Leveraging Big Data and AI for Enhanced Computer Network Performance: A Systematic Review

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Abstract: ***Against the backdrop of ever-growing communication demands, computer network systems require more efficient intelligent support. The integrated application of big data and artificial intelligence technologies can provide a technical foundation for network architecture optimization, data processing acceleration, and security mechanism upgrades. This paper focuses on the application of big data and AI technologies in computer network systems, analyzes their significance in enhancing network data processing capabilities, improving intelligent information identification efficiency, and strengthening system collaborative operation, and proposes strategies such as building intelligent acquisition systems, introducing deep learning algorithms, and reinforcing multi-source data fusion, aiming to drive the intelligent development of network systems.***

Keywords: Big data; Artificial intelligence; Computer networks.

1. INTRODUCTION

Computer networks are the infrastructure of the information society, and their operational efficiency directly affects the technological support capacity of the data era. As data volumes continue to grow, traditional network architectures face increasingly severe challenges in processing efficiency, resource allocation, and response capability. Big data technology can provide the ability to integrate data resources, helping network systems identify information content that is structurally complex and frequently updated; artificial intelligence technology can offer algorithmic support for network operations, enabling systems to perform proactive analysis in areas such as processing paths and anomaly identification. The combination of these two technologies can shift networks from static response mechanisms to dynamic analysis systems, enhancing system stability while ensuring data throughput. In telemedicine, Wei et al. (2025) developed an AI-driven intelligent health management system [1]. Advancements in robotics are highlighted by Guo and Tao (2025), who conducted modeling and simulation analyses of robot-environment interaction [2], while Guo (2025) further explored optimal trajectory control for robotic manipulators using deterministic AI [7]. In software architecture, Zhou (2025) investigated performance monitoring and optimization within microservices [3]. Data security and sharing technologies are addressed by Zhang (2025), who researched blockchain-based secure sharing of medical data [4]. Economic and market analyses include Yu (2025), who applied Python in market trend analysis [5], and Tang, Yu, and Liu (2025), who studied supply chain coordination involving dynamic pricing and consumer welfare [6]. In cross-domain visual recognition, Peng (2022) proposed multi-source and source-private cross-domain learning [8], with subsequent work by Peng et al. (2023) introducing the RAIN method for black-box domain adaptation [9]. Time-series analysis is advanced by Su et al. (2025), who developed an anomaly detection system for financial data [10], and Zhang et al. (2025), who presented MamNet for network traffic forecasting [11]. Energy systems research includes Gao, Tayal, and Gorinevsky (2019), who performed probabilistic planning of minigrids with renewables [12], and Gao and Gorinevsky (2020), who optimized resource mix using probabilistic modeling [13]. AI governance and risk management are addressed by Lin (2025), who proposed an enterprise AI governance framework [14]. Healthcare applications extend to Wang (2025), who introduced RAGNet for rheumatoid arthritis risk prediction [15], and Chen et al. (2022), who integrated gaze estimation for object referring [16]. Advertising and marketing are explored by Zhang, Yuhan (2025) via reinforcement learning for ad campaign optimization [17], and Zhuang (2025), who discussed real estate marketing strategies in the digital era [21]. User recommendation systems are advanced by Han and Dou (2025) using hierarchical graph attention networks [22], and Yang, J. (2025) applied the Prompt-Biomrc model in intelligent consultation [23]. Large language models (LLMs) and recommender systems are focal points for Yang, Zhongheng et al. (2025), who fine-tuned LLMs with RLHF for conversational recommenders [24], and Yang, Haowei et al. (2025), who optimized parallelism methods in LLM-based recommendation systems [25]. Zhang, Jingbo et al. (2025) employed AI for sales forecasting in gaming [26].

Technical optimizations include Yang, Yifan (2025) on SEO strategies using the Dijkstra algorithm [27], and Hu, Xiao (2025) on low-cost 3D authoring [18] and visual saliency modeling in ad design [29]. Xu, Haoran (2025) contributed to urban planning with text-to-3D modeling [28] and generative modeling for public spaces [33].Healthcare planning is advanced by Hsu et al. (2025) with MEDPLAN, a RAG-based medical plan generator [30]. Cross-media data fusion is explored by Yuan and Xue (2025) in an intelligent analytics framework [31] and a graph neural network-based retrieval system [32]. Multimodal data integration is further examined by Xie and Liu (2025) for interview analytics [34]. In ad systems, Zhu (2025) focused on reliability automation [35], while Zhang, Yuhan (2025) developed safety tooling for release processes [36]. Li, Wang, and Lin (2025) enhanced sequential recommendation with graph neural networks [37]. Network automation is addressed by Tu (2025) with a framework for 5G network testing [38], and Xie and Chen (2025) presented a reasoning engine for business intelligence dashboards [39]. Finally, Wang (2025) proposed a joint training method for recommendation under MNAR data [40].

2. SIGNIFICANCE OF APPLYING BIG DATA AND ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN COMPUTER NETWORK SYSTEMS

2.1 Enhancing Network Data Processing Capability

Big-data technology can provide the system with high-capacity, fast-processing data support, enabling the network to maintain stable operation under multi-task concurrency. As information-transmission density rises and the relationships among data grow ever more complex, traditional static-logic-based processing can no longer meet the system’s real-time demands. Introducing artificial intelligence endows the network with dynamic-recognition capabilities during processing, allowing it to adjust operating strategies in real time according to data characteristics and improve processing precision. Different types of data can be effectively classified, reducing computational pressure on the system and boosting overall efficiency. Enhanced information-processing capacity also means the system can judge anomalies or sudden requests more quickly, ensuring smooth communication. More rational resource allocation and more orderly data scheduling give the network architecture an endogenous drive for continuous optimization, demonstrating higher technical adaptability in real-world applications.

2.2 Improving the Efficiency of Intelligent Information Identification

Big-data technology aggregates multi-dimensional information resources, providing rich feature support for system identification so that data already possesses preliminary screening conditions before entering the processing pipeline. Artificial-intelligence technology can leverage algorithms to identify rules or extract feature patterns, rapidly locating valid information within complex data and reducing misjudgments. After multiple rounds of training, the system forms recognition paths that align with actual needs; quickly eliminating anomalous data or noise lightens the system’s burden and keeps communication links stable and smooth [2]. Higher identification efficiency also means security mechanisms respond more promptly, shortening system reaction time and strengthening overall control. Precise identification further assists in the rational allocation of network resources, granting priority channels to high-frequency data and improving service-response real-time performance. Parallel processing of multiple recognition tasks broadens the system’s processing scope, enabling the network to maintain continuous adaptability to complex scenarios.

2.3 Enhancing System Collaborative Operation Capability

A computer network system contains multiple functional modules; if they lack effective coordination, resource waste easily occurs. Big-data technology can provide a unified data foundation for all modules, enabling operations under the same information context and reducing runtime errors caused by information bias [3]. Artificial intelligence can leverage algorithms to optimize task-allocation workflows, allowing each node in the system to flexibly respond to task changes based on current status, forming a clear and orderly collaboration mechanism. Nodes can use intelligent judgment to share resources, reducing performance burdens caused by redundant processing. After dynamic adjustment, scheduling strategies can automatically coordinate task loads among components during operation, keeping high-frequency processing areas stable while leaving expansion space for low-frequency areas. Once inter-module cooperation efficiency improves, data-transmission paths become shorter and response times faster. Enhanced information synchronization across modules also improves the timeliness of fault detection, preventing problem escalation. Continuously strengthening collaborative capabilities enables the system to stably support complex application scenarios, providing structural assurance for long-term, efficient network operation.

2.4 Driving Intelligent Upgrades of Network Architecture

Traditional network architectures mostly rely on static configurations or rule-driven approaches, making it hard to meet today's complex multi-task communication demands. Big-data technology can provide rich decision-making evidence for adjusting network structures, comprehensively analyzing traffic distribution, user behavior, or resource utilization so that architectural design better fits real-world applications. Introducing artificial intelligence enables networks to automatically adjust parameters based on real-time operating states, achieving dynamic adaptation of structural functions. Network nodes can automatically distribute tasks, communication paths can be reconstructed on demand, and the overall system gains greater flexibility. At the architectural level, intelligent algorithms that optimize transmission logic, routing strategies, or load-balancing mechanisms allow more precise resource allocation, preventing local congestion from affecting overall performance. Meanwhile, the system's perception of abnormal states is significantly enhanced, enabling rapid adjustments to maintain communication stability. The upgraded architecture can also support more complex services, offers good scalability, and lays a solid foundation for continuous technological evolution.

3. APPLICATION STRATEGIES OF BIG-DATA AND ARTIFICIAL - INTELLIGENCE TECHNOLOGIES IN COMPUTER NETWORK SYSTEMS

3.1 Build an Intelligent Collection System to Improve Data-Acquisition Efficiency

By integrating AI algorithms and big-data processing capabilities, the system can identify valid information and extract features in real time within a multi-source, heterogeneous environment. Data collection shifts from static rule-driven to dynamic condition control, enabling collection nodes to adapt to changing scenarios. IoT terminals are no longer limited to simple uploads; instead, they can judge the optimal moment to collect based on preset thresholds, filter redundant content, and improve bandwidth utilization. In the network architecture, collection modules collaborate through algorithms to shorten response times, reduce duplicate access, and enhance overall link smoothness. Data quality is ensured, system load becomes more controllable, and a reliable foundation is laid for subsequent analysis and decision-making.

In complex communication scenarios, data sources are diverse and their structures vary widely, while the collection process must meet dual demands for real-time performance and accuracy. By embedding an intelligent collection module into the network system, devices can assess the importance of collection targets based on specific recognition rules. During communication monitoring, the intelligent module can rapidly filter out potentially anomalous content according to packet frequency, protocol characteristics, or behavioral patterns, without indiscriminately extracting all data. This on-demand collection mechanism reduces processing volume, minimizes data redundancy, and improves system response speed. In IoT scenarios, sensors can use edge algorithms to preliminarily evaluate data and upload only valuable data segments, alleviating pressure on core servers. Moreover, a multi-point distributed collection architecture supports task synchronization or scheduling optimization; when some nodes experience delays, other nodes can take over collection tasks according to system policy, ensuring continuous network operation. During data aggregation, the system automatically identifies format differences and performs unified structural transformation, preventing information loss due to format conflicts during transfer. The entire collection process is coupled with a big-data analytics platform, which provides real-time feedback on collection quality and assists operators in adjusting collection strategies. With a robust technical framework, the intelligent collection system enhances data acquisition efficiency and network stability, enabling the network to better handle complex application scenarios (see Figure 1).

Figure 1: Flowchart of the Intelligent Collection System Operation

3.2 Apply Deep Learning Techniques to Optimize Network Operation Logic

Applying deep learning technology can effectively optimize the operational logic of computer network systems and enhance overall decision-making efficiency. Deep learning relies on multi-layered neural architectures to autonomously extract data features, enabling it to distill patterns from historical operational data and provide precise judgment bases under complex network conditions. Leveraging models generated through training, the system can automatically adjust routing choices, traffic control, or resource allocation schemes under varying conditions, reducing human intervention. The decision-making process can dynamically correct itself based on data correlations, ensuring consistent responsiveness when the network faces high-concurrency requests, node fluctuations, or anomalous data. The continuous optimization capability of deep learning also safeguards the system's adaptability over long-term operation, supporting the evolution of network intelligence.

3.3 Strengthen Multi-Source Data Fusion to Enhance Intelligent Judgment

Strengthening multi-source data fusion can improve the intelligent judgment capability of computer network systems. In complex data environments, information sources may differ in format, be structurally dispersed, or suffer transmission delays; judgments based on a single source are prone to bias. Integrating big-data technologies with AI algorithms helps bridge logical gaps between data, allowing the system to extract higher-quality comprehensive information through horizontal integration. Under a unified logic, multi-source data undergoes screening that enables algorithms to recognize intrinsic relationships among patterns and reduce misjudgments. The accuracy of intelligent judgment depends on the completeness of information; by fusing structured, semi-structured, and unstructured data, the system can obtain decision-making references from multiple dimensions and enhance its ability to handle complex network behaviors.

During network operation, collected data may originate from routing nodes, sensor devices, or user actions, and the content attributes and format specifications of these data types vary widely; direct use can fragment processing logic. Through fusion strategies, the system can reorganize information such as protocol logs or operational states according to unified standards before feeding it into AI models for deep analysis. Take network scheduling tasks as an example: judging node load status based solely on transmission-rate data may not accurately reflect reality. When user request frequency, historical traffic trends, and current processing delays are all incorporated, the judgment basis becomes more solid and the output closer to real needs. In security protection, fusing access behaviors, anomalous fluctuations, or protocol features from multiple sources can raise the success rate of attack identification and lower system exposure risk. By learning from these composite data inputs, AI models can extract high-frequency correlation features and establish logically rigorous judgment mechanisms. In service-oriented network environments, different service types have distinct requirements for bandwidth, latency, or reliability; fusing multi-source data allows the scheduling system to precisely identify service characteristics and generate more adaptive resource-allocation strategies. Data cleaning, matching, and standardization during fusion reduce interference from erroneous inputs and improve model-training quality. Through continuous data fusion, the system shifts from single-point responses to multi-dimensional collaboration, achieving higher decision efficiency and accuracy and steadily elevating the intelligence level of network operations (see Figure 2).

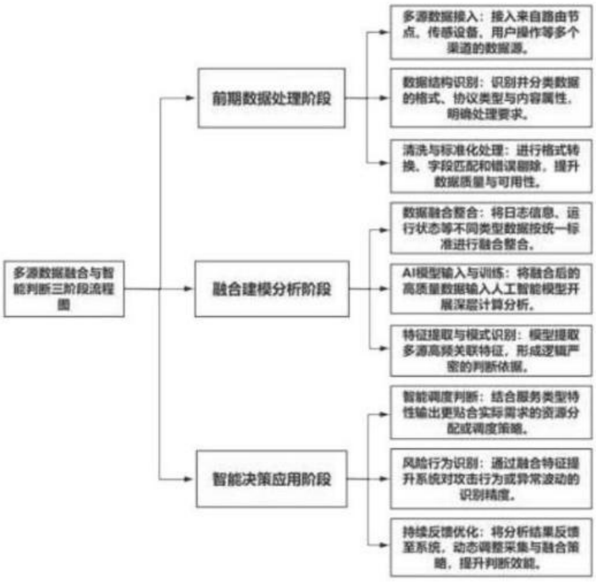

Figure 2: Three-Stage Flowchart of Multi-Source Data Fusion and Intelligent Judgment

3.4 Improve Intelligent Security Mechanisms to Raise Network Protection Levels

Big-data technologies enable systems to uncover latent anomalous features during high-frequency interactions, while artificial intelligence, leveraging trained models, identifies risk patterns to deliver earlier and more accurate warnings. Security mechanisms can employ intelligent algorithms for behavioral recognition or automated response. The system can adjust its defense strategies in real time based on historical attack paths or the current network state, compressing the attack window. Enhanced recognition accuracy equips security mechanisms with proactive judgment, allowing remediation before an attack spreads, thereby safeguarding the overall stability of the network.

Security threats faced by network systems are characterized by high frequency and rapid propagation, making traditional signature-centric protection inadequate. By introducing intelligent analysis, the system can collect multidimensional data in real time—such as endpoint access logs, communication states, and protocol requests—and process them in parallel on a big-data platform. On this foundation, AI models learn specific behavioral patterns and build an attack-feature database, endowing the system with pattern-matching or deep-reasoning capabilities when identifying unknown threats. The system can detect overt risky behaviors like repeated access and high-speed scanning, as well as covert attack signals such as low-frequency distribution, irregular paths, and disguised communications. During processing, the model comprehensively evaluates behavioral intent, communication anomalies, or response delays, outputting risk levels and remediation recommendations. If unexpected data fluctuations occur on a local device, the intelligent mechanism automatically blocks communication ports or reconstructs routing logic based on analysis results, preventing further threat spread. Additionally, the security mechanism supports event-data backtracking and dynamic rule adjustment, enabling continuous optimization after an attack. Data resources serve not only as monitoring evidence but also participate in updating intelligent rules, forming a closed-loop management system. Building an intelligent security mechanism improves the network's response efficiency to known risks, enables reasonable judgments against novel attack methods, establishes a security baseline at the system level, and supports reliable operation in highly complex communication environments.

4. CONCLUSION

The deep integration of big-data and artificial-intelligence technologies can propel computer network systems from data-driven to intelligence-led evolution. The two exhibit high synergy across multiple dimensions such as information perception and risk protection, enhancing network efficiency and expanding system adaptability in complex scenarios. Network architectures gain higher-level self-organizing capabilities through intelligent algorithms, while data resources release stronger decision-making value under the fusion mechanism. Future network evolution will be supported by higher-precision data-recognition capabilities and more comprehensive security systems, establishing an intelligent infrastructure endowed with learning and judgment capabilities.

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