

The end-to-end argument, and the reason why some kind of reconsideration is needed

Fredrik Andersson, KTH, ifrand@kth.se

Abstract

This paper looks into the problems that follow from looking into the design of the Internet in only a technological, i.e. performance, point of view. The rapidly changing political environment as well as the changes in consumer behavioral in the world makes this issue highly urgent and therefore it is of immediate interest these days. The Internet is becoming more and more a part of everybody's life, a more or less indispensable tool for communication in our lives. As it expands into new areas of the world, the Internet changes in a fundamental way; it gains new administrative authorities. Changes in authority also produce changes in administrative policies and mandate new mechanisms to enforce these policies. Both the architecture of the connected Internet and the protocols it uses are evolving away from a centralized core model. This evolution continues as more and more national backbone networks attach.

Introduction

The end-to-end argument is a matter that was a vital part of the Internet in its early days. It concerns how the Internet has been designed and how application requirements should be met in a system. The end to end arguments suggests that application-level functions cannot and should not be implemented in the lower levels of the system – the core of the network. The reason this was stated follows from the original paperⁱ:

The function in question can completely and correctly be implemented only with the knowledge and help of the application standing at the endpoints of the communications system. Therefore, providing that questioned function as a feature of the communications system itself is not possible.

Back then the users of the Internet were solely technicians with a great deal of knowledge about the technology they utilized. The main problems engineers, who were developing the Internet, had to deal with then belonged to performance and reliability. Since those days the Internet has grown into proportions no one could dream of at that time. Regarding to the most recent survey, in January 2003ⁱⁱ the number of hosts in the Internet was 171,638,297 and this is a number that has more than doubled in the last three years. Both hardware and software has evolved with incredible speed. Processor performance has increased over two orders of magnitude, typical memory sizes have increased by over a factor of 100 and network bandwidth of the Internet backbone has risen by a factor of 7000ⁱⁱⁱ.

The pros and cons of low-level function implementation

Advantages of the end to end concept

Even if parts of an application-level function can potentially be implemented in the core network, the end to end arguments state that one should resist this approach if possible. Some advantages of moving application-specific functions up and out of the core of the network are^{iv}:

- The complexity of the core network is reduced, which reduces costs and facilitates future upgrades to the network.
- Generality in the network increases the chances that a new application can be added without having to change the core of the network.
- Applications do not have to depend on the successful implementation and operation of application-specific services in the network, which may increase their reliability.

To utilize the most possible performance out of a net, the least possible functionality must be built-in to that net. Those applications that do not need any functionality *in* the net but only depend on throughput will suffer from any attempt to enhance functionality. Nowadays with the earlier mentioned capacity both in hardware as well as in software, these reasons might be on the decrease but other maybe lesser obvious advantages of the end to end arguments are the fact that the somewhat free attitude of the Internet in the past has in many ways been the source of creativity and innovation we have seen so far. This is in many ways what has produced the numerous amounts of useful and amusing applications we can make use of today.

A more private attitude towards the Internet will probably hamper this innovative and imaginative progress we have witnessed so far. The more regulations and control that is put inside the net will also annihilate the possibility of having a medium with a true freedom of speech, also if someone malevolent gains access to such mechanisms it would on the contrary have the opposite effect.

Objections against the end to end approach

In the last few years, with the growth rate mentioned before, a new kind of user has evolved. Today we can see a growing consumer market on the Internet which brings about other kinds of user groups than the customary engineer or technician that we are used to. Many of the users we meet today are not interested in the underlying technology at all. What those users *really* demand is maybe not so much the clean and easy to implement network-structure as a scientist or technician would want, but their first choice of objective might be to delegate a lot more responsibility to the ISP or some other part. The only interest this group of users finds in the Internet comes from whatever services and benefits they can obtain from using their computer in a much more commercial way.

Yet, some of the users who *do* have some knowledge about the technology are using it in a completely destructive way, misbehaving in a way that would have been out of the question only a decade ago. But this problem might unfortunately grow even larger with a more restrictive approach since many of those who devote themselves to that kind of action are people who find challenge and amusement in proving their magnificence to others who have the same way of thinking. These aspects make the rapid growth of the Internet entailing a great deal of problems regarding trust and service. To obtain security the end-points either have to trust each other, or otherwise trust a third part that can offer them the safety they require.

Today, there are also a new set of applications emerging, such as streaming video and audio. Applications of this kind need some way of constitution of bandwidth and throughput, not to suffer from loss of quality. RSVP handles functions like this in IPv4, but this also implies problems with cost distribution, once the resources are reserved they must be paid for regardless of usage. Another hot issue nowadays is IP-telephony that also requires some help from the lower layers to work well. It is in these areas the larger Internet Service Providers sees an opportunity to make business, in offering differentiated services. To be able to proffer these services, they need some kind of control inside the system that the end-user is not permitted to get in touch with.

In all, this has an effect on the conventional understanding of the “Internet philosophy”: freedom of action, user empowerment, end-user responsibility and lack of controls inside the Net. Perhaps this could even be seen as a paradigmatic shift, since making the network more trustworthy seems to imply more mechanism in the center of the network to enforce “good” behavior.

Emerging nations and the globalization process

The world has become much more complex since the time of Internet’s adolescence but in the U.S. one trend is obvious: the changing role of the government in the Internet. The historic role of enabler is withering, government contributions to the design and operation of the Internet have shrunk. At the same time, as more and more citizens have started to use the Internet and depend on it, government attention to the nature of Internet businesses and consumer issues has grown^v.

The roles, which the government is playing at this time, are consistent with government activities in other sectors in America. With the history of conventional telecommunications, including both telephony and broadcast media: antitrust vigilance, attempts to control consumer fraud, definition of a commercial code, taxation, and so on. There is little their government has done that represents a new role.

Though, one must never lose sight of the international nature of the Internet. As the Internet emerges and grows all over, which it is doing with great speed, the cultural differences in different places and parts of the world will be a major factor in the overall shape the Internet takes. In some countries, the ISP may be the same thing as the government, or the government may impose a set of operating rules on the ISPs that are very different from those expected in the U.S., the nation one might consider to be the native country of the Internet.

China states as a good example of those governments acting more or less as one would expect an ISP to do in the U.S. or a European country, and China with a population of nearly 1.3 billion people^{vi} shows the need for some differences in the network, although too much differentiation surely will have a devastating effect.

New questions are arising about the legal treatment of ISPs also in the U.S. The rise of ISPs and transformations of historically regulated telephone companies, broadcasters, and more recently cable television providers have created new tensions between a broad goal of what usually has been a relaxing economic regulation, having the goals of promoting competition and consumer benefits as well as lower prices and product innovation. Although the U.S. federal telecommunications regulators have eschewed “regulation of the Internet”, topics being debated include whether the legal concept of common carriage that applies to telephone service providers should apply to ISPs^{vii}. Today’s legislative and regulatory inquiries beg the question of whether the ISP business should continue to evolve on its own or whether the transformation of the Internet into public infrastructure calls for some kind of intervention. If this comes about the CIA will doubtless claim to be the trustee of the security issues that will evolve, which might result in, or is already causing an arms race in the area of information and propaganda.

Conclusions

As stated above those users who do not totally trust each other still desire to communicate and of all the changes that are transforming the Internet, the loss of trust may be the most fundamental. The exact details of what service an ISP offers may change over time, and they can be reversed by consumer pressure or law. But the simple model of the early Internet—a group of mutually trusting users attached to a transparent network—is gone forever^{viii}. To understand how the Internet is changing, we need to have a more sophisticated consideration of trust and how it relates to other factors such as privacy, openness, and utility. Trustworthiness motivates both self-protection (which may be end to end) and third-party intervention (which appears to challenge the end to end principles)^{ix}. The institutional providers of Internet services such as corporations, schools and non-profit organizations that operate parts of the Internet have also evolved a much more complex set of roles. Employees have found themselves fired for inappropriate use of the corporate attachment to the Internet, and employers have sometimes been much more restrictive than ISPs in the services they curtail and the rules they impose for acceptable use. The user of the Internet today cannot necessarily do as he pleases: he can do different things across different parts of the Internet, and perhaps at different times of the day.

In the last twenty years the nature of innovation have changed going from a single creative person, working at home in his spare time building applications suitable for people interested in technology, into a large industry providing customers and businesses with *services* making the *applications* a matter of secondary importance. The end to end argument favors in all certainty the small innovator but when it comes to the services and the more large-scale solutions the end to end argument will in most cases inhibit innovation. Therefore it is of highest significance that these issues are brought high up on the UN agenda. Unless some action is taken in this matter the Internet as we have been used to so far might even be on its decline. To maintain the Internet a true “freedom of speech” medium the question of IPv6 is maybe one of the most important questions these days.

ⁱ J.H. Saltzer, D.P. Reed and D.D. Clark, End-to-End Arguments in System Design

ⁱⁱ <http://www.isc.org/ds/host-count-history.html>

ⁱⁱⁱ See Douglas E Comer, Internetworking with TCP/IP, pp. 600

^{iv} M.S Blumenthal, D.D. Clark , Rethinking the design of the Internet: The end to end arguments vs. the brave new world

^v M.S Blumenthal, D.D. Clark , Rethinking the design of the Internet: The end to end arguments vs. the brave new world pp.18

^{vi} <http://www.cpirc.org.cn/eindex.htm>

^{vii} M.S Blumenthal, D.D. Clark , Rethinking the design of the Internet: The end to end arguments vs. the brave new world pp.19

^{viii} M.S Blumenthal, D.D. Clark , Rethinking the design of the Internet: The end to end arguments vs. the brave new world pp.23

^{ix} M.S Blumenthal, D.D. Clark , Rethinking the design of the Internet: The end to end arguments vs. the brave new world pp.20