

Network Engineering in the Era of AI: A Technical Review

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Abstract: Network engineering has undergone a fundamental transformation with the integration of artificial intelligence technologies, shifting from traditional reactive management practices to proactive, data-driven network optimization paradigms. This technical review explores how modern network engineering professionals must master an intricate blend of theoretical knowledge and practical implementation skills across networking protocols, hardware architectures, and software systems while simultaneously developing competencies in machine learning algorithms and automated decision-making systems. The transformation involves multiple organizational scenarios, including enterprise networks focused on reliability and security compliance, service provider scenarios that deal with a level of routing complexity at scale, and cloud environments that require virtualization and elastic scalability. AI-driven transformation will allow network engineers to analyze large quantities of telemetry data through advanced behavioral recognition, implement predictive maintenance, and perform automated optimization of their networks for improved performance. In the future, the work of network engineers will involve operating and overseeing AI systems, making educated decisions for interpreting algorithmic recommendations, and continuing to research and learn new technologies. The transformation is not taking away expertise, but enhancing it for professionals to approach more intricate network problems and have oversight into autonomous intelligent network infrastructure that is able to self-optimize, self-heal, and adapt dynamically to changes in demand.

Keywords: Artificial intelligence networks, network engineering transformation, machine learning optimization, predictive maintenance systems, human-AI collaboration.

INTRODUCTION

Network engineering is one of the rare and advanced fields of network operation in modern information and technology infrastructure; the global artificial intelligence networks market has expanded rapidly because of the demand for intelligent network management and the rise in connected devices in virtually every sector and industry (Size, A. I. H. M. 2024). As organizations have come to rely on highly reliable, scalable, and robust network systems, network engineers have shifted from traditional networking configuration and troubleshooting to a more advanced data-driven emphasis on methodologies facilitated by artificial intelligence. This technical review will review the new landscape of network engineering practice with the introduction of AI, and how traditional skills from network engineering will relate to new AI techniques and processes for network design, optimization, and management.

The technology-enabled use of AI in network engineering is transforming how engineers operate, moving towards proactive or intelligent network orchestration, instead of purely reactive networking problem-solving skills. Current research suggests that there are multiple dimensions of artificial intelligence integration in network technology, including automated network configuration, intelligent traffic management, predictive maintenance, and autonomous fault detection systems (Mahesa, G. *et al.*, 2025). This means that the field of network engineering is undergoing an evolution that necessitates

traditional networking skills and knowledge, as well as machine learning algorithms, data analytics, and automated decision-making systems.

The intricacy of modern networks is unprecedented; large enterprise environments manage/connect many hundreds of thousands of wired, wireless, IoT, and BYOD devices – all of which are continuously creating massive amounts of telemetry data. The scale of the situations to be managed means traditional manual analysis is not only ineffective for the amount of information present, but artificial intelligence is required to track network behavior patterns, closely predict failure rates with high confidence, and intelligently adjust network configurations in real-time. Moving from reactive to predictive approaches in network management clearly shows improvements in reliability, efficiency, and cost across a variety of organizations and environments.

Recent changes in network professional work habits have created a scenario where machine learning algorithms or approaches work with traditional networking protocols and create a new hybrid environment that blends human and artificial intelligence. The process involves sophisticated data collection methods, analytics platforms, and automated systems that respond to changing network scenarios without the aid of analysis or input from a person. The industry convergence presents new opportunities for network enhancement, while also causing new

complications about algorithms, reliability, and performance assurances.

The emergence of AI-based networks has transformed the traditional skillsets of networking professionals, and the appropriate combinations of skill sets that are required in a rapidly changing skill environment are network engineering skillsets and AI-based machine learning algorithms. Engineers need an understanding of how AI systems consume and ingest network data, and how to use the recommendations built on algorithms and control or govern the autonomous decisions they produce. This evolution isn't just a new iteration of technology, but rather a true paradigm shift into intelligent network infrastructure that will be self-optimizing, self-healing, support dynamic new requirements, and still rely on human skills for planning direction, architectural evolution, and complex problem-solving.

CORE COMPONENTS OF NETWORK ENGINEERING SKILLSET

Network engineering embodies a multifaceted technical space, requiring practitioners to blend theoretical information and practical execution knowledge over many variations of networking protocols and standards in active use today (Yasar, K. and Goss, M. 2025). The field exists on three main pillars: networking protocols, network device hardware, and network software systems, where at the professional level, a great deal of specialized training and practical experience is required across the three categories.

Networking Protocols Mastery

At the protocol level, network engineers must possess a deep understanding of how various communication standards interact across different layers of the OSI model, with modern enterprise networks implementing multiple protocols simultaneously for different functions. This includes mastery of routing protocols such as BGP for inter-domain routing between autonomous systems, OSPF for intra-domain routing with hierarchical network designs, and EIGRP for advanced distance vector routing with rapid convergence capabilities. Switching technologies, including VLANs for network segmentation and spanning tree protocols for loop prevention, demonstrate the complexity engineers must navigate (Yasar, K. and Goss, M. 2025).

Emerging software-defined networking protocols like OpenFlow have introduced new paradigms

requiring protocol expertise that extends beyond basic configuration to encompass flow table management and centralized control plane operations. Network engineers need to understand how protocol selections can impact network convergence behavior, bandwidth utilization patterns, and overall system resilience. Protocol knowledge becomes ever important at the point of network design supporting multiple applications with different load profiles, such as real-time network communications, bulk data transfers, and mission-critical business applications, while monitoring performance characteristics in various traffic states.

Hardware Architecture and Restrictions

Network devices' hardware offers yet another layer of complexity that differentiates expert network engineers from novice engineers, as modern high-speed networking infrastructure includes highly-specialized ASICs for each operation that forward packets at astonishingly high speeds while maintaining very low latency characteristics. Knowledge of hardware aspects can become crucial in network designs that require network support for large-scale routing tables, buffered memory distributions, and high port operations for modern modular systems.

Contemporary network hardware demonstrates sophisticated integration between specialized silicon architectures and software-defined capabilities, creating new opportunities for network customization while introducing additional complexity in troubleshooting and optimization processes. Modern network infrastructure increasingly incorporates programmable elements enabling custom packet processing capabilities, while requiring specialized expertise in both traditional networking concepts and contemporary software development methodologies (STL Tech, 2022).

Network Software Systems

The software component encompasses network operating systems supporting extensive configuration parameters, management platforms capable of monitoring large-scale network deployments, and increasingly, containerized network functions achieving rapid deployment compared to traditional hardware-based implementations. Engineers must navigate proprietary vendor ecosystems while understanding open-source alternatives, with cloud-native networking solutions demonstrating

significant cost advantages compared to traditional architectures.

Configuration management systems supporting extensive device populations require automation frameworks capable of processing high volumes of configuration changes, while API-driven network control mechanisms handle substantial transaction volumes in large-scale deployments. The

integration of software-defined approaches has created hybrid environments where traditional command-line interface configuration coexists with modern RESTful APIs, requiring engineers to master both paradigms while maintaining stringent network reliability standards across diverse organizational contexts.

Table 1: Technical Skillset Requirements and Implementation Domains (Yasar, K. and Goss, M. 2025; STL Tech, 2022)

Component Category	Key Technologies & Protocols	Technical Characteristics & Requirements
Routing Protocols	BGP, OSPF, EIGRP	Inter-domain and intra-domain routing with hierarchical network designs, advanced distance vector routing with rapid convergence capabilities, and global routing table management
Switching & SDN	VLANs, Spanning Tree, OpenFlow	Network segmentation, loop prevention mechanisms, centralized control plane operations with flow table management, and software-defined networking paradigms
Hardware Architecture	ASICs, Programmable Switches, Modular Systems	Specialized packet forwarding silicon, high-performance processing with minimal latency, programmable elements for custom packet processing, hardware-software integration
Network Software	Network OS, Management Platforms, APIs	Extensive configuration parameter support, large-scale monitoring capabilities, containerized network functions, and automation frameworks with API-driven control mechanisms

ORGANIZATIONAL CONTEXTS AND CHALLENGES

Various organizational environments face distinct obstacles and learning experiences that influence network engineering practices. For example, enterprise networks facing large endpoint populations, service provider networks that connect a large number of customers, and cloud environments that expand to support massive virtualization of instances across geographically distributed data centers (Yang, H. *et al.*, 2017). While these diverse environments require engineers to adapt their approaches and methodologies, the fundamental networking skills and competencies remain transferable across enterprise, service provider, and cloud contexts.

Enterprise Network Environments

Enterprise networks prioritize stringent reliability targets, comprehensive security compliance with established standards such as regulatory frameworks, and predictable performance metrics, including minimal latency requirements for critical applications and guaranteed bandwidth allocation across organizational departments based on operational needs. Network engineers in enterprise environments must balance significant cost constraints for network infrastructure with demanding performance requirements while

ensuring compliance with extensive regulatory standards involving numerous security policies and corporate governance frameworks.

These networks typically feature complex segmentation requirements supporting extensive VLAN implementations, diverse endpoint ecosystems including substantial IoT device populations, and integration with legacy systems representing major portions of total infrastructure investments that cannot be easily replaced due to business continuity requirements (Yang, H. *et al.*, 2017). Enterprise networks handle substantial daily traffic volumes per employee, with peak utilization during business hours reaching high percentages of available bandwidth capacity across the organization.

The real challenge is to create networks that can support both traditional enterprise applications that require deterministic performance characteristics and modern cloud-integrated services with more dynamic scaling needs, while ensuring that advanced micro segmentation and zero-trust architectural principles can create strict security boundaries. Engineers must design for predictable traffic patterns while accommodating more periodic high-demand scenarios, such as software updates on a large scale, backups that take considerable time, and business fluctuations during

seasonal operational peaks that create significant traffic differences between peaks and valleys.

Service Provider Networks

Service provider environments demand expertise in large-scale routing, managing extensive BGP routing tables, sophisticated traffic engineering across networks supporting massive aggregate capacity, and complex multi-tenant service delivery, maintaining stringent availability commitments with minimal repair time targets. These networks must support diverse customer requirements ranging from residential broadband services to enterprise customers requiring dedicated high-capacity circuits with strict latency guarantees for specialized applications such as financial trading systems.

The scale considerations include managing complex core router configurations, optimizing traffic flows across numerous autonomous systems per major provider, and implementing comprehensive quality of service mechanisms supporting multiple service classes, ensuring equitable resource allocation among customers consuming substantial aggregate bandwidth during peak operational hours (Afolalu, O., & Tsoeu, M. S. 2025). Network utilization typically operates at moderate average capacity levels with engineered headroom to accommodate substantial annual traffic growth while maintaining strict performance commitments.

Network engineers in service provider environments must understand the significant economic implications of their design decisions, with capital expenditure optimization requirements for subscriber access infrastructure and core transport capacity, while balancing operational efficiency requirements, achieving high network automation levels, and demanding service quality standards. This includes expertise in comprehensive network planning supporting substantial customer growth projections, capacity forecasting with extended lead times for equipment procurement, and technology evolution strategies implementing advanced technologies regularly to maintain competitive market positioning.

Cloud Network Architectures

Cloud networks present unique challenges related to extensive virtualization capabilities, elastic scaling, handling dramatic traffic variations between minimum and peak loads, and sophisticated multi-tenancy architectures serving massive concurrent user populations per application instance. Engineers must understand how traditional networking concepts translate to virtualized environments, managing complex overlay networks, advanced container networking, and intricate microservices communication patterns, generating substantial API interactions between distributed application components.

Table 2: Network Environment Characteristics and Engineering Requirements (Yang, H. *et al.*, 2017; Afolalu, O., & Tsoeu, M. S. 2025)

Network Environment	Technical Requirements & Scale Characteristics	Primary Engineering Challenges & Solutions
Enterprise Networks	Stringent reliability targets, comprehensive security compliance frameworks, minimal latency requirements for critical applications, guaranteed bandwidth allocation across departments	Complex segmentation with extensive VLAN implementations, integration with legacy systems, balancing cost constraints with performance requirements, microsegmentation, and zero-trust architectures
Service Provider Networks	Large-scale BGP routing table management, massive aggregate capacity support, multi-tenant service delivery with stringent availability commitments, diverse customer requirements from residential to enterprise	Traffic engineering across numerous autonomous systems, comprehensive QoS mechanisms, economic optimization of capital expenditure, capacity forecasting with extended equipment procurement lead times
Cloud Network Architectures	Extensive virtualization capabilities, elastic scaling with dramatic traffic variations, sophisticated multi-tenancy serving massive concurrent user populations, complex overlay network management	Traditional networking concept translation to virtualized environments, advanced container networking, microservices communication pattern optimization, API-driven infrastructure management
Hybrid	Integration of enterprise, cloud, and	Cross-platform compatibility, unified security

Environments	service provider network elements, unified management across diverse infrastructure types, consistent performance across heterogeneous platforms	policy enforcement, seamless connectivity between different network paradigms, and comprehensive monitoring across diverse technologies
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AI-DRIVEN TRANSFORMATION IN NETWORK ENGINEERING

The integration of artificial intelligence into network engineering practices represents a paradigm shift from traditional reactive management approaches to proactive, data-driven network optimization, with organizations implementing AI-driven network management reporting significant reductions in mean time to resolution and substantial improvements in overall network performance metrics (Aslam, S., & Fatima, T. 2025). This transformation leverages machine learning algorithms processing extensive volumes of network telemetry data daily, predictive analytics achieving high accuracy rates for failure prediction, and automated decision-making systems capable of executing numerous configuration changes per hour to enhance network performance, reliability, and operational efficiency.

Data-Driven Performance Analysis

AI enables network engineers to process vast quantities of network telemetry data per large enterprise network that would be impossible to analyze manually, with machine learning algorithms capable of analyzing extensive network events per second in real-time processing environments. Machine learning algorithms can identify patterns in network behavior across multiple performance metrics simultaneously, correlate performance metrics across multiple network layers involving comprehensive OSI analysis, and detect subtle performance degradations before they impact user experience measured through application response time thresholds (Aslam, S., & Fatima, T. 2025).

This capability transforms network monitoring from threshold-based alerting, generating numerous alerts daily in traditional systems, to sophisticated behavioral analysis that considers historical trends spanning extended periods of data, seasonal variations with high pattern recognition accuracy, and complex interdependencies involving multiple network components per correlation analysis. Machine learning models achieve substantial false positive reduction rates compared to traditional threshold-based monitoring systems while maintaining

detection sensitivity for genuine performance issues.

By observing actual traffic patterns with fine granularity intervals, application behaviors with hundreds of individual applications per network, and network response characteristics measured in precise time intervals, AI systems can recommend configuration changes that involve multiple parameter changes, capacity changes that predict demand months in advance, and architectural changes that significantly improve the performance of an overall network in well-configured deployments.

Anomaly Detection and Predictive Maintenance

AI-based anomaly detection systems have good detection accuracy rates, which makes them effective at recognizing unusual network behaviors that could signal security threats, equipment failures, or configuration errors, and can process baseline behavior models based on long periods of historical performance data. These systems learn normal network operation patterns, analyzing extensive behavioral parameters and flag deviations exceeding established statistical thresholds from baselines that warrant investigation, significantly reducing the time required to identify network issues and resolve network problems with substantially faster resolution times compared to traditional manual troubleshooting approaches.

Predictive maintenance capabilities leverage machine learning algorithms analyzing equipment performance trends across multiple sensor measurements including temperature, power consumption, packet loss rates, and error counters, environmental conditions monitoring numerous parameters such as humidity, temperature variations, and power quality metrics, and historical failure patterns spanning multiple years of operational data to predict when network components are likely to require maintenance or replacement with high accuracy rates and extended prediction horizons (Turn-Key, 2025). This proactive approach minimizes unplanned outages, achieving a substantial reduction in unexpected downtime while optimizing maintenance scheduling and resource allocation, improving technician productivity significantly.

Automated Network Optimization

AI systems can automatically adjust network configurations, implementing extensive parameter changes per optimization cycle to optimize performance based on current conditions measured at regular intervals and predicted future requirements forecasted hours in advance. This includes dynamic routing adjustments, updating

substantial routing table entries, bandwidth allocation modifications affecting multiple network segments simultaneously, and quality of service parameter tuning involving multiple traffic classes that respond to changing network conditions in real-time with rapid response times for configuration deployment.

Table 3: Machine Learning Applications and Performance Enhancement in Modern Networks (Aslam, S., & Fatima, T. 2025; Turn-Key, 2025)

AI Application Domain	Technical Capabilities & Implementation Features	Performance Impact & Operational Benefits
Data-Driven Performance Analysis	Real-time processing of extensive network telemetry data, machine learning algorithms analyzing multiple performance metrics simultaneously, pattern identification across network behavior with high granularity intervals	Substantial false positive reduction compared to traditional threshold-based systems, empirical evidence-based optimization decisions, significant network performance improvements in properly implemented deployments
Anomaly Detection Systems	High accuracy detection of unusual network behaviors, baseline behavior model processing with extended historical performance data, and statistical threshold analysis for deviation identification	Dramatically reduced time for network issue identification, substantially faster problem resolution compared to manual troubleshooting approaches, enhanced security threat detection capabilities
Predictive Maintenance	Machine learning analysis of equipment performance trends across multiple sensor measurements, environmental condition monitoring, and historical failure pattern analysis spanning multiple years of operational data	Substantial reduction in unexpected downtime, optimized maintenance scheduling and resource allocation, significantly improved technician productivity, and cost reduction
Automated Network Optimization	Dynamic configuration adjustments with extensive parameter changes per optimization cycle, real-time routing table updates, and bandwidth allocation modifications affecting multiple network segments simultaneously	Rapid response times for configuration deployment, intelligent workload distribution across network infrastructure, and substantial reduction in over-provisioning compared to traditional approaches
Real-Time Decision Making	Automated decision-making systems executing numerous configuration changes per hour, predictive analytics with high accuracy rates, and continuous monitoring with precise measurement intervals	Proactive network management paradigm shift from reactive approaches, enhanced network reliability and operational efficiency, substantial improvements in mean time to resolution metrics

THE FUTURE ROLE OF NETWORK ENGINEERS IN AI-ENABLED NETWORKS

While artificial intelligence automates many traditional network engineering tasks, the fundamental need for skilled network engineers remains critical and becomes increasingly sophisticated, with industry projections indicating that the majority of network engineering positions will require AI competency in the coming years and organizations reporting substantial increases in demand for hybrid AI-networking expertise (Atul, 2025). The role evolution requires engineers to

develop extensive new competencies while maintaining deep technical expertise in networking fundamentals, with professional development programs requiring significant specialized training to achieve competency in AI-enabled network management.

AI System Oversight and Management

Network engineers must develop expertise in managing AI systems, understanding how machine learning algorithms process extensive network parameters and make decisions, while recognizing when human intervention becomes necessary. This includes configuring AI systems that support

multiple machine learning models simultaneously, interpreting their recommendations, and overriding automated decisions when circumstances require expert judgment in mature AI-enabled network environments (Atul, 2025).

The oversight role requires understanding the limitations and biases of AI systems achieving high accuracy in standard operational scenarios but potentially experiencing degraded performance during network anomaly conditions, ensuring that automated decisions align with organizational objectives and technical requirements across diverse business unit priorities. Engineers must develop skills in AI system troubleshooting, requiring expertise in multiple diagnostic methodologies, model performance evaluation, analyzing accuracy metrics updated frequently, and continuous improvement processes, such as implementing numerous model refinements that enhance AI effectiveness significantly per iteration cycle.

Modern AI-enabled networks require engineers to manage machine learning pipelines processing substantial volumes of training data daily, maintain model accuracy through regular retraining cycles, and coordinate between multiple AI subsystems, including anomaly detection, performance optimization, predictive maintenance, and capacity planning modules. The complexity of AI system management demands that engineers possess an understanding of data science principles, statistical analysis capabilities, and algorithmic transparency requirements to ensure explainable AI decisions for regulatory compliance and operational reliability.

Interpretation and Strategic Decision Making

AI systems excel at processing data, analyzing extensive network events daily, and identifying patterns across numerous network performance variables, but human expertise remains essential for interpreting results within broader organizational contexts and making strategic decisions about network architecture, requiring substantial capital investments and investment priorities spanning multi-year technology refresh cycles. Network engineers must translate AI insights processing extensive optimization recommendations into actionable strategies that consider business requirements, technological constraints, and future growth plans supporting

significant traffic growth projections (Bhupathi, K. K., & RS, I. 2025).

This interpretive role requires enhanced communication skills enabling engineers to explain AI-driven recommendations to stakeholders across multiple organizational levels who may not possess technical networking expertise, with presentation requirements ranging from brief executive briefings to comprehensive technical documentation. The ability to bridge technical complexity with business objectives becomes increasingly valuable as AI systems generate sophisticated analysis involving numerous variables per recommendation and predictive models forecasting network requirements months in advance.

Strategic decision-making capacities need to include the ability to understand AI recommendation confidence levels, the ability to understand risk for automating implementations that affect a large user base on a network, and the ability to understand the cost-benefit of AI-initiated proposed changes to infrastructure with long ROI timelines. Engineers act as facilitators, which means they must consider, assess, and ensure AI recommendations fit an organization's acceptable risk tolerance, budgets, and timelines for strategic tech roadmaps.

Innovation and Continuous Learning

Network engineers are faced with evolving AI technologies. It is increasingly pertinent that they engage in continuous learning in order to remain effective in their role, investing significant amounts of time into professional development and innovation activities as technology environments continue to refresh quickly, especially for AI-enabled components of networks. Continuing professional development is necessitated by more than understanding of AI as technology refresh cycles quicken, network engineers also need to remain cognizant of broadly emerging techniques in AI, such as federated learning, edge based computing technologies, and quantum-resistant algorithms, understand the implications of how new machine learning techniques can lead to employee and stakeholder based solutions across a network when applied to networking challenges with many use cases, and by being engaged in next generation practices through professional organization membership and participation in industry standards committees.

Table 4: Professional Competency Evolution and Human-AI Collaboration Framework (Atul, 2025; Bhupathi, K. K., & RS, I. 2025)

Role Competency Domain	Technical Requirements & Skill Development	Professional Impact & Strategic Value
AI System Oversight	Management of AI systems processing extensive network parameters daily, configuration of multiple machine learning models simultaneously, interpretation of numerous optimization suggestions, expertise in diagnostic methodologies, and model performance evaluation	Enhanced decision-making capabilities with high accuracy in standard operations, significant AI effectiveness improvements through continuous refinement processes, and regulatory compliance through explainable AI decisions
Strategic Interpretation	Translation of AI insights processing extensive optimization recommendations into actionable strategies, enhanced communication skills for stakeholder engagement across multiple organizational levels, risk assessment for automated implementations	Bridge between technical complexity and business objectives, alignment of AI recommendations with organizational risk tolerance and budgetary constraints, and strategic technology roadmap development
Innovation & Learning	Continuous learning investment in professional development activities, expertise in emerging AI techniques, including federated learning and edge computing integration, and contribution to next-generation network engineering practices	Accelerated technology refresh cycles for AI-enabled components, application of machine learning approaches to extensive networking use cases, leadership in professional organizations, and industry standards
Human-AI Collaboration	Coordination between multiple AI subsystems, including anomaly detection and predictive maintenance, understanding of data science principles and statistical analysis capabilities, and management of machine learning pipelines	Sophisticated network topology management involving multiple technology domains simultaneously, substantial efficiency improvements in network operations, and problem resolution time reduction from hours to minutes
Professional Development	Specialized training for AI-enabled network management competency, maintenance of certifications in traditional networking and emerging AI specializations, hands-on experience with extensive network endpoint management	Role evolution requiring hybrid AI-networking expertise, competitive advantages through operational cost reductions, achievement of enhanced network performance, and availability targets

CONCLUSION

The onset of artificial intelligence in the area of network engineering will signal a major shift that improves human skill, not replace it. This shift will enable a degree of proactive network management, performance optimization, and fault resolution possibilities that are not currently available at a manual level. The need to have the human skill to manage, monitor, and translate AI systems into real use will ensure that human skill will remain the backbone of network engineering proficiency, although that proficiency is rapidly evolving. Today's network professionals will develop hybrid skills that combine technical knowledge related to the network and a deep understanding of machine learning, data analytics, and automated decision systems. The enterprise, service provider, and

cloud contexts of previous organizational environments will present a landscape of unique challenges that require tailored approaches while maintaining effective technical skills. Emerging Network engineers will function in dual ways as both a technical professional and an AI partner, taking AI/ML recommendations from the AI partner and converting the recommendations into organizational strategies while also ensuring that the intelligent network infrastructure operates seamlessly and consistently in the background and cost-effectively. These emerging network engineers will succeed in this role in particular if they embrace the fact that AI will help transform the role of the network engineer, and have extensive knowledge of the networking discipline and how to design powerful, scalable, and

intelligent network infrastructures to enable increasingly complex needs for an interconnected digital ecosystem.

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