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APEX STANDARDS

L4S: Elevating 5G, XR, Gaming, and Telemedicine for a Faster Internet Era

L4S, the Low Latency, Low Loss, Scalable Throughput architecture, stands as a pivotal development in internet service architecture, directly addressing the current demands of the Internet for enhanced speed, reliability, and efficiency. This architecture improves internet services, targeting the specific needs for high-speed, reliable, and low-latency communications. In various scenarios where latency, data loss, and throughput are critical, L4S plays a crucial role. Key applications and scenarios where L4S can have a substantial impact include:

Virtual Reality (VR) and Extended Reality (XR): VR and XR applications require extremely low latency to provide immersive and responsive experiences. High latency can lead to motion sickness and poor user experience. L4S minimizes the delay in data transmission, ensuring a smooth and realistic virtual environment. This is crucial for educational, training, and simulation applications in VR and XR.

Online Gaming: Online multiplayer games, especially fast-paced action games, are highly sensitive to latency. L4S can enhance the gaming experience by reducing lag, ensuring that player actions are reflected in real-time, which is crucial for competitiveness and enjoyment.

Real-Time Video Conferencing and Streaming: In video conferencing, delays can disrupt the flow of conversation and reduce the effectiveness of communication. L4S ensures smoother video and audio transmission, leading to more natural and effective remote interactions. This is increasingly important in the context of remote work and virtual events.

Telemedicine and Remote Surgery: In telemedicine, particularly remote surgery, low latency and reliable data transmission are vital. L4S can facilitate real-time remote medical consultations and surgical procedures, where every millisecond counts, thereby expanding healthcare access to remote or underserved areas.

Autonomous Vehicles and Smart Transportation Systems: In autonomous vehicles and smart transportation, timely and reliable data exchange is essential for safety and efficiency. L4S can provide the necessary low-latency communication between vehicles and infrastructure, supporting advanced driver-assistance systems (ADAS) and autonomous driving functions.

Industrial Automation and IoT: In industrial automation, especially with the Internet of Things (IoT), L4S enables real-time monitoring and control of machines and processes. This can lead to improved efficiency, quicker response times, and better management of resources in manufacturing and other sectors.

IETF Internet Draft	Focus Area
draft-ietf-tsvwg-nqb	Low Queue Building (NQB) - a network queue management policy
draft-ietf-tcpm-accurate-ecn	More accurate ECN feedback in TCP
draft-ietf-quic-ack-frequency	Adjusting the frequency of acknowledgments in QUIC
draft-livingood-low-latency-deployment	Deployment strategies for low-latency networks
draft-ietf-ippm-explicit-flow-measurements	Explicit measurements for flow-specific metrics
draft-ietf-tcpm-generalized-ecn	Generalized approach to Explicit Congestion Notification (ECN)
draft-ietf-teas-rfc3272bis	Update to RFC 3272 (Traffic Engineering considerations)
draft-ietf-tsvwg-ecn-encap-guidelines	Guidelines for using ECN with encapsulated protocols
draft-bagnulo-congress-cci	Congestion Control based on congestion exposure (ConEx) concepts
draft-briscoe-iccrg-prague-congestion-control	Prague Congestion Control for fair sharing among different congestion control approaches
draft-ietf-ippm-responsiveness	Standards for network responsiveness
draft-fairhurst-ccwg-cc	Congestion control considerations

Table 1 Overview of IETF Internet Drafts Pertaining to L4S Standardization, sorted by relevance.

Financial Trading: Financial markets, where milliseconds can make a difference in the value of transactions, benefit from L4S. It can provide traders with a competitive edge by ensuring faster transaction times and up-to-date market data.

Cloud Computing and Edge Computing: Cloud and edge computing environments, which host a variety of services and applications, require efficient data throughput and low latency for optimal performance. L4S ensures that cloud-based services can be delivered efficiently, benefiting both providers and users.

Content Delivery Networks (CDNs): For CDNs, L4S can optimize content delivery, live streaming and high-definition video services, by reducing buffering and improving overall viewing quality.

5G Networks: In 5G networks, which promise high-speed mobile internet, L4S can be key in delivering on these promises, particularly for services requiring ultra-reliable and low-latency communications.

Central to L4S's design is the Dual Queue Approach. This system segregates traffic into two categories: "Classic" for traditional internet traffic and "L4S" for traffic requiring low-latency and low-loss handling. This segregation is crucial for optimizing network efficiency and user experience, allowing for specialized treatment of different traffic types.

Another core feature of L4S is its Improved Congestion Control. Contrasting traditional TCP congestion control, which is reactive to packet loss, L4S adopts a proactive stance. It utilizes Explicit Congestion Notification (ECN) mechanisms, enabling network devices to signal impending congestion. This foresight allows endpoints to adjust their sending rates preemptively, effectively reducing latency and packet loss.

L4S supports Scalable Throughput, ensuring that increasing internet speeds do not compromise latency. This scalability is aimed to support bandwidth-intensive applications without quality degradation.

The architecture incorporates Advanced Queue Management techniques, such as Controlled Delay (CoDel) and Proportional Integral controller Enhanced (PIE). These techniques dynamically manage queuing delays, maintaining low latency and accommodating transient data bursts without substantial packet loss or delay.

A notable aspect of L4S is its Transport Protocol Independence. While compatible with existing protocols like TCP, it also supports newer protocols designed for low latency, making L4S a versatile and future-proof architecture capable of supporting emerging technologies and protocols.

L4S enables Differentiated Services by allowing traffic to be handled based on priority, essential for applications requiring low latency, like real-time voice and video, which can be prioritized over less time-sensitive data.

One of the design goals of L4S is ensuring Fairness and Coexistence. The architecture's dual queue system and congestion control mechanisms prevent L4S traffic from disadvantaging classic traffic, promoting equitable resource allocation among different traffic types.

Deploying L4S necessitates changes in both network infrastructure and end systems. This includes updating AQM algorithms, supporting ECN in network devices, and implementing L4S-compatible congestion control algorithms in end systems.

Security and Robustness are critical in any network architecture. L4S includes mechanisms to safeguard against exploitation of its low-latency features and maintains robustness in varied network conditions.

L4S marks a paradigm shift in internet service delivery, eclipsing traditional methods with its innovative approach. By redefining ECT and utilizing dual-queue AQM, L4S effectively segregates traffic, ensuring low latency and enhancing overall internet performance. Its impact is particularly significant in addressing the demands of new and emerging applications, offering a responsive and reliable internet experience.

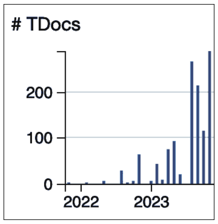

Figure shows increasing 3GPP discussions about L4S.

The integration of L4S into standardization bodies, including its adoption by the IETF and its influence in 3GPP's RAN3 and SA2 groups for packet marking principles, marks a advancement in the development of future network standards. This significance was further reinforced at the latest 3GPP Plenary Meetings in Edinburgh, December 2023, where L4S's role was discussed within the context of Release 19 XR enhancements (Work Item “FS_XRM_Ph2”). TDoc SP-231805, contributed by Nokia and Meta, exemplifies the discussions, reinforcing L4S's role to elevate XR user experiences significantly.

L4S's influence extends to the Broadband Forum (BBF), demonstrating its broad scope and potential to revolutionize web speeds. Its ability to cut down latency has drawn attention from industry giants like Apple, Google, and Comcast, who see in L4S a transformative force for the future of internet connectivity. As the world moves towards increasingly digital and real-time solutions, L4S paves the way for a smoother, faster, and more efficient internet landscape. ∎

Feature	Interpretation	L4S Implementation
Separating	Dividing the media stream into essential and non-essential parts.	L4S's dual-queue system segregates traffic based on latency sensitivity and importance.
Transmitting on different bearers	Sending different parts of the stream on separate channels with varying priorities.	L4S uses distinct queues for different traffic types, ensuring prioritization of latency-sensitive data.
Performing adaptation	Adjusting the media stream in response to network conditions.	L4S dynamically adjusts traffic handling (e.g., congestion control) based on real-time network conditions.
Increasing or decreasing bitrate	Adjusting the quality of the media stream based on the network's capability.	In L4S, bandwidth is managed proactively to maintain quality of service, similar to bitrate adjustments for essential media.
Detecting buffer level changes	Monitoring the level of data in buffers to gauge network conditions.	L4S employs AQM techniques, which may involve monitoring buffer levels to prevent congestion and latency.
Using packet marking	Employing markers on packets to indicate network status (e.g., congestion).	L4S utilizes ECN as a form of packet marking to signal and manage impending network congestion.
Responsive bitrate adjustment	Changing media stream properties (like bitrate, frame rate) based on network feedback.	L4S's congestion control algorithms adjust data transmission rates in response to network congestion signals.

Table 2 Patenting efforts surrounding L4S technologies are on the rise. For example, Ericsson's patent application US20220394076A1 was independently verified by Apex Standards, which prepared a claim chart to evaluate the essentiality mapping of Ericsson's patented features in the implementation of L4S technology. This suggests that Ericsson's patent holds potential for out-licensing opportunities, particularly as L4S technology gains broader adoption.