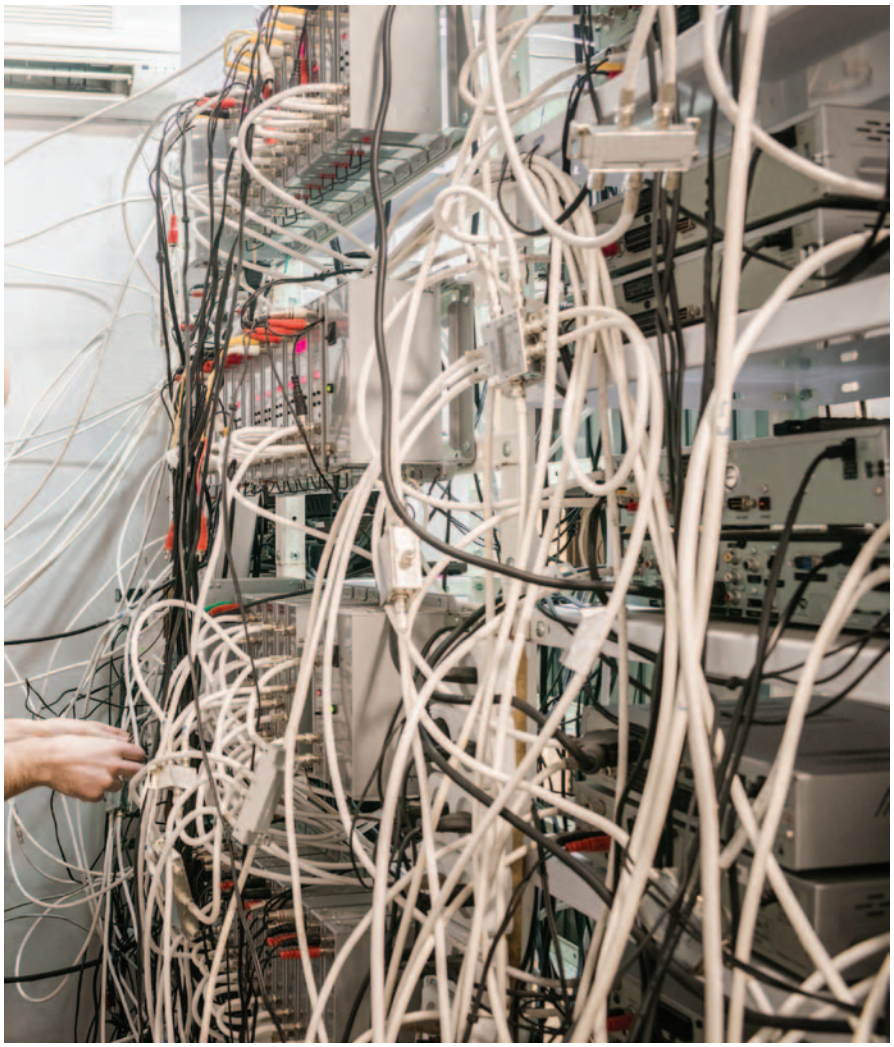
"The Medium Is the Message:"

How Ethernet changed production and content delivery BY ROBERT BELL

THE WORLD OF NETWORKING has evolved from the solitary realm of IT professionals to now include your kids, your grandparents, and most every technician in every department on your stage. Did you know that when asking for your Wi-Fi password, your daughter's friend is politely saying, "I see your SSID and I'd like to join your *IEEE 802.11* network and subscribe to your DHCP server to request an IP lease so I may use TLS/TCP and QUIC to watch cat videos?" Not many do, nor should we have to. The manufacturers of networking gear and the good people at the IEEE (Institute of Electrical and Electronics Engineers) have done all the heavy lifting to make it as easy as possible to share slime recipes on TikTok.

Our industry is tiny in comparison to the consumer electronics world; it behooves us to leverage established standards and chipsets when we want one box to talk to another. There's no point in re-inventing the wheel. From an electrical standpoint, this is exactly what DMX512 did by employing *RS-485* and defining a protocol, or rules of communication, using a vast array of technology developed mostly by others.

Similarly, Ethernet switches produced-for or configured-to work in our industry should adopt the standards that make our jobs easier. The following will provide a bit of history on Ethernet networking and how our industry has adopted it as the preferred medium of transport for almost every discipline in the entertainment industry. See the sidebar for a selection of the standards often used. These are what I call the four-letter words of networking, many of which have become part of our everyday language.



With analog signals, patching was a manual process; if it wasn't plugged right, you had go there to fix it.

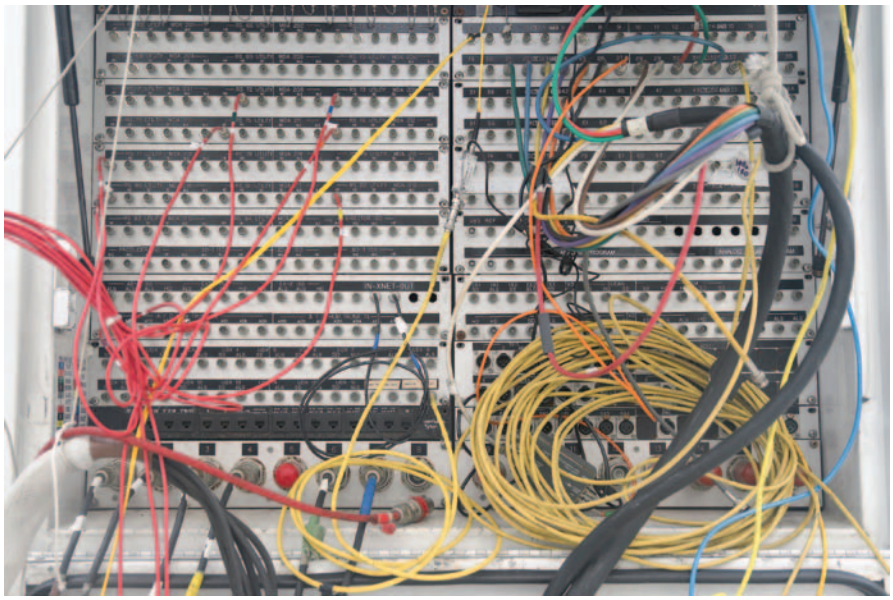
There was a time, not too long ago, where the word "digital" described ground-breaking technology. Before digital applications were viable, each production department built its own infrastructure. Sound departments used enormous, multi-core analog snakes; the video crew used specialized coax cable with BNC connectors; and lighting data was carried either on multi-core or multiplexed analog wiring.

It was unnecessary, undesirable, and even unthinkable that departments needed to share data.

In the early '90s I was working at the CBC in the country's largest broadcasting facility in downtown Toronto. For those that have not lived it, this was a time of tube, not chip, cameras and reel-to-reel video tape. Every department worked semi-autonomously; we all had our own cables, distribution amplifiers, and patch bays. Regardless of how many inputs there were from each department, at broadcast time all our work was pushed down one coax cable and amplified across the country for people to watch.

Around this time, the World Wide Web was immerging and CBC management saw the advent of digital technology. They encouraged the whole corporation to read a book called *Being Digital* (ISBN 0-679-43919-6) written by MIT's Media Lab Director Nicholas Negroponte. He predicted, among other things, the demise of terrestrial analog HDTV in a theory called the Negroponte Switch. Low bandwidth telephone communications would go through the air, and where higher bandwidth was needed, we'd move that data over to copper. Much to my surprise, his prediction has become fact. I remember my roommate at the time described what we'd now call streaming services such as Netflix, Hulu, or Amazon Prime. I scoffed. I knew that the multiband analog signal on the thick coaxial cable that fed our

Watch www.cbc.ca/player/play/1864230584 for a 29-year-old tour shot during my time at CBC when we moved into the Canadian Broadcasting Centre. The video shows cables being laid in the plant and some of the studios we first turned on in the last decade of analog TV production.



The camera and video patch bay of an analog production truck.

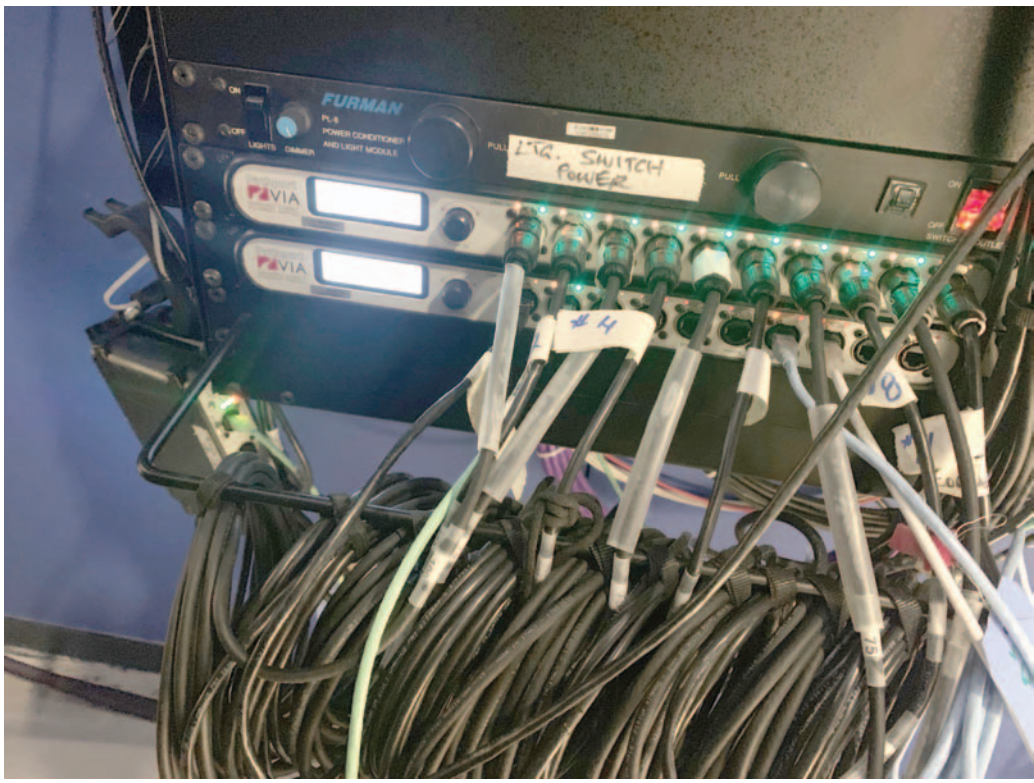
building couldn't even carry the content of the 500-channel universe we were all dreaming of at the time. Our apartment building housed over 1,000 people. What if every one of them was watching their own content; pausing or fast forwarding at will? My roommate was clearly off his rocker. Or, so I thought.

Thirty years earlier, Marshall McLuhan, the Canadian communication theorist coined the phrase "The Medium Is the Message" in his book *Understanding Media* (ISBN 81-14-67535-7). The premise was that the medium, or the method of delivery, is not neutral. Changes in the way content is delivered to us affects the message itself. The method of delivery was evolving quickly and for those producing the message, myself included, it meant the way we were doing things was about to change drastically. All the specialized tools from each department at the CBC would fade away and be replaced by a computer. This had grave effects for organized labour as your union job was defined by the gear you used.

When I started at the CBC, AutoScript prompting, an entire job classification, was done on hand cranked conveyors with closed-circuit cameras. What if the script editor could just push the script from MS Word right to the studio without all the effort of printing, cutting, and assembling the paper version? Film editing was done on Steenbecks flatbeds. At the time, my hard drive was only 40 MB! At standard resolution, that's not even one-foot of film or about a half second of video. Foley and audio sweetening, if not performed live, came from sound carts or perhaps, a rudimentary keyboard with puny samplers. And I, myself, lit many TV shows and news broadcasts on an analog three-scene preset console the size of your living room.

It was difficult to imagine, but within a few short years, every discipline would be using the same tool: the computer. Every bit of the message could be conceived, visualized, produced, edited, and delivered from one computer to another. Nothing would be analog. For context, mobile-phone technology was still completely analog with the Barney Rubble brick phones. The idea of a smartphone that could capture, edit, and transmit video live wasn't even a pipe dream.

If everything was possible using PCs and PCs could talk to PCs over Ethernet, all the specialized plugs, patch bays, and cables quickly became obsolete. Every room, up and down the Broadcasting Centre, had LAN ports and we were moving content around at unthinkable speeds. Even the analog coaxial cable leaving the building was eventually replaced by a digital signal



Pathway Connectivity VIA Ethernet switches in *The National* news studio at the CBC.

traveling via fiber.

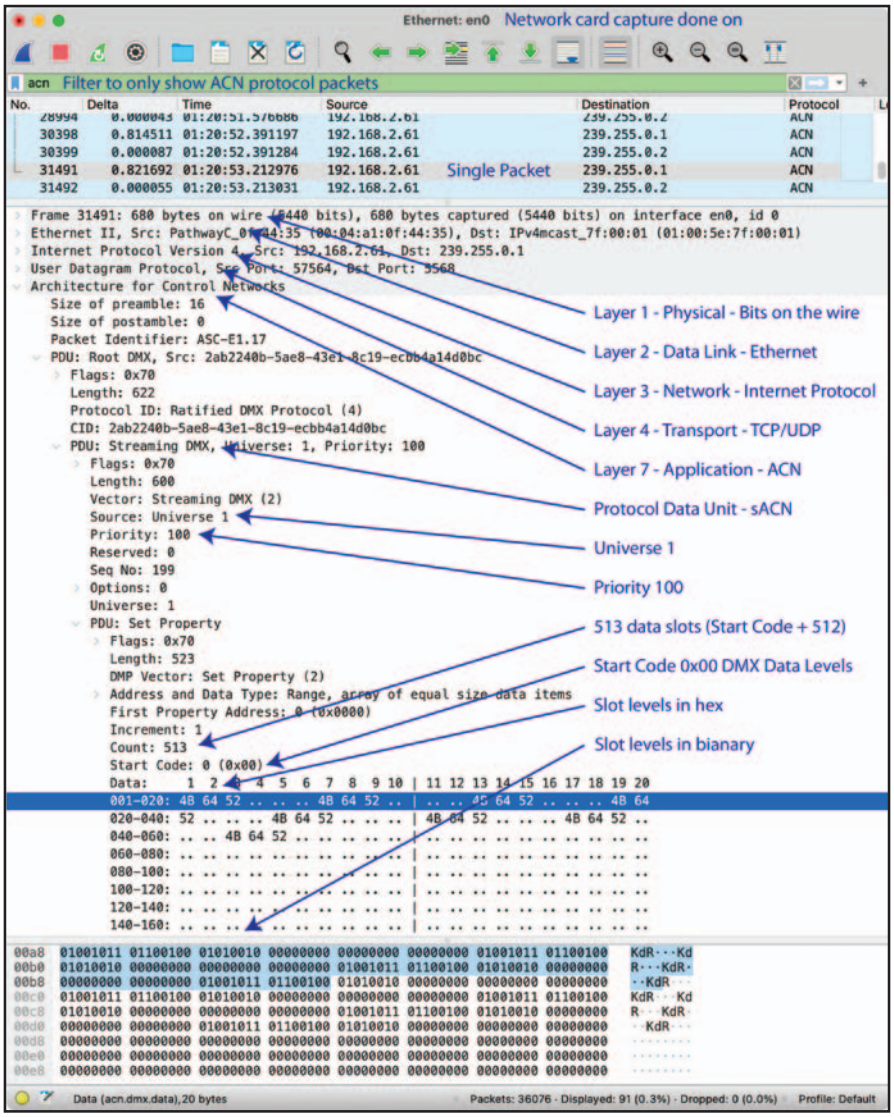
A less technical publication may attempt to unpack the social consequences of what happened when content generation and transmission happens with such ease. I refer you to *Understanding Media*. Let us concentrate on the particulars of how this happened so quickly and what bits we most commonly employ today.

To manage the huge amount of data flowing in every direction between all the departments at the Broadcasting Centre, we could not rely on manually manipulated patch bays. The process needed to be automated, reliable, and fully routable. This ability to route specific traffic to where it needs to be on one day and where it is needed the next is essentially what the Internet is based upon. It's impractical and wasteful to let everything go everywhere. Early on, small local area networks did exactly that with a bit-banging device call a hub. One bit in went to every other device connected in the LAN. It was then up to the individual PC's IP stack to tease out what was important from what was not. This network functioned at the Physical Layer or Layer 1 of the 7-layer Open Systems Interconnection (OSI) model.

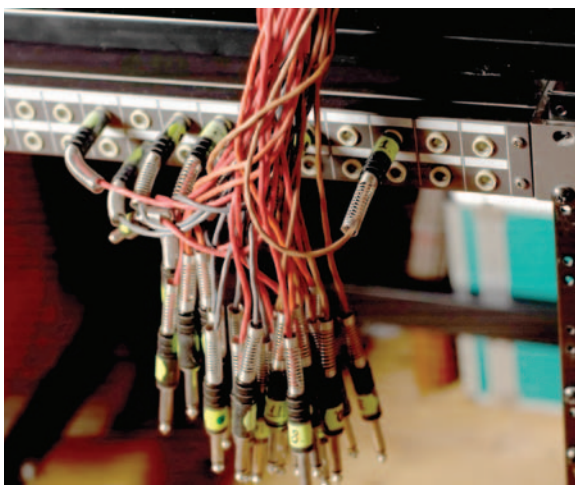
Networking evolved and the improvement on the hub was called a switch. As the name implies, it can direct traffic using Media Access Control tables (MAC addresses of a PC's Network Interface Controller or NIC), forwarding traffic at the Data Link Layer or Layer 2 of the OSI model. This greatly improves overall network efficiencies with unicast (one to one) and multicast (one to many) applications. More advanced switches forward data based on information at the third network layer (oddly enough, called "the Network Layer"), incorporating additional routing functionality at the IP level. We call these routers.

Data flows through networks in bursts of bits on the wire called packets. Wireshark is a freely downloadable network packet analyzer (www.wireshark.org), and it is capable of showing you the distinct layers of the OSI model. After doing a capture you can expand the packet details, the first being the Physical Layer, which is literally the bits and bytes seen by the NIC and historically by hubs. A switch works in the second layer and a router analyzes Layer 3 data. Wireshark also can dissect Layer 7 data in the Application Layer. This is where you see end-user protocols like those used by Dante, MPEG, or sACN, all of which carry the art that we create.

Going deeper into the data packet's header is processor-expensive and could cause latency. The hardware that is analyzing this data must be very fast. You don't want a PC with an operating system and an IP stack doing this work as it would have to contend with the whole packet before it determines what to do with it and where to send it. Audio must be moved through the



Wireshark Network Protocol Analyzer showing an sACN Ethernet packet with the exploded details of the different OSI Layers and other dissected data.



An unbalanced audio patch bay. I can almost hear the hum.

whole production network with less than 10 ms latency. Anything more than that and musicians can't play with each other. Audio/video sync that is out by more than 100 ms or 3 frames is even noticeable by non-professionals.

PCs are versatile and good at many things, but they're not specialized enough to conform to the level of attention needed to push data around. Switch fabric, the highly specialized chips inside switches, is designed to make decisions based on Layer 2 or Layer 3 data, and it can do this at wire-speed. Today that is at speeds of up to 10 gigabits per second, so that's pretty snappy.

But link speed is not the only factor you should consider when deciding what sort of switch is right for you. Sort of like in carpentry, there are all sorts of glues, each having their own purpose depending on the job you're doing. If Ethernet is backbone that glues your production together, don't use a switch that is designed for an enterprise system when your prime application is an entertainment system. There are many standards and protocols used in communications, the office environment, in defense, and in gaming. In the sidebar, I've outlined eight that I find particularly apply to the sort of work we do. Before you buy your next switch, see if you agree you need a switch that not only supports these standards, but is also easy to configure. Patch bays have gone the way of the Dodo and networking is just a means to the end. After all, we're artists, not IT experts. ■

Robert Bell is Director, Product Market at Acuity Brands and oversees the development the entire Pathway Connectivity product line including the VIA entertainment class Ethernet switches. Previously he has worked as a product manager for Strand and as brand ambassador for Vari*Lite. He's well known for his involvement with WYSIWYG and as an author.

Networking's four-letter words

EAPS or *IETF Ethernet Automatic Protection Switching* offers lightning fast switch-over to a secondary link in the case of catastrophic failure on the primary link. Think the Internet: How do you get a message from Los Angeles to New York via Chicago when Chicago has been hit by a nuclear blast? You re-route through Dallas. Set up properly, EAPS can heal a broken link and keep traffic flowing in less than one video frame.

RSTP or *IEEE 802.1w Rapid Spanning Tree Protocol* gives you two levels of protection. Firstly, it blocks traffic on redundant links preventing feedback that will inevitably crash your network. Think the digital version of that squelch that you hear in every movie when the father of the bride approaches the microphone. Secondarily, RSTP offers redundancy protection, similar to EAPS but not as fast, in the case of failure on the primary link.

IGMP or *IETF IGMPv2 – Internet Group Management Protocol* really leverages the power of the switches' roll within the network when using multicast protocols like Streaming ACN, Dante, or *AES67*. This is the prime example of one source being used by many sinks. Each device that is interested in the data subscribes to the multicast group and the switch ensures that only those in the group see the data, and no one else.

VLAN or *IEEE 802.1Q Virtual Local Area Networks* allows you to segregate one network system—one production backbone—across multiple departments without fear of bottlenecks or IP conflicts. Each team can allocate their own IP pools and they can even overlap. They are, essentially, different networks, but all on the same hardware platform. At any time you can jack into any port and just tell the switch "I'm audio" or "I'm in lighting."

LLDP or *IEEE 802.1AB Link Layer Discovery Protocol* is spectacular at identifying what is plugged into where at the 10,000' level even when you are using multiple VLANs. It's impractical to trace the wire between any two devices in the building the size of the CBC Broadcasting Centre. With LLDP you can trace it from switch to switch virtually.

DHCP or *IETF IGMPv2 Dynamic Host Configuration Protocol* allows the switch at the very heart of your network to manage IP address leases. It's silly to maintaining a table of static IPs for all the devices that come and go from moment to moment or from day to day. Machines are much better at building lists. They actually enjoy it. Do what you're good at and leave the mundane things to computers.

QoS or *Quality of Service* is a set of rules to configure several aspects of the network service to account for packet loss, bit rate, throughput, transmission delay, availability, and jitter. Audinate's Dante is a prescribed recipe to make sure musicians don't complain about latency. Drummers are so finicky. With *AES67* you no longer have to boast about your console's 64 inputs, eight subgroups, 16 buses, and the 8x4 matrix. If you want more, you just plug it in and work the patch virtually.

PoE or *IEEE 802.3af* or *IEEE 802.3at* (etc.) Power over Ethernet administers wattage allocation to end devices that suck power from the network. I love it because from anywhere you can initiate a cold-boot sequence on pesky end devices that need a good kick in the pants every so often.