Research Article

Delimiting Channel Capacity: A Scrutiny of Challenges and New Developments

Amaresh Jha[1], Aman Vats[2]

Abstract

Objective: This study aims at identifying the capacity related challenges of communication networks and makes an assessment of conceptual developments to address these challenges. Based on the review of such developments this paper enlists the knowledge gap and provides direction for further research.

Method: This study uses meta-analyses method to combine and amalgamate the previous knowledge in the field of channel capacity optimization.

Findings: Enhancing or optimizing the capacity of present day communication networks needs integration of approaches like providing additional bandwidth to the channel through free space optic technology, dynamic physical layering, algorithmic stacking of data and boosting the capability of network infrastructure.

Limitations: Further elaboration on models of optical packet transmission and deep packet investigation for reducing the load from networks is needed.

Keywords: Channel Capacity, Shannon's Limit, Optimization, Internet, Information Networking, Meta-Analysis

Delimiting the Capacity

The term "bandwidth" is defined as a range of frequencies measured in cycles-per-second. The width of the band represents the numerical difference between the upper and lower frequency limits of a channel of communications. Therefore, a channel is a path used for the transmission of communication signals between two geographically separate points.

The Shannon-Hartley theorem states that the channel capacity is $C=B \log_2 (1+S/N)$ bits/s, where C is the capacity in bits per second, B is the bandwidth of thechannel inHertz, and S/N is the signal-to-noise ratio. This theoremmarked the beginning the field of mathematical studyof Information and reliable transmission of Information over a noisy communicationchannel, known as Information Theory. In that paper, through some original mathematicalarguments, Shannon showed that information can be reliably transmitted over a noisycommunication channel if the rate of transmission of information is less than the channelcapacity, a fundamental quantity determined by the statistical description of thechannel. In particular, the paper showed the startling fact that presence of noise in acommunication channel limits only the rate of communication and not the probabilityof error in information transmission.

[1]Assistant Professor and Ph. D. Research Scholar, [2]Associate Professor, Amity School of Communication, Amity University, Noida, India.

Correspondence: Amaresh Jha, Amity School of Communication, Amity University, Noida, India.

E-mail Id: ajha@amity.edu

Orcid Id: http://orcid.org/0000-0002-6083-1610

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There is a duality between the problems of data compression and data transmission. During compression, all the redundancy in the data is removed to form the most compressed version possible. During data transmission, redundancy is added in a controlled fashion to combat errors in the channel.

If there is no restriction on the symbol, then any one symbol can contain arbitrary entropy. Thus, provided the bandwidth is non-zero, the channel capacity is not strictly limited. The question simply reduces to identify the information content of a symbol, assuming it can be transmitted error free. With symbols that can contain arbitrary amounts of information, even the symbol-rate and therefore bandwidth as well becomes irrelevant.

Therefore, there may be ways to effectively and efficiently use the information passing through the channel to arguably make it error free so that the channel does not near its limit. The theorem proposed by has led researchers to find ways to enhance the capacity of channels using means like channel optimization, boosting the network capacity infrastructures using algorithmic practices and bringing the concept of parallel separable physical layers etc. These fundamental practices have put the assumption of prioritizing the information streams which pass through the channel according to the need of the end users. But these practices need deep packet inspection of the content of the data which is to be smartly prioritized. Theoretical and ethical assumptions for enhancing the capacity of the network using deep packet inspection need to be analyzed and standardized, because when the channels will process the real-time data based on tags of priority, there may be conflict of interest. Suppose for enhancing the capacity of the internet, the video streaming is tagged as priority for real time experience and emails are second on priority, then for the users for whom email was prominent will have to suffer. Here comes the notion of how the internet should be perceived with the change of demand of end users?

Changes in both compression technologies and uses of bandwidth suggest caution in interpreting raw bandwidth (Dahle,1954). As compression technology continues to improve, a fixed amount of data may require less bandwidth. At the same time, changing uses of bandwidth can result in demand shifts. For example, as video compression technology improves, demand for transmitting videos may increase thus requiring increased capacity. Furthermore, there are country-specific policies which may result in different demand patterns.

Fundamental Performance Limit of a Channel

The search for elementary performance limits of networks is prerequisite to sustain the capacity of communication channels. To enhance the network performance capacity it is needed to classify the subject into three key areas- elementary performance higher bounds, layer less dynamic network performance, and application and network. The first area explores new paradigms for higher bounds on network performance, whereas the second explores novel "layer less" networking techniques to edge this performance. In this context a "layer-less" network doesn't impose any predefined protocol structure which may end in suboptimal performance. The explanation for singly exploring higher and lower bounds is that they generally entail totally different tools and views.

Higher bounds exploit abstract mathematical constructs that incorporate the performance of any doable theme, whereas certain area unit less complicated in this any concrete theme provides a lower bound. However, tight higher and lower bounds need insight regarding one another, and it's at the intersection of those analysis areas —once the higher and lower bounds meet, the basic performance limits become prominent.

The last space develops the interface between the appliance and network to realize the most effective end-to-end performance. Investigation of end-to-end network performance, together with best routing and planning protocols additionally as output versus delay tradeoffs, generally depends heavily on analytical tools from management and optimization, instead of the information-theoretic and combinatorial tools utilized in most results thus far on elementary higher and lower performance bounds (Rice, 1993). This distinction in views and tools is essentially answerable for the unconsummated union between scientific theory and network theory. Finally, advances in network utility maximization and random scientific theory have provided breakthroughs in application and network optimization additionally as interconnections with analysis in higher and lower network performance bounds.

The Cloud Challenge

One future challenge is to ensure and unceasingly improve client expertise offered by cloud-based services. Such expertise depends on the End-to-End QoS, and additional typically on individual SLAs in situ for a given service. This includes well-known characteristics, like latency, throughput, handiness, and security, however by adopting the principles of Clouds, additionally physical property, on-demand handiness, lead- and disposal-times, multi-tenancy, resilience, recovery, and similar characteristics vital particularly just in case of cloud-based services. However, so as to ensure this type of service level, network-based service qualities might not be enough. Furthermore, in the future, there will be several Cloud-derivatives providing totally different approaches and levels of QoS support. This can inevitably end in advanced multi-domain eventualities, during which logical Clouds area unit fashioned by totally different infrastructure or platform clouds and sophisticated service compositions at application level. Obviously, such an extremely distributed surrounding needs reliable and capable property and therefore the final client expertise depends on the performance of the service.

Problem of Cross-Talk

Applied theories work well for point-to-point transmission or in systems with many transmitters and one receiver. However when there are two transmitters and two receivers, the matter of cross-talk arises, where a receiver will develop authentication from the incorrect transmitter (Srivastava&Motani, 2005). With the expansion of mesh networks and mobile communications, and even high-frequency transmissions turning previous copper wires into miniature antennas, the point-to-point resolution is not adequate. Considering the conversion of time and house domain, a brand new capacity formula was deduced supported by MIMO (Multiple Input Multiple Output) theory (Goldsmith, 2003). Results indicated that extension equation is in smart agreement with Shannon's data rate equation below the idea of constant signal and noise information measure. However in numerous signal and noise information measure, capacity values calculated by this extension are larger than ones by Shannon's equation, that is the reason for "breaking" Shannon's capacity in MIMO system.

Boosting the capability of Network Infrastructure

Though the history of the net has been successful in organically developing a self-adapting network, this ability could come back besieged because ofunprecedented demand for reliable net access and mass uptake of bandwidth-intensive services and applications. Thenumber of Smartphone, tablets and different network-connected gadgets can total humans by 2020. The quicker and additional powerful mobile devices hit the market at unprecedented levels. International mobile information grew by seventy percent in 2012, consistent with a recent report from Cisco that makes lots of the gear that runs the net. Nevertheless the capability of the world's networking infrastructure is finite, feat several to marvel once we can hit the higher limit, and what to try and do if that happens.

There area number of ways to increase capacity of the channels like adding cables, packing those cables with additional data-carrying optical fibers and off-loading traffic onto smaller satellite networks, however these steps merely delay the inevitable. The answer is to create the infrastructure smarter. For this two main elements would be needed: computers and different devices which can filter their content before moving it onto the network and a network that understands what to do with this content.

There is a limit to everything on this earth—so is the capacity of data to transmit over communications channels. This limit is termed as nonlinear limit. Ittellshow much data one can push into the channel with today's technologies. It is predicted that the present day technologies are nearing the channel capacity limit. Therefore, the challenge before the technologists is to increase the efficiency of the network so that the same channel can carry more data. To eliminate the roadblock of data constraint there cannot be a single approach. So first,researchers and technologists need to make an assessment of the nature of the limits and then the probable ways to enhance the quality of data to make the channel sustainable.

The foremost obvious approach is to extend information measure by providing additional fiber rather than having single transatlantic fiber-optic cable, for instance, increasing the cables according to the need of the traffic of data. That is the brute-force approach, however it's terribly expensive. One ought to acquire the bottom and lay the fiber. One would like multiple optical amplifiers, integrated transmitters and receivers, and so on. An alternate is to explore another dimension: spatial multiplexing, that is all regarding integration. Put simply, on transmits multiple channels at intervals using single cable. Still, boosting the prevailing infrastructure alone would not be decent to fulfill growing communications desires. What is required may be a network that is not just bits and bytes but a packet of relevant knowledge. On a given day does one wish to understand the temperature, wind speed and gas pressure or does one merely wish to understand howone must dress? This can be stated as data networking (Xue& Kumar, 2006).

Information Networking rather than Internet

Internet is often perceived as a "dumb" network, though it's not an ideal term. Initially the internet was for non-real-time sharing of documents and information. The system's biggest demand was resiliency. It had to be operational albeit one or additional nodes [computers, servers and then on] stopped functioning. And therefore the network was designed to ascertain information merely as digital traffic, to not interpret the importance of that information.

Nowadays one tends to use the internet in real time. Therefore, having networks that simply explore bits and computer memory unit isnot any longer decent. The network needed today should become additionally smart to provide knowledge rather than just carrying bits and bytes.

Deep Packet Investigation

Today, if one wishes to understand PC virusesone tends to use computer code to peek into the info packet, one thing known as deep-packet examination. Think about a physical letter one sends through the conventional mail wrapped in envelope with the address mentioned on it. The mail doesn't care what the letter says; it's solely inquisitive about the address. With deep-packet examination, computer code tells the network to open the info envelope and skim a minimum of a part of what's within. If the info contains a deadly virus, the examination tool could route that information to a quarantine space to stay it from infecting computers connecting thereto network. However, one will get solely a restricted quantity of knowledge regarding the info this fashion, and it needs lots of processing power. Plus, if the info within the packet is encrypted, deep-packet examination won't work. A better choice would be to tag information and provide the network directions for handling differing types of knowledge (Fulk,Schmitz &Ryu, 1995). There could be a policy that states a video stream ought to get priority over e-mail, though one isn't presupposed to reveal precisely what's in this video stream or e-mail. The network merely takes these information tags into consideration once creating routing selections.

How to scale back the data traffic?

The Smartphone, computers and different gadgets generate lots of raw informationthat one sends to data centers for process and storage. This cannot scale in the future. Rather, one would move to a model whereselection process is done before it is placed on the network. For instance, if one has got a security camera at airport, one would program the camera or atiny low pc server to perform identity verification locally, rather than bottlenecking the global network with a stream of pictures. Nowadays the cloud is made of massive, centralized information centers. Obviously clouds mix the locally generated information on world scale. In the case of a set-top box, the box would gather information suppose regarding viewer's preferenceswill analyze that information right there within the lounge and will send specific message the cable service provider instead of a stream of information sent to the large network.

The applied scientific perspective of a channel places no restrictions on quality or delay in transmission or reception. In distinction, however, the capacity assumption of asymptotically massive delays is problematic for real time applications and often rises to unconsummated union between network theory and Shannon theory since the previous is essentially supported analysis of queuing delays.

Weak Vs Robust Converse

The weak converse states that the chance of error (average or maximum) at rates on top of capacity is delimited far from zero, whereas for the robust converse this chance approaches one. The weak converse yields a far looser rate region that doesn't coincide with famous accomplishable rates. Moreover, the robust converse provides additional insight into the best committal to writing strategy, since it aligns with the accomplishable rate region supported random binning. Whereas these results apply solely to multiple access channels, they indicate that robust converses area unit a promising space to explore in cracking open capability issues wherever the boundary supported a weak converse is loose compared to the most effective famous accomplishable rate.

Network Equivalence

Given a network of creaky, freelance, memory less links, a collection of user rate demands may be met on the given network if and given that it may be met on another network wherever every creaky link is replaced by a quiet bit pipe of the creaky link capability. This network equivalence is proven by showing that if all know the way to operate a network of creaky links at a given rate purpose; all will notice how to work the corresponding network of quiet links at constant rate point. This approach never answers the question of that rate points area unit accomplishable. It solely demonstrates the equivalence of the capability regions of two networks — one with creaky links and therefore the different with quiet links of the corresponding capacities.

Layer based Dynamic Networks

Optimization determines however the underlying network resources will best be utilized to maximize the application-layer performance metrics related to of these applications. The challenge is distinguishing the foremost promising approaches that yield important performance enhancements over existing ways and, ideally, approach the network performance higher bounds. The notion of generalized network committal to writing, together with ideal relaying and cooperation, holds a lot of promise, and up to date results indicate these techniques may be capacity-achieving for a few specific network topologies.

Network Optimization Algorithm

The optimization algorithmic rule can provide solution to fulfill heterogeneous application requirements: some applications (like: file transfer) would possibly need high information rates however haveno rigorous delay needs, whereas others (like: voice on a handset) could have low rate needs however strict delay and energy constraints. In this algorithm every node acts on native data or obtains it with low communication overhead adjustable to application and network dynamics, ascendable in network size, asynchronous, and sturdy against interference and jam.

Dynamic Networks supported Open Physical Layer

Open physical medium permits many information messages to be encoded and transmitted over constant channel, and permits the upper layer applications to work out expressly the reliability levels of the individual messages. A brand new notion of "capacity" of a channel is delineated by the best trade-off between the rates and reliability of messages it will accommodate (Chiang, 2007). Thus a dynamic network supported open physical layer is planned to ensure the delivery of important messages in dynamic/hostile surroundings, embedding feedbacks, and network management messages in information transmission to boost potency. This contents driven networking prioritizes the planning and routing of knowledge consistent with the exactitude and urgency of the contents.

Contents Driven Heterogeneous Networks

The key purpose of network committal to content is to divide the data into small items, transmitted over totally different links, integrated with different information, and relayed by numerous nodes within the network, till enough data reaches the destination and gets decoded (Lim,2010). This approach has relevancy to the relay operation of a node that receives many information items regarding constant supply from totally different network methods, wherever every bit could undergo totally different level of process on its path. The goal is to integrate and correlate information with an acceptable labeling of confidence level. This problem is again closely associated with the utility of the networks.

Network Utility

Recent analysis in network optimization with efficiency allocates resources among heterogeneous applications supported by a metric of network utility. This approach, stated as Network Utility Maximization (NUM), needs deeper understanding of wire line network architectures and therefore the development of recent protocols. However, there are many shortcomings applied to wireless networks. Above all, the underlying premise of NUM is that network dynamics occur on time scales for much longer than the algorithmic rule convergence time; thus network structures arestatic.

The tools of optimization anddata management are ideal for addressing the challenges of huge networks. The advancements in these areas assume centralized data management and distributed algorithms as a challenge to be addressed. Moreover, application optimization has principally not incorporated the ways and insights obtained through scientific analysis of network performance bounds. This integration is difficult because the tools developed till date is applicable for smallnon-convex networks. Network equivalence and similar techniques that abstract away the small print of the physical layer maintaining capacity-achieving ways at that layer could facilitate progress during this direction. Consummating the union between all these assumptions this study suggests for a framework of elementary performance bounds on wireless networks (Johari& Berry 2009).

A lot of progress has been made on determining the basic performance limits of channels; the physical layer still lacks an elementary theory to guide it. Therefore there is a need to bring forward the various open issues, which set forth approach to the present challenge, and encourage different researchers to hitch our quest toward a theory of elementary performance limits of networks.

Conclusion and suggestions

The transmitted data, in the form of data bits gets recovered at the receiver end as long codes. This coding of data has however simplified the construct of communication, permitting the form of physical layers to get separated from the supply, the network, and from the application. This characteristic of data in electronic communication has potential of optimization. Therefore, bits seem to be the sole natural measure of knowledge. When the bits take the shape of knowledge they may be transmitted without errors which is a guarantee of reliable information.

The study finds that future wireless networks can face numerous challenges, and the foremost amongst them is confirm that the scarce spectrum resource are able to carry the massive predicted information traffic, and avoid inefficient use of spectrum. On a configuration level, this problem is pertaining to the spectrum crunch and denser node deployments. Furthermore “spectrum sharing” becomes a good tool to boost the spectrum usage potency and therefore, to extend the effective quantity of accessible spectrum. However, this assumption and line of though needs further consideration on technological and economical viability.

Optical networks should endure important changes to address the increasing data demand. With growing concern regarding energy potency and carbon emissions, concept of network layers and segments is going to prove beneficial. Therefore, the need is to create optical networks quicker, safer, versatile, and easier to use and to bring them nearer to the end user.

As networks tend to become more advanced, there is a need of optimizing the technologies to support the automation within the network. The physical layers within the networks need more optimization at higher bounds. Acknowledging the new trends in the field of electronic communication this study further suggests for introducing standardized IP interconnection interfaces that will modify video-calls via totally different networks. Therefore the normal network-to-network interfaces would take the shapeof a specific network for video calls. This service would disagree from several current videoconferencing solutions wherever end-points arebridged to a central server that interconnects them.

Interestingly when the channel capacity of a network will get optimized it will get remodeled into a content centric cloud network. This content centric network will fuel the proliferation of knowledge centers and not just information centers. For rising exascale(Exascale computing refers to computing systems capable of making billion-billion calculations per second)information centers, new architecture is needed to deal with next-generation output needs.

The key construct during this scrutiny of recent practices is that the reliability of a physical channel isn't any additional characteristic like error exponent, because the total capacity of the channel will depend on knowledge delivery capacity of dynamic networks. It becomes important also because of its characteristic of providing higher protections to the vital messages. Superior to the present approach of allocating time, frequency, and signal power to totally different messages, layered codes enable many sub-messages to encode along. This way the overall resource within the channel may be optimally shifted from one layer to a different seamlessly. Such new wayswithin the existing channel or network structures make the physical medium really "open" to the upper layer network applications, permitting fine-tuned and highly controlled transmissions of various types of information.

Limitations and Direction for Further Research

This meta-analysis is limited to systematic review of ways of reducing the network traffic and optimizing the capacity of communication networks. The study of layering and optimization decomposition and capacity limits of different types of futuristic channels like MIMOs however are emerging methods for transmitting information, further investigation is needed to have clarity on:

- How to optimize channel capacity of networks without changing the existing technologies?
- How to integrate algorithm with system architecture to enhance the channel capacity?
- How to control the network traffic for controlling the congestion in the network?
- What could be the most appropriate method for multicarrier transmission optimization using associated bandwidths?
- How MIMO channels could be more workable compared to the traditional channels to accelerate the speed of the cellular communication?

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