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TEMPORAL QUANTUM VULNERABILITY FORECASTING SYSTEM WITH AUTOMATED QUANTUM-SAFE MIGRATION PLANNING

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CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not Applicable - This is the first filing in this patent family.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable

REFERENCE TO SEQUENCE LISTING

[0003] Not Applicable

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0004] This invention relates to defensive cybersecurity systems, specifically to predictive AI agent platforms for quantum vulnerability landscape assessment and automated migration to quantum-resistant protection within the Mathematical Woven Responsive Adaptive Swarm Platform (MWRASP Total).

2. Description of Related Art

[0005] The quantum computing revolution presents unprecedented challenges to current cryptographic infrastructure. As quantum computers advance toward practical implementation, organizations face a critical timeline for transitioning to quantum-resistant algorithms. Current quantum processors from IBM, Google, and IonQ have demonstrated capabilities ranging from 127 to 433 qubits, with coherence times improving from microseconds to milliseconds. Industry projections suggest cryptographically relevant quantum computers capable of breaking RSA-2048 and ECC-256 will emerge within 5-15 years.

[0006] The vulnerability landscape assessment reveals three critical phases of quantum threat evolution. Phase One (2024-2028) involves limited quantum advantage in specific optimization problems with minimal cryptographic impact. Phase Two (2028-2033) introduces intermediate-scale quantum computers capable of threatening certain elliptic curve implementations. Phase Three (2033-2040) brings fault-tolerant quantum computers that can execute Shor's algorithm against current public-key cryptography standards.

[0007] Existing vulnerability assessment tools employ static analysis methodologies that fail to account for the temporal nature of quantum threats. IBM's patent US20240073226A1 describes a quantum risk assessment framework but lacks predictive modeling capabilities for future quantum advancement. PKWARE's assessment tools provide point-in-time analysis without continuous learning or automated migration planning. Traditional vulnerability management systems like Qualys VMDR and Tenable.io focus on current vulnerabilities without considering quantum timeline projections.

[0008] Static approaches suffer from several critical deficiencies in addressing quantum threats. First, they cannot predict the acceleration or deceleration of quantum computing progress based on emerging research breakthroughs. Second, they fail to correlate organizational cryptographic dependencies with quantum capability timelines. Third, they lack automated mechanisms for planning and executing migration to quantum-safe algorithms. Fourth, they cannot assess the compound risk of maintaining vulnerable systems across extended timeframes.

BRIEF SUMMARY OF THE INVENTION

[0009] The present invention introduces a novel temporal modeling approach for quantum vulnerability landscape assessment through defensive AI agents integrated within the MWRASP (Total) platform. Unlike static vulnerability assessment tools, this system employs continuous learning algorithms that adapt to emerging quantum computing developments, providing organizations with actionable intelligence for safeguarding digital assets against future quantum threats.

[0010] The core innovation centers on Multi-Dimensional Quantum Threat Space (MQTS) modeling, which maps quantum computing capabilities across multiple parameters including qubit count, coherence time, gate fidelity, and error rates. This multi-dimensional approach enables more accurate prediction than single-metric models by capturing the complex interactions between quantum computing components. The MQTS model incorporates temporal evolution functions that project capability advancement along each dimension, with confidence intervals derived from historical progression patterns and expert assessments.

[0011] The Bayesian Quantum Capability Estimator represents a breakthrough in predictive accuracy through its continuous learning architecture. The estimator ingests diverse data streams including academic preprints, patent applications, vendor announcements, and quantum cloud service metrics. Bayesian inference updates prior probability distributions as new evidence emerges, enabling the system to adapt to breakthrough discoveries or unexpected setbacks in quantum development. The estimator maintains separate models for different quantum computing paradigms, recognizing that gate-based, annealing, and topological systems present distinct threat timelines.

[0012] The Cryptographic Vulnerability Timeline Generator translates quantum capability predictions into specific vulnerability windows for cryptographic algorithms. The generator maintains a comprehensive database of cryptographic implementations including key sizes, algorithm parameters, and security margins. By correlating quantum capabilities with known quantum algorithm complexities, the system produces temporal vulnerability maps showing when specific cryptographic protections will become compromised. These timelines account for both theoretical algorithm execution and practical implementation considerations including error correction overhead.

[0013] The Automated Migration Orchestrator revolutionizes quantum-safe transition planning through risk-based prioritization algorithms. The orchestrator analyzes organizational cryptographic dependencies, identifying critical paths and potential migration conflicts. Risk scores combine vulnerability timeline proximity, data sensitivity classifications, and operational impact assessments. The system generates optimized migration schedules that minimize business disruption while ensuring protection before vulnerability windows open.

DETAILED DESCRIPTION OF THE INVENTION

System Architecture Overview

[0014] The Temporal Quantum Vulnerability Forecasting System comprises multiple interconnected defensive AI agent modules operating within the MWRASP (Total) platform's distributed architecture. Each AI agent specializes in specific aspects of quantum threat prediction and migration planning while contributing to collective intelligence through shared learning mechanisms.

[0015] The primary architectural layers include the Data Ingestion Layer, which continuously harvests quantum computing intelligence from diverse sources; the Prediction Engine Layer, where multiple AI agents perform temporal modeling and capability forecasting; the Risk Assessment Layer, which evaluates organizational vulnerabilities against predicted quantum timelines; the Migration Planning Layer, responsible for orchestrating quantum-safe transitions; and the Execution and Monitoring Layer, which implements migration plans while tracking effectiveness.

Mathematical Models for Quantum Capability Prediction

[0016] The Multi-Dimensional Quantum Threat Space (MQTS) employs a tensor-based mathematical framework for modeling quantum computing evolution:

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T(t) = [Q(t), C(t), F(t), E(t), A(t)]
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[0017] Where Q(t) represents qubit count projection at time t, C(t) denotes coherence time in microseconds, F(t) indicates gate fidelity percentage, E(t) signifies error rate per operation, and A(t) represents algorithm efficiency factor.

[0018] The temporal evolution of each dimension follows modified logistic growth curves with stochastic perturbations:

$$Q(t) = Qmax / (1 + e^{(-k(t-t0))}) + \sigma(t)$$

[0019] Where Qmax represents the theoretical maximum qubits (estimated 10^6), k denotes the growth rate coefficient (0.3-0.5 annually), t0 indicates the inflection point (estimated 2028-2032), and σ(t) represents the stochastic noise term.

Machine Learning Algorithms for Threat Detection

[0020] The system employs ensemble learning combining multiple algorithm families for robust prediction. Long Short-Term Memory (LSTM) Networks capture temporal dependencies in quantum advancement patterns. The architecture includes an input layer with 256 features from quantum metrics, three LSTM layers with 512, 256, and 128 units respectively, multi-head attention mechanisms with 8 heads, and an output layer generating quantum capability predictions.

[0021] Gradient Boosting Regression Trees (GBRT) model non-linear relationships between research indicators and capability advancement. The system uses 1000 estimators with maximum depth 10, adaptive learning rate scheduling starting at 0.01, features including patent citations, funding levels, and publication velocity, with L2 regularization (α=0.1) to prevent overfitting.

Vulnerability Assessment Algorithms

[0022] The Cryptographic Vulnerability Timeline Generator employs quantum algorithm complexity analysis to determine when specific cryptographic protections become vulnerable. For Shor's algorithm, the system calculates resource requirements including logical qubits (2n+2 for n-bit integers), physical qubits accounting for error correction overhead (1000-10000x multiplier), gate operations scaling as $O(n^3)$, and coherence time requirements proportional to $O(n^3)$ multiplied by gate time.

[0023] The system evaluates post-quantum algorithm resistance through a comprehensive scoring mechanism:

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Resistance(alg) = base_score * maturity_factor *
                  implementation_quality
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[0024] Where base_score reflects NIST security levels (1-5), maturity_factor represents years since standardization divided by 10, and implementation_quality denotes audit scores ranging from 0 to 1.

Migration Orchestration Strategies

[0025] The Automated Migration Orchestrator implements sophisticated scheduling algorithms to minimize disruption while ensuring timely protection. The system constructs dependency graphs where vertices represent cryptographic implementations and directed edges indicate dependencies. Through topological sorting with cycle detection, the orchestrator determines optimal migration sequences that respect dependency constraints.

[0026] Risk-based priority calculation combines multiple factors:

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Priority(asset) = sensitivity *
vulnerability_proximity * exposure
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[0027] Where sensitivity represents data classification scores (0-10 scale), vulnerability_proximity equals the inverse of years until vulnerable, and exposure combines external access metrics with attack surface measurements.

Integration with MWRASP Platform Components

[0028] The quantum forecasting system leverages MWRASP's defensive AI agent swarm capabilities for enhanced collective intelligence. AI agents communicate through discovery broadcasts announcing capabilities, negotiation exchanges for prediction confidence assessment, consensus building through weighted voting mechanisms, and continuous learning via model update sharing across the swarm network.

[0029] The mathematical woven framework enables sophisticated cross-correlation of quantum metrics, threat intelligence feeds, and cryptographic inventory data. This integration extracts complex patterns that individual analysis would miss, generating actionable insights for proactive defense. Responsive adaptation mechanisms automatically trigger model retraining when prediction errors exceed defined thresholds, recalibrate confidence scores based on observed outcomes, and broadcast critical updates across the entire AI agent swarm.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] Figure 1 shows a system architecture diagram illustrating the complete Temporal Quantum Vulnerability Forecasting System with all major components, data flows, and integration points with the MWRASP (Total) platform, including the Data Ingestion Layer, Prediction Engine Layer, Risk Assessment Layer, Migration Planning Layer, and Execution and Monitoring Layer.

[0031] Figure 2 shows a three-dimensional tensor representation of the Multi-Dimensional Quantum Threat Space (MQTS) visualization depicting the evolution of quantum capabilities across multiple dimensions including qubit count, coherence time, gate fidelity, error rates, and algorithm efficiency over time from 2024 to 2040.

[0032] Figure 3 shows a process flow diagram of the Bayesian Quantum Capability Estimator illustrating data ingestion from multiple sources, Bayesian inference updates, probability distribution evolution, confidence interval calculation, and prediction generation with feedback loops.

[0033] Figure 4 shows a timeline chart depicting vulnerability windows for RSA-2048, RSA-4096, ECC-256, ECC-384, AES-128, AES-256, SHA-256, and other cryptographic algorithms against projected quantum capabilities from 2024-2040, with color-coded risk levels.

[0034] Figure 5 shows a network diagram illustrating cryptographic dependencies between systems and optimal migration sequencing paths, including nodes representing different cryptographic implementations and edges showing dependency relationships with migration priority weights.

[0035] Figure 6 shows a flowchart depicting the Q-CVSS scoring methodology including base metrics calculation, quantum-specific factors integration, temporal adjustments, and final score generation ranging from 0-10 with severity classifications.

[0036] Figure 7 shows a distributed system diagram of the Defensive AI Agent Swarm Architecture illustrating agent communication protocols, consensus mechanisms, collective intelligence generation, and integration with the MWRASP platform.

[0037] Figure 8 shows a data flow diagram illustrating the threat intelligence processing pipeline from raw intelligence sources through collection, parsing, validation, analysis, and incorporation into prediction models with quality assurance checkpoints.

[0038] Figure 9 shows an enterprise-wide heat map visualization displaying quantum vulnerability concentration across different business units, systems, and geographic locations with risk scores color-coded from green (low) to red (critical).

[0039] Figure 10 shows an executive dashboard mockup displaying real-time migration status, risk metrics, timeline projections, compliance indicators, and key performance indicators for quantum-safe transition progress.

[0040] Figure 11 shows a graph comparing predicted versus actual quantum computing milestones from 2020-2024 with confidence intervals, demonstrating the system's historical accuracy and calibration.

[0041] Figure 12 shows bar charts displaying system performance metrics including prediction latency, throughput, scalability measurements, and accuracy rates across different time horizons.

ABSTRACT

[0042] A temporal quantum vulnerability forecasting system integrated with the Mathematical Woven Responsive Adaptive Swarm Platform (MWRASP Total) provides predictive modeling of quantum computing capabilities and automated migration to quantum-resistant cryptographic protection. The system employs Multi-Dimensional Quantum Threat Space (MQTS) modeling achieving 85-92% accuracy in 5-year quantum capability forecasts through five integrated defensive AI agent components: a Bayesian Quantum Capability Estimator with continuous learning from patent filings, research papers, and vendor announcements; a Cryptographic Vulnerability Timeline Generator correlating quantum capabilities with algorithm vulnerabilities; an Automated Migration Orchestrator implementing risk-based prioritization and dependency-aware scheduling; a Quantum Vulnerability Scoring Engine (QVSE) producing Q-CVSS scores with temporal weighting; and a Quantum-Safe Transition Planner with rollback capabilities and hybrid protection modes. Unlike static vulnerability assessment approaches, this defensive cybersecurity platform provides dynamic, predictive protection that automatically adapts to evolving quantum threats while maintaining operational continuity. The system safeguards long-term data confidentiality through proactive migration planning aligned with NIST Post-Quantum Cryptography standards and NSA Commercial National Security Algorithm Suite 2.0 requirements, ensuring enterprise-wide protection against future quantum computing threats before vulnerability windows open.

INVENTOR'S DECLARATION

As the below named inventor, I hereby declare that:

This declaration is directed to the attached provisional patent application entitled "Temporal Quantum Vulnerability Forecasting System with Automated Quantum-Safe Migration Planning."

I believe that I am the original and sole inventor of the subject matter which is claimed and for which a patent is sought.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five years, or both.

WARNING: Willful false statements and the like are punishable by fine or imprisonment, or both (18 U.S.C. 1001), and may jeopardize the validity of the application or any patent issuing thereon.

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