Refactoring Consumer Electronics

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To the reader

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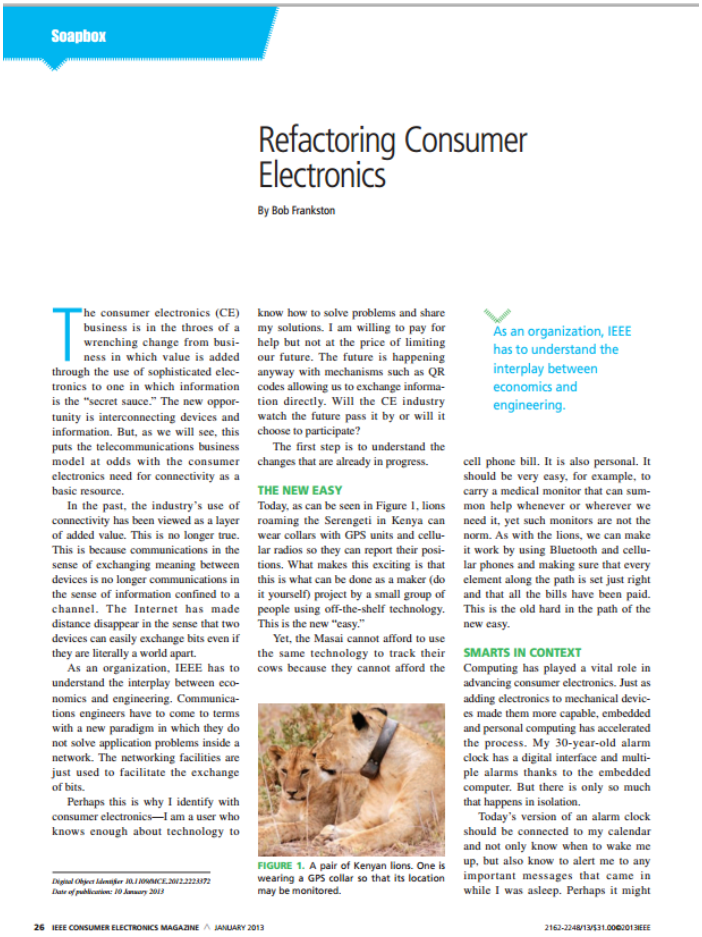

Soapbox

Refactoring Consumer Electronics

By Bob Frankston

The consumer electronics (CE) business is in the throes of a wrenching change from business in which value is added through the use of sophisticated electronics to one in which information is the "secret sauce." The new opportunity is interconnecting devices and information. But, as we will see, this puts the telecommunications business model at odds with the consumer electronics need for connectivity as a basic resource.

In the past, the industry's use of connectivity has been viewed as a layer of added value. This is no longer true. This is because communications in the sense of exchanging meaning between devices is no longer communications in the sense of information confined to a channel. The Internet has made distance disappear in the sense that two devices can easily exchange bits even if they are literally a world apart.

As an organization, IEEE has to understand the interplay between economics and engineering. Communications engineers have to come to terms with a new paradigm in which they do not solve application problems inside a network. The networking facilities are just used to facilitate the exchange of bits.

Perhaps this is why I identify with consumer electronics—I am a user who knows enough about technology to know how to solve problems and share my solutions. I am willing to pay for help but not at the price of limiting our future. The future is happening anyway with mechanisms such as QR codes allowing us to exchange information directly. Will the CE industry watch the future pass it by or will it choose to participate?

The first step is to understand the changes that are already in progress.

As an organization, IEEE has to understand the interplay between economics and engineering.

THE NEW EASY

Today, as can be seen in Figure 1, lions roaming the Serengeti in Kenya can wear collars with GPS units and cellular radios so they can report their positions. What makes this exciting is that this is what can be done as a maker (do it yourself) project by a small group of people using off-the-shelf technology. This is the new "easy."

Yet, the Masai cannot afford to use the same technology to track their cows because they cannot afford the cell phone bill. It is also personal. It should be very easy, for example, to carry a medical monitor that can summon help whenever or wherever we need it, yet such monitors are not the norm. As with the lions, we can make it work by using Bluetooth and cellular phones and making sure that every element along the path is set just right and that all the bills have been paid. This is the old hard in the path of the new easy.

FIGURE 1. A pair of Kenyan lions. One is wearing a GPS collar so that its location may be monitored.

SMARTS IN CONTEXT

Computing has played a vital role in advancing consumer electronics. Just as adding electronics to mechanical devices made them more capable, embedded and personal computing has accelerated the process. My 30-year-old alarm clock has a digital interface and multiple alarms thanks to the embedded computer. But there is only so much that happens in isolation.

Today's version of an alarm clock should be connected to my calendar and not only know when to wake me up, but also know to alert me to any important messages that came in while I was asleep. Perhaps it might

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Since writing this I've come to appreciate the extent to the term "The Internet" is used for a very specific thing designed for interconnecting existing networks rather than as a way to extend peer connectivity. The discussion is also more muddled when people use the term, The Internet, for the web and other consequences of connectivity.

If we're to get the full benefit of connectivity we need to embrace the larger concepts and not limited ourselves to the accidental properties of the current implementation. The current (2020) embrace of 5G is an example of what happens when you focus on the artifacts with understanding the underlying principles. You get something that looks like the Internet but frozen in time.

Refactoring

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which information is the "secret sauce." The new opportunity is interconnecting devices and information. But, as we will see, this puts the telecommunications business model at odds with the consumer electronics need for connectivity as a basic resource.

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Smarts In Context

Computing has played a vital role in advancing consumer electronics. Just as adding electronics to mechanical devices made them more capable, embedded and personal computing has accelerated the process. My 30-year-old alarm clock has a digital interface and multiple alarms thanks to the embedded computer. But there is only so much that happens in isolation.

Today's version of an alarm clock should be connected to my calendar and not only know when to wake me up, but also know to alert me to any important messages that came in while I was asleep. Perhaps it might tell my connected thermostat that I need to wake up earlier than usual. The pieces all exist but connecting them is not easy.

We do need to be careful about getting overly clever. For example, it is not really necessary to start my coffee automatically when, thanks to Keurig, it just takes one minute to brew a cup.

The Internet?

The Internet is really about connectivity. Because connecting at a distance (networking) used to be very hard, we tend to focus on distance rather than relationships. It is really about transcending the mechanics of distance so we can focus on what we want to accomplish. This is not obvious because, as with any new technology, we tend to view it as if it were the same old thing but just a little better.

Pandora.com announced that its music streaming service is radio just like WLS-FM in Chicago, or KIIS in Los Angeles, except without the need for a physical radio or a 50,000-W transmitter without the geographic boundaries and the need to license airwaves. Other than that, it is radio in the sense that consumers think of it. We use the same technology to stream music and videos within our home without going outside or accessing the Internet. This is all very confusing until we reorient ourselves.

Five centuries ago, the solar system seemed complicated with planets apparently wandering about. Then, Copernicus simply shifted the reference frame 1.5×10^{14} meters and planets fell into nearly circular orbits.

Today we have to turn consumer electronics on its side. A television is no longer a set of technologies layered on top of a broadcast system with every element aligned in perfect precision to produce an image on a phosphor. Today, anyone can assemble a television by taking a screen and a computer and getting content from any source, be it cable, over-the-air, or a networked stream. OK, not quite anyone. It takes scale to accomplish distribution and support, but these are not the same skills as traditional electronics.

It is also not that simple because of digital rights management (DRM) policies that make failure the default. Protocols such as IEEE-1934 and HDMI also add complexity by building knowledge into the path.

Companies that benefit from adding intelligence to networks and devices find their business threatened as these smarts move to the edge. Dealing with this requires us to reinvent consumer electronics.

What Do You Mean?

I am fascinated by language and how it works in the real world; the interplay of words, meaning, and context is everything, particularly multiple contexts and interpretations. In other words, it depends…

Throughout this article, you will see a lot of words in quotes. This has been done in an effort to remind the reader to be aware of the sense in which the word is being used.

If you ask a communications engineer, you will hear all about channel capacity and information theory. A communications major would be baffled because communications is about getting ideas across. Yet, we have a Federal Communications Commission (FCC) that conflates the two by managing speech in the name of managing technology. This confusion makes some sense when we go back to the days of scribes, when you explained your message to an intermediary who then carried it to its destination. With the advent of telegraphy, we applied technology to the task, with the telegram being treated as a valuable cargo.

As with radio, we had a business model and a technology that went hand-in-hand. The business model was so similar to railroads in that the FCC was modeled on the Interstate Commerce Commission (ICC) that was established to assure an orderly market in carrying freight via railroads and later via trucks. With the talking telegraph (the telephone), we no longer needed a scribe or an operator, but we kept the business model because keeping voice understandable over long distances was difficult and also expensive.

A Bit of Change

This is why the phone companies (primarily AT&T) led the development of digital technologies. Knowing there only two symbols, a one and a zero, you could use this knowledge to take a noisy signal and turn it back to a one or zero. That is, regenerate the signal without knowing anything about the message being carried.

No harm is done. Or so it seemed. After all, we still needed intelligence in the network to carry bits just like we needed intelligent network engineers to shepherd analog voice along the path.

Things may have stayed this way except that “digital” was the basis for computers. And with computers, we could embody intelligence in machines.

Getting Connected

In 1958, John McCarthy had the idea of sharing a computer among users at teletypes. This idea of timesharing (similar to today’s cloud) grew rapidly. Not only did we connect our dumb terminals to the computer, but we wanted to exchange data between these systems.

One of the most interesting experiments was ALOHAnet in Hawaii, in which computers would send packets of bits to each other using radios. If a packet got lost, it was easy enough for the sending program to just resend it. Ethernet took this idea one step further by using a coaxial cable as the medium (ether), thus avoiding having to deal with regulations on the use of radio waves.

We need to be careful as these local area networks (LANs) are not networks in the sense of a telecommunications service; they are networks more like a social club where we do our own networking.

This loose use of language did not matter so much until the two models crossed paths as intelligent devices started to interconnect across a public network that had its own “ideas.” Notice the use of anthropomorphic terms here. After all, if we talk about intelligence then we can talk about ideas for the policies built into the software. We do need to be careful about not confusing emergent properties with intent.

Interconnecting LANs presented an interesting challenge because the understanding of what is being said is entirely outside. The network operator can’t know how the packets related to each other and couldn’t know what resources would be required nor how to correct errors. This was fine for low-demand applications such as transferring files and exchanging e-mail. So, what if you sometimes lost a packet? As long as enough got through, we would eventually transfer the message. All we required was best efforts.

The delays inherent in sending packets over a distance through multiple nodes also required a more sophisticated algorithm than a quick retry. Transmission Control Protocol (TCP) gave the intelligent systems outside the network a way to get reliable streams and cooperate in sharing the common medium.

The applications still had access to the raw packets via User Datagram Protocol (UDP) for those times when never is better than late. After all, if you are sending the current temperature reading, you do not want to resend it. Instead, you send the new current temperature.

Each of these packets can go to a different destination. Even with TCP, there are multiple streams, each to a different destination. This is a poor match for a telecom infrastructure designed for preallocating resources along the path.

Channels and Tuning

The end points of these destinations represent the relationships between applications and their users. These relationships exist entirely outside the facilities used to exchange bits.

Here, I am careful to avoid talking about networks because that is the old paradigm. Today, we can use any means or path to exchange bits. When we are interconnecting our LANs, we are treating the entire telecommunications infrastructure as just one possible resource for exchanging bits. Yet, as we have seen, a primary focus of communications engineering is pipes and channels. More importantly, the business model of telecommunications is all about monetizing the path through the control of pipes.

We can see the problems with the pipe model in living color when we look at spectrum allocation—the idea of creating channels by assigning a different frequency for each transmitter. It is as if we only used shirt color to distinguish between people. Of course, there would be confusion when two people with the same color sat near each other. In practice, we do not confine ourselves to a single channel of information; we use rich information including both what we see and what we know.

Calling this confusion interference makes it seem as if we have a physics problem rather than simply a problem that emerges from narrow-minded heuristics. As an aside, this same use of rich information is the basis for what we call big data. It is not big in the sense of huge flows of data; it is simply big in having a wider scope.

In communications theory, there is indeed some use of out-of-band information to increase the effective capacity, but we have to free our minds of the layering paradigm if we are to enable innovation in consumer electronics. The math and heuristics (such as layering) are correct. The value and meaning come from context.

Ambient Connectivity

Ambient connectivity is an architectural alternative to the network framing. It takes an application perspective and assumes that you can simply connect anywhere without having to worry about being tripped up by the path. We can then focus on the task at hand, while separately pursuing policies and business practices to increase the scope of ambient connectivity.

Working with Ambient Connectivity

The key to taking advantage of resources is to work with what you have. You need to discover what you can do with the capabilities available. For example, you may discover that you can only exchange a limited number of bits with another end point. You can then limit what you can do or be clever. For example, instead of sending the content of a book, you may send an ISBN number as a representation. Torrents are yet another approach. Streaming applications are clever about filling in the gaps and adjusting capacity dynamically as well as by using local caching.

The constraint is that we cannot buy our way out of problems, because the copper, radios, and fibers are resources to achieve connectivity. There is no service provider though we can use the existing networks as paths just as today's Internet uses the existing telecom facilities when needed. The reason we have VoIP (Voice over IP) today is that we did not bake it into the Internet. We did try this experiment and got SS7 (Signal System 7 which controls the carriers' phone network), which is simply too expensive to compete with VoIP which has no cost in itself-it's t's just a way we use bits. Instead, VoIP started working when we got sufficient capacity as a byproduct of satisfying the demand for the Web. Of course, cleverness also helps. Skype and Vonage earned an advantage by recognizing the opportunity early and having the engineering skills to make it work.

The key is to understand the opportunity dynamic. SS7 could not promise video, so it simply had to forego it. Skype makes no promises and thus can let video work when the capacity is available. This is also the secret behind Netflix—it need only deliver video to customers who already have the capacity. It does not have to invest in its own infrastructure.

Home Networking

Consumer electronics began at home with devices such as radios and electronic gramophones (phonographs), so it is appropriate to look at connectivity within the home for insights into connectivity in the large. When I was at Microsoft in 1995 thinking about home networking, the term "home network" was associated with home automation as well as networking. We still have a legacy of this confusion in the efforts to provide service silos for the home.

The Platform

The key enabler is the ability to exchange bits using all available facilities. We can then build connected devices and provide services without having to build them into the network. This includes video content. If we depend on the transport (such as an RG-6 cable) to preserve the signal we are at the mercy of any losses along the path. We see this problem in this image from my FiOS connected TV. Though the

transport may be digital the image is vulnerable to any failure in the lower layer. If we only expect best efforts we learn to be resilient and can deal problems like lost bits.

Instead, the adaptive approach that Skype and Netflix use allows us to use any path available. Some paths may be of high capacity, while others may not. The solution is to increase the capacity without having to do something special for a particular kind of content. We also need to be careful about depending on accidental properties. The Network Address Translator (NAT) that allows us to use a single IPv4 address has the accidental property of isolating the physical home network from the world. This is a bug, not a feature. We see the problem when using an app to choose video content (i.e., a cable remote) and find it does not work because we are on the "wrong" LAN.

The home network is a work-in progress and has to continue to improve but this will only happen if we keep the market fluid by not creating silos that make apps tied to the past rather than being able to benefit from improvements. While there may be a physical network within our home, we should think of it as a shared personal space. You can be connected whether you are physically at home or on vacation. If you have a water leak detector in your basement, you should get an alert even if you are not at home.

Using the Platform

Even though consumer electronics began at home, the home is pretty much a backwater of connectivity. The major focus is on updating the home theater. "Cable" content is still delivered using RG-6 as faux broadcasting content. But this does not explain why more of our mundane devices are not connected or even when they might sport some new electronics for which they do not have much use.

Turning on a light should be a simple task of sending a message to the bulb saying that you want it to shine. In fact, you can buy retail LED bulbs with radio transceivers for less than US$30 that can do just that. So why do we still use wires to define relationships and cut the supply of electricity to get the light bulb to stop shining? Why can't we have a policy that provides light with an LED source as just one option? The "smart grid" is another example of a silo that does not play well with others, and protocols like DLNA cost money just to learn about them.

Imagine if the technology in today's smart phones could be used as a basic building block in our homes. Today the capabilities of the devices are limited by the providers' needs. To add injury to insult, we have to buy a new device each year to get the latest features with older models simply piling up in our landfills.

Protocols

The home can be the starting point for the next generation of protocols in the same way that LANs forced us to accept the idea of exchanging packets between intelligent end points without depending on services from a provider in the middle. But how can we get connected devices when we have a bunch of silo protocols that go to the physical layer such as IEEE-1394, USB, Bluetooth, and Insteon? Of course, the list should include the analog "protocols" such as speaker wires. It would make more sense to send a digital signal and convert it from digital to mechanical motion at the speaker itself.

Once we can assume a degree of ambient connectivity, we can turn our attention to protocols that make it easy to have stable relationships between end points. Today, we have various peer-to-peer solutions that provide stable naming and address issues of trust and security. We will need to build on these as we develop common protocols and practices for a connected world. For now, the challenge is simply being able to connect without finding intermediaries blocking the path.

Getting Down to Business (and Policy)

Extending ambient connectivity (if we want to speak loosely, "more Internet") is about economics and business—how we pay for facilitating the exchange of bits. Again, more loosely, how we pay for networks keeping in mind that the networks emerge from how we use the facilities available.

Monetizing the Path

As we have seen again and again, many of the problems we have in creating connected applications and connected devices stem from having to negotiate with a path provider, even when we are not aware that one exists. This occurs for two reasons. The first is the idea that the network must understand the meaning to preserve the message across an analog path. As we have seen, where the network is just carrying bits and not meaning, this is no longer an issue. The second is economic—we fund the facilities by taking a portion of the value being transported. But this cannot work because, again, there is no intrinsic value in the bits. This value is entirely external. So, the current model is no longer viable.

We try to make it work against all reason because we have an owner who must make a profit to invest in facilities even though this investment cannot pay off. The current telecommunications market seems to work because the providers differentiate themselves and make a profit by providing valuable services such as cable content and (still) charging for phone calls. Given how well VoIP

works, we have to wonder why we still pay for phone calls as if nothing changed in the previous century.

With customers creating these services themselves, we have a dynamic that pits the service providers against their own customers. This goes to the heart of the new consumer electronics industry. There is a conflict between the old idea of communications where a carrier pays for the path by, in effect, taxing the information carried and a consumer electronics industry that depends on unfettered connectivity.

In effect, the telecommunications industry is like a scribe who insists on carrying a message. This might work if they understood the language, but if we have two Chinese-speakers trying to communicate, it is not simply that the intermediary does not add value, a tone-deaf English-speaking scribe cannot even hear let alone understand the message and thus becomes a costly impediment. This is what it is like when my Android watch wants to use its Wi-Fi connection at an airport—it does not read English so it cannot figure out how to "agree" to a legal contract without my help.

Stakeholders

We achieve ambient connectivity by enabling us to communicate by exchanging bits. We can do this very locally by using the wires and radios within our homes and cover the local geographic area by working with friends and neighbors and hiring people (or vendors) to facilitate the exchange of bits. This idea of facilitating is similar to getting together to pave sidewalks and roads. We can walk on the grass, but sidewalks and roads make it easier. We extend our ability to do networking by working together. The network is then an emergent property just like the road system, which emerges from all the individual efforts. We can make roads seem more like a unified system by putting up route number signs.

Local ownership makes the users stakeholders in their own fate. This should be obvious. Why do we find it so difficult to escape idea that the Internet is just another broadband telecommunications service? Shouldn't IEEE be leading this transition? But then again, IEEE's premier consumer facing magazine is called Spectrum. IEEE heal thyself?

That[i] Darn Internet

I have tried to be careful to talk about connectivity in general rather than emphasizing the Internet itself. This is because today's Internet is a work-in-progress. The idea of having the means of facilitating the exchange of bits without having a stake in the meaning is a transformational concept. Yet the protocols we use do not offer stable relationships that applications designers need. The protocols must be designed around application, not network needs. We can no longer assume that the network knows best.

The IP address is transient and changes when we reconfigure the network or simply move the end point. The only reason for the mobile to be special is that today's Internet implementation dates back to a simpler time when machines just did not move.

The domain name system is supposed to provide stable identifiers, but we do not own these identifiers. The Web is designed to unravel. The domain registrars' incentives are to maximize their revenue by keeping the system in turmoil.

Unlike Bluetooth, Wi-Fi's roots were closely aligned with the Internet's idea of having a way to exchange bits. But, there are continuing efforts to build in mechanisms such as billing and special treatment for special bits. Rather than moving toward ambient connectivity, we see deals being made to extend cellular fiefdoms to Wi-Fi.

We see a strong emphasis on high speed Internet because of the perception that more speed the more value. This is one reason medical monitoring isn't happening —these monitors just do not generate enough traffic for revenue. More bits are actually less valuable. More to the point, speed is easy thanks to Moore's law processes.

We do need to be careful; speed is really about capacity, since all electrons travel at the same speed. It is like electricity in the sense that more current does not mean faster electricity.

This comparison with electricity demonstrates the risk of misguided metaphors. We treat the Internet like a consumable in accepting limits on usage and capacity. And, we talk about it being accessed as if it were a thing out there somewhere rather than a powerful idea. What would have happened to personal computing and consumer electronics if we had taken the same approach to computing and Intel charged for each minute of computing? It would have had a strong incentive to prevent Moore's law. It is no accident that the price of telecommunications goes up rather than continuing to follow the improvements in price performance in the rest of electronics. The consumer electronics industry's interests are very different than those of traditional telecommunications. We need to recognize that the scarcity of capacity is due to business incentives and not technology. We are no more running out of spectrum than the shirt industry is running out of blue.

Today's telecommunications industry has to prevent unbilled bits from passing to make a profit. The idea of preventing us from communicating so we can pay to communicate makes no sense. Funding infrastructure to support ambient connectivity is vital to the future of consumer electronics.

Refactoring

At the heart of the traditional consumer electronics business is a device like a television, carefully engineered for its purpose, commanding a high price for the value delivered. Today this same television is basically a commodity screen with a general-purpose computer and software.

The traditional telecommunications industry is about a path-owner creating value by carrying meaningful messages (such as a telegram). Today this value is added entirely outside of the network. Some find the answer in new services but often these services are thinly disguised efforts to create recurring revenue from commodity hardware.

Coming to terms with the new landscape is not easy. We need to learn from experience; this parallels the time when the U.S. steam locomotive companies had to come to terms with the world of diesel locomotives. They could all manufacture perfectly fine diesels, but diesels are essentially commodities. A business model based on high-value personal relationships did not work for selling a commodity product—even an expensive one.

We need to learn from their experience and understand that the new business is not just faster/better/ cheaper. It is different. A telecommunications company can be refactored by utilizing its skills in managing physical infrastructure and creating companies that reward these skills in their own right rather than just treating them as cost centers in a service company.

Their customers would be the communities that own their local infrastructure. We can already see Comcast shifting its focus by investing in the content business in their purchase of NBC.

There is no shortage of opportunity. As we see in the home, we are still using century-old technologies for the most basic functions. We have not even started to embrace unsaid possibilities.

Our public policies also have to come to terms with the lesson of the Internet. Today's regulatory policies came into being to address a dysfunctional industry. Instead of arguing for or against regulations, we need to address the root cause—a 19th-century industry in the 21st century. Manufacturers as well as users need business models that enable connectivity.

Transitions are always difficult and fraught with uncertainty. The lesson of the Internet, perhaps, is that we become stronger by embracing uncertainty and taking responsibility. The market favors agile responses to change. Customers are no longer merely just "consumers." Some of them will be able to—and want to—create and share. For the most part, they will still want to buy services and devices, but with the new easy it is not enough just to package a solution in a box and sell it. There will be a demand for building blocks (such as "smarts" without the "phone") and services, but they can now constitute separate markets. New technologies such as 3-D printing create new markets, but require new thinking. The formula for success in this new landscape is simple. All you need to do is…. The answer will appear in the 2023 edition of this publication.

Don't Wait

While the IEEE article is focused on how the CE industry has to make money. Connectivity is does not need to be a profit center. We don't have to wait till 2023 to start deploying alternatives starting with owning the connectivity locally starting with, for example, apartment houses and then growing to cities and beyond.

Call Outs

- As an organization, IEEE has to understand the interplay between economics and engineering.
- A television is no longer a set of technologies layered on top of a broadcast system with every element aligned in perfect precision to produce an image on a phosphor.
- Interconnecting LANs presented an interesting challenge because, for intelligence outside the network, the operator could not know how the packets related to each other and could not know what resources would be required.
- The delays inherent in sending packets over a distance through multiple nodes also required a more sophisticated algorithm than a quick retry.
- The current telecommunications market seems to work because the providers differentiate themselves and make a profit by providing valuable services such as cable content and (still) charging for phone calls.
- The idea of having the means of facilitating the exchange of bits without having a stake in the meaning is a transformational concept.
- A telecommunications company can be refactored by utilizing its skills in managing physical infrastructure and creating companies that reward these skills in their own right rather than just treating them as cost centers in a service company.
- The network address translator that allows us to use a single iPv4 address has the accidental property of isolating the physical home network from the world.

[i] The online version says "This Darn Internet" – I missed that during proofing. Perhaps it is my fault for assuming everyone recognized the name of the 1965 Disney movie *That Darn Cat.*