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The True Cost of Video Latency

Amounts Already Lost to Slow Streaming on CDNs Will Soar into the 10s of Billions without Widescale Access to Real-Time Interactive Streaming

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INTRODUCTION

Global revenue losses attributable to live-streamed video latencies could soar into the tens of billions of dollars annually without rapid widescale conversions to real-time interactive video streaming infrastructures.

Any calculation of the true cost of video latency should not only take into account revenue losses attributable to poor streaming performance in traditional one-way live streaming scenarios. The amounts at stake must also include a reasonable estimate of revenues to be generated by next-generation use cases that are entirely dependent on real-time interactive video streaming capabilities that are beyond the reach of traditional content delivery networks (CDNs).

True Cost of Video Latency = $160.89 Billion

By the conservative estimates described below, the true cost of video latency that would result globally from exclusive dependence on the dominant Hypertext Transfer Protocol (HTTP) mode of streaming through 2026 totals a whopping $160.89 billion.

We estimate that the annual revenue loss incurred worldwide as a result of excessive one-way live video streaming latencies over CDNs is on course to hit $1.9 billion in 2021. Were HTTP streaming infrastructures to remain the dominant alternative for one-way live streaming use cases through 2026, the accumulated loss total between now and then would come to over $9 billion.

But those costs pale next to what would be lost without support for real-time interactive streaming across a vast array of use cases now taking hold in consumer, enterprise, and other market segments. These include established video streaming operations that stand to benefit from interactive video connectivity as well as emerging applications that can't exist without it.

In all cases, infrastructure supporting such connectivity must be able to stream video in any direction from any video-capable device in any location to any number of recipients with no discernable delay end-to-end. Without wide, easy access to such capabilities by 2025, we calculate the revenues at risk that year would total $75.9 billion. They would continue at that rate or higher for every year the absence of the required connectivity persists.

Looking at what the loss would come to through another year puts the total at $151.8 billion. Insofar as we're not calculating the revenue losses the absence of such infrastructure would be responsible for in the intervening years, this seems to be a conservative estimate of the consequences of delayed implementation of the required live streaming infrastructures at a global scale.

In the discussion that follows we begin with calculations of the costs of unacceptable latency in the major usage categories where one-way video streaming delivered over conventional CDNs has made video the dominant component of internet traffic worldwide. We then turn to an assessment of what's at stake in terms of the value of use cases that can't exist without a foundation built on real-time interactive streaming infrastructures operating at massive scales.

It's important to note that we undertook this analysis of the cost of latency to provide insight that's been missing in the outpouring of data about the video streaming marketplace from industry researchers. Fortunately, that gap is about to be closed with the release of findings on the true cost of video latency from one of the leaders in the field, Rethink Technology Research.

Stay tuned for an in-depth report on their analysis. Meanwhile, based on discussions with their team, our findings appear to be in sync with what we'll be hearing from Rethink.

PART 1
COSTS ATTRIBUTABLE TO ONE-WAY STREAMING LATENCY

One-Way Live Streaming Latency Is Now the #1 Issue in Video Distribution

Much of the current alarm over poor video latency performance centers on consumer dissatisfaction with sports and other live-streamed viewing experiences. The intensity of such concerns was reflected in an annual survey of service provider executives and video technologists conducted by Digital TV Europe, which reported that respondents from 64 countries ranked issues related to live-streaming latency, along with live-stream scaling issues, as the top challenges confronting the digital video distribution business.

The biggest latency issue, which was rated a "very important problem" by 57% of the 560 respondents, was the need to deliver online streams and TV broadcasts for live sporting events simultaneously. This is essential to avoiding the notorious spoiler effect that occurs when broadcast viewers react to something happening on the field before online viewers have seen it. Ensuring all players and viewers see esports gaming action simultaneously was also cited as a very important challenge by 47%, while 46% cited the elimination of latency in betting services related to sports as another major issue.

A number of studies tracking how consumers react to unsatisfactory latency performance illustrate why this has become such a big issue. The research also provides metrics that can be used to estimate how revenue losses accrue with consumer dissatisfaction. Data used in such calculations include all elements impacting consumer behavior: the delay between the user's request and the video startup time, the time consumed by rebuffering, and the ongoing lag between when events occur at the source and when they are seen on viewers' devices.

Challenge #1: Buffering

According to global consumer research performed by Limelight Networks, the biggest quality of streaming issue among consumers is video rebuffering during playback, which was ranked as the primary online viewing frustration by 44% of survey respondents. This applies to live streaming, our primary concern here, as well as content streamed on-demand.

Rebuffering is intrinsic to the Transport Control Protocol (TCP) predominantly used with HTTP streaming over CDNs. This is not the case with leading real-time streaming modes, which rely on the User Datagram Protocol (UDP) in conjunction with advanced forward error correction (FEC) and other techniques to deliver continuous flows without rebuffering.

As noted in a paper by researchers from Princeton University and Microsoft, the TCP rebuffering problem is not just the consequence of poor bitrate selection in adaptive bitrate (ABR) streaming, which occurs with inaccuracies in messaging between clients and servers when buffers are full. More fundamentally, beyond the ABR control plane issue, which is intermittent, there's a persistent data plane issue related to the sequential download of video segments in the streaming process, which disrupts the interactions between TCP congestion control mechanisms and routers in the segment queueing process.

One measure of the toll buffering takes on viewer satisfaction was produced by the analytics firm NPAW. Looking at over 100 billion plays across 150 video services, NPAW found that when consumers experience buffering time ratios representing 2% or more of total viewing time, the share of video streams viewed to completion falls by 25% to 51% compared to a 68% completion rate for videos with buffering ratios at 0.2% or less.

This is not as big a problem as it once was. According to metrics generated by video performance tracker Conviva, the buffering ratio as measured across over 180 billion streams reaching more than 500 million users has dropped from a global mean of 1.12% in 2018 to just 0.28% in 2021. But the fact that buffering persists as consumers' number one dissatisfaction with video streaming suggests there's still a large percentage of users experiencing buffering ratios above the 2% threshold cited in the NPAW study.

Challenge #2: End-to-End Lag Time over Broadcast

When it comes to the impact of end-to-end high latency with live content streaming over CDNs, consumer responses to the Limelight survey make clear why latencies exceeding broadcast lag times are of such great concern to service providers. Limelight reported 64% of all surveyed consumers said they were more likely to stream a live event if they knew it would line up with broadcast latency.

That's still a stretch. ABI Research has found that the global average for live video streaming latency across browser-based and mobile use cases hovers around 40 seconds vs. 5 seconds for broadcast. Some studies narrow the gap by a few seconds, but just how hard it is to reduce streaming latency over HTTP to broadcast levels was reflected in the 2020 Super Bowl streaming metrics reported by Fox Sports. The network used a multi-CDN strategy to improve performance over what it experienced with its previous Super Bowl coverage in 2017, but, according to CNET, broadcast-level latency still proved to be out of reach with some streams running a full minute behind the broadcast feed.

Challenge #3: Delayed Start Times

As for the impact of video start delays, one landmark study underscoring the impact HTTP-based streaming latency has on user behavior was conducted by researchers from the University of Massachusetts Amherst and Akamai Technologies, who used data supplied by Akamai to analyze viewing patterns of 6.7 million people across 23 million sessions over a ten-day period. The team found that two seconds into a delayed video start, the abandonment rate over the next second hit 5.8% and continued escalating with every additional second of delay.

There's obviously a substantial amount of live video delivered with startup times exceeding 2 seconds, as evidenced by the fact that the global average for video start times is 4.3 seconds with the lowest regional rate registering in Asia at 3.87 seconds, according to Conviva's Q2 2021 report. Previously Conviva reported that delayed starts were responsible for a 16.7% rate of complete abandonment with live-streamed video in 2018.

Challenge #4: Advertising Hiccups

Any assessment of revenues losses attributable to poor streaming performance must take into account amounts lost by virtue of subscription cancellations and falloffs in ad views. In the case of subscription losses, the previously cited NPAW research shows that when playback is subpar with over 2% of all viewing sessions on a platform, new user churn rates can go as high as 50%, which is more than double the average OTT churn rate in the U.S.

When advertising is involved as a source of revenue on video streaming services, losses occur whenever ads don't play, as well as when consumers cut off viewing in reaction to lengthy ad buffering, delayed video startup times, high end-to-end latency or other issues with core content streaming performance. Globally, Conviva's 2021 metrics recorded the mean ad buffering ratio at 0.7%, and the mean ad start time at 0.34 seconds. This suggests these issues did not significantly impact ad views, which registered a 4% increase over Q2 2020.

However, by Conviva's reckoning, 16% of streamed video ads didn't play in Q2 2021, which over a full year would amount to a significant loss. Ad placement and playback have improved significantly compared to 47% failure rates for in-stream ads recorded by Conviva in 2018. While there are many causes for such failures, some are directly related to HTTP streaming issues involving inaccurate or failed placement of ad-break markers in the ABR packaging process and miscommunications between clients and ad servers.

Challenge #5: Poor Performance of Video Conference Systems Used with CDNs

Beyond the loss factors discussed so far, there are losses tied to the limitations in reach and quality imposed with efforts to socialize CDN-based live viewing experiences through reliance on third-party video conferencing or watch-party platforms. As documented in this white paper, the inadequacies of these platforms have grown more significant with the emergence of hybrid approaches to work life, education, trade shows, and much else.

In all these areas, remote participation via video connections in real time has become an integral adjunct to in-person engagement in the wake of the Covid 19 pandemic. One infrastructure suited to all needs in the live video space is the obvious course going forward. What would be lost in terms of spending in these markets the longer that transition is delayed is impossible to calculate, but we can assume the amount would add billions of dollars annually to the potential losses associated with emerging use cases.

Assessing the Market Value of Live Video Streaming

The metrics from all these different sources over many years tell the same story of significant revenue-impacting issues from poor performance with regard to startup times, buffering, and the end-to-end time gap between live action and reception with live-streamed content. This data can be used to roughly calculate revenue losses attributable to these latency-related issues as they apply to live-streamed content over HTTP-based CDNs.

The calculations begin with an estimate of the share of global OTT revenue generated by live-streamed content. Big numbers about market sizes are often misleading because, along with including estimates of revenue generated by advertising and subscriptions in the M&E market, they cover money spent on distribution platforms and streaming applications related to enterprise and other uses of video. While poor streaming performance can and does impact enterprise and other use cases unrelated to consumer

services, the economic impact is mitigated by sustained efforts to fix problems rather than the abandonment of streaming instances.

A study by Market Research Future tracking live video streaming revenues found that the global revenue total for live streaming on the services side of the ledger, at 18.4% of the combined platform/services market total, was on course to hit $10.3 billion in 2021, expanding to $46.5 billion by 2028. But, by the calculations of other researchers, this study seemed to be understating the service revenues.

More reliable measures are probably to be found with studies laser-focused on the revenue-generating power in each of the dominant live-stream market segments, sports and esports. According to Verified Market Research, advertising and subscription revenue generated by live-streamed sports will total $22.03 billion in 2021 and reach $87.34 billion by 2028, nearly twice the amount projected by Market Research Future.

As for esports, estimates of total revenue generated in the category vary widely, ranging, for example, from $1.1 billion projected for 2021 by esports market researcher Newzoo to $2.1 billion projected by Juniper Research. Based on these and other research findings, the share of esports revenue attributable to streaming-related advertising and subscriptions fees adds up to about 28% of the total, which would put the combined amount somewhere between $254.5 million and $588 million, based on the Newzoo and Juniper projections.

We'll split the difference and peg the 2021 esports live-streaming revenue at $421 million. Combined with the live-streamed sports revenue estimate from Verified Market Research, the total representing the lion's share of revenue generated by live streaming in 2021 comes to $22.42 billion.

Based on the total streaming revenue calculations from the previously cited Research and Markets report, which, at a projected CAGR of 14%, would jump from $81.6 billion in 2020 to $93.02 billion in 2021, the $22.42 billion in live-streaming revenue would equate to 24% of the global streaming revenue total in 2021. As to how the live-streamed revenue total divides between subscription and advertising revenues, we can assume it adheres fairly closely to the 71% subscription/29% advertising split identified by Research and Markets for all streamed video use cases, including on-demand as well as live. That would put the live-streamed video subscription total for 2021 at $15.92 billion with advertising accounting for $6.50 billion.

Calculating Annual Latency-Related Losses with One-Way Video Streaming

Using these numbers, we can calculate losses attributable to latency-related issues using previously discussed metrics. We're defining the amount lost as the difference between what would have been generated with flawless performance versus the actual revenue totals, which requires a calculation based on this formula: the loss amount equals [B/(1.00-x%)]-B, where B is the actual revenue amount and x% is the percentage of the projected loss.

In estimating losses attributable to high buffering rates, we'll take a very conservative approach despite buffering's ranking as the top consumer streaming issue. If, as Conviva's metrics indicate, the average global buffering mean has fallen to 0.28%, any consequential losses attributable to the NPAW study's findings that completion rates drop by 25% when buffering ratios reach or exceed 2% would be limited to areas of the world where the mean is well above the global average.

This would include Africa at a mean of 1.16% and Asia at 1.13%. Asia, in contrast to Africa, is a big streaming market. If, say, 10% of streams reaching users in those markets were a percentage point or so over the mean, the impact on advertising revenues globally from the 25% drop-in completion rates on those streams would be just a small fraction of the global live-streaming ad revenues but would still add up to a significant amount in raw dollars.

For example, if total streams in those markets represent 20% of the 500 billion-plus streams monitored globally by Conviva, 10% of that 20% or 2% of the global stream volume would impact revenue losses. If a 25% drop in completion rates equates to a 25% cut in potential ad revenues on those streams and the global live-streamed ad revenue comes to $6.5 billion as calculated above, the global ad revenue losses attributable to excessive buffering would equal 2% of the potential revenue total that would have been reached without these losses, which comes to $130 million.

In addition, if half of the 16% ad failure rate recorded by Conviva in 2021 is attributable to HTTP streaming issues, the loss total, using the previously described formula for calculating the difference between potential and actual revenues would come to 8% of the $7.74 billion that would have been collected without the failure, equating to a loss of $619 million.

Losses attributable to slow live streaming start times can be calculated based on the previously cited 5.8% per second abandonment rate with every second above a 2-second start delay. With the global video start delay averaging 4.3 seconds as measured by Conviva in Q2 2021, the abandonment rate would equal 5.8% multiplied by 2.3 seconds, or 13.3%. With 2021 live-streamed ad revenues hitting $6.5 billion as calculated above, the revenue total without this level of abandonment would have been $7.5 billion, which translates to a loss of $1 billion.

Excessive start time delays also impact churn rates, given that NPAW found that churn rates increase to as much as 50% when playback is subpar with more than 2% of viewing sessions on a given distribution platform. Insofar as start delays are averaging well above 2 seconds in every region of the world and start failures as measured in the Conviva 2021 report are averaging 0.78% worldwide, there's undoubtedly some persistency in subpar performance exceeding 2% of viewing sessions on some percentage of streaming platforms.

Taking a very conservative approach to calculating how this churn factor impacts revenue losses, we assume 10% of the excessive start delays and start failures occurred with persistency exceeding 2% of streaming sessions on streaming platforms accounting for 10% of total streams.
While 50% churn was found to be the top level resulting from this issue, we are on more solid ground if we use a much lower churn increase in the range of ten percentage points over industry averages.

The revenue loss would equate to the difference between what these platforms would garner at the average vs. their higher churn rates. If subscription revenues on these platforms represent 10% of the global live-streaming subscription revenue total as calculated above at $15.92 billion, their revenue would come to $1.59 billion, which reflects the higher churn rate. Without this level of persistent start delays, a 10-point reduction in churn rates across all affected platforms would allow them to recoup about $159 million in lost subscription revenues.

Finally, in calculating revenue losses attributable to live streaming latencies exceeding broadcast lag times, we shift to more speculative ground with reliance on Limelight's finding that 64% of consumers are more likely to stream a live event if it comports with broadcast latency. In fact, to keep our calculations within very conservative bounds we'll forgo estimating what the lost revenue tally might be resulting from subscribers dropping or declining to subscribe to live-streamed sports services.

But it's clear user concerns over latency are impacting live-streaming take rates. In 2018, trade publication Multichannel News reported a third of consumers indicated they would consider canceling a live sports service with subpar latency performance. That article also noted that Amazon's *Thursday Night Football* streaming service was garnering review ratings of 2.5 out of 5 stars as a reaction to latency problems.

Summarizing, our conservatively skewed calculations of total revenue losses stemming from poor HTTP streaming performance with live-streamed video add up as follows:

Revenue Source	Issue	Lost Revenue 2021
Advertising	Excessive buffering	$130 million
	Slow streaming start times	$1 billion
	Streaming-related placement failures	$619 million
Subscriptions	Persistent poor performance impact on churn	$159 million

Total revenue lost to live-streaming issues in 2021: $1.91 billion

Arriving at a 5-Year Loss Total for One-Way Video Streaming Latency

As to how the losses will add up over the next five years if the market persists in relying on HTTP-based streaming for the generation of live-streamed video revenue, we can assume current levels of performance will improve marginally as revenues continue to soar at high levels of CAGR. As Conviva notes in its Q2 2021 report, the marginal performance gains have diminished to where there's not much room for improvement in mature markets but while significant improvement can be expected in less developed markets.

Let's say that, over the course of the next five years, better performance globally cuts the ratio of losses to total revenue by half. Currently, that ratio based on our calculations stands at $1.91 billion in losses against total live streaming revenue of $22.42 billion or 8.5%. We'll set the projected loss ratio to average out at 4.25% through 2026.

CAGR projections for live-streamed video among researchers cited in this article range from a low of 11% in one esports projection to 21% for sports and 28% for live-streamed services in general. We'll stay on the conservative side and use the 14% CAGR levels projected by Research and Markets for the OTT streaming market as a whole. Applied to the $22.42 billion 2021 live streaming revenue total we're using in our calculations, that 14% CAGR would lead to the following revenue totals and losses over the next five years:

	Live-Streamed Service Revenue	Lost Revenue Ratio	Lost Revenue Total
2021	$22.42 billion	8.5%	$1.91 billion
2022	$25.56 billion	4.25%	$1.09 billion
2023	$29.14 billion	4.25%	$1.24 billion
2024	$33.22 billion	4.25%	$1.41 billion
2025	$37.87 billion	4.25%	$1.61 billion
2026	$43.17 billion	4.25%	$1.83 billion

Traditional live streaming lost revenue total through 2026: $9.09 billion

While we have not found any reliable estimates of current global revenue losses attributable to poor HTTP streaming performance with live-streamed content, it's useful to compare our findings with what little is available in the way of past estimates. One metric is from Verizon Digital Media Services in 2016; the other from Conviva's previously cited abandonment rate for 2018.

In 2016, Verizon estimated OTT video services encompassing both live and on-demand content were losing as much as 25% in revenue as a result of delivering average or poor-quality experiences. Applying this metric to today's live-streamed services, even half that loss rate would equate to $2.8 billion globally, or about $900 million more than we've calculated.

As noted, Conviva reported abandonment rates on live-streamed video hit 16.7% in 2018 as a result of poor performance. Conviva has not reported abandonment rates since then, but if that 2018 rate persisted in 2021, the cost in lost ad revenue would be on the order of $1.3 billion, well above our $1-billion estimate of abandonment-related losses attributable to delayed start times beyond 2 seconds. It would have taken a reduction in abandonment rates to 12.9% in 2021 to cut losses to the level we are using in our estimates.

PART 2
REVENUE AT RISK WITH POOR LATENCY IN NEXT-GEN USE CASES

XDN Infrastructure Sets the Optimum Performance Benchmark

Looking beyond the losses resulting from poor HTTP streaming performance with traditional one-way live-streaming services, the much larger loss risk has to do with the need for an interactive real-time mode of streaming that can't be achieved through the legacy CDN approach. How much in projected revenues from these use cases might be lost depends on how long it takes before streaming infrastructures like those supported by Red5 Pro's Experience Delivery Network (XDN) platform are readily available wherever needed.

As described at length in this white paper, this is infrastructure based on a multi-cloud architecture that supports streaming in any direction at any distance to and from any number of users with end-to-end latencies no greater than 400ms. Lower latencies at 50ms or below are attained in instances where usage is limited to a small geographic area or the applications running on the XDN rely on 5G connectivity to users, as occurs in the tie-ins between XDN infrastructure and 5G as described in this blog.

The revenues at risk in terms of next-generation use cases that won't work with reliance on HTTP-based infrastructure depend on how fast the capabilities embodied in XDN architecture become a mainstream component of video streaming. As described in many blogs and white papers, the pace of XDN adoption is accelerating rapidly across all use cases where real-time interactive video streaming is a fundamental requirement.

But, for our purposes here, we're looking at a worst-case scenario to calculate losses that would accrue without recourse to XDN capabilities. We do this by assessing the share of spending projections that can be associated with networked applications in each category of such use cases.

The Accelerating Emergence of XR

Much of this future revenue potential revolves around XR technologies – virtual, augmented, and mixed, known respectively as VR, AR, and MR. This is spending that will impact activity in multiple market segments, many of which tie directly into networked hybrid life applications.

Where VR is concerned, the technology has weathered years of well-publicized disappointments to gain a significant, albeit still limited role in entertainment, social networking, game playing, workplace collaboration, employee training, general education, and health care. Researchers have scaled back earlier projections but are in broad agreement that we can expect rapid increases in global spending on VR across all segments

Research and Markets predicts the spend will go from $6.1 billion in 2020 to $20.90 billion in 2025, equating to a 27.9% CAGR. Grandview Research valued the VR market at $15.81 billion in 2020 with an 18% CAGR putting it on track to reach $36.17 billion in 2025. Another take on the prospects comes from Fortune Business Insights, which forecasts the global spend will increase at a 44.8% CAGR from $6.30 billion in 2021 to $27.7 billion in 2025.

Projections for AR and MR are even more aggressive, with wide agreement these categories have already surpassed the VR market. For example, the Research and Markets report foresees a 38.1% CAGR for AR/MR from revenues that totaled $15.3 billion in 2020 to $77 billion in 2025.

VR's strongest growth is occurring where the technology has practical ramifications beyond entertainment. Just a third of the spending documented by Grandview is going toward consumer uses of VR while 53% is related to commercial applications in retail, real estate, and other sales arenas. The remaining share of projected spending goes to healthcare, the fastest-growing segment, enterprise, aerospace, and defense.

Assessing the Value of Networked XR Use Cases

As yet, most activity involving VR technology doesn't rely on network connectivity, given that there's nothing approaching ubiquitous support for live-streamed VR applications involving incessant real-time transmission of volumetric payloads in multiple directions. To ensure a simultaneously shared experience,

those payloads must keep pace with every action impacting what's happening in the virtual space, delivering each participant's unique view of the unfolding scene in tandem with every turn of the head.

But there's wide recognition that the anticipated surge in VR and other XR revenues depends on support for such connectivity. Analysts at ABI Research voiced these views in a recent press release in reference to the firm's Augmented and Virtual Reality Device Connectivity Report.

"Ubiquitous connectivity is necessary for users to interact with the surrounding environment and receive on-demand information anytime and anywhere," said ABI principal analyst Eric Abbruzzese, "New business models that can leverage connectivity capabilities and bring value to end users wherever they are operating need to be developed."

These requirements are a major force behind 5G with its ability to deliver high bandwidth and eliminate unacceptable over-the-air transmission latencies. Expectations along these lines were well articulated in a Forbes article by Sol Rogers, CEO and founder of immersive content creator REWIND.

"The lack of a suitable supporting network is one of the factors that has contributed to a slower than expected uptake in mainstream adoption of VR," Rogers wrote. "5G will usher in the next era of immersive and cloud-connected experiences. Faster, more uniform data rates, lower latency, and lower cost per bit will ensure it."

However, as Simon Forrest, principal analyst at Futuresource Consulting, is quoted as saying in a recent Streaming Media article, "We're still around 5 to 7 years away from blanket 5G service coverage in most developed regions, and certainly, devices won't be ubiquitously connecting at gigabit speeds, since this would necessitate a massive densification of 5G network infrastructure."

But is ubiquitous 5G connectivity really essential to the liftoff for networked XR applications? Not really, given that mobility is only absolutely essential to some relatively small subset of use cases.

Where fixed connectivity is concerned, cable and fiber networks are rapidly creating a high-speed broadband footprint across much of the developed world that's adequate to VR bandwidth needs. For example, cable companies, the leaders in fixed broadband penetration, are rapidly evolving their access networks to 1 gigabit-per-second capacity with a technology roadmap that envisions reaching up to 10 Gbps over the next five years. Notably, Comcast says it's now offering a 1 Gbps broadband tier in all its U.S. markets with return speeds set at 35 Mbps.

Indeed, most fixed broadband networks in most of North America, Western Europe, and Asia can deliver the bandwidth in the 50-100 Mbps range that's essential to utilizing the advanced tiling and other modes of bandwidth-reducing techniques supporting live VR streaming. Some sports producers, as in the case of the U.K.'s BT, have even begun using tiling to live-stream VR coverage formatted to 8K resolution to avoid the pixelating effects that occur with head-mounted device viewing surfaces.

But higher bandwidth alone, whether via fixed or mobile networks, is not sufficient to meet the requirements for live streaming VR or, for that matter, other XR content, including the standalone holograms intrinsic to MR applications supported by eyewear like Microsoft's HoloLens, Nreal's Light and Magic Leap's glasses. Often lost in the 5G and cable multi-G discussions is the fact that network access to XR applications depends on an XDN-caliber internet streaming infrastructure that can interoperate with

high-speed access networks to deliver XR payloads to and from the cloud in any direction at any scale and distance.

These connections must operate at sub-50ms latencies to support the instantaneous interactions that enable network delivery of content specific to what any user is looking at moment-to-moment within the 3600 panoramic viewscape. In the case of 5G networking support, this can't be done unless the tens of milliseconds to multi-second delays incurred by traffic traversing cell sites, metro and regional aggregation centers to get to and from the cloud are eliminated.

The ability to deploy XDN infrastructure with AWS Wavelength Zones offers an illustration of how this can be done. Wavelength Zones are instantiations of AWS compute and storage services housed in carriers' edge-based datacenters to aggregate local cell tower traffic for direct access to AWS cloud facilities. By deploying XDN infrastructure in Wavelength Zones, applications developers, service providers and the carriers themselves can deliver interactive video streams at end-to-end latencies well below 50ms between any user and source locations served by these AWS on/off ramps.

The path pioneered by the partnership between AWS Wavelength and Red5 Pro is just the beginning of the global transition to the integration between next-generation real-time internet streaming and 5G technology. Other cloud operators, including Microsoft Azure and Google Cloud, are following Amazon's lead with their own 5G edge strategies.

With such solutions becoming viable, it's clear the time will come when the full revenue-driving potential of networked XR applications can be realized. The question we're exploring is what would be lost if the XDN option didn't exist.

Today the overwhelming share of revenues derived from goods and services in the XR markets is unrelated to network connectivity. At some point, the opposite case will prevail when most uses of XR technology revolve around reliance on that connectivity. Adhering to our conservative approach to these calculations, let's say that just half the projections researchers have set for XR-generated revenues four years from now will be derived from network-based usage of the technology.

Based on the sum of the Research and Markets 2025 projections for VR and AR/MR market revenues at $97.9 billion, that would put our estimate of revenue that will depend on XDN-caliber XR connectivity by 2025 at $48.95 billion. And we'll forego the inclusion of any potential revenue estimates from earlier years in our calculation of what would be lost without adequate network connectivity.

The XDN Imperative in other Use Cases

As for other categories of emerging use cases beyond XR and those involving non-immersive instances of hybrid life applications that wouldn't exist without support from a real-time interactive infrastructure, the most significant involve new approaches to video surveillance and the use of interactive video streaming in the e-commerce phenomenon known as live-stream shopping. Here we should also note that we have excluded calculations related to non-VR versions of fast-action multiplayer games like Fortnight, which are already thriving with support from networking devoted to their needs.

Video Surveillance

Video surveillance encompasses a vast range of use cases ranging from home and business security to emergency responses and support for military and space operations. But impediments to real-time streaming, including the inability to aggregate multiple camera feeds for timely panoramic field analysis, prevent full realization of the benefits to be derived from video surveillance.

When traditionally-streamed camera feeds are delivered out of sync, with seconds of lag time behind what's happening in real time, operators must await extraction and pooling of critical information from individual video streams to formulate what amounts to an after-the-fact view of the situation.

These delays can be a matter of life and death during fires, floods, energy outages, hurricanes, tornadoes, robberies, mass shootings, military operations, and all the other crises first responders have to deal with. And delays in full-perspective visual assessments of malfunctions in factory production, oil drilling, space flight, and other complex industrial operations may add significant costs to damage control.

This is why we believe a large share of projected video surveillance revenue would be at risk without the ability to use real-time networking technology to overcome these limitations. Faster, smarter reactions to developments become the norm when it's possible to analyze tightly synchronized high-resolution camera feeds aggregated in real time from all locations relevant to momentary dynamics, whether cameras are positioned terrestrially, offshore, underwater, on drones, or in smartphones carried by field personnel.

As noted in this white paper, many companies are taking advantage of XDN technology to deliver these advanced surveillance capabilities to the marketplace. Video surveillance is spreading globally at an unprecedented rate, as reflected in researchers' market projections. Emergen Research predicts $86.33 billion will be spent globally on video surveillance technology and services in 2027, representing a 9.6% CAGR over the $41.26 billion registered in 2019. In a five-year forecast, BIS Research says spending will grow at a 10.06% CAGR, going from $31.8 billion in 2020 to $51.36 billion in 2025. Allied Market Research puts the growth rate even higher, predicting a 14.6% CAGR will lead to a $144.85-billion spending total in 2027.

Given the benefits to law enforcement, emergency responders, border patrols, military operations, and the everyday security needs of businesses and residences, it's reasonable to assume that at least 25% of this spending will go to systems that provide tightly synchronized real-time coverage and analysis of events across spaces monitored by multiple cameras.

Averaging the out-year projections of the cited research using the given CAGRs to set numbers for 2025, the total predicted spend for that year would come to $77.7 billion. The 25% that would not be spent if there were no way to provide network support for the advanced surveillance mode discussed here equals $19.4 billion

E-Commerce – Live-Stream Shopping

Live-stream shopping is a fast-growing segment of consumer product marketing that resembles traditional TV shopping on channels like QVC and HSN but with the added benefit of direct interactivity between presenters and viewers. Pitches delivered by salespeople or celebrity hosts are streamed on platforms that support direct in-video purchasing options and chat links that presenters can respond to live as part of the webcast.

According to Yahoo!, a report from Coresight Research predicts that live-stream shopping sales in the U.S., pegged at $11 billion for 2021, will increase to $25 billion by 2023. The trend is a key element to the massive acceleration in online purchasing during the pandemic, which retailers believe has taken hold as a permanently higher proportion of their sales. Forbes reported digital sales, in general, jumped from 20%-30% of retailer revenues in 2019 to 40%-50% in 2020

Globally, according to projections from Market Research Future, revenue from live-stream shopping sales will increase from $55.96 billion in 2021 to $150.69 billion in 2025. Apparently this excludes China, which was expected to top that number in 2020. McKinsey predicts live-stream shopping could account for 10%-20% of e-commerce sales by 2026, which based on Grandview Research's global e-commerce projections, would put the 2026 global live stream sales total somewhere between $579 billion and $1.19 trillion.

So far, the chat input from viewers has largely been text-based, but, with real-time interactive video infrastructure support, the obvious next step would be to enable a synchronized real-time viewing experience in conjunction with real-time video communications from audience members, no matter how many might be watching.

The ability to stream video interactively from any direction to any number of people in real time will allow viewers' questions to be posed via video rather than chat alone. Marketers who choose this approach will benefit from viewers knowing they have an opportunity to be seen during the presentation. This could be worth a lot of money in terms of sales generated through larger audience participation.

Many observers point to the upside potential of including video input from viewers, including live-stream interactions with viewers through AR or VR. "In the future, consumers may be able to have virtual face-to-face conversations with a show host just as though they were speaking in a store," McKinsey noted. Commenting in the Yahoo! Article, Elissa Quinby, senior director of retail marketing at Quantum Metric, observed that the appeal of interactive video extends beyond engaging talking heads.

"You're going to see things like trainers interacting with clients: Picture doing squats and having someone critique your form. Having a professional watching on the other side will become the norm in online selling," Quinby said. "People want to shop socially and have a storytelling experience."

The future revenue gain generated from audience participation via video input is impossible to know. But it seems reasonable to anticipate at least 5% of projected sales would be attributable to higher audience engagement resulting from support for such capabilities through real-time interactive video streaming infrastructure. Using the conservative Market Research Future projections for live-stream shopping sales, we'll add $7.55 billion to our calculations of revenues depending on real-time interactive video streaming infrastructure by 2025

There are other e-commerce components we could add related to online auctions and live online gambling venues, but the amounts in the timeframe we're looking at would likely be insignificant next to what we've already calculated.

Tabulating Next-Gen Use Case Revenue Gain Attributable to XDN Connectivity
Here, then, is the summary of calculations discussed above:

2025 Global Revenue Totals in Next-Gen Use Cases Attributable to XDN Capabilities

XR	$48.95 billion
Video Surveillance	$19.40 billion
Livestream Shopping	$7.55 billion

Total: $75.9 billion

Of course, beyond 2025, the annual total would rise, but, for our purposes, we'll keep it simple by saying that, beginning that year, this is the amount that is riding on having an XDN-caliber infrastructure in place at sufficient scale to accommodate global support for these emerging use cases. Combining the 2025 and 2026 totals, we get an amount, $151.80 billion that very conservatively reflects what's to be gained with the transition to XDN capabilities between now and YE 2026 or, in terms of the true cost of latency, what would be lost without such a transition.

Adding everything lost and to be gained through 2026, we get:

Traditional live streaming lost revenue total through 2026	$9.09 billion
Revenue attributable to live-streamed support for next-gen use cases	$151.80 billion

Total: $160.89 billion

CONCLUSION

The internet economy has reached a point where any further delay in the implementation of real-time interactive video streaming at global scales will lead not only to ongoing losses on traditional one-way live video services; it will also delay generation of revenues attributable to a broad array of next-generation use cases that would be impossible to bring to market without the support of streaming infrastructure with performance parameters matching those of the XDN platform.

While there have been no studies tallying losses incurred by poor legacy performance over CDNs, there's enough research pointing indirectly to loss factors that can be reasonably extrapolated from the data. In doing so, we have shown those losses add up in 2021 to at least $1.9 billion and, through 2026, will aggregate to $9.09 billion.

As noted in the Introduction, Rethink Technology Research is about to fill the gap in formal research about the cost of video streaming latency. We expect a forthcoming white paper reporting on their findings will reach similar conclusions, at least as they pertain to the costs stemming from high latency on traditional one-way video streaming.

As to future projections, it remains to be seen how Rethink looks at what's in store. But we've entered an era when dependence on real-time interactive streaming has matured to where failure to utilize XDN-caliber streaming technology will result in vast amounts of lost revenue. Looking at the worst case, i.e., one in which the world fails to realize the revenue potential of these use cases in the 2025-2026

timeframe (and disregarding what might be lost before then), we calculate the amount at stake to be $151.80 billion.

Of course, lost opportunity on this scale will never happen, given the fact that the XDN platform is already in wide use and will be gaining market penetration rapidly in the years ahead. But the numbers do suggest why, whether for streaming traditional live content or providing streaming support for the next-gen use cases, there's every reason to accelerate the availability of XDN infrastructure immediately.

Immense opportunities abound for companies that want to get ahead of this curve by exploiting the revenue benefits of the XDN platform sooner than later. To learn more, contact info@red5pro.com or schedule a call.