Making the Transition from ISDN to IP

History

Integrated Services Digital Network (ISDN) is a set of standards established in 1988, which regulate the digital transmission of voice, video, data, or other media simultaneously over the public switch telephone network. ISDN standards were designed to ensure reliable, low latency delivery of voice and data over circuit-switched networks, but additionally, to provide access to packet-switched networks. ISDN systems can be used for a variety of functions, including Internet access, high quality telephony, and remote broadcasting.

In the 1990s, ISDN gained popularity within the telecommunication industry for the delivery of voice and data. The technology posed an exciting alternative to POTS as a way to deliver simultaneous voice, data and teleconferencing services between distant users. However, the 128kbps data limitation quickly limited its usefulness for Internet and teleconferencing applications, as IP technology advanced and bandwidth requirements for these applications increased.

Nonetheless, ISDN became the primary method for delivering remote radio broadcasts due to the reliability of the service and relatively low bandwidth requirements for transmitting encoded audio. Due to the reliability of the service, and relatively low bandwidth requirements for transmitting encoded audio, broadcasters could reliably assume that ISDN could supply stable, predictable connections.

Hello! I'm back again to interject useful and pithy comments on all things related to codecs. As always, feel free to ignore these notes as there is no test at the end of this primer.

Present Day – Why the Telcos Hate ISDN

For over twenty years, ISDN has been the King of the Hill for remote broadcasts. In the past, ISDN circuits were easy to get installed. Connections were fast and stable, with reliably outstanding audio quality achieved using hardware ISDN codecs (like the Comrex Nexus or Comrex Matrix). Coding algorithms like the ubiquitous G.722 offer reasonable fidelity (about 7 kHz frequency response) with about 6 milliseconds of delay in each direction.

But in spite of this, phone companies hate ISDN, primarily because ISDN never really found mass acceptance in the U.S. in consumer homes and businesses as it did in other countries. In the US, there were never any ISDN "killer applications." Teleconferencing services made limited use of ISDN line and the banking industry used to ISDN to connect ATMs to banks. Eventually, due to its 128kbps bandwidth limitation and its limited usefulness for Internet connections, ISDN use for most of these applications was phased out.

Even though broadcasters have embraced ISDN, the market is niche and relatively small in comparison to other markets serviced by the major telcos. Much of the Central Office hardware for ISDN and POTS circuits, such as the 5ESS and DMS100 Central Office switch, is antiquated and parts are no longer manufactured, making repair or replacement difficult or impossible. Troubleshooting ISDN circuits is a difficult task and many experienced ISDN technicians have retired.

"State of the Art" Nortel DMS100 Switch circa 1979

As the telcos have migrated their voice and data infrastructures to IP-based packet-switched networks, there has been little need to train new technicians on ISDN services, especially as subscriptions have dwindled. Some voice providers have even declared that all of their traffic will be sent over the packet-switched public Internet within the decade. This would preclude the use of ISDN services since they require a circuit-switched data network. Many providers have punctuated this with the announcement that new ISDN services will no longer be offered in many parts of the U.S.

Major telephone companies have significantly changed their business models in recent years. They are no longer providers of traditional public switched-network telephony services; instead, they are now primarily focused on becoming data providers. Telcos have eliminated their crumbling physical infrastructure, and overhauled their networks to interface with the public Internet, in order to accommodate the data demands of both the mass consumer and business. The cost savings that they have been realizing by converting their internal networks to IP based technology are massive; in the billions of US dollars annually. Unfortunately, the dependable circuits that broadcasters long depended on, such as equalized lines, POTS and ISDN, have been relegated to the annals of history along with the telegraph and public payphones.

IP (and IP Codecs) to the Rescue

IP based hardware codecs are the heir apparent to ISDN technology. Packet-switched based IP data circuits tend to be easy to access and relatively low cost and they come in many packages--both wired and wireless. Broadband cable, DSL, MPLS, Wi-Fi, ISM band radios, Wide Area Networks, Cellular data services such as 3G and 4G LTE, satellite data services all provide the ability to transport IP data. Some provide a secured, "closed" private network while most provide access to the public Internet. Compared to traditional circuit-switched data services like POTS and ISDN, IP data services are much faster, more cost-effective, and simpler to install.

Just as IP data services have become more and more prevalent, so have hardware-based IP audio codec offerings from broadcast equipment manufacturers. In fact, IP has touched every single aspect of the modern broadcast facility, to the point where any old naysayers who once trumpeted "IP is not ready for prime time" or "IP audio can never be broadcast quality" will be looked at as a bit crazy. Many broadcast equipment manufacturers offer products for transporting IP audio over every IP data circuit imaginable with a wide range of applications, for a wide range of budgets.

Professional broadcast IP codecs are often times called on to perform miracles on less than miraculous data circuits. How well an IP audio codec performs, especially on the public Internet, is generally all about the manufacturer's "Secret Sauce." High quality, low latency coding algorithms, dynamic jitter buffer management, error correction techniques, NAT Traversal, redundancy and many other "tricks" typically make up a codec manufacturer's arsenal of IP transmission management tools. Comrex BRIC Technology takes it several steps further by employing unique UDP Reliability and Congestion Avoidance tools known as BRUTE that make our award winning "Secret Sauce" better than the rest.

But Wait…

In this age of instant gratification, nobody really likes to wait for anything. The word 'delay' generally has negative connotations, but no more so than in broadcast. Delay can kill momentum and create a stilted two-way conversation. So, before we herald the coming of IP as the savior of the remote broadcast, it's worth pointing out a few of the drawbacks of IP, particularly the public Internet.

Most of us remember our first experience streaming audio over the Internet. Perhaps we were using Windows Media Player or RealPlayer to stream a song. It might play for a bit and then stop to buffer for several seconds while we endured the silence. Then it would play some more, then buffer, so on and so forth. That's not exactly the kind of experience that one would consider broadcast quality. Can you imagine your adrenaline filled afternoon sports host doing a remote from a crowded sports bar having to deal with buffering delays while talking to a major sports celebrity? Not pretty.

A lot of times we hear the term "jitter" bandied about during discussions regarding IP audio coding delay. The term "jitter" is commonly misused to refer to delay. However, jitter itself is actually distinct from delay! To be clear, the term "jitter" used in relation to IP audio is not the same jitter observed in general electronics (related to clock reference), nor is it related to drinking too much caffeine. In this case, jitter is a measure of the variation in packet arrival time caused by various network conditions that can cause overall latency of the audio transmission.

BRIC

Early on in the IP audio for broadcast game, Comrex engineers knew that providing a broadcast quality "ISDN-like" experience would be critical for the success of a product that relied on IP data circuits for connectivity (particularly one that would be used on the public Internet). BRIC (Broadcast Reliable Internet Codec) Technology was developed to mitigate the challenges of transmitting broadcast content across contentious networks. We created a comprehensive suite of tools that included an intelligent jitter buffer manager, tasked with maintaining minimal latency while assuring the integrity of the audio content.

A complete library of very high quality and low delay encoding algorithms was also a key component. The AAC family of algorithms was selected to provide the user with a range of acceptable quality and encoding delays that would best be suited for the user's particular application. Also, due to the difficult nature of Internet peer-to-peer connections, a method of making easy connections from the field was developed. This was based on Traversal protocols to help navigate tricky router and firewall issues. The SwitchBoard Traversal Server is covered later in this document. Subsequent development has added sophisticated packet retransmission technology and other reliability features to the BRIC toolbox.

Because of the development of BRIC Technology, Comrex IP codec users have been able to achieve broadcast results that have far surpassed the early days of streamed audio. Full bandwidth audio (20Hz to 22kHz) with round-trip delays times of just a few hundred milliseconds with no program interruptions are regularly realized by IP codecs users even when using challenging 3G and 4G cellular data services.

When Comrex introduced BRIC Technology back in 2005, we published a handy dandy IP Primer at the time that delves into the challenges and advantages of IP Audio. This document is still available in PDF format on the Comrex website (www.comrex.com) and it contains lots of useful insight from yours truly. ;)

Getting ISDN-Like Performance from IP

In order to successfully replace ISDN, the solution you choose needs to be as good as or better than ISDN. So, what can we do to make that happen? While IP codecs can provide ISDN-like results, the simple fact of that matter is that the quality of your connection will only be as good as the quality of your circuit. And let's face it: not all IP circuits are alike. Those of us who have depended on the robustness of ISDN service over the last several decades cannot help but be skeptical of IP networks' ability to provide "ISDN-like" results. But, as previously noted, the difficulty with ISDN lies in availability and trouble-free installation. Most likely, you are no longer able to call up your local telco provider and order a BRI or PRI circuit for the big Music Fest coming up in a couple of weeks. If you've tried to make that call recently, you know what we mean.

When looking for a suitable replacement for ISDN, there are a few things to consider. First, IP data circuits typically offer 10 to 20 times the bandwidth of the traditional BRI at a fraction of the cost. Considering the advantages of the latest in coding technology, you can send a high quality, 20 Hz to 20 kHz stereo signal, compressed to 64kbps across a network with 1Mbps upload and 5Mbps download for as little as $40 USD a month. That's a pretty good deal with lots of "elbow room." That additional bandwidth would easily allow you to deploy multiple IP codecs on that single circuit as well as realize additional cost savings over the cost of multiple BRI circuits. As long as you don't make the mistake of sharing that bandwidth with every user in your facility, you can get amazing results that will make you forget ISDN faster than…well, faster than telcos have forgotten about ISDN.

Not All Codecs Are Created Equal

Broadcast IP codec manufacturers are keenly aware of the fragility and inherent unreliability of the public Internet. Most have developed their own "Secret Sauce" to improve the dependability of their products when used on compromised data networks. While every manufacturer of IP audio codecs tends to address this in their own unique way, all codecs generally cover these main areas in their offerings:

- Jitter buffer management for maintaining very low delay (this can be static or dynamic)
- Error correction/protection
- Variety of encoding algorithms
- A way to ease peer-to-peer connections (NAT Traversal)

Each of these items is critical for dealing with the unpredictability of sending encoded audio over an IP network, especially if it is compromised or contentious. Many other factors come into play when determining the success of an IP broadcast. So, when choosing your broadcast quality hardware IP audio codec, consider the following things:

- Does the codec provide high quality encoding algorithms capable of producing audio quality acceptable for my broadcasts?
- Does it provide dynamic receive buffer management for maintaining the lowest latency possible while maintaining maximum reliability?
- Does it provide error protection or concealment techniques to accommodate for dropped packets?
- Does it provide compatibility with IP codecs from other manufacturers?
- Does it provide fall forward/fall back redundancy?
- Is it optimized to be used on both wired and wireless data networks including the public Internet? What about cellular data and satellite services?
- Will it perform well on compromised or marginal data networks?
- Does the system provide a method to navigate NAT routers and firewalls?
- Does it provide a user friendly control interface and form factor?
- Can it use multiple data networks simultaneously?

For what it's worth, Comrex codecs, like the ACCESS and BRIC-Link, handle all of these tasks exceptionally well. You can find out more about them at the Comrex website. One thing we haven't touched on yet is interoperability with other manufacturers' device. There is a standard, known as Tech3326, that defines how all IP audio codecs should connect to one another. But there's still a lot of work to be done to make this completely seamless. Comrex codecs are compatible with the standard. You can learn more about this by googling "**EBU Tech3326**."

There are many other considerations to make when choosing the right tool for your specific application. Enough cannot be said about the importance of being able to demonstrate the product's ability to function in a real world environment. Make sure the manufacturer of the codec or codecs you are considering offers a demo program that provides you with a suitable trial period for evaluation in multiple situations.

Going the Extra Mile for the Last Mile

If you've ever depended on an ISDN codec for your broadcast, you know that it would be absurd to even consider the possibility of sharing that 128k of bandwidth with another user. It would simply make your transmission impossible. While IP is not quite the same and bandwidth is not quite so limited, the same general principle applies. If you are using an IP codec for the transmission of an important broadcast, why would you risk its potential failure by sharing that bandwidth with other users?

There's a common misconception that if there's a 100Mb pipe available for a broadcast, there will be plenty of bandwidth available. But what many fail to realize is, when made available to all of the users in your facility, that bandwidth can disappear quickly. More importantly, increased data traffic on the same network as your IP codec can cause packet loss, resulting in audio "dropouts", and add significant delay to your transmission.

It is of paramount importance to make sure that you have dedicated bandwidth for your IP codec that is not susceptible to being usurped by other users.

As there are many ways to accomplish this, it is up to you and your IT professional to determine the best way for this to happen. But here are a few simple suggestions to get you started:

Get a dedicated broadband connection (fiber optic, cable or DSL) for your codec

In most cases, you'll find that for as low as $40/month you'll have more than enough bandwidth for your application. As a rule of thumb, you'll want to have twice as much bandwidth for your data connection as the algorithm that you are using. For example, if you're transmitting using AAC-LC at 128kbps, a minimum data connection should be 256kbps. It's not uncommon to find that the lowest cost DSL service provides a minimum of 1Mbps download and 512kbps upload.

So in most cases, you'll be covered for transmitting high quality audio over IP. Be sure this data rate is specified for both the upload and download sides of the link. As we've mentioned throughout this primer, Comrex codecs have been carefully designed to work exceptionally well on even challenging data networks. Thousands of Comrex customers can attest to the fact that ACCESS and BRIC-Link codecs perform flawlessly on consumer grade broadband cable and DSL circuits where other, less advanced codec solutions fail. BRIC Technology makes this possible by providing superior audio algorithms, error correction/protection tools, dynamic jitter buff management and redundancy/bonding modes that are unmatched in the broadcast industry.

Get the very best circuit you can afford

Enterprise Wide Area Network services such as Frame Relay and Multiprotocol Label Switching (MPLS) networks are expensive, but provide a high degree of reliability. At 20 to 100 times the price of basic Internet connectivity, they'd better be. But when distribution of content is tied to significant revenue, it's an important to consider the cost vs. benefit. There are plenty of data circuit options out there. If you're only billing $300 per day on your station or program, then standard, consumer grade phone company DSL might be right for you. However, if your content provides significant revenue to your company's bottom line, the high cost might be worth it.

Approximate Cost Comparison of Available Data Circuits (actual costs vary)

Circuit Type	Install Cost	Usage Cost	SLA
ISDN BRI	(if available) $300 to 800	$50 to 150/mo for access .10/.22 per minute usage per channel	not available
ISDN PRI	$1200 on average	$500/mo for access .02/per minute usage per channel	not available
DSL/Broadband Cable	$200 to 500	$65 to 150/mo	Business level 99% uptime
T1	$1000 to 2000	$300 to 500/mo	Dedicated with full suite of SLAs
MPLS	$1000 to 2000	$400 to 1000/mo	Private network with full suite of SLAs

Get a Service Level Agreement (SLA) from your provider

An SLA basically compels your Internet Service Provider to "put their money where their mouth is." It's a written agreement from the ISP that guarantees consistent network upload and download speeds, and that your service will be available with no or little downtime. Some agreements also offer guaranteed latency across the network. If the service fails to perform based on the terms of the agreement, the service provider will financially compensate for the interruption.

But make sure to read the fine print. While an SLA might guarantee that your service will be up 99.9% of the time, it basically means that you could effectively be off the air for over eight hours a year. That's eight hours that could be costly if you're in the middle of a stopset during drive time. SLA's are different and mean different things for different providers. Make sure you dig into the details before signing on the dotted line.

As you can see from the chart below, the percentage of network availability changes tremendously with every nine you add as does the price of the SLA!

Availability %	Downtime per year	Downtime per month	Downtime per week
90% ("one nine")	36.5 days	72 hours	16.8 hours
99% ("two nines")	3.65 days	7.20 hours	1.68 hours
99.9% ("three nines")	8.76 hours	43.8 minutes	10.1 minutes
99.99% ("four nines")	52.56 minutes	4.38 minutes	1.01 minutes
99.999% ("five nines")	5.26 minutes	25.9 seconds	6.05 seconds

Employ network redundancy

Having two networks, each from a different ISP, can be very useful, especially if you're using your IP codec as a Studio To Transmitter Link (STL) or for other "mission critical" applications. Some codec manufacturers, including Comrex, have introduced features that integrate this ability into their products. There are also third party products that offer the ability to automatically switch between networks should one become unusable.

Wireless backup

While a wired Internet connection always is the best primary connection strategy, sometimes a wireless backup can be a lifesaver. 3G, 4G, Wi-Fi and even satellite data services have been successfully deployed by IP codec users to get their stations on the air during natural disasters and can be something to consider as part of an emergency backup plan.

Work with a Telephony Services Aggregator

In this brave new world of voice and data communications, a new breed of service providers has emerged that will help you reduce your overall costs and simplify the process of ordering services. These companies will analyze your existing usage, suggest ways to optimize your services, and work directly with the various ISP and service companies to provide the services you need - all while reducing your overall costs. This provides you with a single point of contact whenever you need to drop in a data circuit for a remote at the local nightclub, as well as someone to manage all of your incoming office phone lines.

Two (or Three) Networks Are Better Than One

For the past several years, Comrex has been developing a technology that we refer to as CrossLock™ for our line of Video over IP products. Starting with firmware 4.0, Comrex IP audio codecs will be updated to include CrossLock, which expands upon the current BRIC technologies in several powerful ways.

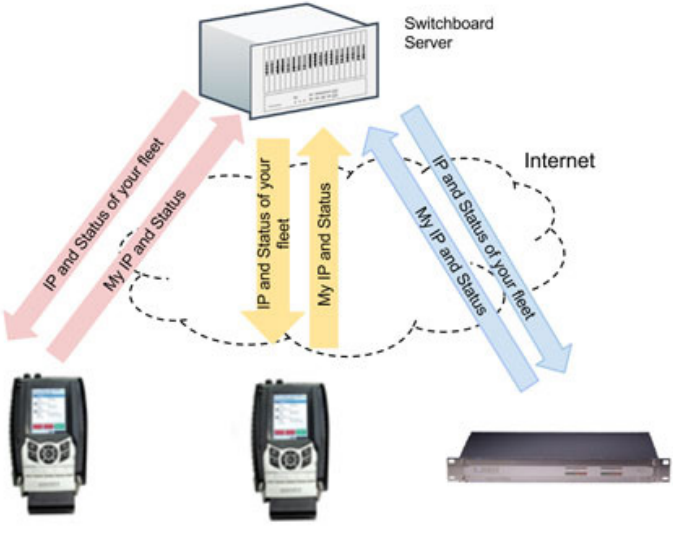
First, it allows for the simultaneous use of multiple network devices to increase available network bandwidth and improve reliability. Second, it includes the next generation of BRUTE (BRIC UDP Transmission Enhancement) reliability tools offering an expanded array of techniques including improved congestion detection, redundant transmission, forward error correction, and deadline-sensitive retransmission. Third, it includes an adaptive management engine that monitors the performance of each network link and applies the most appropriate tools for the current network conditions. Finally, CrossLock adds strong authentication and other security protections to prevent unauthorized interruption of normal operation (not available on all products).

Although the addition of CrossLock has expanded greatly on the capabilities of the system, we have made sure that the system provides the same ease of use that Comrex users have come to expect. Devices running CrossLock-capable firmware remain fully compatible with devices running older firmware (such connections will not utilize the new CrossLock features, of course). In addition, CrossLock is fully integrated with Comrex SwitchBoard.

SwitchBoard Traversal Server

One of the key aspects of BRIC Technology is the ability to make connections across the public Internet and mitigate the challenges of NAT and firewalls. Our SwitchBoard Traversal Server is a great way to eliminate the need to have an IT professional present when trying to connect to devices that are connected to the Internet but located behind a router or firewall on a private LAN. A full explanation of this concept can be found on our website at www.comrex.com

But SwitchBoard also offers the ability to manage and control a whole fleet of IP codecs in order to be able to connect to any of them quickly without having to know their IP addresses. This is certainly an advantage over the old ISDN paradigm of needing to know SPIDs and LDNs on the local side of the ISDN connection and the remote dialing number on the other side.



SWITCHBOARD
TRAVERSAL SERVER

Challenges and the Future

IP data networks are rapidly changing and improving. This is mostly due to the fact that the demand for bandwidth, dictated by bandwidth hungry devices, is rapidly increasing. So the news for the future is both a mix of good and bad. The promise of an end-to-end fiber optic Internet and incredibly fast 50Mb up/down speeds on wireless 4G LTE services is offset by the fact that everyone with a smartphone, tablet and PC is using data - even automobiles are streaming high bandwidth content at rates that no one could have predicted just ten years ago. Broadcasters are competing with this overwhelming demand for bandwidth while trying to provide that same content which is being streamed by consumers.

Since 2004, Comrex has been at the forefront of developing techniques and perfecting methodologies to keep broadcasters one step ahead of the game when it comes to transmission of broadcast quality content over IP. The good news in all of this is that IP technology, unlike POTS and ISDN, shows no indications of going the way of the Dodo bird. By all indications, we are just at the beginning of this story.

ISDN is going away.

It was great while it lasted! Predictable, reliable, standardized: perfect for remote broadcasting. But, for telcos, ISDN is more expensive than it is profitable. And because it comes down to money, no amount of begging and pleading will save ISDN from obsolescence.

Fortunately, there's a replacement for ISDN: IP networks. They're easy to access, relatively low cost (especially compared to ISDN lines), and often don't require installation ahead of time. Multiple IP codecs can be used on one IP connection (unlike a BRI circuit, which can only handle one ISDN codec at a time), saving even more money.

IP networks do have drawbacks; they aren't standardized (like ISDN is), and so it is possible to run into problems with delay or network instability. Fortunately, codec manufacturers have been developing IP codecs for over 10 years now, and have found lots of solutions for handling problematic networks.

Choosing a codec that provides advanced error concealment techniques, superior audio quality, and maximum reliability with minimum delay will substantially improve performance. Similarly, broadcasting on dedicated, wired IP circuits, and always having backup networks available, will ensure seamless broadcasts.

We've prepared this primer to give you some guidance on how to get ISDN-like results with the new breed of IP audio codecs that are available today.

If you have any additional questions, or need assistance,
feel free to call us at (978)-784-1776, or write to us at info@comrex.com.

COMREX
BROADCAST RELIABLE
www.comrex.com • email: info@comrex.com
19 Pine Road, Devens, MA 01434 USA
Tel: 978-784-1776 • Fax: 978-784-1717