Considerations on Internet Consolidation and the Internet Architecture
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Abstract

   Many of us have held a vision of the Internet as the ultimate
   distributed platform that allows communication, the provision of
   services, and competition from any corner of the world. But as the
   Internet has matured, it seems to also feed the creation of large,
   centralised entities in many areas. This phenomenon could be looked
   at from many different angles, but this memo considers the topic from
   the perspective of how available technology and Internet architecture
   drives different market directions.

Status of This Memo

1. Introduction

   Many of us have held a vision of the Internet as the ultimate
   distributed platform that allows communication, the provision of
   services, and competition from any corner of the world. But as the
   Internet has matured, it seems to also feed the creation of large,
   centralised entities in many areas.

   We use the term Internet consolidation to refer to the process of the
   increasing control over Internet infrastructure and services by a
   small set of organizations. Such concentration has an obvious effect
   on traffic flows or whose services and systems are in daily use by
   large population of Internet users, but it can also create secondary
   effects, where the ability to collect information or to affect
   something is concentrated in the small set of organizations.

   Consolidation may also affect technology choices and the evolution of
   the Internet architecture, e.g., large organizations or organizations
   providing important technology components may have a significant
   impact on what technology is deployed for large numbers of users or
   by other organizations.

   Our first question is whether Internet is indeed consolidating? It
   certainly appears so, though more quantitative research on this topic
   would be welcome. It is also possible that there's only a perception
   of consolidation, as market forces have caused business changes in
   new areas of business. Arguably, today's consolidation areas seem to
   be more in the application space than further down in the stack or in
   the operating systems, as was the case some years ago. The second
   question is if we're seeing consolidation simply moving to new areas.

   This phenomenon could be looked at from many different angles, but
   this memo considers the topic from the perspective of how available

technology and Internet architecture drives different market
directions. Our third question is if the Internet technology has
influenced the consolidation trends in some manner? And conversely,
the fourth question asks how is Internet consolidation influencing
the development of the Internet infrastructure and architecture?

The engineering remit at the IETF is to focus on technology, but of
course we also want to understand the implications and externalities
of the technical arrangements we design. Technology affects
economics and vice versa. The Internet technology community
continues to make decisions that have ramifications on Internet
systems, just as we are subject to forces that affect them.

As technologists, our fourth question is whether there are changes in
technology that would help reduce those large-player advantages that
are technically-driven.

This memo reviews areas where consolidation may be occurring in the
Internet, and discusses the potential reasons for this. The memo
starts by review other work in this area in Section 2. Section 3
discusses consolidation and the reasons behind the creation of larger
entities, and Section 4 looks at some actions that might alleviate
the situation.

If you are interested on this or other architecture-related topics,
please subscribe to the IAB architecture-discuss mailing list as one
forum for discussion. Similarly, the Internet Society has chosen
consolidation as a focus topic for their year 2019 activities. Their
report is in [ISOC].

2. Other Work

One of the causes for the current consolidation of the Internet
infrastructure can be traced back to some of the assumptions that
were made during the commercialization of the Internet in the early
1990s [Abbate], even though [RFC1192] already describes some
potential issues that could arise. Overall it was expected the
combination of commercialization, together with the technical and
architectural characteristics of the Internet, such as its modularity
and layering principles, would lead to perfect markets, free
competition and decentralized structures [LitanRivlin].

But as we know now, this did not happen entirely as expected. Some
even argue that 'market concentrations, control and power struggles
are categories to adequately describe the fundamental dynamics of the
commercial Internet' [DolataSchrape]. While the privatization was
supposed to lead to competition and innovation [Cowheyetal]

[VanSchewick], some argue that it actually led to the emergence of
Internet oligopolies [Mansell] [Smyrnaios].

Current scientific economic thinking harbors two different schools
vis a vis efficient markets and monopolies. The school based on Adam
Smith argues that unfettered markets tend to concentration of wealth
and income, whereas liberal economist believe in efficient markets
that stimulate competition.

On the other hand, according to Joseph Stiglitz 'many sectors -
telecoms, cable TV, digital branches from social media to Internet
search, health insurance, pharmaceuticals, agro-business, and many
more - cannot be understood through the lens of competition'
[Stiglitz]. The considerations of technologists and policy makers at
the time of the commercialization and privatization of the Internet
infrastructure might have been based on a belief in efficient
markets, whereas we are now finding out this might not always be how
markets function.

It cannot be denied that 'market actors have contributed immensely to
the evolution of the Internet in terms of investment, products,
services, and infrastructure, and the government's light-handed
approach to regulation has given producers and consumers substantial
freedom to innovate and to self-regulate with respect to many issues
affecting the Internet community in ways that have produced
substantial social benefits' [Frischmann]. But the current
consolidation in ownership of and control over the Internet
infrastructure was not foreseen [Clark], and arguably the loss of
decentralized control goes against its design objectives. For
instance, [RFC1958] says:

This allows for uniform and relatively seamless operations in a
competitive, multi-vendor, multi-provider public network.

and

Heterogeneity is inevitable and must be supported by design.

And [RFC3935] says:

We embrace technical concepts such as decentralized control, edge-
user empowerment and sharing of resources, because those concepts
resonate with the core values of the IETF community.

3. **Factors Driving Consolidation**

   Consolidation is driven by economic factors relating to scale and
   ability to easily reach a large market of users over the Internet.
   This kind of setting tends to enable winners to take large market
   shares, whether those winners came about through the model that
   liberal economists believe in or the model that Adam Smith believes
   in.

   The most visible aspects of this involve well-recognized Internet
   services. Internet Society's report summarised the market position
   of popular Internet service brands as follows [ISOC]:

   o Facebook and Google have been estimated to account for 84% of
      global digital advertising investment (excluding China).

   o Amazon is expected to account for 49.1% of all online retail
      spending in the US. Similarly, Alibaba is estimated to have close
      to 60% of the e-commerce market in China.

   o Google alone holds 90% of the global search market, over 60% of
      web browsers, and has the number 1 (by far) mobile operating
      system (Android).

   o Facebook - incorporating Facebook Messenger, WhatsApp, and
      Instagram - holds 4 of the world's top 6 social media platforms.

   But it is important to recognize that the Internet is a complex
   ecosystem. There are many underlying services whose diversity, or
   lack thereof, are as important as that of, say, consumer-visible
   social networks. For instance, the diversity of cloud services,
   operating systems, browser engines is as important as that as of
   application stores or the browsers themselves.

   Of course, the Internet allows plenty of choice both in these and
   other areas. Too many or too few choices create different kinds of
   problems.

   It would be useful to break these general factors and observations
   down a bit further. In particular, it is useful to distinguish
   market or economic factors from technical factors.

3.1. **Economics**

   Scaling benefits are natural for many types of businesses. And many
   Internet-based businesses can potentially serve a very large customer
   base, as the cost of replicating and delivering their service to new
   customers or areas is small.

However, typically the network effect has an even more pronounced
impact. Each additional user adds to the value of the network for
all users in a network. In some applications, such as the open web,
this value grows for everyone, as the web is a globally connected,
interoperable service for anyone with a browser can use.

There is an important distinction between different applications of
the network effect, however. Consider email as another example;
anyone with an account at any email server can use it globally.
However, here we have seen much more consolidation into few large
email providers, both due to innovative, high-quality services but
also because running email services by small entities is becoming
difficult; among other things due to spam prevention practices that
tend to recognize well only the largest entities.

In some other applications, such as social media, the services have a
more closed nature. The value of being a customer of one social
media service depends highly on how many other customers that
particular service has. Hence, the larger the service, the more
valuable it is. And the bigger the value difference to the
customers, the less practical choice they have in selecting a
service.

In some cases, these developments also allow asymmetric relationships
to form, with the customers having less ability to affect the service
than they would perhaps wish.

3.2. Interdependencies

Entities with a large role in a market place tend to have inertia, of
course through having many customers, but also due to their
interconnectedness with the rest of the ecosystem. These
interconnections can range from business relationships to peering
connections, linking, and the use of various infrastructure services
from an entity as building blocks in applications.

These interconnections make it difficult for a market to move away
from a large entity. Indeed, even for an individual it can be a
challenge to not use the most commonly used Internet services
[Gizmodo].

Optimistic technologists ("digital libertarians") tend to have a
beliefs that states have limited ability to regulate the Internet:
"The Net interprets censorship as damage and routes around it"
[Gilmore]. However, as argued by [Boyle] states may have multiple
ways to influence and monitor the Internet. One of the issues
related to consolidation is that it tends to be easier to exert
control of few large entities, than a large set of small, distributed

players. This concern is particularly acute around intellectual
property rights or surveillance capabilities, particularly when
extra-territorial requirements are placed on the large entities.
These entities cannot avoid comforming to regulation and laws in any
of the locations they have presence in.

As a result, there's an added angle of interconnectedness with
governments. At the same time, this of course also provides an
avenue for control of market forces, e.g., in the form of competition
law.

[3.3](#). Data- and Capital-intensive Services

The scaling advantages are only getting larger with the advent of AI-
and machine learning -based technologies.

The more users a service has, the more data is available for training
machine learning models, and the better the service becomes, bringing
again more users. This feedback loop and the general capital-
intensive nature of the technology (data and processing at scale)
makes it likely that the largest companies are ahead in the use of
these technologies.

One could also take the pessimistic view that many of the ongoing
disputes in standards organizations relate to which market actors
will ultimately be able to collect the more data from private persons
and how. The question isn't as much about the protection of the
user's privacy but rather whether one or another industry (or
country) will be able to benefit from access to data.

[3.4](#). Permissionless Innovation

The email vs. social media example also highlights the interesting
roles of interoperability and the "permissionless innovation"
principle - the idea that a network can be simple but still powerful
enough that essentially any application could be built on top of it
without needing any special support from anyone else. Permissionless
innovation has brought us all the innovative applications that we
enjoy today, on top of a highly interoperable underlying network,
along with advances in video coding and other techniques used by
applications.

Paradoxically, if the underlying network is sufficiently powerful,
the applications on top can evolve without similar pressures for
interoperability, leading to the closed but highly valuable services
discussed above. We call this the Permissionless Completeness
Problem.

3.5. Fundamentals of Communication

   There are also fundamental issues. For instance, speed of light;
   low-latency services can fundamentally only be provided through
   globally distributed data centers. These are often provided built by
   large organizations, although collaborative and data center or cloud
   computing service approaches also exist.

   A similar issue has arisen in recent years around large-scale denial-
   of-service attacks, and how various entities can deal with them.
   While the largest attacks affect all players (see, for instance, the
   Dyn attacks in October 2016), it is also true that large cloud- and
   content delivery providers can better deal with such attacks due to
   their scale. This is one reason that attracts many network services
   to such providers.

3.6. Technology Factors

   One of the key questions is whether we are seeing developments that
   are driven by economic factors or whether fundamental reasons or lack
   available technology drives particular models. For instance,
   centralised solutions might desirable due to business incentives, or
   they might be necessary because there is no distributed,
   collaborative solution.

   For instance, some technical issues have historically not been easy
   to solve, such as e-mail spam, which has led to reliance on non-
   technical solutions. Today, it is becoming increasingly difficult to
   run your own mail services, essentially forcing many organizations
   and individuals to employ larger providers. The issues relate
   directly to size of entities; no one can afford to disconnect from
   the largest providers. But as a small entity, there is little
   leverage to convince peer entities or various supporting white/
   blacklist entities to deal with you properly.

   Many Internet services are based on gathering data about users, and
   using that data for, for instance, targeted advertisements. More
   data from more users makes it possible to run a service more
   accurately or with better results; here again scale brings
   advantages.

   Another trend is that more and more content is becoming available
   locally, from a content delivery or provider function directly on
   your own ISP's network. We predict that eventually most content will
   be delivered this way, reducing the role that global IP connections
   across the Internet play. By some metrics this has already happened;
   what practical - positive or negative - impacts might this have on
   the Internet technology?

There are also security tradeoffs. Large entities are generally
better equipped to move to more recent and more secure technology.
For instance, the Domain Name System (DNS) shows signs of ageing but
due to the legacy of deployed systems, has changed very slowly.
Newer technology developed at the IETF enables DNS queries to be
performed confidentially, but its deployment is happening mostly in
browsers that use global DNS resolver services, such as Cloudflare's
1.1.1.1 or Google's 8.8.8.8. This results in faster evolution and
better security for end users.

However, if one steps back and considers the overall security effects
of these developments, the resulting effects can be different. While
the security of the actual protocol exchanges improves with the
introduction of this new technology, at the same time this implies a
move from using a worldwide distributed set of DNS resolvers into,
again, more centralised global resolvers. While these resolvers are
very well maintained (and a great service), they are potentially
high-value targets for pervasive monitoring and Denial-of-Service
(DoS) attacks. In 2016, for example, DoS attacks were launched
against Dyn, one of the largest DNS providers, leading to some
outages.

[4]. Call to Action

Are there assumptions about the Internet architecture that no longer
hold in a world where larger, more centralised entities provide big
parts of the Internet service? If the world changes, the Internet
and its technology/architecture may have to match those changes.

It appears that level the playing field for new entrants or small
players brings potential benefits. Are there technical solutions
that are missing today?

Of course, it may well be that technology improvements are hard to
come by. Nevertheless, recognizing the risks of consolidation in
both current and proposed future technologies is the first step in
proactively avoiding those risks where possible.

Assuming that one does not wish for regulation, technologies that
support distributed architectures, open source implementations of
currently centralised network functions, or help increase user's
control can be beneficial. Federation, for example, would help
enable distributed services in situations where smaller entities
would like to collaborate.

Similarly, in an asymmetric power balance between users and services,
tools that enable the user to control what information is provided to
a particular service can be very helpful. Some such tools exist, for

instance, in the privacy and tracking-prevention modes of popular
browsers but why are these modes not the default, and could we
develop them further?

It is also surprising that in the age of software-defined everything,
we can program almost anything else except the globally provided,
packaged services. Opening up interfaces would allow the building of
additional, innovative services, and better match with users' needs.

Silver bullets are rare, of course. Internet service markets
sometimes fragment rather than cooperate through federation. And the
asymmetric power balances are easiest changed with data that is in
your control, but it is much harder to change when someone else holds
it. Nevertheless, the exploration of solutions to ensure the
Internet is kept open for new innovations and in the control of users
is very important.

o What IETF topics that should be pursued to address some of the
   issues around consolidation? Some of the topics for consideration
   are discussed in Section 4.1 and Section 4.2.

o Are there open source efforts that should be pursued or kept being
   pursued to ensure that a diversity of operators and networks can
   use a particular technology? This is further discussed in
   {{opensource]].

o What measurements relating to the developments centralization or
   consolidation should be pursued? And what other research, such as
   distributed Internet architectures, should be driven forward?
   Some potential topics are discussed in Section 4.4.

4.1. Open Interfaces

Standards and open source efforts continue to build many open
interfaces and APIs that allow systems interoperability and tailoring
of services. In some cases, however, the availability of open
interfaces definitions and software has not lead to the realization
of actual interfaces in this open manner. For instance, different
instant messaging systems have had a technical ability to be
interoperable with other systems, just like e-mail is interoperable
across systems, but have chosen to be disconnected.

Work in determining what open interfaces can provide benefits to
users as well be successfully deployed in the Internet ecosystem
would of course be useful.

4.2. Specific Standardization Choices

   Sometimes the issue is not the availability of interfaces as such,
   but rather fundamental architectural choices with regards to how
   Internet systems should be built.

   Often this relates to how centralized or distributed deployments are
   targeted. And even if a distributed, broad deployment model is
   targeted, he expectations may not match reality when economies of
   scale, DDoS resilience, market consolidation, or other factors have
   come into play. These factors can result in the deployed reality
   being highly concentrated.

   This is a serious issue for the Internet, as concentrated,
   centralized deployment models present risks to user choice, privacy,
   and future protocol evolution. On occasion, the differences to
   expectations can be immediate, but can also occur much later.

   Some examples of these issue include current work in DNS where we may
   see concentration through the use of globally available common
   resolver services, which evolve rapidly and can offer better
   security. But the concentration of these queries into few services
   creates new security and privacy concerns.

   Another example is email, which started out as many providers running
   in a largely uncoordinated fashion, but which has since then seen
   significant market consolidation and a need for coordination to
   defend against attacks such as spam. The coordination and
   centralized defense mechanisms scale better for large entities, which
   has fueled additional consolidation.

   Awareness of these issues while working on standards would be useful,
   so that the issues can be taken into account and appropriately
   mitigated. To begin with, those of us Interested in the broader
   questions about Internet development and Internet researchers are
   needed to identify some of the effects that new technology
   developments may pose.

4.3. Open Source

   Many key Internet infrastructure services (e.g., DNS servers), end-
   user applications (e.g., browsers) and technology components (e.g.,
   operating systems or protocol implementations) are commonly
   implemented using open source solutions.

   This is often true even if there's a large entity that is in charge
   of large fraction of development and deployment for a particular
   technology. This is a good thing, as it ensures that others have a

fair chance of changing the technology in question, should the large
entity drive their use of the technology in some direction that does
not benefit the users. For instance, users and other organizations
have traditionally been able to either run their own browser versions
or provided extensions that suit their needs better than the default
system.

As a result, continuing to have this ecosystem is important safety
valve and competition opportunity.

4.4. Research Challenges

There are number of different research directions for which further
work would be useful.

The first is about measurements; is the Internet indeed
consolidating, and if so, by how much, and in what aspects? Also,
where are Internet's traffic flows concentrating, and how is this
changing over time?

There are also questions about the trends and their relationships to
technology: Has Internet technology influenced the consolidation
trends in some manner? And conversely, how Internet consolidation
influences the development of the Internet infrastructure and
architecture?

Finally, research on topics that would likely yield results that
increase the diversity and de-centralization in the Internet would
obviously be welcome. This can include any de-centralized
technologies, but in particular distributed Internet architecture is
an Interesting topic.

5. Contributors

Much of the text in this memo is from a blog article written by Jari
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