TCP & UDP Based Performance and Efficiency over Campus Network Optical Fibre Backbone: The Case Study of H.P.U, Shimla, India

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Abstract:
This paper presents the performance and efficiency of Campus Wide Optical Fibre Network (CWOFN) phase I and II commissioned in Himachal Pradesh University (HPU) Shimla, (H.P.), for TCP and UDP. These two protocols play a very important role in having a reliable and sustainable online education system. This work has been done within the framework of B-Node theory and its abstraction given by Cikara et al (2006). CWOFN has been tested on User Datagram Protocol (UDP) using Jperf software, an end-to-end bandwidth measurement tool. It has been done in four phases: i) The various stand-alone component performances has been measured on TCP and UDP and its comparisons has done with Cikara et. al (2006). ii) The various network segment performances have been measured on TCP and UDP protocol. iii) Using the efficiency parameters given by Cikara et al, for different nodes, efficiency of different network segment have been calculated and compared with the measurement values obtained from CWOFN. iv) Finally, a comparison of TCP vs. UDP for the segment/ component-wise efficiencies measured for CWOFN has been presented and was found that TCP performs better than UDP in data transfer.

Keywords: UDP, TCP, Performance, Efficiency, B-node theory.

I. INTRODUCTION

In the present era, online academic system has emerged as a most important component of education system India. This method of education has been emerged as great tool for providing a quality education in the geographically tough areas where the affordability and availability of human as well as other resources is very difficult. Online education system practices become the fundamental part of higher education. To diffuse knowledge and learning opportunities as an alternative service, Indian Government has taken a lot of initiative to create the quality Infrastructure for online education system. NMEICT (National Mission on Education through ICT), NKN (National Knowledge Network), NPTEL, ERNET (Education) are some key projects by Indian Government to improve the scenario in higher education by the use of online education system in India. Online education system are having the practical viability only due to the drastic improvements in available bandwidth, computing power and ICT infrastructure in higher education system. ICT is not only a single technology but it is a combination of multiple technologies. ICT has been defined as a “Diverse set of technological tools and resources used to communicate, create, disseminate, store and manage information,” [1, 2]. As ICT is a diverse set of technological tool and it becomes more important to choose the combination of component, so as to give the best and most efficient system. In a recent paper, an interesting approach of B-Node theory by Cikara et al (2006) [3] has been presented. This theory provides us a very simple and efficient method for measurement of performance of individual component of a system. The thumb rule of this theory is that, the capacity and Limitation imposed by each system is measured and accordingly the value of efficiency of that particular component is measured. In this theory each node is treated as individual B-node (Bandwidth Node). Product of all these B-node gives the performance of overall system. B-node theory helped us to identify the weakest link in the chain and justify the principal that “the strength of chain is limited by its weakest link” and accordingly we can made improvements in our system by removing the bottleneck identified, which is a high level bandwidth-centric abstraction used to decouple. An efficient and well integrated ICT system is required for implementing a good online education system and where as computer network has been identified as a backbone of any ICT system. Network technology has made it possible for the organizations to create share and access the electronic resources any where any time. Now a day’s researchers utilize a substantial amount of web information resources in their formal and informal scholarly communications [4]. The high volume requirement of electronic learning media has created great expectations both in business market and higher education system[5]. So the need of the time is to fully utilize the potential of Information technology as e-learning resources and base for online education system to become the strong knowledge economy in the world map. If the universities do not embrace the e-learning and online education technology that is readily available, they will be left behind in the pursuit of globalization [6]. The performance of computer networks defines the level of quality of service for any ICT system under consideration. Computer Network can be defined as a group of computer interconnected with each other in some ways to exchange the data. Following are the most important considerations for implementing network in any organization [7]:

- Flexibility : Higher level of flexibility is required
- Reliability: Network should be highly reliable, for this network should be equipped with redundant components.

- Sustainability: Network should be sustainable for long time duration.

- Security: Highest level of security is required. No compromise on this feature.

- Performance: Need for high level of performance, to support bandwidth hungry application such as online education system, video conferencing, etc.

- Interference: No interference is acceptable, wired LAN can only ensure this feature up to required level.

- Connectivity: Should be easy to connect to new users.

- Management and Troubleshooting: Should be easy to manage and trouble shoot.

- Cost: Cost effective network solution is required.

- Documentation: Every aspect of network should be documented in proper way.

- Compatibility: New network infrastructure should be fully compatible with existing network infrastructure.

The communication procedure between two computer systems has been defined by International Standard Organization (ISO) by giving a Open System Interconnection (OSI) model [8]. This model is very much popular as ISO - OSI model. This model has presented a layered approach for the process involved in communication between two computer systems. This layered approach has made it easy to build, operate maintain and troubleshoot the computer network system. A number of protocol and device options are available to get the specified job done. Each protocol has its specific responsibility with respect to the layer it belongs. The type of protocol in use will be decided by the type of service to be provided on the network. Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) are the two most important protocol options available in the transport layer of the OSI model. The support level of these two protocols on various type of component used in building a computer network, effect the level of performance and efficiency of the network.

In this paper performance and efficiency has been measured of Campus Wide Optical fibre Network implemented in Himachal Pradesh University for TCP and UDP protocol. The objectives of this study were as following:

1. To find the overall efficiency of CWOFN on UDP protocol in real time environment.

2. To find the component wise performance of network on UDP protocol.

3. To identify the bottleneck of CWOFN for the performance on UDP protocol. (If any)

4. To Study the performance behaviour of CWOFN segment and stand alone component on TCP and UDP with its comparison.

II. METHODOLOGY

The steps involved in achieving the objective laid were as given below:

- The Campus Wide Network of Himachal Pradesh University has been selected as a site of study for performance evaluation. This University is located in the state of Himachal Pradesh of India. The detail of network implemented is presented in next section.

- A study of CWOFN architecture has been done and accordingly the key network segment has been identified, which covers all the possible combination of component used.

- Jperf tool has been selected as a performance measurement of CWOFN on UDP protocol.

- B-Node theory has been selected as base for calculating the component and segment wise efficiency of the network.

- Using the Jperf tool the measurement of all components in standalone manner is done for UDP protocol.

- Then segment wise efficiency is measured for key segment of the CWOFN for UDP protocol.

- A calculation of individual and segment wise performance has been made for CWOFN on UDP.

- Then a comparison of TCP and UDP values have been made and accordingly the result has been presented.

- Comparison of UDP results with values presented by Cikara et. al. calculated on conceptual network.

III. TECHNICAL SUMMARY:

3.1 Network Architecture of CWOFN Phase I & II, Himachal Pradesh University:

The Campus wide optical fibre network (CWOFN) of Himachal Pradesh University is having a very good architecture. Network architecture is very secure, redundant, reliable and scalable. CWOFN is basically a hierarchical network topology. The network is divided into three basic different levels depending upon the load processing capacity:

a. Core level

b. Zonal level

c. Edge level/ Departmental Level

The edge level/department level is responsible for the processing the layer 2 traffic of the concerned department. For this purpose a 3 com make, model 4400, 10/100 mbps Implemented in the year 2007 (phase I) and S5300 series 10/100/1000) layer 2 switch has been deployed in the year 2016 in phase II. Zonal level is responsible for handling complete inter-department
traffic of the university. To get this job done university has used a 3Com make, model 5500, 10/00/1000 implemented in the year 2007 (phase I) and manageable switch S9303 of Huawei 10/100/1000 layer 3 device in phase II Core level is responsible for all inter zone and outside world traffic of the University. A 3Com make, model 7000, 10/100/1000 Mbps multi layer switch has been deployed. Load sharing in CWOFN has also been done on the basis of campus geography of the university. On the basis of geography of University campus, it can be divided into three zones, in order to cater the load of each zone a independent Layer 3 switch has been deployed. In total, university has used 3 layer devices catering the need of respective zone. University has also ensured the route wise and logical redundantly in the network, so as to provide uninterrupted services to their users. For the inter-building backbone, Optical Fibre has been used and CAT6 cable has been used for within building connectivity. Implementing individual VLAN for each and every department has ensured department wise data security. A sufficient a scope for future extension as been made in the network. Security and efficient utilization of the network has been ensured by deploying and proper implementation of Cyberoam, a UTM Device.

3.2B- Node theory:

Cikara et al (2006) have proposed B- Node theory to evaluate the performance of individual component in a network. In this theory they have treated each individual component as a B- node means bandwidth Node. This theory has provided a greater level of abstraction in the process of calculating the performance of individual node in the network. To demonstrate these Cikara et al (2006) [3, 9] has used a hypothetical network and performance values computed for UDP is given in the table 1.a below:

Table.A. Eip= Efficiency of IPv4, Epc-pc = Efficiency of PC to PC communication, ELII = Efficiency of layer- 2 switches, ELIII = Efficiency of Layer- 3 switch. Ecs = Efficiency of core/ multi layer switch taken at higher end.

| Efficiency parameters on UDP for various B-Nodes, (Cikara et al, 2006). |
|-----------------------------|-----------------|-----------------|
| Eip                         | E ipv4          | 95.71           |
| Epc-pc                      | PC -PC          | 98.93           |
| ELII                        | L2 switch       | 99.97           |
| ELIII                       | L3 switch       | 59.50           |
| Ecs                         | Core switch     | 59.86           |

Values presented in the table 1.a can be used to compute the performance of overall system by using following equation:

\[ E = \sum_{i=1}^{n} E_i \]  \hspace{1cm} (1)

3.3User Datagram Protocol:

User datagram protocol (UDP) is an important protocol of transport layer of OSI- Model. UDP is used to transmit the data over IP network without the prior information to receiver. In this protocol sender does not use any handshaking protocol with receiver to send the information. The data packet sent using this protocol is known as Datagram. This protocol was designed by David P. Reed in 1980 and formally defined in RFC 768 [10]. Service provided by UDP protocol comes under the category of unreliable services but it provides a faster way to transfer the information. Datagram in UDP protocol may take different path for same destination and may be reached out of order at destination. Time sensitive applications often use UDP because dropping packet is preferable to waiting for delayed packets, which may not be an option in real-time preferable to waiting for delayed packets, which may not be option in real time system[11].

The format of UDP protocol in IPv4 is as given below [4].

<table>
<thead>
<tr>
<th>Offset (bits)</th>
<th>0 - 15</th>
<th>16 – 31</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Source Port Number</td>
<td>Dest. Port No.</td>
</tr>
<tr>
<td>32</td>
<td>Length</td>
<td>Checksum</td>
</tr>
<tr>
<td>64</td>
<td>Data</td>
<td></td>
</tr>
</tbody>
</table>

Major applications that use UDP protocol are - Domain Name System, streaming media application such as IPTV, Voice over IP (VOIP), Trivial File Transfer Protocol (TFTP) and many online games. Due to its widespread use it becomes very important to measure the performance of a computer network infrastructure over UDP protocol. This will enable us to ensure the minimum level of service guarantee to our end users.

3.4 JPerf Tool:

Jperf is graphical version of Iperf, a command line based tool used for network performance measurement. Jperf provides us GUI to Iperf functionality. It provides us functionality to test end to end performance of various transport, application and network layer protocols on various parameters. In this live experiment, Jperf ver 2.2 [12] has been used to measure the performance of CWOFN of Himchal Pradesh University. IBM R-60 laptops have used to measure the performance of CWOFN network segments.

IV. PERFORMANCE AND EFFICIENCY OF CWOFN:

4.1 CWOFN performance Analysis on UDP:

The technical and other relevant details of CWOFN has already mentioned in section 3.1. The performance analysis of CWOFN has been done in following phases.

1. In the first phase, the performance of individual component has been measured using jperf and calculated on the basis of B-Node theory, presented in the table 1(b). A comparison of these values (table 1(b)) has been done with values computed by Cikara et al, 2006 (table1 (a)) and has been presented in graph 1(a). From the graph 1(a), following can be observed:
Table B. CWOFN, component wise efficiency value on UDP.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Component</th>
<th>Experimental Maximum Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>pc-pc</td>
<td>0.9092</td>
</tr>
<tr>
<td>B</td>
<td>core</td>
<td>0.9524</td>
</tr>
<tr>
<td>C</td>
<td>LIII</td>
<td>0.8924</td>
</tr>
<tr>
<td>D</td>
<td>LII</td>
<td>0.1128</td>
</tr>
</tbody>
</table>

a. The efficiency value for IP is same for both the experiment, having reason of theoretical computation in both experimental measurements (i.e. TCP & UDP).

b. The efficiency value for E pc-pc is quite comparable having the reason of similar type of configuration of system used.

c. For next components i.e. core switch and layer 3 switch efficiency value is very high in CWOFN as compare to values presented by cikara et al. The reason for this difference is high capacity switches used in CWOFN implementation. The backplane for switches is very high, so a high throughput has been received by these switches.

d. The performance value of LII component is very low in CWOFN measurement as comparison to the cikara et al 2006 having the reason that in CWOFN LI switches are of 100Mbps capacity, where as pc component used were 1000 Mbps capacity. So this becomes bottleneck for the performance.

Graph 1(a): Comparison of Cikara and CWOFN experimental values for Component on the UDP protocol.

2. In the second phase, efficiency of key segments of CWOFN has been measured on the UDP protocol and has been presented in table 1(c). pc-CS graph of jperf for UDP is presented in Fig 1(a) as a sample. From the table 1(c), following can be observed.

Table C. Segment wise efficiency of CWOFN on UDP.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Eq. (1) from</th>
<th>Experiment</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B- node</td>
<td>B- node</td>
<td>B- node</td>
</tr>
<tr>
<td></td>
<td>theory, and</td>
<td>values</td>
<td>values</td>
</tr>
<tr>
<td></td>
<td>from table 1b</td>
<td></td>
<td>from table 1b</td>
</tr>
<tr>
<td>pc-cs-pc</td>
<td>A*B</td>
<td>0.865917701</td>
<td>0.8286</td>
</tr>
<tr>
<td>pc-cs-Liii-pc</td>
<td>A<em>B</em>C</td>
<td>0.77275468</td>
<td>0.7393</td>
</tr>
<tr>
<td>pc-cs-liii-lii-pc</td>
<td>A<em>B</em>C*D</td>
<td>0.087166728</td>
<td>0.08516</td>
</tr>
</tbody>
</table>

A. The experimental efficiency of first two segments is quite good and comparable.

B. The efficiency of last segment is very low having the reason of low capacity (100mbps) layer two switches used in the CWOFN acting as a bottleneck in the performance.

Figure 1(a): Jperf PC-PC graph for UDP measurement.

4.2 TCP vs. UDP performance on CWOFN:

This section presents a performance comparison of CWOFN on TCP and UDP protocol in IPv4. The performance value on TCP for these segments has been obtained from a recent paper presented by Sharma et al (2010) [13-19]. The compiled table of performance values is presented in table 1(d) and graph for the same have presented in graph 1(b).

Table D. CWOFN performance values for TCP and UDP.

<table>
<thead>
<tr>
<th>Segment</th>
<th>TCP</th>
<th>UDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PC-CS-PC</td>
<td>0.8465</td>
</tr>
<tr>
<td>2</td>
<td>PC-CS-Liii-PC</td>
<td>0.8061</td>
</tr>
<tr>
<td>3</td>
<td>PC-CS-Liii-Liii-PC</td>
<td>0.3279</td>
</tr>
</tbody>
</table>
Graph 1. (b): CWOFN performance comparison for TCP and UDP.

Following observation can be made from the above experimental measurements:

a. The behavior of CWOFN segment is quite comparable for TCP and UDP in the case of PC-C/S-PC segment. This is due to the support for the large packet/segment size by core switch.

B. The difference in the performance of CWOFN on TCP and UDP becomes somewhat significant due to introduction of Layer 3 switch which has some lesser support for the performance dependent factors.

c. The gap keeps on increasing by introduction of Layer two device in the segment due to very limited processing speed and support for lesser variables of performance dependents factors e.g. packet size, segment size, buffer size etc.

V. CONCLUSIONS

This paper presents a comparative study of performance, efficiency and utilization of the bandwidth on two most popular protocol of transport layer i.e. TCP and UDP. Performance of these two protocols over the network plays a major role in providing e-resources to the academic community. Further, the experimental efficiency (component wise) has been determined for a typical case of real, functional network system (CWOFN) of H.P. University, Shimla, which has been compared with that obtained from the B-node theory.

Conclusions of this work are as follows:

• The network or component performance may differ upon the type of application or service one wants to offer. Performance of CWOFN on TCP is quite high as compare to UDP protocol.

• The CWOFN implemented by HPU-Shimla is good for data transfer but some performance factors may have to be compromised in the case of real time application such as gaming, video conferencing etc.

• To achieve the maximum performance from the system the mix of components/technologies must be chosen in such a way that all of them should be compatible with each other. A non-compatible or lower grade component such as layer 2 devices in CWOFN can limit the performance of network system.

• B-node theory can be made a basis for implementation/evaluation of various architecture/design for the system under development. We can choose the system depending on our requirement keeping in mind that the performance may vary from 1 to 5 % in the case of UDP.

VI. ACKNOWLEDGMENT

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VII. REFERENCES


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