DOM ROBINSON

CONTENT DELIVERY NETWORKS

FUNDAMENTALS, DESIGN, AND EVOLUTION

WILEY

Content Delivery Networks

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Fundamentals, Design, and Evolution

By Dom Robinson

Co-Founder, Director and Creative Fire-Starter
id3as-company ltd.

WILEY

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Frontispiece

Provides the reader with comprehensive insight into the structural decisions that can to be made when architecting a content distribution system that uses IP-based networks

The narrative of this book draws on a wealth of real-world and practical experience that the author has accrued through two decades of coalface experience architecting and delivering large, mission critical live video, webcasts, and radio streaming online, over both the Internet and private IP networks.

From this loosely defined "tradeperson's" standpoint, rather than the often explored tightly academic or business-sales point of view, this book takes a broad, humored, and at times pencil-sucking look at the art of building content delivery workflows.

Topics Include

- Delivery of live, catch-up, scheduled, on-demand, TVOD and SVOD
- CDN topologies including edge-caching, stream-splitting, Pureplay, Operator, Satellite, and Hybrid
- Computation hosting and orchestration in models such as dedicated appliances and virtualization
- Format considerations and achieving adaptive, format resilient operator networks and backbone infrastructure
- General comments on market forces over cycles and eras of evolution of these technologies

This book aims to talk in backroom engineers' English about the challenges faced in the real world, and to stimulate the reader to think extremely broadly about the options and problem spaces, and how to ensure that delivery is always, at the least, "good enough" for the operator's and consumers' commercial objectives.

As we enter what the author calls the "third generation of CDN," architects who are new to the area can use this text to draw on the author's own practical experience over the first two generations.

The book will also be an interesting read for those who have themselves built large infrastructure, providing a moment to reflect on other ways around problems. It will be a useful quick-start tool for those who are trying to understand the complex challenges of large-scale content delivery.

Not one for hiding opinion, the author also throws a number of challenging "what if" scenarios into the discussion to highlight some possible long-term design architectures that today may be a little fantastical but tomorrow may evolve based on the clear demand that such architectures could reach, should the commercial model evolve in line.

This discussion zooms in on the recent evolution of software-defined networking and the changes that this schism will bring as capabilities for many players in the network stack become unlimited, and infrastructure allocated to a particular task can be repurposed at the flick of a bit.

About the Book

While content delivery network architecture texts typically focus on current and forthcoming best practice, few take a deep retrospective view and embrace the cycles in the sector. CDNs also typically comprise 20% of their engineering work on video despite its being 80% of their traffic overhead. The author has focused on live video and audio transmission because the problems span so many layers of the network stack. There are, of course, many application-specific challenges, with particularly gaming and conferencing and to a lesser extent dynamic website acceleration and small object or large file delivery. Some of these do cause network layer issues, but generally the traffic is not impacting to a network operator – it is impacting to the Software as a Service provider or the application user. There are many complex issues that can be explored, and many are touched on in this book; however, for the main part, the core focus of this book is on live (and to a lesser extent on-demand) video delivery – TV, radio, video, and live audio over IP networks.

Synposis

Starting in 1973, streaming audio and subsequently video have been baked into the IP protocols. With the web making the quick discovery of content near ubiquitous, the demand for not only huge volumes of text but also for web apps, and significantly for high-quality video, has exploded.

The likes of the BBC, YouTube, Netflix, and countless other online publishers, have lit up the information highway with literally inconceivable amounts of information conveyed in huge quantities of bytes. Those data have to be delivered to destinations by someone, and the dark art these people practice is called content delivery networking.

Over the past 20 years we have seen several trends emerge, and these exist at both the micro level, where we are encoding pixels of video into a streaming format, and the macro level, where millions of users are able to consume content from hundreds of thousands of servers, reliably and with a great deal of resilience.

Trends in GPUs are changing how encoding resources are deployed. Evolutions in distributed computing are bringing about a macro change in the architecture of these types of services.

This evolution promises greater service levels, more flexibility to meet the customers' exact requirements, and new security challenges as infrastructure becomes increasingly shared in multi-tenant public cloud models.

Telecoms network operators are now seeing IP services as a core part of their businesses, and their understanding of their own internal content delivery architecture requirements is a key driver for their rapid adoption of a software operating model. Soon operators will, at-will, be able to deliver the CDN as an SaaS model on their own infrastructure, and additionally offer other SaaS models in the same infrastructure, providing risk mitigation as they try to underpin services for an ever more divergent target market.

Unique Perspective

The book describes the historical context of the streaming media and content delivery market from the unique perspective of the author who is a true native to the sector. It draws heavily on personal experience and hands-on examples from 20 years of live webcast production through to public company infrastructure architecture. There are few in the industry who can boast such a rich and varied practical experience across the sector, and this unique insight is fundamental to the narrative.

Aside from the anecdotal and practical commentary, the book takes the implementer through a wide range of design considerations for different network topologies, starting with the author's own requirement filtration processes through to initial sketches, through to roles and responsibilities, and to the complexity of managing change in established teams, agile as opposed to waterfall considerations, in the context of large blue chips, security and commercial models, and value chain alignment.

This widely embracing viewpoint, supported by examples ranging from IETF discussions, regulatory considerations, policy formation, coders, hardware vendors network operators, and more, is rarely available from one author. The author draws on conversations with peers in the industry, and in the course of writing, he gathers their comments and input too.

While many books on these topic slice and dice these seemingly unrelated schools of thinking into their constituent parts of commercial, technical, operational (etc.), this book can help service designers embrace the world-view of influences that need to be considered when architecting a robust and high-quality content delivery service for today's online consumers and business users.

Market Need

Today's market is just about to fully enter what the author call its third generation.

- The first – which spanned until around 2005 – was the appliance era dedicated hardware and software
- The second – which spanned from 2005 until around 2014 – was the virtual machine era when software could be moved machine to machine
- The third – which started in 2014 – is the emerging container era characterized by software that is highly componentized and is deployed to the resource best suited to the task as the capability is required

As the SDN/NFV models stimulate understanding across the Telco sector, there is about to be a tech refresh like no other: all the hardware that has traditionally been dedicated to task is going to become software driven in entirety. The Telco operators who were about to deploy Gen2 CDNs are holding back to see how the underlying infrastructure is going to evolve, to then deploy their CDN as a gen3 model using the network's built in resources to deploy the CDN as an SaaS and when a client needs it.

That cycle is going to take a further three to five years.

As it happens, service architects are going to be planning more against customer requirement than against "productizability," and this requires a breadth of thinking at the COO / CTO level from every engineer and commercial participant too.

Designing a CDN for tomorrow is a broad challenge – and this book strives to get the reader thinking like a content delivery network designer.

Audience

Target: Streaming media readership, IP / cable/ satellite / Telco / mobile and TV operators, content producers, ISPs, policy and regulatory (net neutrality and content rights), and all stakeholders in networks that may deliver large quantities of video or audio (and data / applications too).

The book is intended to start with a basic introduction, and while it will expect to push the limits of even advanced academics at times, the narrative will attempt to keep even nontechnical readers immersed in the commentary.

1

Welcome

1.1 A Few Words of Introduction

I am literally buzzing from the past few days. When the team at Wiley got me involved in the previous title I worked on with them (*Advanced Content Delivery, Streaming, and Cloud Services,* 2014), I was feeling some way out of my comfort zone. I normally write extensive commentary around the streaming media and content delivery network sector for a variety of trade presses, and very much with a hands-on tradeperson's view. This was the first time I was to contribute some writing to the community among recognized academics: a notably different focus to the engineers in enterprises who read the trade press that has been my writing home for two decades.

While I am no academic, I was bought up at the knees of academics. My godfather was head of Maths and Physics at Sussex University for many years, and he was my favorite babysitter! The opportunity to build the first Mac network at the university in the mid-1980s (unboxing the gift from Apple was a way to occupy a 9-year-old during a holiday), through to, at 17 in 1991, having a log-in (including an email and remote access to the William Herschel Telescope) to Starlink, which was one of the early global IP networks, my teenage years were spent as a geek.

However, I left two different degree courses (Astrophysics and Artificial Intelligence) to pursue commercial ventures. I was typically always naturally more entrepreneurial and impatient more than patient and academic, so I wanted to get to the place where the interesting changes could be made by applying the right technology at the right time. And I believe I have been lucky enough to be in a sufficient number of good places at the right time, and – importantly – with the right people, to have achieved some interesting things, both in delivery of that new technology but, more importantly, achieving the end goal that the technology was underpinning.

The academic world has, to an extent, caught up with the front line of practical implementations of the types of solutions, architectures, and services that

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I am familiar with, and the previous title was exciting, in part for its success and recognition but also, for me, to write for a wider audience than those who read trade magazines!

My style was welcomed by Wiley, and the team felt that my perspective added a lot of context. Immediately after publication there was a hint that, should I have some ideas that could commit to paper, there may be interest in another publication.

Over the summer this past year I came to the conclusion that there may be some use not in trying to define an empirical best practice, but to impart a more general range of insights and to write more gutturally about the overall experience and insights I have gained from the front lines in evolving many CDN architectures, and using many others.

While my idea was being discussed with the Wiley team during these last weeks, I chaired the Content Delivery World 2015 conference (a regular "gig" for me). A speaker couldn't show, so I was asked to fill a 30 minute slot at short notice. With discussion about this book fresh in my head, I filled the 30 minute slot by talking from the top of my head about many of the topics in these pages. The room filled up to about 300 people – many CTOs and chief architects of large global blue chip Telcos, mobile networks, and broadcasters – and afterward I had a rain of business cards inviting me in to follow up. For me, this was some validation of the relevance of a sector-tradesperson's experience to the community, and reinforced my feelings that this book would have some value to readers.

The Wiley team contacted me literally as I returned from that conference and said "let's do the book," sent me the contract, and I returned it within a few minutes.

Well, you only live once. So if this isn't the right time to record some of my insights and experience, I have no idea when it will be!

I hope you find the book fun, enlightening, at times challenging, and, if nothing else, stimulating to your thought processes as you develop your content delivery strategy.

1.2 The "Why" of this Book

Today there is a wealth of excellent documentation available to the CDN architect that defines best practices. Be that for the core technical services architectures, compute paradigms, CoDec configurations, hardware setups or any other aspect, there is generally speaking both a "For Dummies" guide and a "Master Engineer" pool of literature.

There is, however, a complete lack of middle ground material. Most people who engage with streaming media, video delivery, and scaling large service platforms tend to pass through the space, and their interest is part of a specific

project or role they have taken for a while in a larger corporation. They require deep understanding to address the problem space they are in, but once they acquire or develop those insights, they may move on to a new role with different responsibilities or even a completely different focus. This means that as each generation passes through some of the niche, their specific learning is then diffused away. To use an analogy, the "aural" tradition of the "bush hunter" is lost to the anthropologist's archive, and the practical tips and tricks that are only learned on the job, or spoken about at 2 am during the drive home from an event, fail to get passed on in any formal text. I aim to capture some of this and share it with you.

There is an intentional levity in my writing. I have been writing about deeply technical subjects for years, and in trade press if you don't instantly engage the reader, the reader will turn the page. My style is to develop a sense of backroom chat, and so from that perspective I hope you will allow me some creative scope and license – particularly on the analogies, which quite often are not supposed to microscopically represent the accurate details of a story but aim to help contextualize the next part of the voyage.

Do feel free to jump around: you will for sure have your own focus and reasons to pick up the book. While I try to take the reader on a voyage from start to finish, some of you will want to go head deep into my opinions on a certain scope. Do it! I am not a linear person, and I myself tend to read books in many directions! Don't be hesitant! Make it work for you.

… And do email me dom@id3as.co.uk if you want to throw virtual eggs or discuss any of the finer points!

1.3 Relevant Milestones of the Personal Voyage

So at the risk of writing what could become a CV – and no, I am not looking for a job (as you will see I have rather an awesome job) – let me give you a little potted history of some of my key milestones that will form the spine of the coming journey.

As mentioned, I was brought up on a university campus and was essentially computer conversant by the time I was squeezing pimples. In my generation that was unusual: the nerds were the ones who would get bullied by the "jocks" at school, unless they were me and large enough to give as good as I got. So I was largely left alone to geek-out, building radio telescopes and working out how to do wireless telemetry between early personal computers (BBC Micro/ZX81 being my early platforms of choice!). You got the picture. I am assuming I am among company.

However, as university loomed, and girls got more interesting, I became more interested in music. In fact I got more interested in music and production than in astrophysics and computers. While computers were becoming

more dominant, I was drawn extensively to event production/PAs/sound engineering/video production/VJing, and so on. After a few months working at Raves, and a longer spell putting on drum and bass and "chill out" club nights I left university to one side.

Two key things happened at this time.

The first, I was encouraged by a friend, Chris Daniels, to focus not on club promotion but on the promotion of micro-billing systems.

In 1994 and 1995 the UK Premium Rate Information Services and Paging Services were all the rage, and I essentially had an idea to give pagers to all the students at a very large local university for free. The plan was to allow the university to message the students with email headers if they had something in their university email (saving the poor students traveling in for email to the university network, as 90% did at the time in the pre-laptop era), and all the while charging a premium tariff to friends and family for messages sent to the students pager. The idea was well received by a variety of key people and with the support of not just the vice chancellor but also the government committee that had just published a report about how critical it was to "wire up" the students. So I – and a friend, Steve Miller-Jones, who will feature again later in the book – managed to raise £250,000 for the pager CAPEX from a wealthy venture capitalist, who himself ran a large cable network operation across Europe called UPC.

The second major thing that happened was that while the club promotion was still ongoing, I was invited to bring our Brighton club night to the Ministry of Sound in London for that year's London Institute Student Union's freshers' night festivities.

And so it was in 1996 that we wired a Real Audio encoder stream from the decks at the Ministry of Sound to an online-hosted server and then relayed it to our "normal" club in Brighton in "stereo" over a phone line. Yes, it was a 48 kbps audio feed. Yes, it was impressive that we managed to make it work at all, and yes, it was life changing.

Through that single event I saw quite how much the Internet was about to change the "music industry." The disintermediation of the record company's Vinyl monopoly was only a matter of time.

In what was *so nearly* my sharpest move, I missed registering the domain mp3.com by two weeks but managed to grab m3u.com – which was the streaming meta-file that was universally associated with mp3 and enabled instant playback through what is called progressive download.

Meanwhile my pager project had hit some issues in its test. We had a sample of 30 pagers and a class of computer science students. They were to help us measure if the revenue from their friends and family messages would help show significant enough return for us to commit the £250k investment and launch the business across the university. The test was scheduled to run for one month.

We failed to allow for the fact that the "meme" of a student's pager number needed to propagate to many places and have enough opportunity to be used

before a sufficient volume of friends and family would call back and generate the level of income we required.

In the 30 days of our 30-person trial, of course, that did not happen. There was only one thing to do – to take that £250k cheque back to its owner intact. That I did.

At once that decision put me out of pocket, but in a place of deep regard with the venture capitalist. The VC then in turn asked what else I was working on, and I explained about mp3.com and m3u.com.

He instantly invested in "me," providing me expenses for R&D, travel and a living salary. Within a few months I was in the full throes of the late 1990s dot-com boom. I was in a plane every other day traveling Europe, East Coast US, and West Coast, meeting some of the folks from companies that then became internationally known. We helped get the download mp3.com functioning with its "listen now" feature, replacing the.mp3s with.m3us that pointed to the mp3s in their charts – simple but an instant effect. I recall being seated in their facilities as the my.mp3.com furore hit, and as their valuation went into the billions, and at the same time became the pre-Napster hot potato.

I knew Napster and Scour as they kicked off – having met them at early Streaming Media Conferences (one at which Bill Gates gave the keynote), although was in practice closer to mp3.com myself. I also engaged with Real Networks and Microsoft Netshow Theatre as it became Windows Media.

It was an awesome, electric time.

However, in 2000 the bubble was already showing severe signs of deflation, and it was time to come back to focus on the UK and establish my own base and business, rather than continue to work in an Incubator that itself was struggling to turn out some big wins in a turning tide.

So I set up as a streaming media and IPTV consultant and webcaster, and went about getting my first major client. Thanks to another crazy, but close friend – known as Timmy or "TT" – who is one of the more fearless sales guys I have ever met, we essentially walked up to the UK Prime Minister's office and engaged the webmaster there in a discussion about improving the PMO's communications using video (and a demo of streaming live drum and bass to an HP Jornada over a 9.6 band infrared modem on a Nokia phone!).

From there I was put forward to help a small company, Westminster Digital, with their deployments of video workflows for both the PMO and for Parliament; in particular, I helped develop the workflow that brought the weekly Prime Minister's questions to the web.

With that on my CV, establishing engagements with interesting broadcasters and Internet companies proved much easier, and my freelance consulting and webcasting managed to keep me fed, while the stability of regular article writing for the ISP *World and Streaming Media* helped with both marketing and cash flow. I managed to hook into most of the London-based former DVD authoring – now webcasting – companies as their ad hoc live encoding