

REVIEW

on a doctoral dissertation for awarding the educational and scientific degree
"Doctor" (PhD)

Author of the dissertation: Genka Ivanova Slavova-Torres

Dissertation title: Methods and Tools for Optimizing Writes in a Networked Storage Environment

Reviewer: Assoc. Prof. Stanislav Dimitrov Gyoshev, PhD, Eng. – Institute of Information and Communication Technologies – Bulgarian Academy of Sciences

Scientific Field: 5. Technical Sciences

Professional Field: 5.3. "Communication and Computer Engineering"

Doctoral Program: "Computer Systems, Complexes and Networks"

Scientific Supervisor: Assoc. Prof. Vladimir Ivanov, PhD

1. General Characteristics and Relevance of the Topic

The dissertation by Genka Ivanova Slavova-Torres is dedicated to a highly relevant and practically significant topic in the field of computer networks and storage systems—the optimization of write operations in Storage Area Networks (SAN).

The author correctly identifies the systemic issue that despite the rapid development of physical storage media (transition from HDD to SSD and NVMe/NVMe-oF) and the increase in their nominal throughput, write management in SAN environments remains a complex and poorly predictable process. Against the backdrop of growing parallelism and multi-tier architectures (host, fabric, controllers), traditional average performance metrics prove insufficient to define stability. The dissertation properly focuses attention on queueing effects, non-linear behavior, and so-called "tail latency" (p95, p99), which are critical for modern database management environments and transactional applications.

The work is excellently structured into an introduction, six chapters, a conclusion, a list of scientific and applied contributions, a bibliography, a list of author publications, and an appendix.

2. Analysis of Content and Structure

The dissertation follows a clear and logical progression—from the analytical and systemic definition of the problem, through the formulation of a system model and experimental methodology, to conducting in-depth experiments, synthesis, and deriving an optimization framework.

- **Chapter 1: "Problem, Goals, and Tasks"** substantiates the relevance of the research and formulates the scientific challenge. The objective is clearly defined (development and validation of a system model to determine tail

latency and derive optimization principles), along with nine specific tasks. The research thesis is articulated, stating that sustainable optimization depends on aligning workload characteristics with queue management mechanisms across the entire write path, rather than solely relying on the nominal speed of components.

- **Chapter 2: "System Model of Write Operations in Storage Area Networks (SAN)"** presents the conceptual framework of the study. The author traces the historical evolution of bottlenecks—from mechanically constrained HDDs, through controller/interface bottlenecks in SSDs, to queueing and coordination challenges in NVMe and NVMe-oF. The write path is formalized as a multi-tier system of interacting queues (host-level, fabric/transport layer, and storage controllers). Important statistical and analytical metrics are introduced (ECDF, p50, p95, and p99 percentiles) through queueing theory principles.
- **Chapter 3: "Experimental Methodology"** details the research model, controlled testbed environment, measurement tools, and reproducibility criteria. The methodology treats the workload as an independent variable, ensuring isolation of individual system factors under strictly fixed and variable parameters.
- **Chapter 4: "Experimental Results"** forms the core of the empirical investigation. It includes a baseline experimental scenario (reference behavior) and four fundamental experiments:
 1. *Impact of Queue Depth (QD)* on latency and tail inflation;
 2. *Impact of workload pattern* (uniform flow vs. bursty mode);
 3. *Coordination vs. Raw Speed* (comparison between coordinated and uncoordinated submission modes);
 4. *Impact of a competing host ("Noisy Neighbor" effect)* on a shared logical volume.
- **Chapter 5: "Analytical Synthesis and Interpretation"** compares the experimental results and formulates a comprehensive optimization framework for SAN environments. Concrete guidelines and principles are derived for managing parallelism, bounding tail percentile inflation (p_{99}/p_{95}), and achieving inter-layer coordination without requiring additional hardware resources.
- **Chapter 6: "Conclusion and Future Work"** summarizes the main results, outlines the research limitations, and sets directions for future research.

3. Scientific and Applied Contributions

The dissertation contains original scientific, scientific-applied, and applied contributions, which are well supported in the content of Chapters 2, 4, and 5.

The main contributions can be summarized as follows:

- **Scientific Contribution:** Formulated and formalized an original system model of the write path in a SAN environment as a sequence of interacting queues and service mechanisms, interpreted through the principles of queueing theory.
- **Scientific-Applied Contribution:** Developed and validated a controlled experimental methodology for analyzing non-linear latency effects and high-tail percentiles (p_{95} , p_{99}) using Empirical Cumulative Distribution Functions (ECDF).
- **Scientific-Applied Contribution:** Experimentally established and proved key dependencies causing latency instability resulting from Queue Depth (QD), bursty workload characteristics, lack of inter-layer coordination, and the presence of interfering competing traffic ("Noisy Neighbor").
- **Applied Contribution:** Formulated a practical analytical framework and specific guidelines for optimizing write operations in SAN environments aimed at maintaining stable latency behavior through parallelism control.

4. Strengths and Remarks

Strengths:

- **Methodological Systematization and Rigor:** The PhD candidate demonstrates exceptional academic maturity by applying a holistic system approach to SAN environments rather than analyzing isolated components.
- **Focus on Real-World Practical Challenges:** The analysis of tail latency and high percentiles (p_{95}/p_{99}) reflects the real requirements of modern enterprise business applications and database systems.
- **Rich and Precise Experimental Data:** The conducted experiments are well-designed, strictly controlled, and illustrated with numerous graphs (ECDF, time profiles) and structured tables.

Remarks and Recommendations:

- The study is focused primarily on write operations (which is thoroughly justified by the author). For future research, it is recommended to extend the developed model to mixed workloads (concurrent read and write operations) to analyze read-write interference.

5. Evaluation of the Abstract

The abstract accurately, fully, and correctly reflects the main content of the dissertation, the set goals and tasks, the conducted experiments, the formulated conclusions, and the scientific and applied contributions.

6. Conclusion

The dissertation by Genka Ivanova Slavova-Torres is a complete, thorough, and high-level scientific study. It fully satisfies the set objectives and tasks, providing significant scientific, scientific-applied, and applied contributions to the field of storage area networks and computer systems.

The author demonstrates excellent theoretical knowledge and strong skills in conducting independent experimental and analytical research.

The work fully complies with the requirements of the Development of Academic Staff in the Republic of Bulgaria Act (ZRASRB) for awarding the educational and scientific degree "Doctor" (PhD) in Professional Field 5.3. "Communication and Computer Engineering".

I propose that the esteemed Scientific Jury evaluates the dissertation by Genka Ivanova Slavova-Torres **positively** and awards her the educational and scientific degree "Doctor" (PhD) in Professional Field 5.3. "Communication and Computer Engineering".

Sofia, 09.09.2026

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(Assoc.

