a market cap of $574.4M, with its native token, KSM. *[1]

[1] The KSM market capitalization data was accurate as of December 18, 2024, and is subject to change. For the latest figure, please refer to updated market data sources.

What is the Spammening?

The Spammening emerged from the desire to measure throughput under real-world conditions instead of a controlled lab environment. Initially proposed by Amforc, a Polkadot ecosystem validator team, it evolved into a series of coordinated tests on Polkadot and Kusama. By testing on Kusama, which mirrors Polkadot's architecture in a more experimental environment, we could push network limits without imposing certain risks, while mirroring the likely higher results achievable by Polkadot.

Objectives of the Spammening

The Spammening stress tests aimed to demonstrate Polkadot's readiness to support high-throughput applications while providing actionable insights for further network optimization.

The experiment's framework focused on two critical aspects:

1. **Scalability**
   Measuring maximum sustainable throughput and resource utilization.

2. **Stability**
   Assessing network behavior under sustained high loads, including finality and block times.

This report examines how Polkadot's infrastructure responds to extreme transaction loads, analyzing both controlled and community-driven stress test scenarios. The findings establish new benchmarks for blockchain infrastructure performance and demonstrate Polkadot's readiness to support high-throughput applications at scale.

Methodology

How do you test the limits of Polkadot's performance? By designing experiments that push the network to real-world extremes.

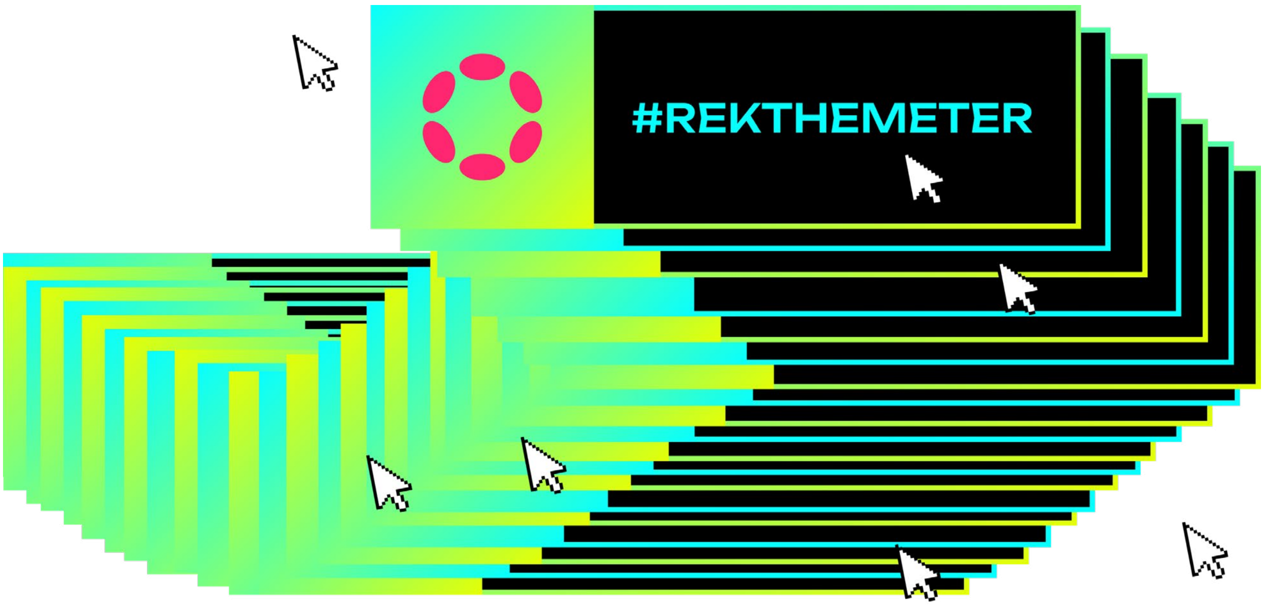
Two Polkadot ecosystem teams conducted the Spammening stress tests, of which set out to evaluate Polkadot's performance, resilience, and efficiency across various metrics. Parity Technologies led the primary network-wide performance evaluation on Kusama and the subsequent community test. A supplementary Polkadot Chain test by Amforc is detailed in the appendix.

Understanding the environment

Unlike conventional blockchain stress tests that rely on isolated testnets, these experiments were conducted on live mainnets with real economic activity. The Spammening was the **first large-scale throughput demonstration on live networks**. It consisted of two distinct experiments, each with their own parameters:

- **Network-wide stress test**
  Conducted by Parity Technologies, this test flooded Kusama rollups with transactions to simulate extreme demand.

- **Community test**
  This experiment invited participants to manually execute live spam transactions through an intuitive interface in an attempt to best the peak TPS recorded during the network-wide stress test.



Network performance test

Parity Technologies conducted a comprehensive network stress test on Kusama by deploying rollups dedicated for transaction spam, sending millions of transactions onchain. These rollups were flooded with transactions to simulate conditions of extreme network demand. Since Kusama and Polkadot share the same underlying codebase and architecture, the results provided valuable insights into Polkadot's real-world performance capabilities.

Parameters

The experiment was conducted on the Kusama mainnet, which includes ongoing economic activity, existing rollups, the Kusama relay chain, and a decentralized validator set of 1000 nodes. Kusama's runtime has all three components of Polkadot 2.0—Elastic Scaling, Asynchronous Backing, and Agile oretime—fully live. To establish controlled experimental conditions, dedicated spam rollups were deployed, each with a predefined number of cores. Parity also leased additional cores to power the spam rollups during testing, which expired on December 6, 2024, at 08:09:11 UTC.

Existing conditions

- **Existing rollups**
  Live rollups already operating on Kusama.
- **Kusama relay chain**
  Same standard consensus mechanism as Polkadot.
- **Network of decentralized validator nodes**
  1000 active decentralized validator nodes operating on Kusama were responsible for transaction validation. Validators are nominated through Polkadot's Nominated Proof of Stake (NPoS), ensuring decentralization and diversity. Baseline hardware specifications and uniform technical requirements further reduce variability, though real-world conditions mean these are not guaranteed.

New variables

The following test components were specifically created for the experiment:

- **Dedicated spam rollups**
  As per Polkadot's rollup model, the spam rollups had dedicated tokens, which were used exclusively for the experiment. From the network's perspective, these tokens were indistinguishable from value-bearing assets, ensuring metrics reflected raw technical capabilities.
- **Agile Coretime**
  Resources were leased to sustain the spam rollups during the experiment.
- **Community input**
  The unpredictable nature of live community testing revealed critical findings that went beyond controlled testing

Approach

The initial stress test was conducted on November 26, 2024, on Polkadot's live Kusama network. To minimize disruption, the test utilized 15 out of 100 available cores, sustaining high volumes of batch and non-batch transactions across all designated spam rollup chains. The test ran for 60 minutes (10:00–11:00 UTC), with transaction data logged at approximately 30-second intervals.

A subsequent live interactive Spammening experiment took place on December 4, 2024, expanding to 23 cores. This test invited community participation through an intuitive interface, where 1,933 users manually executed transactions to spam the network. Participants selected a spam rollup and clicked "Spam," which generated new accounts preloaded with tokens to enable transaction activity during the Spammening. The diverse participation styles during this ~30-minute-long test revealed unique network behaviors and trends that could not have been observed in controlled testing scenarios.

Transaction types

By employing two transaction types, the test aimed to simulate various real-world transaction scenarios, offering a comprehensive evaluation of the network's performance.

- **Batch transactions**
  Optimized one-to-many transactions designed to handle multiple outputs within a single operation, akin to airdrops. These are highly efficient.
- **Non-batch transactions**
  Peer-to-peer (1:1) transfers, such as payments or token exchanges

Data collection

Data was collected for three chain categories: spam rollups, existing rollups, and the Kusama relay chain. A combined "total" category was calculated as a total of all chains in the network.

Metrics recorded at 30s intervals included:

- Transaction volume
- Transaction throughput (tx/s)
- Average block time (seconds)
- Average time to finality (seconds)

Considerations

These controlled parameters and conditions were essential to maintaining the integrity of the experiment, ensuring that results directly reflect Polkadot's technical potential while avoiding interference with the economic operations of the live network.

- **Core utilization**
  Less than a third of Kusama's full core capacity was used.
- **Hardware limitations**
  Kusama validators have half the hardware specifications compared to Polkadot validators, meaning performance on Polkadot would likely be higher.

Results & analysis

Polkadot's performance under pressure tells a compelling story of its ability to scale, adapt, and excel in demanding scenarios. The findings are analyzed through the lens of scalability, stability, and resilience.

The Spammening experiment provided a rare opportunity to stress-test Polkadot's multichain architecture in a live, real-world environment via Kusama. By subjecting dedicated spam rollups to extreme transaction volumes, the test sought to uncover operational boundaries, resilience under pressure, and capacity for sustained high performance.

Key analytical lenses

The results are presented through two key lenses: first, through a combination of performance trends and key metrics that showcase the network's raw capabilities, and second, through comparative insights benchmarked against other blockchains. This dual approach contextualizes the findings within broader blockchain performance standards.

Specifically, we examined:

Stress adaptability
How spam rollups, with the addition of new Polkadot features such as Asynchronous Backing, Agile Coretime, and Elastic Scaling, perform under high loads and how these stressors ripple across the network.

Network-wide impact
The interplay between stress on spam rollups and the Kusama relay chain, highlighting whether bottlenecks or inefficiencies emerge at scale.

Competitive benchmarking
A comparison of the spam rollups' performance against leading blockchains, providing a tangible measure of Polkadot's position in the industry.

By evaluating the results in these key areas, which align with the objectives guiding our analysis, we provide a framework to contextualize Polkadot's real-world readiness, its strengths in handling high-demand scenarios, and any opportunities for improvement to meet the demands of a rapidly evolving blockchain landscape.

High-speed scalability beyond limits

Speed and scalability are essential for blockchain networks to support real-world applications. Metrics such as peak TPS and resource utilization validate Polkadot's capacity to handle high transaction volumes efficiently while maintaining the flexibility to adapt to future demands.

During the live community Spammening, Polkadot's Kusama reached peak throughput with a maximum recorded value of 143,343 TPS while utilizing only 23% of available cores. If all 100 cores were utilized, this would deliver a max theoretical throughput of approximately 623,230 TPS at 100% capacity. Even at just 15% of available core usage, batch transactions achieved a max throughput of 85,103 TPS, and non-batch transactions achieved 10,920 TPS.

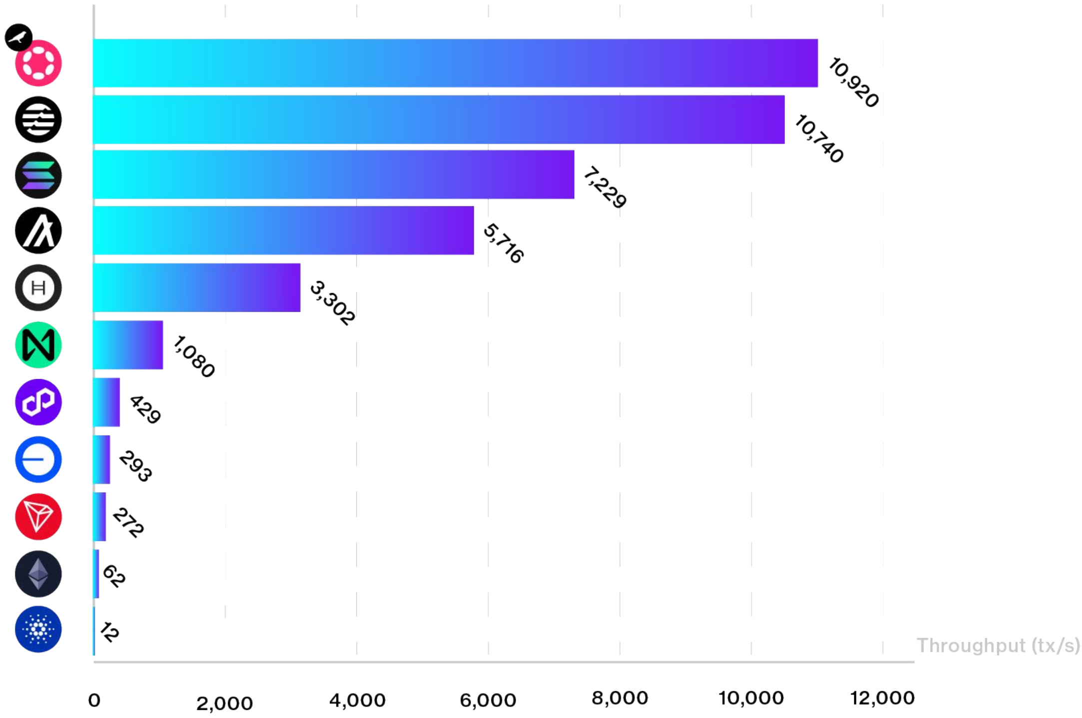
Polkadot's Elastic Scaling feature takes throughput further by enabling rollups to scale dynamically up to three cores each, with plans to support up to 12 cores per rollup in 2025. During the stress tests, single rollups using three cores achieved 3,273 TPS for non-batch transactions and 19,450 TPS for batch transactions.

Both performance tests far surpass other blockchain ecosystems, showcasing Polkadot's efficiency in handling routine transactions and demand surges while positioning Elastic Scaling as an effortless and efficient way to scale single-rollup throughput—enough for the vast majority of use cases, including most enterprise applications.

		Theoretical TPS	
Spam Rollups	Max Recorded TPS	100 Cores	200 Cores
Utilizing 23 Cores	143,343	623,230	1,246,461
Utilizing 15 Cores	85,103	567,353	1,134,706

Competitive comparison

Polkadot's performance on just 15 cores in non-batch transaction testing already outpaces top competitors like Solana and Aptos, proving its technical edge. These results, while impressive, only scratch the surface of Polkadot's true potential. With batch transactions, Polkadot achieves significantly higher efficiency, reaching a peak throughput of 85,103 TPS on 15 cores and 143,343 TPS on 23 cores.



The throughput values presented for other chains were derived from data provided by Chainspect.

Unstoppable resilience under pressure

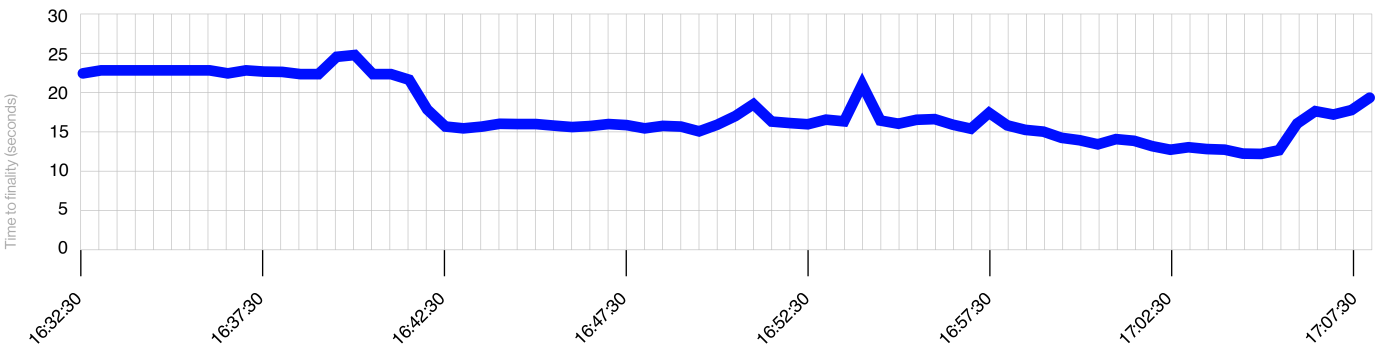
Resilience under stress demonstrates a blockchain's maturity and reliability. Metrics like block times and time to finality highlight Polkadot's ability to deliver consistent performance under heavy loads, ensuring suitability for mission-critical applications.

The network maintained remarkable stability even during peak load conditions, demonstrating reliability during high-stress conditions.. Block time continued steadily at an average of ~6 seconds, and finality remained consistent with an average of ~16 seconds, even as throughput climbed to 143,343 TPS.

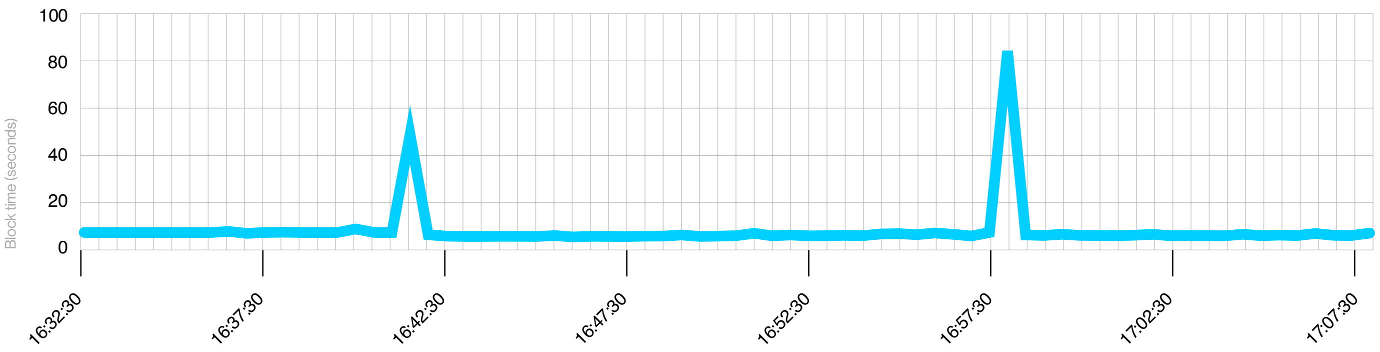
Key takeaway

Stability during peak loads reflects Polkadot's robust validator performance and efficient network operations, demonstrating Polkadot's capacity to deliver interruption-free performance.

Avg. finality time during the Spammening



Avg. block time during the Spammening



Discussion

The Spammening stress test offers critical insights into Polkadot's readiness to support real-world applications. The findings underscore Polkadot's unique strengths in scalability and resilience while shedding light on nuances such as the complexity of measuring performance in a multichain architecture. Here, we explore the broader implications of these results and address considerations for interpreting metrics like TPS.

Signals in the spam

The Spammening results revealed several key insights about Polkadot's network performance and architecture, demonstrating both its current capabilities and future potential. From record-breaking throughput to consistent stability under pressure, the test data paints a compelling picture of a network ready for enterprise-scale adoption.

Unmatched throughput

Polkadot's spam rollups peaked at 143,343 TPS—far exceeding household names like Solana and Base—all while running on just 23% capacity. These figures highlight Polkadot's ability to handle intense workloads without compromising its core functions. The network's linear scaling characteristics point to theoretical projections of 623,320 TPS on 100 cores and 1,246,461 TPS on 200 cores—capabilities expected to become available in 2025 through ongoing developments.

Rock-solid stability

Throughout the stress test, Polkadot's pipelined architecture--built to prioritize high throughput and security—maintained reliably consistent performance. Even during peak loads, the network's average block time held steady at approximately 6 seconds, with an average time to full finality around 16 seconds. These speeds outpace typical rollup finality times in other ecosystems, demonstrating Polkadot's efficiency and lightning-fast block confirmations. These results indicate Polkadot's resource optimization and scalability, making it well-suited for high-demand use cases such as DeFi, gaming, or enterprise.

Throughput metrics are complicated

While the results position Polkadot as a leader in blockchain scalability, they also underscore the inherent challenges in measuring a seemingly simple metric like transactions per second. Polkadot's layer 0 architecture, which orchestrates multiple blockchains running in parallel, defies the straightforward TPS calculations used for monolithic layer 1 blockchains. This complexity makes TPS a controversial and often misunderstood metric.

Key factors contributing to the complexity of measuring Polkadot's performance:

Multichain parallelism
Unlike single-chain blockchains, Polkadot enables multiple rollups to operate independently, each optimized for specific use cases. This makes the aggregate throughput across all rollups more meaningful than a single TPS metric.

Shared security
The Polkadot Chain and the Kusama relay chain coordinate consensus and provide shared security, introducing a multi-layered validation process that doesn't conform to traditional TPS metrics.

Asynchronous operations
Rollups on Polkadot process transactions asynchronously, with throughput varying based on activity and design, adding another layer of complexity to TPS measurements.

Customizability
Each rollup can have customizable architecture, including block sizes and transaction priorities, further complicating any attempt to define a single TPS metric.

Reframing metrics

Throughput-wise, Polkadot's performance is more accurately measured through network-wide throughput, taking into account the specialized functionality of its rollups. However, the best type of measurement would be to assess blockchains in terms of computational resources rather than vague processing metrics like TPS. Even under this metric, Polkadot is a clear frontrunner.

The Spammening results demonstrate Polkadot's readiness to support high-performance applications while highlighting the limitations of TPS as a standalone metric. Third-party platforms may misrepresent Polkadot's capabilities due to its multichain architecture. To provide a more accurate picture, stakeholders should focus on broader metrics like aggregate throughput, validator efficiency, and block utilization.

These metrics provide a more complete view of Polkadot's technical capabilities and readiness to meet the demands of a rapidly evolving blockchain landscape.

Polkadot's performance at a glance

143,343 Max Recorded TPS

Polkadot's achievement of 143,343 TPS on just 23 of 100 cores demonstrates its exceptional scalability and efficient protocol design. Using only a fraction of its capacity, Polkadot showcases its readiness to support high-demand applications while maintaining decentralization and stability.

623,230 TPS at 100% capacity

Polkadot projects a theoretical maximum of 623,230 TPS on 100 cores. This capability positions Polkadot as the platform of choice for high-volume applications in gaming, DeFi, and enterprise solutions.

16.5s average finality time

Polkadot consistently achieved an average finality time of 16.5 seconds, even under intense load. This reliability ensures fast and predictable transaction processing where timing is critical.

23% network utilization

Operating at just 23% of its network capacity during the Spammening, Polkadot demonstrated its scalability, reinforcing its readiness to support massive growth and high-demand applications.

6.3s average block time

Polkadot maintained a steady average block time of 6.3 seconds during the Spammening stress test, underscoring the efficiency and reliability of Polkadot's multichain architecture in handling demanding scenarios.

What's next after the Spammening?

From its inception, the Spammening set out to test the limits of Polkadot under real-world conditions, moving away from conventional testnet environments to showcase its performance in a dynamic, user-driven setting. The results offer a new perspective on blockchain infrastructure capabilities, proving that stability, scalability, and speed—long considered competing priorities—can successfully coexist in Polkadot's production environments.

Broader implications

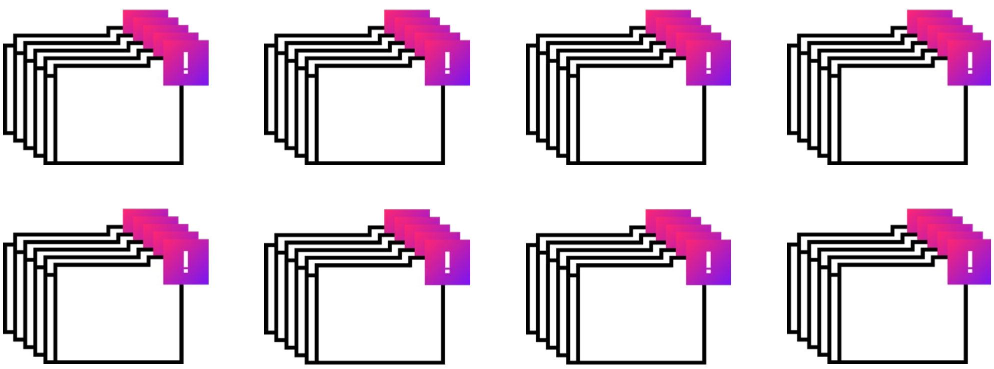
The Spammening's impact extends beyond raw performance metrics. In an industry saturated with theoretical benchmarks derived from idealized conditions, this initiative establishes a new framework for meaningful evaluation based on live network conditions. It also reveals specific opportunities for technical refinement, ensuring Polkadot remains at the forefront of blockchain innovation.

To spam, again and again

The Spammening has demonstrated the immense value of real-world stress testing—not just as a measure of throughput, but as a powerful driver of continuous improvement. Building on its success, the Spammening will become a recurring initiative as part of Polkadot's ongoing commitment to technical excellence. This marks the beginning of a systematic approach to advancing blockchain capabilities, setting a new standard for impactful blockchain evaluation.

"The next logical step is to perform the Spammening on Polkadot itself. With Polkadot's beefier nodes and stronger connections, Polkadot's infrastructure offers the potential to push these metrics even further, surpassing the already impressive results achieved on Kusama."

— Gavin Wood, Founder of Polkadot, Co-Founder of Ethereum



Appendix: Relay chain performance test

Alongside the primary network-wide evaluation, Amforc conducted targeted stress tests focused on the coordination layer (relay chain) of both Polkadot and Kusama networks. These tests explored distinct performance aspects from the main Spammening experiment, providing valuable context for understanding the networks' broader capabilities under stress.

Parameters and approach

Given the decentralized nature of the Polkadot and Kusama networks, most variables were inherently unpredictable. Conducted on live networks rather than testnets, the tests were subject to real-world conditions. Using traditional RPC methods, Amforc submitted ~3 million transactions to the Polkadot Chain and ~4 million transactions to the Kusama relay chain.

Considerations

The details from this experiment are included in the appendix since testing transaction throughput directly on the relay chain is not directly comparable to the primary rollup-based tests.

1. **Architectural design**
   Polkadot and Kusama were built for modular, parallel processing. User and application-level transactions are intended to occur on rollups, while relay chains focus on consensus and shared security. Directly testing transaction throughput on the relay chain does not reflect its intended utility.

2. **Test configuration**
   These tests intentionally pushed the networks into edge-case scenarios by deploying transactions directly on the relay chains rather than its rollups.

3. **Consistency**
   To align with Polkadot's architecture and reflect real-world use cases, the focus remains on Polkadot's ability to scale through rollups.

As the network evolves, upcoming upgrades will reduce direct relay chain transaction usage to zero by 2025. This shift is not a limitation but a deliberate design goal to optimize throughput and efficiency across the entire network.

About the report

Polkadot

Polkadot's architecture is designed to enable a scalable, interoperable, and secure multichain ecosystem. At its core, Polkadot is a Layer 0 protocol, providing the foundational framework that connects multiple rollups, allowing them to operate independently while benefiting from shared security, scalability, and interoperability. The Polkadot Chain acts as the central hub, coordinating consensus and facilitating communication between rollups. Each rollup can optimize for specific use cases, allowing for specialized functionality without compromising the performance or security of the overall network.

Polkadot 2.0 enhancements

Polkadot's architecture is enhanced by Polkadot 2.0 technologies, which enable the network to handle greater volumes and adapt to changing needs. Polkadot 2.0 features include the following:

Elastic Scaling
Allows rollups to tap into multiple Polkadot cores simultaneously, tripling their throughput and block production rate. This enables rollups to achieve horizontal scaling without added complexity.

Asynchronous Backing
Enables faster finality and doubles throughput by reducing block times from 12 seconds to 6 seconds, improving overall scalability.

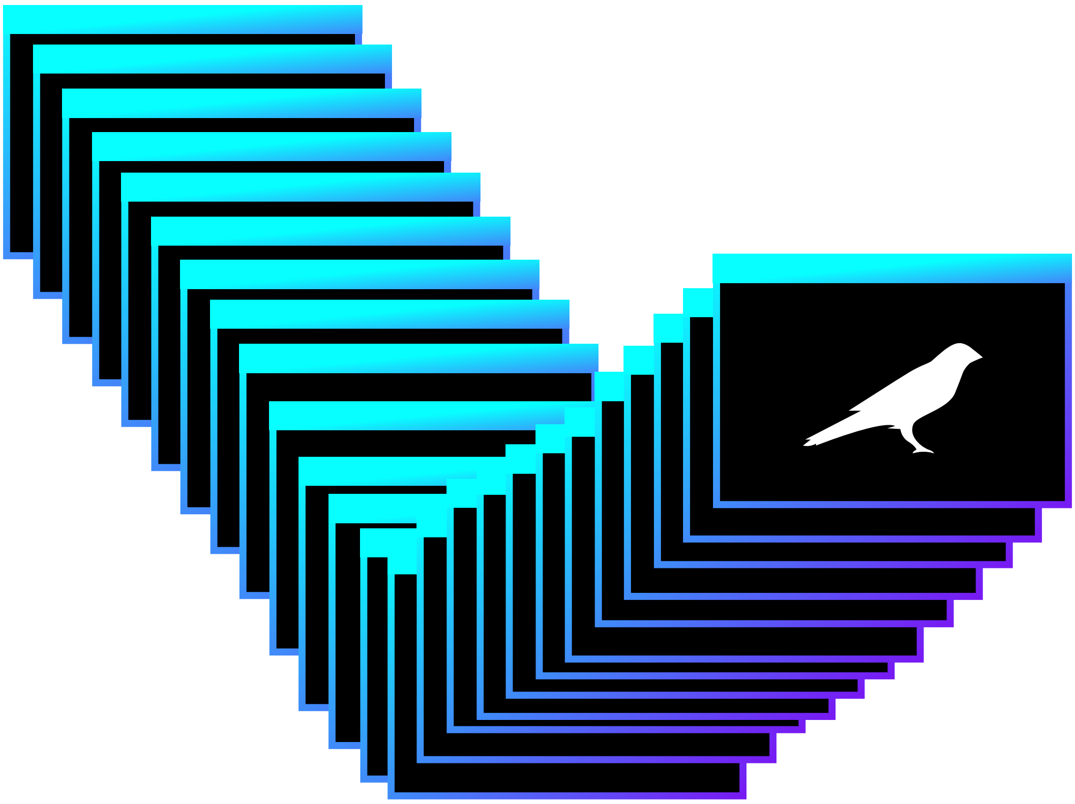
Agile Coretime
Optimizes block production times, reducing barriers to entry and improving resource allocation efficiency.

These innovations are key to Polkadot's adaptability and future growth, enabling the network to remain flexible, efficient, and capable of handling a rapidly expanding multi-chain ecosystem. Polkadot's ability to support a growing number of interconnected blockchains while maintaining shared security and cross-chain interoperability enables it to accommodate a vast array of use cases. This flexibility and scalability position Polkadot as a versatile platform capable of supporting various decentralized applications and innovations as the blockchain ecosystem continues to evolve.

Kusama: Polkadot's experimental sister

Kusama is a live, cutting-edge production environment targeting users who prioritize early access to Polkadot's latest features over stability—hence its tagline: Expect Chaos. Sharing the same codebase, architecture, and design as Polkadot, Kusama operates in a more experimental environment. Because it mirrors Polkadot's functionality, Kusama is ideal for testing new features, performance upgrades, and extreme stress conditions in a live, real-world setting without risking the stability of the main Polkadot network. The insights gained from Kusama are invaluable for ensuring Polkadot's readiness to handle similar conditions in the future.

Importantly, Kusama is a fully operational, live blockchain with real economic value and a thriving ecosystem of independent and commercial projects—a distinction that makes it a unique feature of Polkadot's ecosystem. With a current market cap of $574.4 USD* and its native token, KSM, Kusama serves as both a launchpad for Polkadot-bound initiatives and as a standalone network supporting its own growing community.*[1]



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Acknowledgment

The success of the Spammening was made possible through the extensive collaboration, coordination, and execution of multiple teams:

Distractive distractive.xyz
Played a central role in planning, coordination, communication, and execution, including creating the report, designing branded assets, amplifying the initiative on social channels, and overseeing all aspects of the Spammening from start to finish.

Parity Engineering Team parity.io
Led the design and execution of network-wide tests and developed real-time dashboards to monitor and analyze performance.

Parity Data Team data.parity.io
Managed data collection and conducted detailed analysis to evaluate and contextualize results.

Amforc amforc.com
Designed and executed relay chain stress tests, contributing critical insights into the coordination layer's performance.

SPAMMENING