Peer and File Sizes Distributions for Energy Efficient Bit Torrent Networks

Sharjeel Afridi[1], Abdul Rehman Gilal[1], Shahnawaz Shah[2] , Muhammad Yameen Sandhu[1]
[1]Sukkur Institute of Business Administration, Sukkur, Pakistan
[2]Zhejiang University of Technology, China

Abstract
Information and Communication networks are expanding rapidly as the internet coverage and capacity increases. Two main players of content distribution networks: Peer-to-Peer (P2P) and Client server are utilizing the great chunk of energy consumption. In this paper, we study the impact of different swarm sizes and different file size distributions on the energy consumption of P2P Bit Torrent networks by developing a Mixed Integer Linear Programming (MILP) model. Realistic data are used for the analysis of energy consumption of Bit Torrent network. Results indicate that the average file size to be shared on the network rather than the distribution, decides the overall energy consumption trends. It is also found that the energy consumption of energy efficient Bit Torrent networks do not increase linearly with the swarm size as the locality play an important role in limiting the growth of network cross traffic. Simulated results show the locality also reduces the energy consumption as we increase the peer size per swarm.

Keywords
Bit Torrent, Mixed Integer linear programming, locality, P2P

1. Introduction

Recent studies have demonstrate that the ICT networks energy consumption appears as a major and aggravating part of overall energy consumption of today's world. In [1] author claimed that the energy consumption for internet in the US is about 350 Billion kWh per year, while it was 868 Billion kWh per year for the whole world in year 2002, which represents 5.3% of total electricity consumption of whole world. In report of 2011 NY times[2], claimed that the Google data centres alone which are distributed around the world consumes 260 million watts, which approximately equals to quarter output of nuclear plant or can be used to supply electricity to 200,000 houses. This will lead us to implement some novel and energy efficient protocols and applications. Internet devices like Routers, switches and data centres are the major energy consumers in the network, whereas on physical layer EDFA's, router ports and amplifiers are the major contributors. For distributing the contents over internet, the major responsibility is taking by client-server and peer to peer networks. In client-server we have a centralized system, whereas peer to peer adopts decentralization of its nodes. A P2P protocol plays an increasingly important role in internet content distribution. The widespread adaptation of these protocols delivers large amount of data at a global scale due to their scalability and robustness properties while compared with the traditional client/server file sharing (such as FTP, WWW). The performance of peer-to-peer network improves by increasing the number of its peers, which efficiently distribute contents to end user depending on the computing power of its peers.

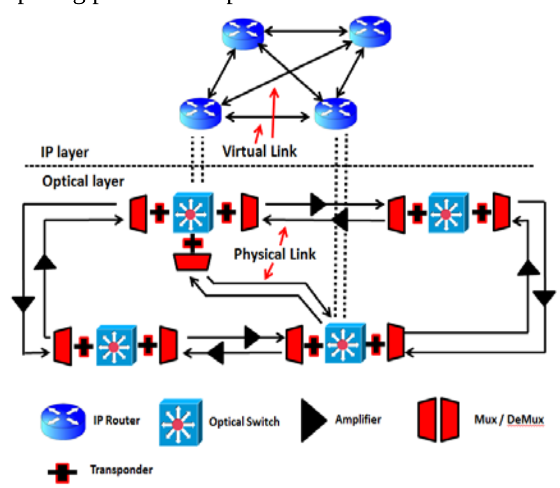

Figure 1. IP Over WDM Networks

Now days, the most popular P2P file sharing protocols is Bit Torrent [5] which has significant edge over the traditional clients-server model as a content distribution networks. For peer to peer networks, Bit Torrent has a major contribution for distributing the contents over internet. In [3], author stated that Bit Torrent accounts for 95% of internet traffic today. Whereas, some authors [4],[5] claimed it as 47.5% and 75% in different reports. In Bit Torrent every peer is barter for chunks of files, which means they have to share data at the same time when they

Manuscript received November 5, 2017
Manuscript revised November 20, 2017

are downloading the data. This bartering minimizes parasitic behaviour of users, means it is not possible to download without sharing content. It also lacks in searching criteria which is compensated by an advanced download distribution protocol that leaves the competitors far behind. We deployed our Bit Torrent system on WDM networks for optimizing the power consumption on network side instead on peer's side. IP over WDM networks shown in figure 1 are promising kind of network for next generation telecommunication networks which offers very high bandwidth via optical medium. We will look into by linear mathematical modelling, that how co-location awareness, known as locality, reduces Bit Torrent cross traffic and consequently reduces the power consumption of Bit Torrent in IP over WDM network.

2. IP Over WDM Networks

Now a day's demand of energy in ICT and telecommunication networks gaining immense importance due to the world energy crisis. So as the ICT networks expands in capacity and coverage their energy consumption of the equipment's is also increases. Previously, we always consider the transmission and switching as a barrier for the expansion of internet, but now the energy is also a vital player or barrier in the expansion of internet[8]. Some research has been started as " Greening the Internet" for saving the energy of internet by the idea that we can adopt different strategies to save energy from component and network, like we can enable router and switches to go in sleep mode when the traffic is low and when the most the users at dormitory state[9]. Today's research also focused on energy saving in backbone IP over WDM networks, which consumes certain amount of total energy of ICT networks. The IP router in IP layer connected to optical switch node which aggregates data traffic from low end access routers, whereas optical layer provides capacity for the communication between IP routers. Physical fibre links are interconnected with optical switch nodes which contain multiple fibres. The optical switch box could be either automatically controllable optical cross-connect (OXC) or a dumb optical patch panel which is used to fulfil the switching functionality. Transponders are connected with each wavelength with OEO processing capability. OEO (optical in electrically processing optical out) means it receives a lower power optical signal, converts it into powerful (amplified) electrical signal, reshapes it and converts it back to optical signal and retransmits it'. Finally, to enable optical signals to travel a long distance via the fibre links on which EDFA amplifiers are deployed. EDFA (Erbium doped fibre amplifier) is a kind of fibre optic amplifier which is used to strengthen the weak signal in a single fibre without changing the signal into an electrical. They are transparent to a data rate with high gain and low noise and can be found in amplifiers, optical cross connects, wavelength add-drop multiplexers and broadcast networks[7]. There are two ways to implement IP over WDM networks[8, 10].

- Light Path Bypass. It allows all the light paths, whose destination is not the intermediate node to bypass via a cut through shown in figure 2.
- Light Path Non-Bypass. All the light path passing through an pass through an intermediate must be terminated, i.e., all the data is processed and forwarded by IP router shown in figure 3.

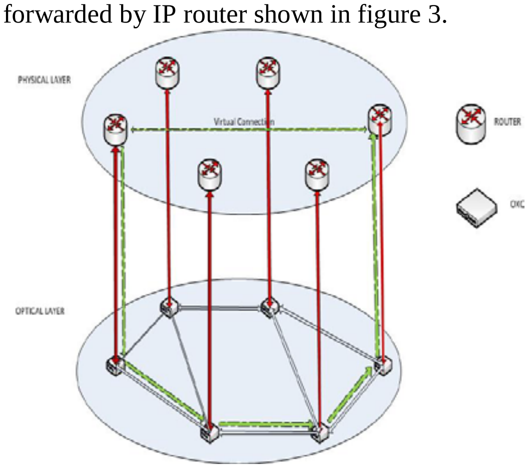

Figure 2. Light path Bypass for IP over WDM Networks

Light paths are treated as virtual links which significantly reduces the total number of IP router ports under light path Bypass condition. IP router are the major consuming element, therefore minimizing the number of IP router ports reduces the power consumption in IP over WDM networks. However, non-bypass approach allows security monitoring and deep packet inspection and bypass approach must need intelligent nodes to support optical bypassing. Therefore, it is important to evaluate the network under both approaches.

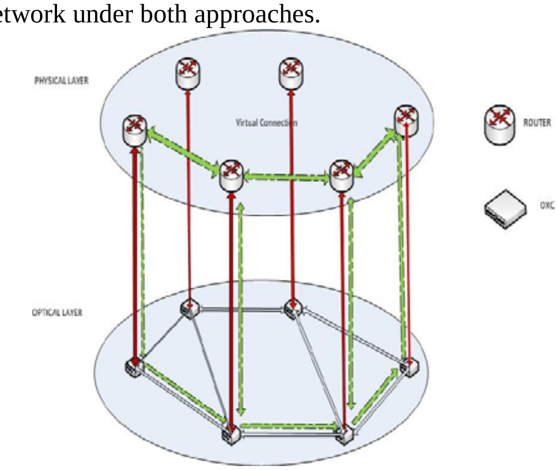

Figure 3. Light path non bypass for IP over WDM networks

3. Bit Torrent Systems

Bit Torrent is a file distributing protocol for peer-to-peer network generating approximately 18% of overall internet traffic [12]. The load on source increases very modest, when multiple number of same file is downloading by the single source. So, it enables downloader's to upload to each other the content they downloaded. Bit Torrent is a swarm-based protocol consist of a group of peers, in which some peers shared their files and contents called 'Seeders' and some peers downloading files called 'Leechers. The ability of these peers to share or upload their content while downloading that content is actually make Bit Torrent more effective for the 'flash crowd than other P2P protocols who want to complete download before offering it for upload[13]. When a downloader seeking to download any file, it gets a Meta data file of '.torrent' extension from a torrent server. These files contain the information about file, its length, name of a tracker and list the names of pieces of file to be downloaded. A tracker is kind a host server that contains list of all clients or swarms (having Seeders and Leechers) who uploading and downloading the file of torrent. The peers in swarms who have a complete copy of file called Seeders, so that they can upload their files and the peers who do not have all the pieces of files and want to download are called Leechers. So, the client or peer send a request called 'scrape' to ask about the statistics of torrent, status of tracker that either it is on or offline, the reason for offline and the number of Seeders and Leechers. To use scrape message would prevent us from more bandwidth consuming function for asking to send a peer list. Send a list of peers in the swarms would also give the same information which we get by scrape message, but it is more bandwidth consuming. After get a list of existing peer in the swarms who have pieces of that file, we entered them into the list of peers. The client peer uses a TCP connection to get connected with other peers. So the connected peers share information of pieces which they have among each other, and it allows them to request the pieces which they don't have by another peer. To get a maximum download the peer take on 'Choking algorithm'[14], where they provide the download rate to another peers by analysing the upload rate which they are receiving. They also keep trying to connect with new peers in the swarm to test if the new peer offers them a good download rate then the existing peer[15].

4. Choking Algorithm

Bit Torrent always tries to get maximum from its downloading, peers try to do this by downloading data from where ever they get according to tit-for-tat mechanism[14]. The choke algorithms assure a significant reciprocation of uploading and downloading of data. It unchokes 4 peers based on tit-for-tat criteria in which peers are likely to give data to other peers at a high rate The fifth peer is randomly choose for optimistically unchoked. By default every connection is unchoked but optimistically Unchoked allows new peers to bootstrap after every 30 seconds. Bit Torrent choking algorithms are also attempt to achieve pareto efficiency by considering if any two peer are both getting poor reciprocation for their upload and download, they can start uploading more efficiently to each other so that both get a better download rate than they had before, also on other hand it achieves reasonable level of efficiency with full guarantee of a viable system by fostering reciprocation, preventing free riders to attack the stability of a system with excess capacity[16-17].

5. Locality

A Bit Torrent network usually avoids traffic expense of ISPs and generates a huge amount of high back bone and cross ISP traffic by ignoring the underlying internet topology and chooses neighbours randomly among all peers in the network. More importantly in [18] some selfish P2P routing often results in conflicts with ISP controlled routing policies of network which also cause huge loss to ISPs. For sake to reduce the energy consumption of Bit Torrent adopts different locality techniques, such as to deploy throttling or band width limiter, which reduces the rate of cross-ISP traffic at the cost of higher download time which actually deteriotes the user experience. Another technique called ISP-Biased neighbour selection [19] also enhance traffic locality by making connection with the peers present within the same ISP taking internet topology into consideration. ISP biased neighbour selection significantly minimizes the backbone and cross ISP traffic in the network, reduces power consumption on network with improved download performance[20]. In [21] author suggested the benefits of peer assisted video on demand, which shows that locality-aware peer to peer solutions can significantly reduce the inter-ISP traffic.

6. Energy Efficient Bit Torrent

Bit Torrent networks are not energy friendly but by implementing MILP model for Bit Torrent we can make it energy efficient. Peers select other peers randomly regardless of the impact on underlying network; a seeder might unchoked a remote leecher in different ISPs while neglecting its neighbouring leecher located in a same ISP. This will generates the cross traffic and as well as extra fees have to paid to other ISPs, such sort of behaviour is known as location unawareness. Several studies proved that employing locality in peer selection can reduce ISP cross traffic while maintaining acceptable performance for energy efficient Bit Torrent. In [19], author discusses that ISPs can reduce the cross traffic by bandwidth throttling but it will significantly increases the download time, when there is a high bandwidth for the seeding. Also by biased neighbour selection in [19], which actually depends on rarest first algorithm, a peers chooses most of its neighbour from the same ISP and very few from other ISP to make visible the content of outside world. This will significantly the reduce energy consumption of Bit Torrent while keeping optimal download performance and by reducing the cross ISP traffic of the network. Another technique discussed by [19, 24] to reduce cross ISP traffic by using a cache to eliminate traffic redundancy. In [25], author discuss the concept of gateway peer, which ISP chooses from its peers so all the peers are connected to each other but only the gateway peer is also connected with the external peers. It usually exchange contents with other peer from external world and have high upload rate to avoid increased download time. In [26], energy efficient Bit Torrent model is discussed to reduce the energy consumption of Bit Torrent in IP over WDM network, the similar model we used to examine the impact of different swarms sizes and different file sizes distribution on energy efficient bit torrent network. We consider the measurement studies of internal and external factors like realistic file sizes, Choke algorithm, Rarest first algorithm and fairness and optimistic unchoked make it interested for researchers to study through measurements studies [30]. And finally get compared with the client server system[31,39].

7. Results

Here we studied the impact of different file size distribution and peer size distribution in Bit Torrent network. We used AMPL/CPLEX to run the linear programming based mathematic model. .We implemented the MILP model for Bit Torrent network having 160,000 groups of downloader's which are downloading different file sizes (in GB), having uniform and Gaussian distribution among swarms in the network. Each group have a 100 peers set which are known as swarms. A peer could be a seeder or leecher. Each seeder has a upload capacity of 1 Mbps. Due to processing constraints of PC, we run model for 20 Swarms, each have a 100 peers and assume that the network contains 8000 replicas of these 20 Swarms. So it will result as a 160,000 swarms. National science foundation (NSF) network in [26, 32] having a traffic demand between each node pair for different time zones is 82 Gbps. So with 160,000 of 100 peers each having a upload capacity of 1 Mbps, 50% traffic of NSFNET network would be achieved. The value of α is so large to show to average download rate at a compare able level of power consumption while doing calculation. In Bit Torrent, we fixed the total number of peers to 100 to have a same upload capacity of 16 Tbps with the same as NSF network. We also change the number of Seeders from (15 to 85) to calculate the energy consumption. The structural layout of NSF network is shown in figure 4.

In Bit Torrent, we usually found these video formats to download the files

- Xvid. It is just an MPEG-4 video codec, which can be played with DVD and DivX players. It has a usual file size of about 700 MB.
- Dvd-5. It is single sided and single layer DVD disc, which can store upto 4.7 GB
- .Mkv. It is short for Matroska video/audio files. It is very much like .Avi and .Mov formats. It usually have a size of below then 2 GB
- Dvd-9. It is very much like DVD 5, but its single sided with dual layer. Because of its double layer, it has maximum capacity upto 7.95 GB.
- Dvd Rip. It usually ranges from 300 MB to 1.36 GB[38].

TABLE I. INPUT DATA FOR THE MODEL

Router port power consumption Rpp	1000 w [33]
Transponder power consumption Tp	73 w[34]
Power Consumption of an optical switch in node i	8 w [35]
EDFA's power consumption	85 w [36]
Mux/Demux power consumption	16 w[37]
No of wavelength in fibre	16
Bit rate of each wavelength B	40 Gbps
Span Distance between EDFA	80 Km
Upload slots	4
Upload capacity of each peer	0.001 Gbps
Total download capacity of each peer	0.01 Gbps
Average download rate weight α	1000,000
Power weight β	0 or 1

Here we use 5 different file sizes which are available for downloading on different torrent websites. So we consider [700 MB, 1.46 GB, 3 GB, 4.3 GB and 5.04 GB] file size of different video formats indicated above, and try to distribute them among different swarm's sizes[39]. First we run our model for 5 real time file sizes related to different video formats mentioned above, which have uniform and Gaussian distribution among 5 swarms and20 swarms, available on Bit Torrent websites for downloading. We calculate the energy consumption for particular set of Seeders. By multiplying the power consumption with average download time we get the total energy consumption of that particular scenario. The average download time is calculated by dividing the files sizes by average download rate. So for each file size we have different download time which is distributed among different swarms. The results in figure 5 indicates that the distribution of file sizes is irrelevant in terms of energy consumption and only the average file size decides the overall energy consumption in the network. The reason is that majority of swarms will have to download the file size which averages the overall set of file sizes regardless of the distribution used. The result in figure 6 shows the different energy consumption graphs for each swarm size. For less number of peers we have less leecher downloading from same Seeders. But for high number of peers with fix number of Seeders, we got very high number of Leechers, which actually results in less download time. Therefore energy consumption is not linear as we increase the locality of peers among the swarms by increasing number of peers. Figure 7 shows different number of swarms with different peer sizes having different energy consumption. The results indicate that 10 swarms each having 200 peers cause less energy consumption compared to 40 swarms each having 50 peer size. We model for different percentage of seeder to have clear comparison among all graphs. This is because less number of swarms and high peers number results in more localized peers that are downloading the same file, leading to less energy consumption.

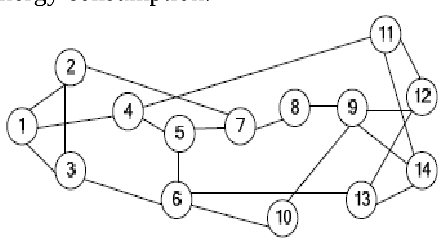

Figure 4 National science foundation (NSF) network

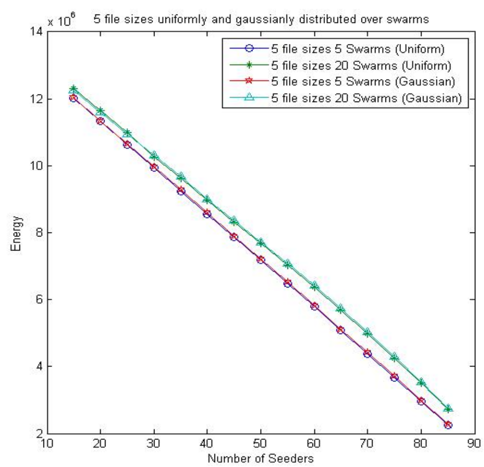

Figure 5. Energy consumption for different file sizes having uniform and Gaussian distribution.

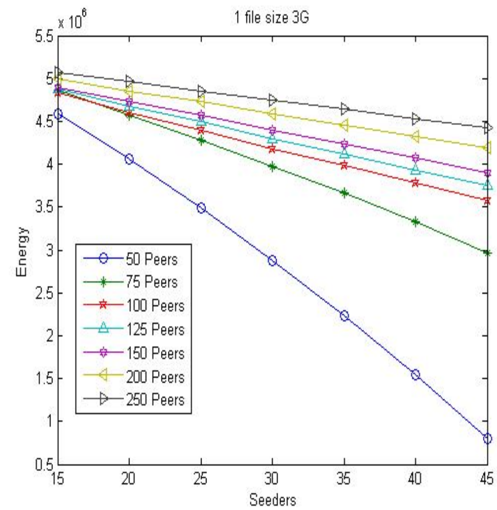

Figure 6. Energy consumption of different peer sizes with fix number of swarms

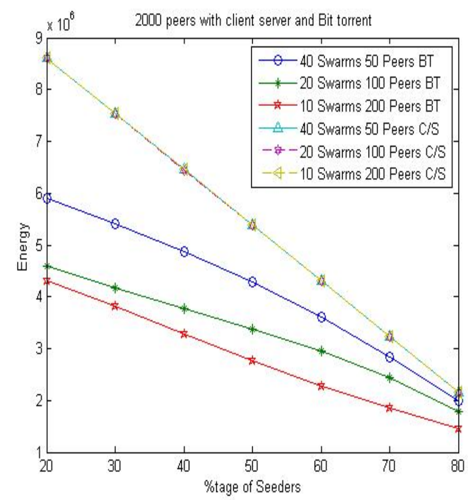

Figure 7. Energy Consumption of different swarm sizes and peer size.

While 40 swarms each having 50 peers will have less peers in each swarm, so they have more energy consumption due to less localized peers. We incorporate the client server model [31] in our graph which shows clearly that the downloader's distribution is irrelevant to the client server system as long as the total number of peers is kept constant leading to the same energy consumption regardless of the how many peers are interested in a particular file.

8. Conclusion

This paper has mainly considered three aspects related to energy efficient Bit Torrent networks. The first aspect is to see the different file sizes having uniform and Gaussian distribution among swarms. In which, it is shown that uniform or Gaussian distribution of file sizes among swarm is irrelevant for energy consumption and the most of swarms have to download the file size which averages the set of files that determine its energy consumption. Secondly, we distribute the different peer sizes among swarms which show that increasing the number of peers per swarm will not increase the energy consumption linearly proving that the increase in locality of peers will not increase the energy consumption linearly. Finally, the more number of swarms and less number of peers consume more energy compared to the opposite situation where we have less number of swarms with more peers due to locality impact on the cross traffic between nodes, which leads less energy consumption for more peers per swarms, and also by incorporating client server system, results show that the distribution of downloader's is irreverent if the total numbers is kept constant.

REFRENCES

[1] Sarokin, D. (Augast 2007) Energy Use of Internet.

[2] Glanz, J. (September 2011) Google Details, and Defends, Its Use of Electricity

[3] Nedevschi, S., S. Ratnasamy, and J. Padhye, Hot data centers vs. cool peers, in Proceedings of the 2008 conference on Power aware computing and systems. 2008, USENIX Association: San Diego, California. p. 8-8.

[4] Sandvine (Fall 2011) Global Internet Phenomenon Report.

[5] Simon, S., Peer-to-peer network management in an IBM SNA network. Network, IEEE, 1991. 5(2): p. 30-34.

[6] E.Keiser, G., A Review of WDM technology and Application. Optical Fiber Technology, July 21, 1998. 5(1): p. 3-39.

[7] Black, U., Optical Networks, Third Generation Transport Systems. Advanced Communication Technologies. 2002: Prentice Hall Series.

[8] Gangxiang shen, R.S.T., "Energy minimized design for IP over WDM networks". Journal of Optical Communication and Networking, June 2009. vol.1(1): p. 176-186.

[9] M Gupta, S.S., "Greening of the Internet". SIGCOMM '03 Proceedings of the 2003 conference on applications, technologies, architecures and protocols for computer communication, Aug, 2003: p. 19-26.

[10] X.Dong, T.E.G., J.M.H Elmirghani " Green IP over WDM Networks with Data centers". Journal of Light Wave Technology, June 15 2011. Vol 29(12): p. 1861-1880.

[11] David R. Choffnes, F.E.B., "Taming the Torrent: a practical approach to reducing Cross-ISP Traffic in Peer-to-Peer Systems". Proceedings of the ACM SIGCOMM 2008 conference on Data Communication., Oct 2008. vol. 38(4): p. 363-374.

[12] Matthew Forshaw, N.T., "A novel approach to energy efficiant content distribution with Bit Torrent". Imperial college Energy and Performance Colloquium, Imperial College London, June 2012.

[13] Jeremy Blackburn, K.C., " A Simulation Study of a New Green Bit Torrent", in IEEE International Conference on Communication Workshops. June 2009. p. 1-6.

[14] Cohen, B., " Incentives Build Robustness in Bittorrent". Workshop on Economics of Peer-to-Peer Systems, 2003.

[15] Chandra, J., et al. Optimizing topology in Bit Torrent based networks. in Computer Communications Workshops (INFOCOM WKSHPS), 2011 IEEE Conference on. 2011.

[16] A. legout, G.U., P. Michiardi. " Rarest first and choke algorithms are enough" in 6th ACM SIGCOMM Conference. 2006. NY, USA.

[17] Xinuo, C. and S.A. Jarvis. Analysing BitTorrent's Seeding Strategies. in Computational Science and Engineering, 2009. CSE '09. International Conference on. 2009.

[18] Hui Wang, J., C. Dah Ming, and J.C.S. Lui. Modeling the Peering and Routing Tussle between ISPs and P2P Applications. in Quality of Service, 2006. IWQoS 2006. 14th IEEE International Workshop on. 2006.

[19] Bindal, R., et al. Improving Traffic Locality in BitTorrent via Biased Neighbor Selection. in Distributed Computing Systems, 2006. ICDCS 2006. 26th IEEE International Conference on. 2006.

[20] Chen, T., et al. Improving BitTorrent Traffic Performance by Exploiting Geographic Locality. in Global Telecommunications Conference, 2008. IEEE GLOBECOM 2008. IEEE. 2008.

[21] Huang, C., J. Li, and K.W. Ross, Can internet video-on-demand be profitable?, in Proceedings of the 2007 conference on Applications, technologies, architectures, and protocols for computer communications. 2007, ACM: Kyoto, Japan. p. 133-144.

[22] Bo, L., et al. Locality Analysis of BitTorrent-Like Peer-to-Peer Systems. in Consumer Communications and Networking Conference (CCNC), 2010 7th IEEE. 2010.

[23] Bo, L., et al., Locality-Awareness in BitTorrent-Like P2P Applications. Multimedia, IEEE Transactions on, 2009. 11(3): p. 361-371.

[24] Logic, C. Cachelogic - Advanced solution for Peer to Peer Networks. http://www.cachelogic.com.

[25] Karagiannis, T., P. Rodriguez, and K. Papagiannaki, Should internet service providers fear peer-assisted content distribution?, in Proceedings of the 5th ACM SIGCOMM conference on Internet Measurement. 2005, USENIX Association: Berkeley, CA. p. 6-6.

[26] Ahmed Q. Lawey, T.E.H.E.-G., Jaafar M.H.Elmirghani, On the Energy Efficiency of Bit torrent content distribution in Optical Networks, in Submitted to ICC 2012. 2012.

[27] Kaminsky, P. (13 September, 2000) Introduction to AMPL, A Tutorial.

[28] Robert Fourer, D.M.G., Brian W. Kernighan, AMPL. A Modeling Language for Mathematical Programming. Vol. Second edition. 2003: Thomson Learning . Brooks/Cole.

[29] Holmes, D. (18 Augast, 1995) AMPL(A Mathematical Linear Programming).

[30] Lin Ye, H.Z., Fei Li, Majing Su, "A Measurement Study on BitTorrent System," International Journal of Communications, Networks and system sciences, 2010. Vol. 3(No. 12): p. 916-924.

[31] Xiaowen, D., T. El-Gorashi, and J.M.H. Elmirghani, Green IP Over WDM Networks With Data Centers. Lightwave Technology, Journal of, 2011. 29(12): p. 1861-1880.

[32] Yen-Wen, C. and C. Chung-Chi. Traffic modeling of a sub-network by using ARIMA. in Info-tech and Info-net, 2001.

Proceedings. ICII 2001 - Beijing. 2001 International Conferences on. 2001.
[33] Data Sheet of CRS-1 16 Slots chassis power system.
[34] Data sheet of Cisco ONS 15454 10 Gbps multi-rate Transponder card.
[35] Data sheet of Cisco ONS 15501 EDFA.
[36] Data Sheet of Glimmerglass Intelligent optical system 500.
[37] Data sheet of Cisco ONS 15454 100 GHz 4-CH Multi-Demultiplexer.
[38] (Accessed on 21 Augast 2012) http://www.afterdawn.com/glossary/term.cfm/dvdrip.
[39] A. Q. Lawey, T. E. H. El-Gorashi and J. M. H. Elmirghani, "BitTorrent Content Distribution in Optical Networks," in Journal of Lightwave Technology, vol. 32, no. 21, pp. 4209-4225, Nov.1, 1 2014.doi: 10.1109/JLT.2014.2351074

Sharjeel Afridi received his bachelor of engineering degree from Mehran UET, Jamshoro, Pakistan in 2007 and did his MSc Communication Engineering from University of Leeds, 2012. He is currently a Ph.D. Student at University of Leeds. He worked as a Research Associate at institute of information and communication, University of Sindh from January 2009 to July 2009. Now he is working as a lecturer in department of Electrical Engineering, Sukkur IBA University since July 2009. His Area of interest in research includes Communication systems, Microwave filters and measurements.

Abdul Rehman Gilal is a faculty member of Computer Science department at Sukkur IBA University, Pakistan. He has earned a PhD in Information Technology from Universiti Teknologi Petronas (UTP), Malaysia. He has been mainly researching in the field of software project management for finding the effective methods of composing software development teams. Based on his research publication track record, he has contributed in the areas of human factor in software development, complex networks, databases and data mining, programming and cloud computing.

Shahnawaz Shah did his Bachelor and Masters in Telecommunication from University of Sindh Jamshoro Pakistan in 2007 and 2016 respectively. Currently a PhD student at the electromagnetic academy, Institute of information science and electronic engineering, Zhejiang University, Hangzhou China. He worked as a lecturer at Isra University Hyderabad, Sindh, Pakistan during 2008 to 2009. His area of interest in research is propagation and scattering of electromagnetic and light wave in Left Handed Materials (LHM), Metamaterial.

Muhammad Y.Sandhu (M’16) received the B.Eng. degree from the Mehran University of Engineering & Technology, Jamshoro, Pakistan, in 2009, and the M.Sc. and Ph.D. degrees from the University of Leeds, Leeds, U.K, in 2011 and 2014, respectively. From 2014 to 2016, he has worked as a Research Fellow with the University of Leeds, where he was involved in microwave powder processing. He is currently working with Sukkur Institute of Business Administration University, Sukkur, Pakistan, as Assistant Professor. His current research interests include passive filter design and microwave material processing.