EDHOLM'S LAW OF BANDWIDTH

Telecommunications data rates are as predictable as Moore's Law

BY STEVEN CHERRY

TELECOM

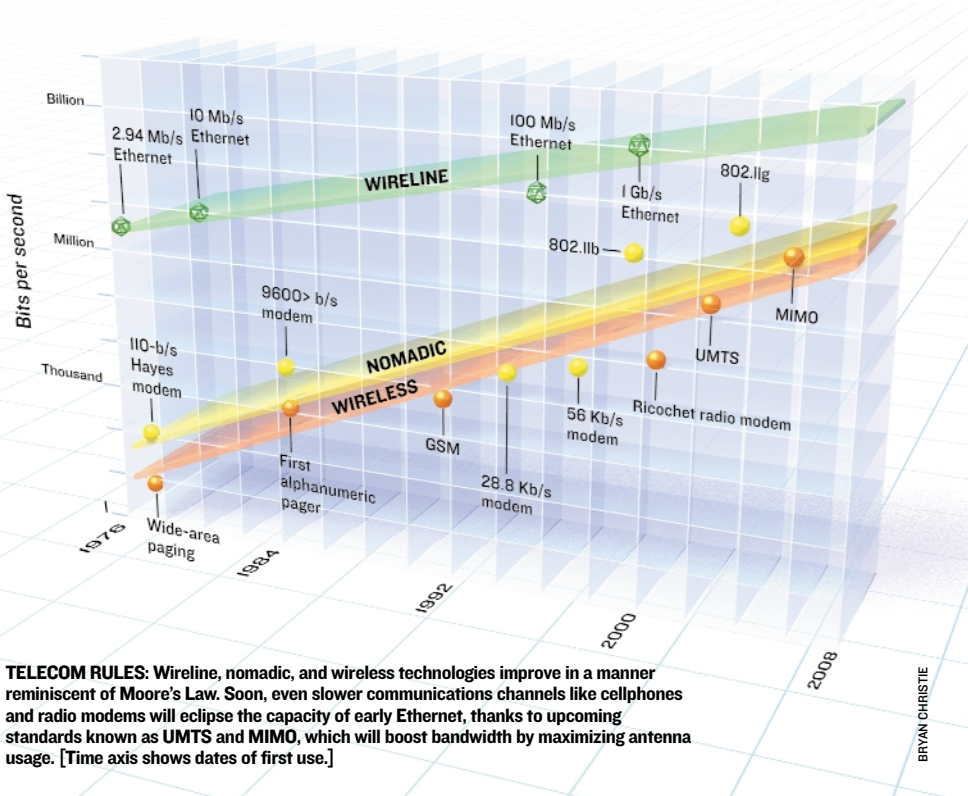
Some telecommunications technologies, like cellular telephony, can be used as you move around freely. Others, like Wi-Fi, can be used while moving from place to place but aren't fully mobile. A third category can be used only with equipment tied to a specific location, as Ethernet is to your office's desktop computer. For lack of better terms, we'll call these three categories wireless, nomadic, and wireline.

It seems intuitive that the least mobile systems have the highest data rates. And it's obvious that all three get faster over time; we now routinely achieve cellular data rates that match those of the best dial-up modem speeds of the early 1990s.

But there's even more to say about data rates. At a recent conference devoted to Internet telephony, John H. Yoakum of Nortel Networks, in Brampton, Ont., Canada, presented a new law that he attributed to a colleague, Phil Edholm, Nortel's chief technology officer and vice president of network architecture.

According to Edholm's Law, the three telecommunications categories march almost in lock step: their data rates increase on similar exponential curves, the slower rates trailing the faster ones by a predictable time lag. As the chart shows [see "Telecom Rules"], if you plot data rates logarithmically against time, you can fit three straight lines to the results: the three maintain more or less the same relationship. (Interestingly, though, extrapolating forward indicates a convergence between the rates of nomadic and wireless technologies around 2030. Perhaps that's not too surprising, since both rely on the same core technology, radio.)

For example, five years ago, wireless ran at about 5 to 10 kilobits per second, the nomadic bandwidth—dial-up—ran at 30 to 56 kb/s, and the typical office local-area network (LAN) ran at about 10 megabits per second. Today, wireless technology delivers 100 kb/s through cellular networks, and nomadic bandwidth for a home wireless LAN with DSL or



TELECOM RULES: Wireline, nomadic, and wireless technologies improve in a manner reminiscent of Moore's Law. Soon, even slower communications channels like cellphones and radio modems will eclipse the capacity of early Ethernet, thanks to upcoming standards known as UMTS and MIMO, which will boost bandwidth by maximizing antenna usage. [Time axis shows dates of first use.]

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cable broadband access is about 1 to 2 Mb/s. The typical wireline LAN is way up there at 100 Mb/s.

If we project forward, Edholm's Law says that in about five years 3G (third-generation) wireless will routinely deliver 1 Mb/s, Wi-Fi will bring nomadic access to 10 Mb/s, and office desktops will connect at a standard of 1 gigabit per second.

AS THE DATA RATES of these transport modes increase, applications can successfully migrate from wireline to nomadic to wireless. Take streaming music, which wasn't practical on a home desktop machine until about 1998. We could stream music wirelessly to a laptop in a coffee shop by 2003 and should be able to do the same thing to a cellphone by about 2008.

At a recent conference in New York City, Hossein Eslambolchi, president of AT&T Labs, in Bedminster, N.J., made an observation similar to Edholm's. In fact, he asserted that telecommunications data rates aren't rising just in a Moore's Law–like way; they're rising at exactly the Moore's Law rate: doubling every 18 months. If the state of home access in 1980 was a 1200-bit-per-second narrowband modem, we would expect a thousandfold increase in 21 years. Sure enough, Eslambolchi says, 2001 was the year we started to see consumer adoption of broadband faster than 1 Mb/s.

One consequence is clear: whenever the bandwidth demand of an application native to one transport category meets the rising edge of another category, there is a perfect opportunity for an adoption explosion by a new and larger pool of potential users.

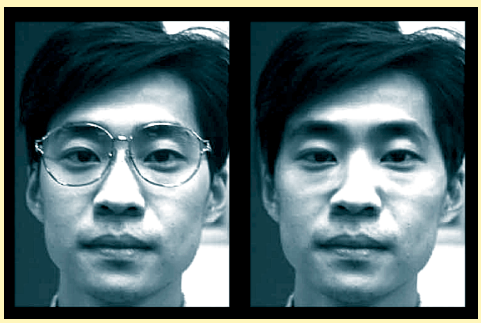
Another consequence, Edholm notes, is that we may someday see the end of wireline. Its continued use depends on a consumer need for ever-higher data rates, and he believes that there may come a time when no more is needed. But applications such as HDTV, high-quality videoconferencing, and three-dimensional displays all have the potential of continuing to require more and more bandwidth. And beyond these, holographic imaging, virtual reality, immersive reality for telemedicine distance learning, and other high-bandwidth applications will probably continue to keep the demand for wireline connectivity strong.

At some point, though, we'll reach some fundamental human limit: the human eyeball can process only so many pixels per second, for example. When wireless can hit those limits, we can abandon our wirelines, and all telecommunications will be completely untethered and mobile. ■

PLEASE REMOVE YOUR GLASSES

PROGRESS

Ever wonder how those old photos of you would look if you hadn't been wearing glasses? Experimental software developed at Microsoft Corp. can help. The program will automatically remove eyeglasses from photos of faces. Starting with an image of a person, the program locates and isolates the face. Then it uses a statistical learning method to find the eyeglasses, remove them, and fill the blanks in with the appropriate pixel colors.



Determining these fill colors is where the statistical learning really shines. The system uses models based on prior knowledge of which colors and textures belong underneath glasses to work out how to replace the missing pixels. The group's work is the first to perform this type of editing on entire objects, such as glasses, instead of on individual pixels. What's more, the statistical approach can be used to automatically edit out a wide variety of objects—someday, perhaps even unfortunate facial piercings. ■

Automatic Eyeglasses Removal from Face Images, by C. Wu, C. Liu, H.-Y. Shum, Y.-Q. Xu, and Z. Zhang, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, March 2004, pp. 322–36.

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