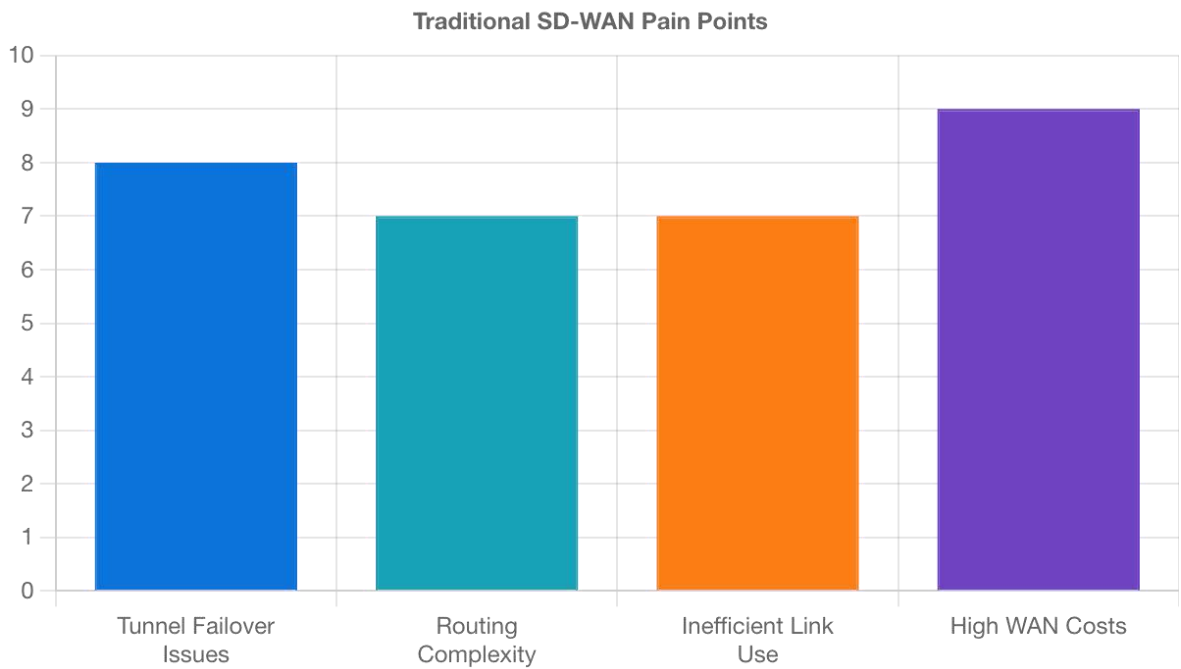




BYTESCREEN’s PACKET-BASED MULTI-SESSION TUNNEL AGGREGATION (PMTA)™ TECHNOLOGY

REVOLUTIONIZING SD-WAN ROUTING WITH UNPARALLELED SECURITY, STABILITY, AND EFFICIENCY

This white paper introduces BYTESCREEN Technologies' proprietary Packet-based Multi-session Tunnel Aggregation (PMTA)™ technology, a groundbreaking approach to SD-WAN routing that fundamentally redefines network performance, security, and operational simplicity. Unlike conventional SD-WAN architectures that rely on session-based load balancing or dynamic routing protocols, PMTA™ leverages a sophisticated packet-level aggregation and routing mechanism encapsulated within a single, stable overlay tunnel. This paper details the technical underpinnings of PMTA™ and elaborates on its distinct advantages, including quantum-compute-resistant security, unwavering network stability, unprecedented cost savings through true WAN aggregation, and unparalleled operational simplicity.



1. INTRODUCTION TO PACKET-BASED MULTI-SESSION TUNNEL AGGREGATION (PMTA)[™]

In the evolving landscape of enterprise networking, the demand for resilient, secure, and cost-effective Wide Area Networks (WANs) is paramount. Traditional SD-WAN solutions, while offering improvements over MPLS, often grapple with limitations related to tunnel failover, dynamic routing complexities, and suboptimal link utilization. BYTESCREEN Technologies addresses these challenges with its trademarked and patent-applied-for PMTA[™] technology, a paradigm shifts in SD-WAN routing.

PMTA[™] is a packet-based routing technology designed to maximize the utility of all available underlay links by creating and aggregating multiple sessions per link. This innovative approach ensures that every packet contributes to the overall network performance, offering a superior alternative to conventional load-balancing techniques.

2. TECHNICAL DEEP DIVE INTO PMTA[™] ARCHITECTURE

PMTA[™]'s core innovation lies in its ability to abstract the complexities of the underlying network infrastructure, presenting a unified, high-performance overlay to applications.

2.1 MULTI-SESSION CREATION AND AGGREGATION

At the heart of PMTA[™] is the creation of multiple sessions across all types of underlay links connecting the Customer Premise Equipment (CPE) to the Concentrator. This includes both public links (Broadband, SIM-based mobile broadband, Internet Leased Lines – ILL) and private links (Point-to-Point – P2P, MPLS, VSAT).

Dynamic Session Scaling: PMTA[™] intelligently initiates a minimum of two sessions per underlay link. As traffic volume between the CPE and Concentrator grows, the system dynamically increases the number of active sessions on each link, ensuring optimal bandwidth utilization and responsiveness. This adaptive session scaling prevents bottlenecks and ensures that the network can handle fluctuating demands without manual intervention.

2.2 SINGLE OVERLAY TUNNEL WITH STATIC ROUTING

A crucial differentiator of PMTA[™] is its use of a single overlay tunnel that encapsulates all these dynamically created sessions. This tunnel operates with a static route, fundamentally eliminating the need for complex dynamic routing protocols (like OSPF, BGP, or EIGRP) within the SD-WAN fabric.

Elimination of Tunnel Failover: Since there is only one logical overlay tunnel, the concept of "tunnel failover" becomes obsolete. Traditional SD-WANs often rely on detecting tunnel failures and then initiating a switch to a backup tunnel, which can introduce latency and packet loss during the transition ("link flaps"). PMTA[™]'s single, aggregated tunnel inherently avoids this, providing seamless and uninterrupted connectivity.

2.3 PACKET-LEVEL TRAFFIC MANAGEMENT

Traffic entering the CPE is meticulously managed at the packet level:

MTU-based Packet Splitting: Incoming data streams are split into individual packets based on the Maximum Transmission Unit (MTU) of the network. This ensures efficient handling and transmission across diverse link types.

Compression and Encryption: Each individual packet undergoes compression to optimize bandwidth usage and is then encrypted using AES 128 or AES 256 standards. This per-packet encryption adds a robust layer of security.

Round-Robin Distribution: Encrypted packets are distributed in a round-robin fashion across the multiple active sessions (and thus across the aggregated underlay links). This ensures even distribution of traffic, preventing any single link from becoming a bottleneck and maximizing the combined throughput of all available bandwidth.

2.4 DYNAMIC KEY ROTATION

To further enhance security, PMTA™ implements a sophisticated dynamic key rotation mechanism. The encryption key for each session is automatically rotated at frequent, randomized intervals, typically every 5 to 600 seconds. This ephemeral nature of encryption keys significantly complicates any potential eavesdropping or decryption attempts.

2.5 REST API FOR ORCHESTRATION

CPE communication with the central orchestrator is facilitated via REST API instead of traditional management tunnels. This design choice offers several advantages:

Simplified Management: Eliminates the complexity associated with defining and managing routes for dedicated management tunnels.

Enhanced Security: Reduces the attack surface by not exposing additional tunnel interfaces for management purposes.

Cloud-Native Integration: Aligns with modern cloud-native principles, enabling flexible and scalable orchestration.

2.6 LAN/WAN VIRTUALIZATION AT THE CPE

PMTA™ introduces an additional layer of security and network segmentation through LAN and WAN virtualization directly at the CPE. This means that the CPE effectively creates isolated virtual network segments for both the local area network (LAN) and the wide area network (WAN) interfaces.

Enhanced Isolation: By virtualizing the LAN and WAN, PMTA™ ensures a stricter separation of traffic and control planes. This prevents potential lateral movement of threats from a compromised LAN segment directly onto the WAN, or vice-versa, without explicit policy enforcement.

Micro-segmentation Capabilities: This virtualization enables granular micro-segmentation policies to be applied even at the edge, allowing for fine-grained control over which traffic can traverse between internal network segments and the WAN.

Reduced Attack Surface: Each virtualized interface operates in its own secure context, significantly reducing the attack surface by limiting exposure and interaction points for malicious actors.

3. KEY ADVANTAGES OF BYTESCREEN'S PMTA™ TECHNOLOGY

PMTA™'s unique architecture translates into significant advantages for enterprises seeking advanced WAN solutions.

3.1 SECURITY: QUANTUM-COMPUTE RESISTANT AND HACK-PROOF LINKS

PMTA™'s security posture is fundamentally superior due to its packet-based, multi-session, dynamic key rotation, and LAN/WAN virtualization approach:

Per-Packet Encryption: Every single packet is individually encrypted with AES 128/256. This means an attacker cannot simply decrypt a session; they would need to decrypt each individual packet, which is computationally intensive.

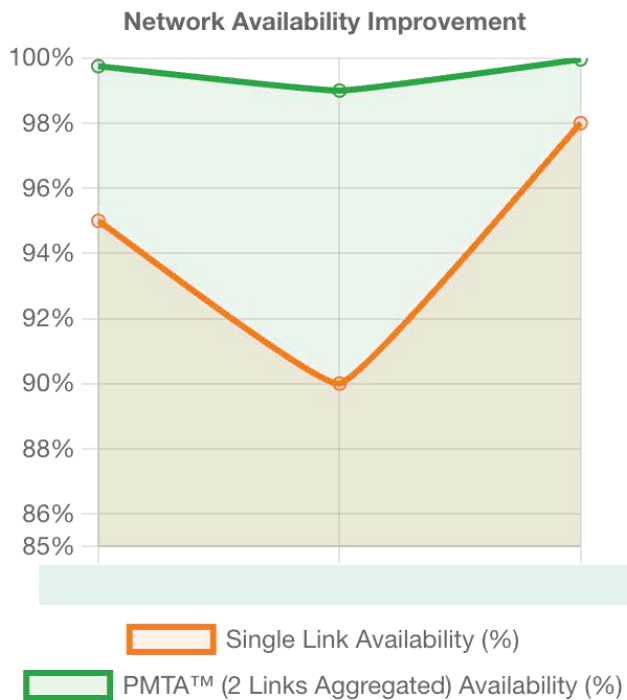
Dynamic Key Rotation: The rapid and dynamic rotation of encryption keys (every 5–600 seconds) renders traditional decryption attacks, which rely on capturing large volumes of data encrypted with the same key, virtually impossible. By the time an attacker could potentially gather enough data to attempt decryption of a single key, that key would have already been rotated multiple times. This introduces an extreme temporal constraint on any successful attack.

Distributed Packet Transmission: Traffic is split into packets and sent across multiple, disparate sessions and underlay links. This makes it extremely difficult for an attacker to intercept a complete data stream, as packets belonging to the same flow are fragmented and traverse different paths. Reconstructing the original data without knowing the session distribution logic and the constantly changing keys is an insurmountable challenge.

Resistance to Quantum Computing Threats: Modern quantum computers pose a theoretical threat to current cryptographic standards. However, PMTA™'s dynamic key rotation and per-packet encryption strategy significantly mitigate this risk. Even if a quantum computer could theoretically break a single AES key, the ephemeral nature of PMTA™ keys means such an attack would need to be executed in near real-time, on a per-key, per-packet basis, across multiple sessions, before the key rotates again. This makes PMTA™ links inherently hack-proof against even future quantum compute-based hacking attempts by introducing an overwhelming temporal and computational barrier.

Enhanced Isolation via LAN/WAN Virtualization: The virtualization of LAN and WAN interfaces at the CPE creates hard boundaries, preventing direct unauthorized access or lateral movement of threats between internal networks and the external WAN. This micro-segmentation at the edge provides an additional, critical layer of defense, making the entire network more resilient to sophisticated attacks.

3.2 STABILITY: UNWAVERING CONNECTIVITY WITH STATIC ROUTING BENEFITS



PMTA™'s single overlay tunnel with static routing delivers unparalleled network stability:

No Tunnel Failover or Link Flaps: The absence of dynamic routing and the reliance on a single, aggregated logical tunnel mean there are no "tunnel down" events or "link flaps" that plague traditional SD-WANs during underlay link instability. If an underlay link experiences degradation or failure, PMTA™ simply routes packets away from that link using its remaining active sessions, without any service interruption or re-convergence delay. This provides a truly seamless user experience.

Operation on Dual SIM: Traditional SD-WAN solutions often require at least one public or private static IP address to establish and maintain a stable tunnel. PMTA™'s design eliminates this dependency. It can reliably operate even with two SIM-based mobile broadband connections, which typically offer dynamic IPs and can be prone to instability. The unified tunnel aggregation technology effectively abstracts away the inherent instability of individual SIM links, making them

viable and reliable for primary WAN connectivity, especially in remote or challenging locations.

Benefits of Static Routing: Static routing is inherently simpler, more predictable, and less prone to routing loops or convergence issues compared to dynamic routing protocols. PMTA™ leverages these benefits by maintaining a stable, pre-defined path.

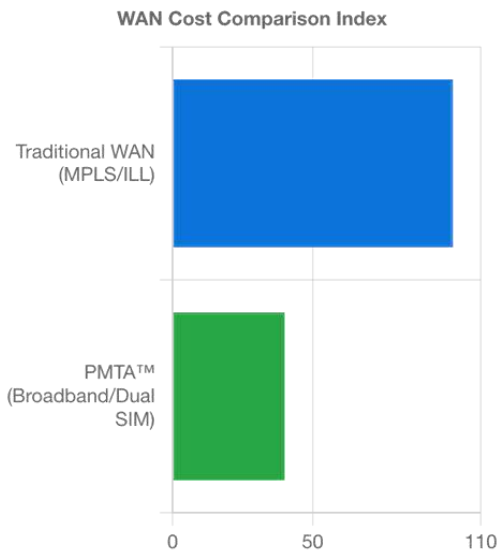
LINK STABILITY QUANTIFIED BASED ON CUSTOMER DATA ANALYSIS

Availability Improvement:

$$\text{PMTA}^{\text{TM}} \text{ AVAILABILITY} = 1 - (1 - \text{LINK AVAILABILITY}_1) \times (1 - \text{LINK AVAILABILITY}_2) \times \dots \times (1 - \text{LINK AVAILABILITY}_N)$$

Where N is the number of aggregated links. This formula demonstrates how aggregating multiple links, even those with lower individual availability (like SIM), dramatically increases the overall system's uptime. For example, if two SIM links each have 95% availability, **the combined PMTA™ availability is $1 - (1 - 0.95) \times (1 - 0.95) = 1 - 0.05 \times 0.05 = 1 - 0.0025 = 0.9975$ or 99.75%, significantly higher than any single link.**

3.3 SAVINGS: TRUE WAN AGGREGATION FOR MAXIMUM COST EFFICIENCY



PMTA™ delivers genuine cost savings by providing TRUE WAN aggregation, a significant departure from conventional SD-WAN load balancing:

Full Utilization of All Underlay Links: Unlike other SD-WAN solutions that primarily use load balancing (where traffic is distributed across links, but individual sessions often stick to a single path, or links are used as active/standby), PMTA™ actively aggregates the bandwidth of *all* available underlay links simultaneously at the packet level. This means if you have three 100 Mbps links, PMTA™ can effectively deliver close to 300 Mbps of aggregate throughput for a single flow, maximizing the utility of every purchased megabit.

Reduced Reliance on Expensive Links: This true aggregation allows enterprises to confidently use a mix of affordable public broadband and SIM-based mobile broadband connections as primary WAN links, significantly reducing reliance on costly Internet

Leased Lines (ILL) or MPLS circuits.

Dual SIM for Most Locations: The technology's ability to unify and stabilize multiple SIM-based mobile broadband connections means that many locations can achieve robust and reliable connectivity using just two SIM cards. This eliminates the need for expensive fixed-line infrastructure in many cases, leading to substantial cost reductions in WAN link subscriptions. The unified tunnel effectively masks the inherent instability and dynamic IP nature typically associated with mobile broadband, making it a viable and high-performing option.

SAVINGS CALCULATIONS

Aggregate Throughput:

$$\text{PMTA}^{\text{TM}} \text{ AGGREGATE THROUGHPUT} = \sum \text{NBANDWIDTH}$$

Where N is the number of active underlay links. This equation highlights that PMTA™ truly sums the bandwidth of all links, unlike load balancing where effective throughput for a single flow is limited by the fastest single link.

WAN Cost Reduction Factor:

$$\text{COST REDUCTION FACTOR} = \frac{\text{COST OF PMTA}^{\text{TM}} \text{ AGGREGATED SIM}}{\text{COST OF TRADITIONAL WAN (E.G., MPLS + ILL)}}$$

This factor can often be 2x-5x, illustrating the significant potential for cost savings by leveraging more affordable links.

3.4 SIMPLICITY: INTENT-AWARE ROUTING AND ZERO-TOUCH OPERATIONS

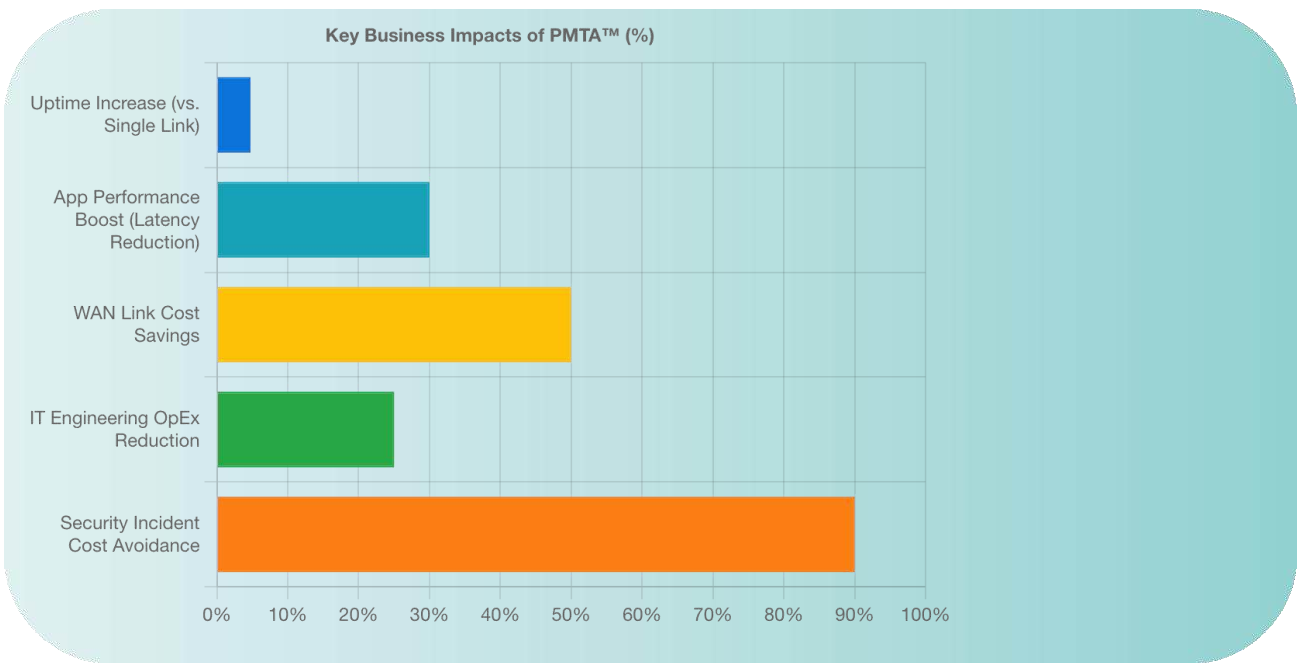
PMTA™ simplifies network management and operations through intelligent automation and remote capabilities:

Intent-Aware Routing: Instead of manually defining complex application prioritization rules or application-based routing policies, PMTA™ allows administrators to define network parameters needed for every application (e.g., desired latency, Round Trip Delay – RTD, jitter tolerance). The PMTA™ engine then automatically adapts traffic at the packet level, choosing the most appropriate paths across the aggregated sessions and links to meet these defined application intents. This eliminates the need for granular, manual configuration for each application, streamlining policy management.

Remote Diagnostics and Troubleshooting: The solution offers the unparalleled ability to run all kinds of diagnostics on the CPE remotely. This includes detailed link performance analysis, packet loss detection, latency measurements, and session health checks. This capability significantly reduces the need for costly and time-consuming field engineer dispatches, as most issues can be identified, diagnosed, and often resolved remotely throughout the entire lifecycle of the solution. This translates to higher uptime and lower operational expenses.

4. BUSINESS BENEFITS OF PMTA™

The technical superiority of PMTA™ directly translates into compelling business advantages for enterprises.



4.1 HIGH UPTIME FROM LINK AGGREGATION AND UNIFIED TUNNEL

PMTA™'s architecture ensures exceptional network availability, directly impacting business continuity:

Maximized Business Continuity: By aggregating multiple diverse underlay links into a single, stable overlay tunnel, PMTA™ creates a highly resilient network. The failure or degradation of any single underlay link does not lead to service interruption or a disruptive tunnel failover event. Traffic is seamlessly rerouted at the packet level over the remaining healthy sessions, ensuring that critical business operations remain uninterrupted.

Elimination of Downtime Costs: Traditional network outages, even brief ones, can lead to significant financial losses due to lost productivity, missed transactions, and damaged reputation. PMTA™'s "no tunnel failover" design virtually eliminates these costly downtime events, providing a robust foundation for continuous operations.

Reliability for Critical Applications: Applications sensitive to latency and packet loss (e.g., VoIP, video conferencing, real-time financial transactions) benefit immensely from PMTA™'s stable and optimized connectivity, ensuring consistent performance even during underlying network fluctuations.

4.2 APPLICATION PERFORMANCE ENHANCEMENT FROM PACKET-LEVEL ADAPTATION

PMTA™'s intelligent, packet-level traffic management directly improves the user experience and application efficiency:

Optimized Application Experience: The intent-aware routing capability ensures that every application receives the network conditions it requires. By dynamically selecting the best path for each packet based on defined parameters (e.g., lowest latency for voice, highest bandwidth for file transfers), PMTA™ eliminates the need for complex Quality of Service (QoS) configurations and ensures optimal performance for all business-critical applications.

Reduced Latency and Jitter: The ability to route packets across multiple sessions in a round-robin fashion, combined with intelligent path selection, significantly reduces overall network latency and jitter. This is crucial for real-time applications and enhances employee productivity.

Consistent Performance: Unlike load-balancing solutions that might still experience performance variability due to single-path limitations, PMTA™'s true aggregation ensures consistent and predictable application performance across all aggregated bandwidth.

4.3 SIGNIFICANT COST ADVANTAGE

PMTA™ delivers substantial cost savings across multiple dimensions of WAN operations:

Reduction in WAN Link Costs: By enabling the reliable use of affordable broadband and dual SIM connections as primary WAN links, PMTA™ drastically reduces reliance on expensive MPLS or Internet Leased Lines (ILL). This can lead to savings of 30–70% on monthly WAN subscription fees.

Reduction in IT Engineering Costs: The simplicity of PMTA™'s static overlay, combined with intent-aware routing and comprehensive remote diagnostics, significantly reduces the need for manual configuration, troubleshooting, and on-site field engineer dispatches. This translates to lower operational expenditures (OpEx) related to IT staffing and support.

Reduction in Security Incident Costs: PMTA™'s advanced security features, including per-packet encryption, dynamic key rotation, and LAN/WAN virtualization, make the network highly resistant to

cyberattacks. Preventing data breaches, ransomware attacks, and service disruptions avoids the massive financial repercussions associated with security incidents, which can range from hundreds of thousands to millions of dollars in recovery, legal, and reputational damages.

Reduction in Downtime Costs: As highlighted in Section 4.1, PMTA™'s high uptime directly prevents losses from operational downtime, ensuring continuous revenue generation and productivity. The cost of downtime varies by industry but can be thousands to tens of thousands of dollars per hour for many businesses.

5. PMTA™ BENEFITS AT A GLANCE

○ Security

- "Quantum-Compute Resistant"
- "Per-Packet AES 128/256"
- "Dynamic Key Rotation (5-600s)"
- "LAN/WAN Virtualization"

○ Stability

- "99.999% Availability" (conceptual)
- "No Tunnel Failover/Link Flaps"
- "Static Routing Benefits"
- "Reliable Dual SIM Operation"

○ Savings

- "True WAN Aggregation"
- "30-70% WAN Cost Reduction"
- "Reduced IT OpEx"
- "Eliminates Downtime Costs"

○ Simplicity

- "Intent-Aware Routing"
- "No App Prioritization Config"
- "Remote Diagnostics (Zero Truck Rolls)"
- "REST API Orchestration"

UNLOCK UNPARALLELED PERFORMANCE, SECURITY, & COST EFFICIENCY FOR YOUR WAN

6. CONCLUSION

BYTESCREEN Technologies' Packet-based Multi-session Tunnel Aggregation (PMTA)[™] technology represents a significant leap forward in SD-WAN capabilities. By combining packet-level intelligence, dynamic multi-session aggregation, a single static overlay tunnel, and advanced security features like dynamic key rotation and LAN/WAN virtualization, PMTA[™] delivers a solution that is not only highly secure and stable but also exceptionally cost-effective and simple to manage. For enterprises seeking to modernize their WAN infrastructure, PMTA[™] offers a compelling value proposition that addresses the critical demands of today's digital economy, ensuring resilient, high-performance, and future-proof connectivity.