

Humpty Dumpty

"When I use a word," Humpty Dumpty said, in rather a scornful tone, "it means just what I choose it to mean - neither more nor less." "The question is," said Alice, "whether you can make words mean so many different things." "The question is," said Humpty Dumpty, "which is to be master - that's all."

1 Introduction

What follows are some thoughts on the misuse of the term Internet¹/internet traffic. I have been monitoring this misuse for some time now, but with the ongoing discussion on "Big Tech" paying a "fair share" to Telcos² for network usage, this intervention may be of some value?

Note that this analysis is from an engineering perspective and not an economic one³. In addition, what started as a thought piece on my part, has developed into a rather critical review and note, there are no external sponsors for this paper.

By way of an introduction and using the recent Axon Partners⁴ (ETNO) paper as a reference point, the term "traffic" is mentioned on 118 occasions, but there is no definition of the term nor any associated metric⁵. Perhaps more interestingly, some of the data used by Axon Partners (via Frontier Economics⁶) also mentions the term traffic 82 times, but again with no definition. C'est la vie.

My approach within this paper is to briefly review the origins of traffic within circuit switched networks, review the development of "internets", and then attempt to draw parallels with the strong body of work associated with circuit switched network definitions and the measurement of traffic, and will close with some observations. Fundamentally, my concerns are over the use of the term Internet "traffic" i.e., is there an agreed engineering definition coupled with an associated measurement metric?

As a starting statement therefore and based on my ongoing research⁷, I postulate that there is no agreed definition of the term Internet/internet traffic⁸ nor any agreed measurement metric. This is not some statement plucked out of the air, as I have researched numerous sources for any such definition, namely the IEEE, IET, ACM, ETSI, ITU, the Internet Society (IETF⁹), and various "classic"¹⁰ texts to name a few. Maybe Humpty Dumpty's dictum is correct?

There is one exception from my research to counter the above postulate, however, which rather ironically, was jointly authored by individuals from Orange Labs and Telefonica¹¹ – no definition, I hasten to add, but a very good read and I commend it to the house.

It could be argued that this piece of work is not necessary (see examples that follow), but as an engineer, I struggle when loose and ill-defined metrics are being used to support an argument – hopefully, this piece of work may initiate a wider debate – we shall see.

A further note in that I am keen to receive constructive feedback from any interested party and to quote Ledbelly (via Little Richard)¹² "Oh I may be right and I may be wrong, but you're gonna miss me when I'm gone."

¹ For clarity, the Internet is the global network of networks – whilst an internet is a network of networks normally "contained" within one management domain.

² the term Telco is an oxymoron which is briefly expanded upon within this document.

³ Reference is made to numerous sources within this paper - some of which are based on economic arguments rather than engineering rigour.

⁴ <https://etno.eu/library/reports/105-eu-internet-ecosystem.html>

⁵ In my world, when you introduce a term for the first time, then it must be **defined**.

⁶ <https://www.telekom.com/resource/blob/1003588/384180d6e69de08dd368cb0a9febf646/dl-frontier-g4-ott-report-stc-data.pdf>

⁷ I've confined my research into non-wireless networks – I gave up on wireless whilst studying Maxwell's equations. More seriously, others have introduced research in this area. Having said that (and I'll probably be told off for this), all networks be they fixed, or mobile, rely upon connectivity between nodes.

⁸ Feel free to prove me wrong otherwise!

⁹ In defence of the IETF, they have produced some excellent work and are to be applauded for their past and ongoing efforts.

¹⁰ See Section 5.4 of Kleinrock, Queueing Systems, Vol 2, 1976, where the ARPAnet is discussed in context.

¹¹ Internet Traffic Analysis: A case Study from Two Major European Operators, Moufida Feknous, et al, IEEE Symposium on Computers and Communications (ISCC) 2014



Note that Dr Mark Norris and Dr Chris Lilly provided critical comments on my arguments and document flow, for which I am grateful.

¹² <https://www.youtube.com/watch?v=8dEYvILd9rg>

2 These are the roots of rhythm And the roots of rhythm remain¹³

Here, I briefly examine some of my thoughts on the evolution of circuit and packet switching. Note that these are drawn from my personal experiences but, be assured, I have “trawled” the literature (extensively).

2.1 An introductory model – “Just deliver the bits”.

As an opening statement, we have moved from the analogue (circuit switched) domain to the digital (packet switched) domain, but in both cases “networks” are a mechanism for transferring signals – see Figure 1. and illustrates one working model.

Figure 1. is a simplified model and illustrates signal transfer in one direction only. For future analysis purposes, I will use “traffic” as a verb for the “transfer” of bits within a network. I am also introducing the concept of “flow¹⁴.”

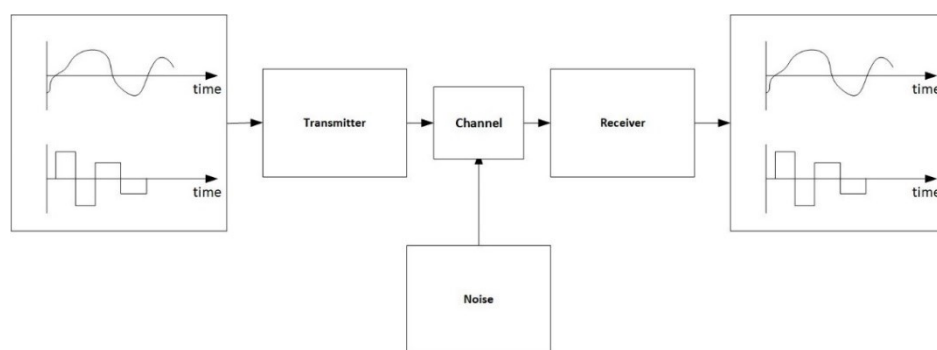


Figure 1 - Signal Transfer

Continuing in that it is useful to go further (for illustrative purposes) to reduce Figure 1. to a black box as illustrated in Figure 2.

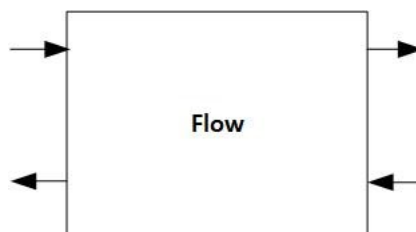


Figure 2 - A Black Box approach

The Black Box¹⁵ model is just that and I will use it to illustrate/simplify my thought process in a later section of this paper.

Isenberg¹⁶ captured this concept very well i.e., “Just Deliver the Bits, Stupid” and would now suggest that any engineering company which is in the bit delivery business as being a “**Bitco**.”

¹³ Under African Skies – Paul Simon (Graceland)

¹⁴ See “Traffic Theory and the Internet”, Jim W. Roberts, IEEE Communications Magazine, Jan 2001 and in particular Roberts suggests “By traffic theory we mean the application of mathematical modelling to explain the traffic-performance relation linking network capacity, traffic demand and realized performance. Since demand is statistical in nature, performance must be expressed in terms of probabilities and the appropriate modelling tools derive from the theory of stochastic processes.” As a starting point, I would further suggest that Roberts paper is stapled to the foreheads of the bozos who are promoting the “fair share” consultation. In addition, the IETF also mention flow at <https://datatracker.ietf.org/doc/rfc2722/>

¹⁵ I was lucky in that I was taught engineering systems theory by Lynton Spence (RIP). If I recall correctly, one of his many pearls of wisdom was “gather the facts, build a model and then test.” Wise words indeed.

¹⁶ <https://bit.ly/36SkoMp>

2.2 Statement

To set the scene, I have extracted some words from an early IET reference¹⁷

“Time-honoured representations of network traffic by pure-chance streams, which have worked well for many years, are now insufficient. The new data networks display a complexity of behaviour which requires a corresponding richness of input, and this has required the development of a multitude of traffic descriptions.”

2.3 Circuit Switching

In my early days with BT¹⁸ (1971 onwards) and, at the risk of “teaching granny how to suck eggs”, the public telephone network in the UK was managed by the predecessor of BT (with the honourable exception of Kingston upon Hull) with Figure 3 illustrating a typical architecture.

One advantage of this single entity approach (read management domain) was that telephone traffic and demand planning was well understood and adhered to sound engineering principles. In retrospect, the demand planning/forecasting unit was an invaluable group within BT.

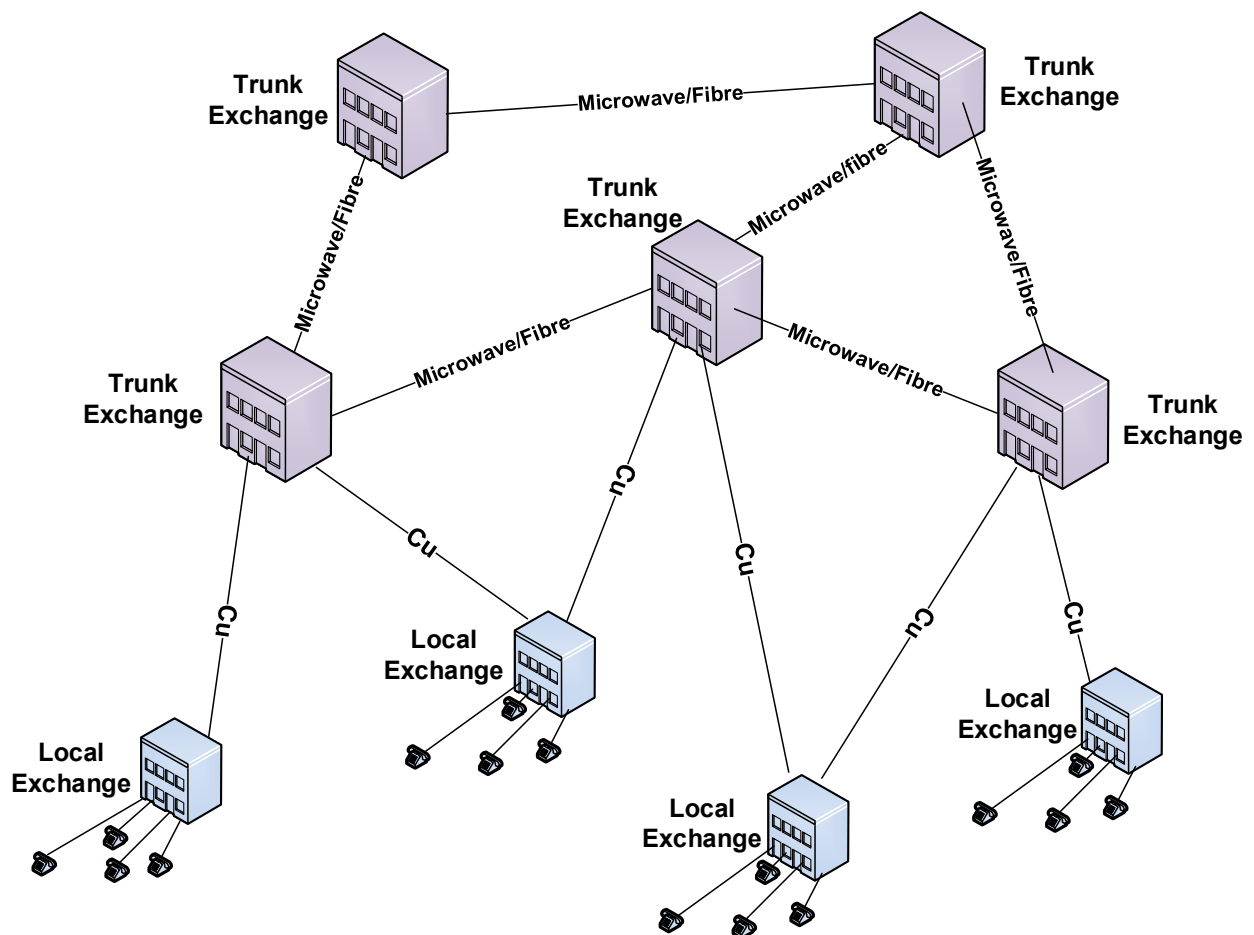


Figure 3 - An example of a circuit switched telephone network.

¹⁷ Telecommunications Systems Engineering, IET Press, 2002, Chapter 2, N W Macfadyen

¹⁸ Here, BT is an all-encompassing term which includes historical changes from being a public sector body to a private one. In my working memory, these include The British Post Office; Post Office Telecommunications; British Telecom; and BT Group Plc.

2.4 Traffic within a circuit switched network – a definition.

The unit of “Traffic Flow” within a circuit switched network is introduced at¹⁹ and quoting directly from this document is **“The average number of simultaneous calls in progress during a period is known as the traffic flow, or intensity, and is measured directly in units known as Erlangs²⁰.”**

Others have published extensively on traffic engineering from the switched circuit perspective. One such paper²¹ introduces probability and queueing theory in some depth, particularly with Chapter 15 “Traffic measurements” which has offered some weight to my current thought process. Note that the ITU reference is dated 2005 and I cannot find an updated document within ITU archives.

For planning purposes, the BT document referred to above uses the busiest hour of the day, the busy hour²², as the period T, and unless stated otherwise ‘erlangs of traffic’ refer to a period of one hour. During my telephony days, the weekly daily hours were 09:00- 10:00 and 15:00-1600.

Although the BT and ITU approaches and any measurement process are rarely used today (if at all), there are models which can be referenced i.e., they have rigour in definition and use. More importantly, the definition and to a lesser extent the measurement approach has been agreed within international standards bodies. Note that the BT reference document mentioned above was published in the early 60s.

As a further observation, traffic planning within a circuit switched network was invariably within a single management domain – being able to “observe” the ingress and egress of a flow assists considerably.

2.5 The move from circuit switching to packet switching (and thence the Internet)

Some background, in that my early days with BT were heavily focused on telephony and circuit switching. During this period, I was aware of the developments within BT on packet switching (EPSS), but I was not aware of the work being conducted on packet switching in the USA²³, France, and the also the UK. From the US perspective, luminaries such as Baran, Roberts, Cerf²⁴, Khan, Kleinrock, and Day are worthy of mention and from the UK and France, Davies²⁵ and Pouzin are also identified as pioneers.²⁶ Skipping over the many developments in networking (both circuit and packet switched), the development of the ARPAnet and the eventual adoption of the Internet Protocol Suite (IPS) has led to today’s Internet and its relative complexity.²⁷

Some further background, in that I spent circa eight years with NatWest Bank where we “built” the DIN.²⁸ NatWest Bank were not alone at that time, as most UK Banks were implementing similar projects²⁹. The DIN packet network was a serious piece of engineering in both its design and ongoing support and was comparable to BT’s PSS at the time in terms of coverage, capability, etc.,. Amusingly, the DIN packet network used BBN packet switches i.e. those used within the original ARPAnet, but with X.25 interfaces – if only we had eliminated the X.25 interfaces.³⁰ Whilst on the subject of the DIN and the elusive definition of traffic, the Bank’s capacity planning team had the

¹⁹ http://www.samhallas.co.uk/repository/edu_pamphlets/ep_draft_telephones_6_3.pdf

²⁰ Rather interestingly, I never came across an Erlang measurement instrument in my time with BT (joke)

²¹ ITU–D Study Group 2 Question 16/2 Handbook “TELETRAFFIC ENGINEERING” – Jan 2005 (see https://www.itu.int/dms_pub/itu-d/opb/stg/D-STG-SG02_16.2_1-2002-PDF-E.pdf)

²² I pose the question “is there a busy hour in packet switched networks?”

²³ See “Circuits, Packets, and Protocols: Entrepreneurs and Computer Communications, 1968–1988” by Pelkey, et al at <https://dl.acm.org/doi/book/10.1145/3502372> and “Data Communications at the National Physical Laboratory (NPL) -1965 to 1975” by Martin Campbell-Kelly for UK perspective at <https://dl.acm.org/doi/10.1109/MAHC.1987.10023>

²⁴ See <https://spectrum.ieee.org/vint-cerf> - a very good read.

²⁵ Communication Networks for Computers (Wiley Series in Computing) 1973 – see <https://dl.acm.org/doi/10.5555/578780>

²⁶ Some additional background in that whilst I was with NatWest Bank (circa1992 onwards), I attended internet school. My teacher was Dr. Ron Catterall of the Imperial Cancer Research Fund (ICRF) – it could be argued that the ICRF network was the first production user of the IPS in the UK (circa 1988).

²⁷ IMHO, we are far, far, away from the original ARPAnet concept of simplicity. See also

<https://cacm.acm.org/magazines/2023/2/268956-extracting-the-essential-simplicity-of-the-internet/fulltext>

²⁸ See - <https://bit.ly/3E8IG4v>

²⁹ The DIN project was led by an engineering team – the economics of this approach was tested in later years – painful.

³⁰ This is worthy of a future piece of work (very painful), but in hindsight, but it would have made the introduction of the IPS easier.

luxury of knowing the ingress and egress of “traffic” and that, coupled with “management” by a single domain ensured capacity planning was a defined and well tested process.

To expand upon my comment re complexity, I must offer my sincerest thanks to Angelos Antonopoulos, et al, for permission to use an example from their recent paper³¹. As the title suggests, the paper examines the relationships between Internet stakeholders and net neutrality.

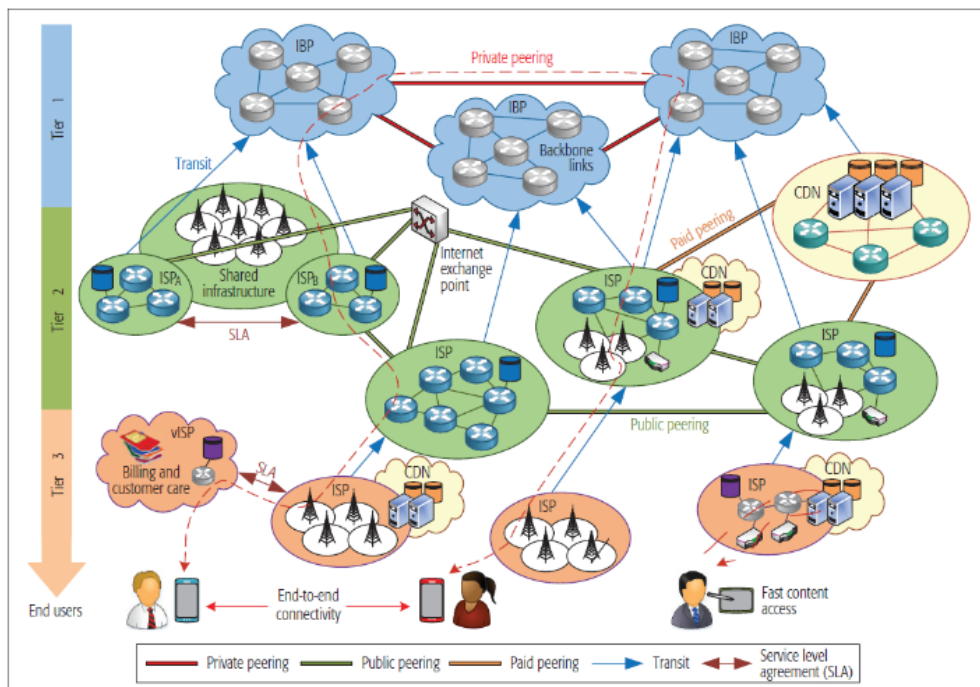


Figure 4 - An example of Internet complexity³²

Figure 4. highlights the multi-tier structure of an Internet model and indicates that the number of stakeholders involved within an Internet delivery chain can be extensive. As illustrated, the notion of a single provider managing the delivery of an Internet service is a non-sequitur and should be continually challenged (by all).

2.6 A note on ISP, Peering, and Telco

Figure 4 is an excellent descriptor of Internet model and illustrates several interconnected parties delivering Internet services. The role of peering is briefly discussed in Section 3, but fundamentally, exchanging “flow” is essential to the success of the Internet (which may change – see opening comments within the introduction to this paper). Where I struggle is understanding where the “Telco” sits within the peering process? Is the Telco nothing more than a Tier 1 provider and if so, we must stop using the term Telco³³ to avoid further confusion?

At this stage, and using Figure 4 as a reference model, I ask “at what point(s) is Internet/internet traffic measured and (more importantly, perhaps), what is the measurement unit?”

Are there lessons to be learnt from the circuit switching world?

³¹ “Shedding Light on the Internet: Stakeholders and Network Neutrality”, IEEE Communications Magazine, Volume: 55 Issue:7

³² It should be noted that the diagram doesn't identify the term “Telco” – although ISP and IXP are heavily represented.

³³ I say this as someone who has worked extensively in Telco (fixed and mobile) in the past (and hopefully, the future). Telco (to me) implies a legacy organisation who, at one stage delivered monopoly telecommunications services. See BT Group as an example and as mentioned previously, I prefer the term “Bitco.” More recently, I have noticed a trend to use the term “Operator” which is a step in the right direction.

3 Internet Traffic³⁴

3.1 Introduction

Here, I briefly introduce initial thoughts on this topic³⁵ based on examples taken from the public domain. In addition, it is a good opportunity to comment on international standards and how they apply to Internet traffic (if at all). In scanning the literature, I have identified three examples³⁶ on the use of the term Internet traffic - these are briefly summarised in Table 3.1 below.

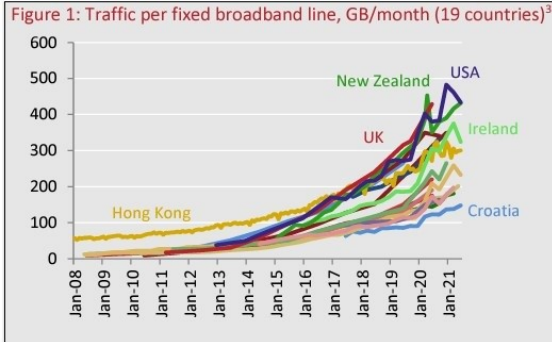
Source	Definitions and Metrics	Observations																												
Andrew Odlyzko ³⁷ https://www-users.cse.umn.edu/~odlyzko/doc/networks.html	Internet traffic growth: Sources and implications, 2003, https://www-users.cse.umn.edu/~odlyzko/doc/itcom.internet.growth.pdf An example from this paper. Table 1. Traffic on Internet backbones in U.S.. For each year, shows estimated traffic in terabytes during December of that year. <table><thead><tr><th>year</th><th>TB/month</th></tr></thead><tbody><tr><td>1990</td><td>1.0</td></tr><tr><td>1991</td><td>2.0</td></tr><tr><td>1992</td><td>4.4</td></tr><tr><td>1993</td><td>8.3</td></tr><tr><td>1994</td><td>16.3</td></tr><tr><td>1995</td><td>?</td></tr><tr><td>1996</td><td>1,500</td></tr><tr><td>1997</td><td>2,500 - 4,000</td></tr><tr><td>1998</td><td>5,000 - 8,000</td></tr><tr><td>1999</td><td>10,000 - 16,000</td></tr><tr><td>2000</td><td>20,000 - 35,000</td></tr><tr><td>2001</td><td>40,000 - 70,000</td></tr><tr><td>2002</td><td>80,000 - 140,000</td></tr></tbody></table>	year	TB/month	1990	1.0	1991	2.0	1992	4.4	1993	8.3	1994	16.3	1995	?	1996	1,500	1997	2,500 - 4,000	1998	5,000 - 8,000	1999	10,000 - 16,000	2000	20,000 - 35,000	2001	40,000 - 70,000	2002	80,000 - 140,000	Odlyzko is also a highly respected mathematician i.e., is not subject to hyperbole. Of note are Odlyzko's conclusions from this paper and I quote "Internet traffic continues to grow vigorously, close to 100% per year."
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Communications Chambers http://www.commcham.com/	PATTERNS OF INTERNET TRAFFIC GROWTH,2021 http://www.commcham.com/pubs/2021/10/5/patterns-of-internet-traffic-growth-2021.html Example analysis from this paper. Figure 1: Traffic per fixed broadband line, GB/month (19 countries)³ 	Communications Chambers are active participants ongoing discussions on Internet growth, so similarly to Odlyzko, they are worthy participants within ongoing discussions. I understand that the data used by Communications Chambers in this illustration is drawn from the public domain. The paper identified here is a good read, as is additional material published by Communication Chambers on this topic.																												
Telegeography ³⁸ https://www2.telegeography.com/	Annex within "State of the Network (2022)" i.e., Peak Traffic "is the 95th percentile of traffic across a link in one month. This is calculated by dividing one month's traffic into five-minute increments, ranking the traffic levels of each increment, and removing the top 5%."	"Traffic" is mentioned, but I'm not sure this definition is widely adopted.																												

Table 3-1 – Examples on the use of the term "Internet Traffic"

³⁴ Just to re-iterate there is no agreed definition of the term Internet/internet traffic, nor any agreed measurement **metric**.

³⁵ Circuit switching (as I knew it) is rarely mentioned within the Internet today, but see Moshe Zukerman and "Back to the Future" at IEEE Communications Magazine, November 2009 and also "Lightpaths on Demand" at <https://bit.ly/2V0XakI>

³⁶ There are more and therein lies the ongoing challenge.

³⁷ Andrew Odlyzko is a pioneer in this subject area with his numerous papers/ppts a good read – see <https://www-users.cse.umn.edu/~odlyzko/doc/networks.html>

³⁸ Telegeography publish quality reports covering several "traffic" figures, but their methodology and approach for assembling their **useful** output is not available within the public domain. I will ask.

Without dwelling too heavily on these illustrative examples, all three suggest Humpty Dumpty may have to deliberate.

3.2 “Internet Traffic” – real world examples³⁹

There is value in examining “real time” measurement of “Internet Traffic” with both LINX and INEX kindly allowing sample screen shots of their monitoring systems to be re-produced⁴⁰, in Figures 5 and 6 below. For information, both LINX and INEX are IXPs⁴¹ and, for both companies, there is substantial information on the role IXPs play within the global Internet ecosystem on their respective web sites and at Euro-IX.⁴²

3.2.1 LINX (<https://www.linx.net/about/>)

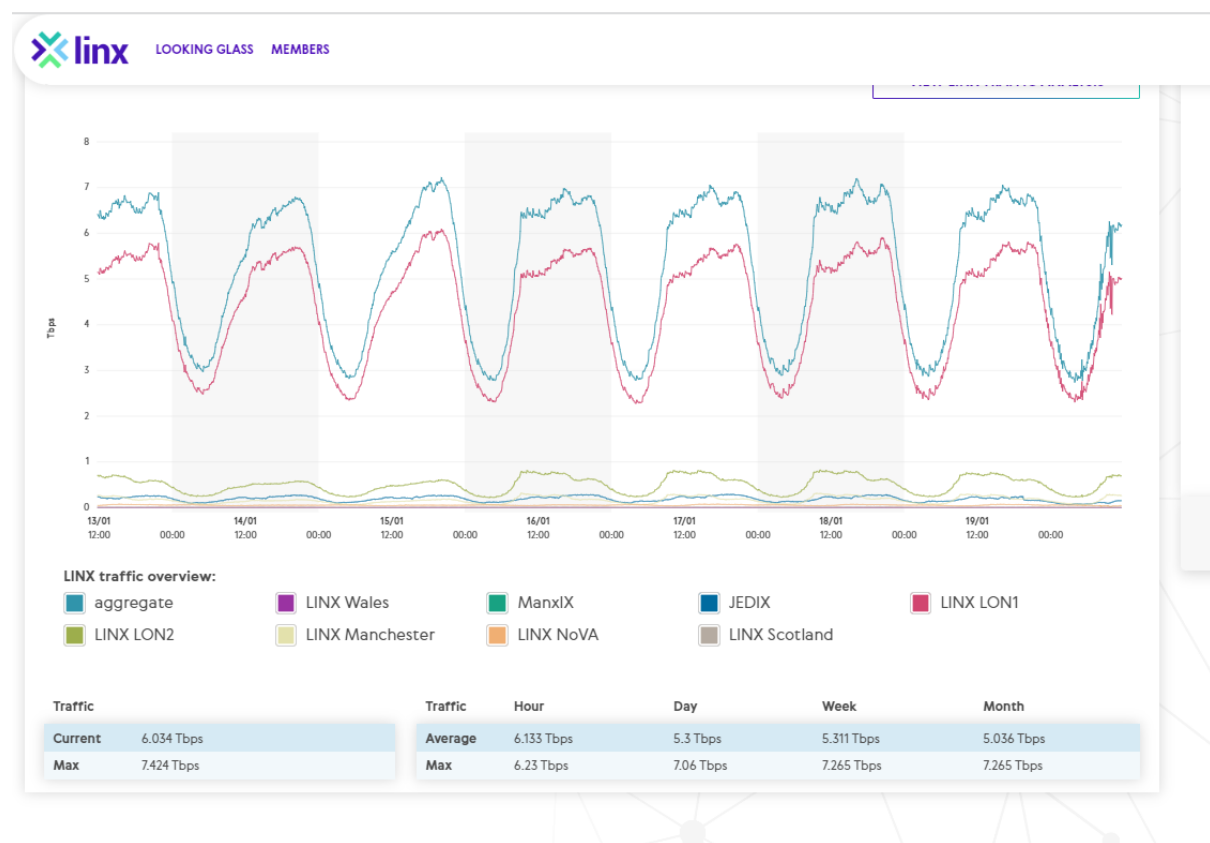


Table 3-2 - LINX screenshot (20 Jan 23)

Of interest here is that LINX “Traffic” follows a repeating daily pattern, but more importantly, the measurement metric is defined by hour, day, etc and uses bits per second (bps) as the measurement unit.

³⁹ Note that I have not approached the Telco community for any such metric, primarily as I couldn't find any – if any Telco would like to comment here, please be my guest.

⁴⁰ Unfortunately, the screenshots in Figures 1 and 2 do not do full justice to both the LINX and INEX set of metrics, and I would suggest visiting their respective web sites for further information.

⁴¹ Internet Exchange Points and should be contrasted with the term Telco. For reference an IXP is network facility that enables the interconnection of more than two independent Autonomous Systems, primarily for the purpose of facilitating the exchange of Internet traffic. An IXP provides interconnection only for Autonomous Systems.

⁴² See <https://www.euro-ix.net/en/> for a Europe wide perspective, and their 2021 report.

3.2.2 INEX (<https://www.inex.ie/>)

INEX Public Traffic Statistics

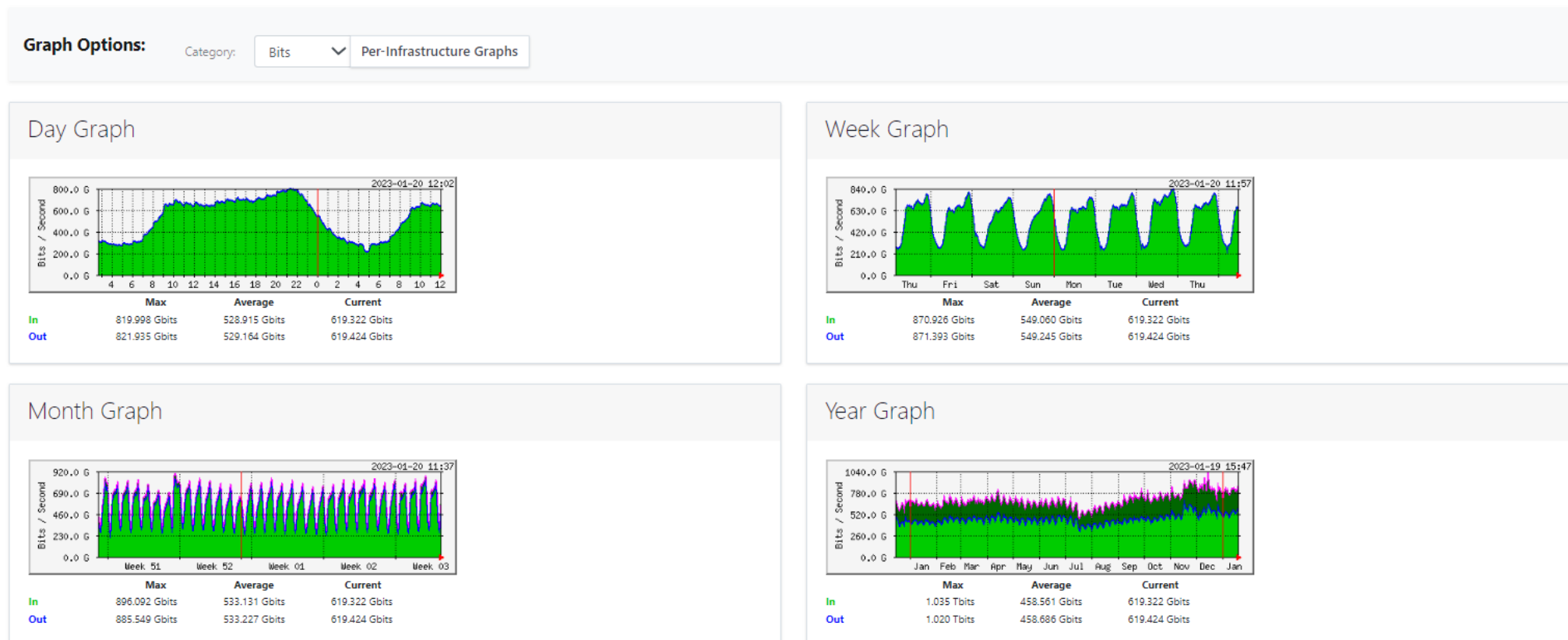


Table 3-3 - INEX Screenshot (20 Jan 23)



Of note here is the weekly graph, which bears some resemblance to the LINX counterpart, but with the measurement unit being bits⁴³. In both cases, there is some symmetry and suggests an equivalent to the circuit switched “busy hour”⁴⁴.

Unfortunately, I do not have any recent operational expertise as to how the LINX and INEX “traffic” measurements are collected and used within their respective organisations⁴⁵, but what we do have in these two examples of “traffic” being measured (and recorded) in real time⁴⁶ i.e., there is a unique audit trail.

There is an interesting quote from Section 1.2 of the euro-ix 2021 IXP Report⁴⁷ i.e.:

“Not all IXPs share their traffic statistics. We have not estimated values where public figures were not presented. All information has been gathered on a best effort basis and relies on the information that is provided by individual IXPs. This report is only as accurate as the information that has been published by these IXPs. If you want to base decisions on this information contained in this report, we advise you to check the information against up-to-date data. Not all IXPs measure their peak traffic using the same periodic average or use the same method. Most IXPs choose to take samples every five minutes, some have chosen to take these samples more or less frequently.”

See also⁴⁸ for an excellent graphical illustration on connectivity amongst IXPs also the IXP database⁴⁹ for further information on how IXPs support the Internet.

3.3 Initial Observations

1. All the examples illustrate “traffic” in /out of the respective IXPs, but where does this “traffic” go⁵⁰, and where is the next measurement point?
2. Continuing with the flow model introduced earlier, traffic must enter/exit a network and hence:
 - a. Where are these measurement points from within the “Internet”⁵¹?
 - b. What is the measurement unit?
 - c. What is the standard (and agreed) definition of Internet traffic?
 - d. Who owns the collation of measuring point information⁵²?

Using 2. above, perhaps a realistic definition of Internet traffic could be achieved, but without any such agreed definition, all parties should recognise that any of the many descriptions of Internet traffic are meaningless.

⁴³ I’m being a pedant here, but prefer the ITU term i.e., bit/s.

⁴⁴ More on this later.

⁴⁵ My guess is that they are used for capacity planning (amongst other operational processes).

⁴⁶ It is interesting to note the possible disparity of measurement units.

⁴⁷ <https://www.euro-ix.net/en/services/euro-ix-reports/>

⁴⁸ <https://www.internetexchangemap.com/>

⁴⁹ <https://ixpdb.euro-ix.net/en/>

⁵⁰ A slightly rhetorical question as I am familiar with BGP, albeit a long time ago.

⁵¹ To re-state, the Internet is a network of networks each with a unique management domain.

⁵² My best guess is the Internet Society at <https://www.internetsociety.org/>



4 The need for Internet standards and governance - what do we call “it” and how do we measure it?

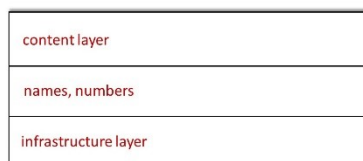
4.1 Standards

As an introduction, I observe that there are numerous bodies involved in the definition and creation of Internet standards and to use Humpty’s Dumpty’s earlier dictum i.e. **“The question is, said Humpty Dumpty, which is to be master - that’s all.”**⁵³

For guidance, I am indebted to the work of Jim Kurose⁵⁴, of whom I first met (virtually) via “The Networking Channel”⁵⁵, which is a highly recommended knowledge source. Illustrated below is a useful introduction to the need for standards within the Internet and used by permission. As can be seen (and this is but a sample) there are several players.⁵⁶

Who “controls” the Internet: breaking the problem down

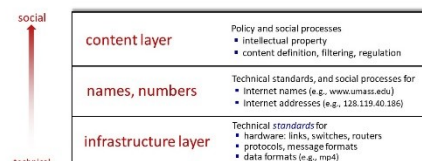
Reference model for discussing governance (different from Internet/OSI protocol stack):



Source: network 1.1

Who “controls” the Internet: breaking the problem down

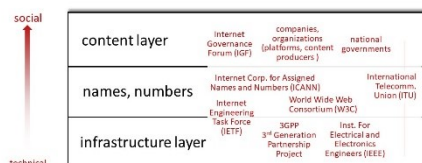
Reference model for discussing governance (different from Internet/OSI protocol stack):



Source: network 1.1

Who “controls” the Internet: some of the players

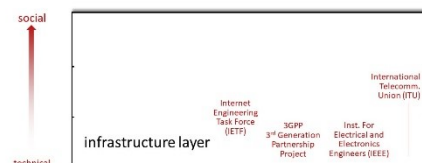
Reference model (different than Internet/OSI protocol stack) for discussing issues:



Source: network 1.1

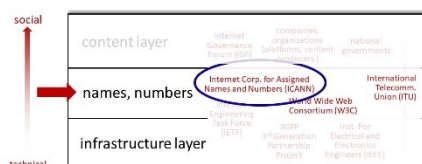
Who “controls” the Internet: some of the players

Reference model (different than Internet/OSI protocol stack) for discussing issues:



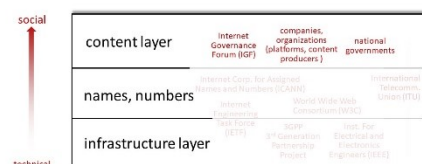
Source: network 1.1

Who “controls” the Internet: some of the players



Source: network 1.1

Who “controls” the Internet: some of the players



Source: network 1.1

Unfortunately, and with the increasing number of players, consensus can be a challenge - which standards body has primacy and agreed by all players?

Although, I have views on the role of the ITU, as an example it is an exemplar of quality documentation, but maybe mired in bureaucracy (my words). The IETF⁵⁷, by contrast uses a different model which suggests a speedy identification of potential standards, testing, and subsequent publishing for implementation.

⁵³ I have thought of another and is from Tolkien, viz: “One ring to rule them all.”

⁵⁴ Distinguished University Professor in the College of Information and Computer Sciences at the University of Massachusetts Amherst – see https://gaia.cs.umass.edu/kurose_ross/index.php

⁵⁵ <https://networkingchannel.eu/>

⁵⁶ This is, at best, a small sample – there are many more bodies who are also actively involved.

⁵⁷ The unofficial mantra of the IETF is “We believe in rough consensus and running code” – an interesting angle, maybe?



My observation on standards setting is that without an agreement on standards and supporting documentation, we cannot progress. The challenge (and I have experienced this) is interpretation. By way of a link to topic in question and in my trawl of “Internet” standards⁵⁸, I could not find a definition of “Internet Traffic” – this is explored in the next section.

It should be noted that almost (if not all) standards bodies carry out ongoing liaison with each other – an observation is perhaps we need another “Ring to rule them all?”

4.2 A note on Internet Governance

Without delving too deeply into the evolution of the Internet and perhaps slightly off topic, Internet Governance discussions are emerging. More recently, I attended a virtual lecture delivered by Prof. Victoria Baines⁵⁹ of which, I thoroughly recommend and addresses some of the Governance issues superbly.

My own rather (and perhaps naïve) comment on this is that no one body has supremacy, and hence regulatory intervention is of concern to me. Cubbin and Curry explored regulatory intervention back in 2002⁶⁰ and although they were addressing the British telecommunications market at the time - some may be surprised with their conclusions.

Within the lecture, Prof. Baines illustrated the work of the Group 04 team at the Politecnico di Milano 1863, who are working on a project entitled “The Physical Internet”⁶¹ Interestingly, the Group 04 work is based upon data imported from the Telegeography team and is highly commended and would suggest interested parties should reach out to the Group 04 team for further information.

⁵⁸ I found many, but the challenge is once again, a definition.

⁵⁹ See https://www.youtube.com/watch?v=tJS_I EU-7oU

⁶⁰ See <https://bit.ly/3CGIt7E>

⁶¹ See <https://densitydesign.github.io/teaching-dd15/course-results/es01/group04/>

5 Internet Traffic – is there an agreed definition?

Earlier, I mentioned my “trawl” of several standards bodies and hence what follows are my brief observations of both the ITU⁶² and IETF⁶³ approaches.

5.1 ITU

The ITU was established many years ago and evolved from what was, the monopoly telegraphy /telephone companies in countries across the globe and is currently an agency of the United Nations. Earlier, I introduced the ITU document “TERMS AND DEFINITIONS OF TRAFFIC ENGINEERING” which is an excellent example of ITU quality documentation. Unfortunately, it was first published in 1988 and is heavily biased towards circuit switching.

Of relevance perhaps is the ITU-T Q.3960 Recommendation ITU-T Q.3960 (2016)⁶⁴ “Framework of Internet related performance measurements” is worthy of investigation, if only for the diagram on page three within the ITU document – this is reproduced as Fig 5 below and describes a measurement process.

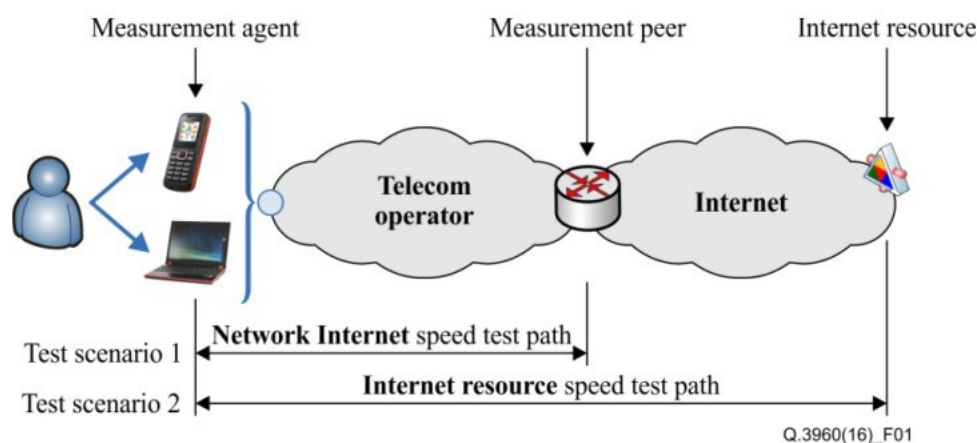


Figure 5 -A Testing Process

5.2 IETF

It has been some time since I was an active participant within the IETF (time and diminishing intellectual capabilities, I’m afraid). However, there are four exemplars of IETF documentation which are worthy of further discussion, viz:

1. RFC 3272⁶⁵ is a first-class document with this observer commenting that it follows the engineering thought processes of the ITU document mentioned above. The standout statement from within RFC 3272, is “**Even though Internet traffic engineering is most effective when applied end-to-end, the initial focus of this document is intra-domain traffic engineering (that is, traffic engineering within a given autonomous system). However, because a preponderance of Internet traffic tends to be inter-domain (originating in one autonomous system and terminating in another), this document provides an overview of aspects pertaining to inter-domain traffic engineering.**”
2. RFC 2722⁶⁶ Another excellent document and in summary “This document provides a general framework for describing network traffic flows, presents an architecture for traffic flow measurement and reporting, discusses how this relates to an overall network traffic flow architecture and indicates how it can be used within the Internet.
3. RFC 2702⁶⁷ – In summary “This document presents a set of requirements for Traffic Engineering over Multiprotocol Label Switching (MPLS). It identifies the functional capabilities

⁶² International Telecommunications Union – see <https://www.itu.int/en/Pages/default.aspx>

⁶³ Internet Engineering Task Force – see <https://www.ietf.org/>

⁶⁴ <https://www.itu.int/rec/T-REC-Q.3960/en>

⁶⁵ <https://datatracker.ietf.org/doc/rfc3272/>

⁶⁶ <https://datatracker.ietf.org/doc/rfc2722/>

⁶⁷ <https://datatracker.ietf.org/doc/rfc2702/>



required to implement policies that facilitate efficient and reliable network operations in an MPLS domain. These capabilities can be used to optimize the utilization of network resources and to enhance traffic-oriented performance characteristics.

These documents are all dated circa early 2000s and except for RFC 3272, I cannot find any updates to 2722 and 2702. As a set of documents, however, they do follow the work of the engineering “principles” of ITU documentation quite well. More recently, the IETF published RFC 3272bis⁶⁸ which is a complete overhaul (dated October 2022) of RFC 3272, and I quote from its introductory paragraph, viz:

“This document describes the principles of traffic engineering (TE) in the Internet. The document is intended to promote better understanding of the issues surrounding traffic engineering in IP networks and the networks that support IP networking, and to provide a common basis for the development of traffic engineering capabilities for the Internet. The principles, architectures, and methodologies for performance evaluation and performance optimization of operational networks are also discussed.”

Is this set of IETF documents applicable to today’s Internet/internet traffic debate? – if so, a definition of Internet Traffic should be here?⁶⁹

As an observation, all the documents listed above do indeed discuss an engineering approach towards an Internet/internet engineering approach. Our challenge perhaps, and to restate can we “learn from history?”

Note and as a long-standing member of various professional bodies⁷⁰, I sought guidance from the plethora of conferences containing the term “teletraffic” and noted that there was an ongoing conference i.e., “The Internet Measurement Conference⁷¹” – the latest event (and previous) suggests some promise on the elusive definition.

⁶⁸ <https://datatracker.ietf.org/doc/draft-ietf-teas-rfc3272bis/>

⁶⁹ See 1.1 of RFC3272bis – an excellent summary of a process combined with 1.4, which mentions a “Busy Hour”, which is a useful starting point and like that of the circuit switching world. Note this document has yet to be approved by the IETF.

⁷⁰ IET, IEEE, ACM to name a few.

⁷¹ <https://www.sigcomm.org/events/imc-conference>

6 Zip's Internet Model⁷²

6.1 Overview

In the absence of an agreed standard in the definition and measurement of Internet traffic⁷³, can we apply the approach of the circuit switch engineering to the Internet? RFC 3272bis, as an example, describes a process model (Section 3.) which is worthy of further investigation. In addition RFC 2722, introduces (and I quote):

"This document provides a general framework for describing network traffic flows, presents an architecture for traffic flow measurement and reporting, discusses how this relates to an overall network traffic flow architecture and indicates how it can be used within the Internet."

6.2 A diagram always helps?

To assist in my initial analysis, I have redrawn Figure 4 as Figure 6 below.

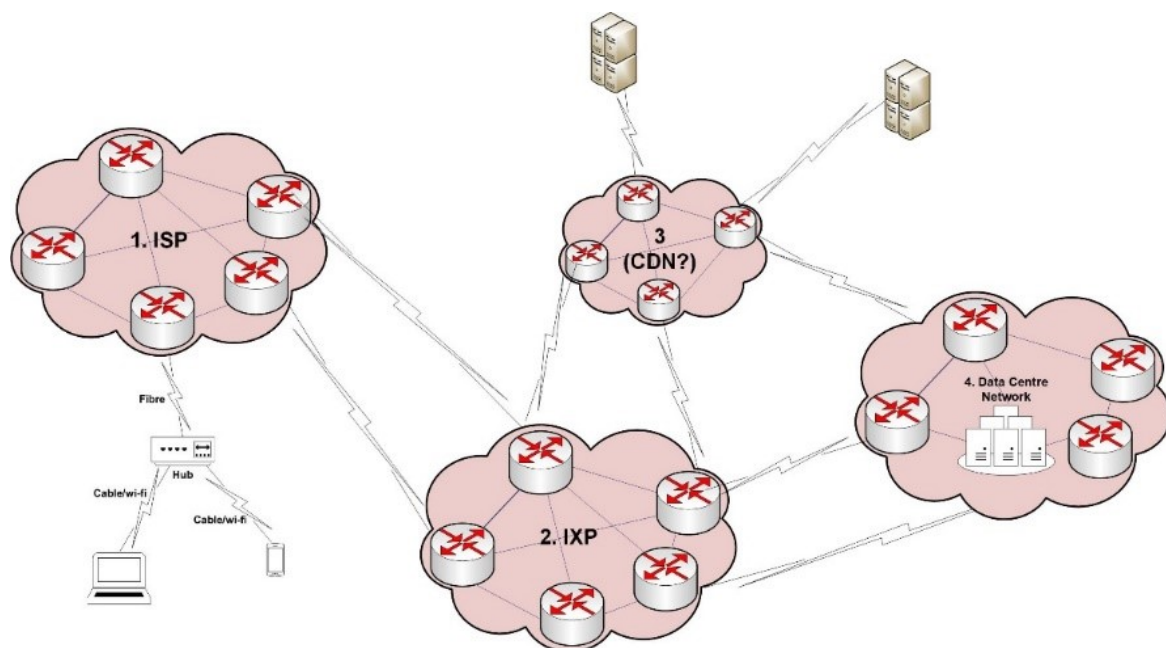


Figure 6 - Zip's Internet Model

I've done so to illustrate the concept of the Internet as a network of networks, which by observation is not under the control of a single management domain i.e., it could be argued that (currently) that an end-to-end mechanism to measure and manage Internet traffic is not achievable?

This is the basic tenet of my thinking i.e., **"if there is no agreed end to end mechanism for doing so, why do so many commentators describe (and quantify) Internet traffic with such gusto?"**

⁷² Zip was my nickname when I was with BT in the early 70s.

⁷³ If there is one, please put me out of my misery.

6.3 Zip's Internet Model as a series of interconnected queues

To answer the question addressed in 6.2 above, I'm suggesting one approach for further consideration and earlier, I briefly made reference to Leonard Kleinrock and his work on Queueing Systems. Whilst most of Kleinrock's two volumes are way above my intellectual capability, Chapter 5 of Volume 2 is of interest here, perhaps? Using Figure 7 below as one possible approach to modelling the Internet.

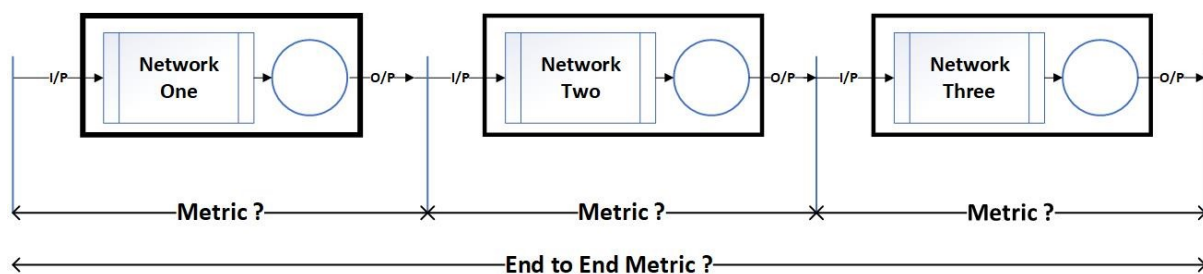


Figure 7 - A possible model for determining end to end Internet traffic.

Here, I'm representing Internet flow measurement by modelling the Internet as a series of interconnected queues. As can be seen, each network has input and output and, at the micro level, a flow (measured in bit/s?) can, at any one point in time, can be measured – a “busy hour” to stretch the circuit switching analogy, perhaps?

The challenge, as I see it is that each network within the model illustrated in Figure 7 is invariably, under the control of a unique management domain. Whilst systems can measure traffic (again in bit/s, or multiples thereof?) within a network management domain, how do we measure traffic that flows across multiple management domains? To continue, at what period of time and duration, do we measure and who “owns” the measurement?

My thought process is that such a model could be a starting point to address the above, but will need all interested parties to participate – logically this should progress under an IETF workgroup, or maybe there is an existing workgroup any such an activity?

What unit do we use – I currently observe (see examples in Section 3) multiple instances of the use of bit/s (again, or multiples thereof). Are these examples indicating the x bit/s flow across the Internet? The only way to confirm this is by measurement.

7 Closing observations

I have yet to find that elusive definition of Internet traffic and similarly to earlier comments, if I am wrong, I will gladly promote that approach. It may be that this paper is a starting point.

In summary, and from this research:

1. Continuing with the flow model introduced earlier, traffic must enter/exit a network and hence:
 - a. What is the standard (and agreed) definition of Internet traffic?
 - b. Where are these measurement points from within the “Internet”⁷⁴?
 - c. What is the measurement unit and (perhaps more importantly) where are the measuring points?
2. Who owns the collation of measuring point information?
3. If there is no agreed end to end mechanism for doing so, why do so many commentators describe (and quantify) Internet traffic with such gusto?”
4. As mentioned within the introduction to this paper, my interest was originally piqued following many discussions within the “fair share” debate. My question to the protagonists is quite simple “prove it i.e., demonstrate the amount of traffic being used by Big Tech over the Telco infra” – this must be an engineering piece of analysis, otherwise it is an exercise in futility.
5. Speaking on behalf of an engineering approach (rather than the loose commercial model promoted by many) that a definition and metric for Internet traffic should be promoted and supported by all, and I am tempted to suggest we plagiarise the circuit switching approach using RFC 3272bis as the starting point. This is where the IETF may be able to help?

I further observe that there is some confusion from within the current EU Regulatory⁷⁵ body, concerning the terminology of the Internet and Telcos being “intertwined” – this is reported upon at⁷⁶ and considers the ramifications of a recent consultation. The politics of the review are of no interest to me, but without an agreement of a metric, such a review is meaningless. I am further suggesting we name any such metric a “Poisson.”⁷⁷

Further work is necessary, if only to dispel, mis truths.

In the absence of any agreement, we will continue to sow the seeds of confusion and to use an often-quoted phrase of mine “this is where the bunfight starts.”

⁷⁴ To re-state, the Internet is a network of networks each with a unique management domain.

⁷⁵ Will the output of such a review be mandated in the UK, and more importantly, the rest of the world?

⁷⁶ https://telecoms.com/522114/european-commission-vows-to-fix-fragmented-telco-market/?utm_source=eloqua&utm_medium=email&utm_campaign=SP_News_TelecomsDaily_NL_20230607&sp_cid=1563&utm_content=SP_News_TelecomsDaily_NL_20230607&sp_rid=6825526&sp_aid=2061&sp_eh=550c2196e385bec535e6f987cd_b567b7aa4dbaf7c46700f2ab27c7bd968f2098

⁷⁷ For some reason, engineers like to use mathematicians to name measurement units – Poisson was a giant in the development of probability theory, of which traffic theory is but a subset.