Boosting bandwidth

While physics could provide the answer to a looming capacity crunch in communications, **Andrew Ellis** says we first need to think about what society needs before solving the issue

This year marks a number of major anniversaries in communications technologies. It is 200 years since the first electronic telegraph was made, 150 years since the mirror galvanometer increased the reliability of transoceanic links and 50 years since the commercial use of optical fibre was first proposed. More recently, this year also marks the 20th anniversary of the first optically amplified transoceanic link and 10 years since the installation of the first high-capacity super-channel for high data rates.

These technologies have helped increase our communication capacity by over 12 orders of magnitude. From simple telegraph symbols, through to telephone calls, fax and video, today it is possible to transmit live-studio-quality 4k images from *all* of the TV cameras at *all* football league matches simultaneously over a single optical fibre. As each new application is delivered, new ambitions arise with continuing demand for yet more innovation and connectivity.

With so many anniversaries, this year is perhaps a good time to celebrate the impact of telecommunications, acknowledging the contributions from physicists including James Clerk Maxwell, Lord Rayleigh, John Tyndall, J J Thomson, Albert Einstein and Erwin Schrödinger as well as many others since. The tremendous unseen progress in communications technology now underpins modern life through social media, globalization, manufacturing and "smart cities". So it is also an opportunity to recognize the ceaseless efforts of the current protagonists of the optical communications industry. However, we need to discuss global connectivity for more sobering reasons.

Since the first transatlantic cable was laid in 1858, newer, faster and more energy efficient cables have been regularly deployed that have made each old cable obsolete. But at a Royal Society meeting last year, fears were raised that optical-fibre capacities are restricted by a trade-off between quantum noise and nonlinear distortions. Of course, when this limit is reached we can just install more systems, which for many operators is

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Crunch time Should we just keep on increasing communications capacity without questioning it?

possible for inland networks using existing fibres. But with overall communications demand doubling every five years since 1816, and Internet traffic within the UK's core network currently doubling every 18 months, there is only so much growth that can occur through the duplication of equipment.

Energy demands

Exponential growth always results in resources being exhausted with customers buying more and more stuff and using up ever-growing amounts of energy. Indeed, network providers have already been accused of consuming around 1.5–2% of the UK's electricity on powering the Internet. While this is a small fraction of overall energy usage, this is a level at which "Pigouvian" taxes – those that are designed to influence behaviour – are typically imposed. An example of such a tax is air-passenger duty in an industry that represents around 2% of all global carbon-dioxide emissions.

One tactic used by BT, which operates the UK's main network, is to switch off obsolete equipment. This will help contain the firm's energy consumption below 2% of the UK's total until 2030. Eventually, however, exponential traffic growth will inevitably bite. These, and other challenges are keeping many scientists and engineers busy. For example, the UK's Engineering and Physical Sciences Research Council (EPSRC) has funded projects such as UNLOC and HYPERHIGHWAY to address fundamental optical-fibre transmission issues, while other EPSRC programmes focus on the other hot spots.

There are two challenges to overcome. The first is keeping up with bandwidth demand, the current bottleneck being in customer connection – your broadband or 4G connection speed. The second is to avoid resources being exhausted as capacities continue to grow. A particularly promising approach for the former is to install fibre all the way to the home, eliminating electronics not only from street cabinets, but also local telephone exchanges. This approach removes many bottlenecks from the network and offers the prospect of essentially unrestricted capacity irrespective of distance. We know how to do this, products are available, but we are not doing it despite the obvious energy savings.

Given the current regulatory environment and the large investment that will be needed, commercial realities – not physics – will dictate when a truly all-fibre network will fully replace the copper network. However, for new housing estates there is little practical reason to deploy new copper cables when fibre is cheaper and we can look forward to a time when passive optical networks are featured in the marketing material for new homes. Planning regulations should be adjusted to encourage or even enforce this move, and we must introduce tax relief to encourage existing communities in a particular area to commission their own fibre networks.

The second challenge is more difficult but an area where perhaps physics can help. Radical solutions will be needed beyond 2030 to prevent energy consumption from increasing in proportion to bandwidth, and interdisciplinary efforts across science and industry will be essential to develop a truly lasting solution with sufficient headroom to allow exponential growth.

Yet given some of the alleged negative consequences of the Internet – be it trolling, identity theft or reduced face-to-face social contact – it is perhaps time to take a step back. We should ask what we want our destination to be before we tackle the traffic jam of technical challenges, Pigouvian taxes and market forces that constrain bandwidth use. May I therefore be the first to ask you: are we there yet?

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