# A Study of Efficiency- Campus Networks in Western Himalayan Universities of India

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***Abstract*-The present study focuses on efficiency of various networks commissioned on different campuses of six universities in the Western Himalayan region of India, within the framework of B-Node theory given by Cikara et. al. (2006). The study has been presented in three phases: i) The evaluation of efficiency for different campus networks as per their architecture. ii) The data handling capacity per user in the respective networks, which has been discussed in terms of throughput of core-switch and the efficiency of the network. iii) Finally, the segment/ component- wise efficiencies are measured for the real network system on the campus of H.P. University, Shimla,India, as a typical case, using Jperf software tool, and compared with those obtained by Cikara et al. The results are found consistent with a difference arising from the coupling factors.**

***Keywords-component: B-Node Theory, Efficiency.***

## I. INTRODUCTION

An efficient Internet network system supported with reasonably higher bandwidth and well developed computer technology, has become indispensable Information Communication Technology (ICT) facility in all the higher educational institutions for their effective functioning, whether it is wired network, wireless network, adhoc network or any other type of network

Educause Centre for Applied Research (ECAR) conducted a survey in various states of USA, on the theme 'IT Networking in Higher Education' in 2005, whose findings and recommendations are found to be quite significant in the context of performance of Campus Networking and its optimization [1]. These may be summarized as follows:

- The University's mission and strategic directions set the context for the networking goals and vision, investment drivers and barriers to deliver network services. The goals were identified as reliable & super speed network to provide demand driven, leading edge performance and best quality internet services [2] to the academic/ research community.
- The existing wired network should be supplemented with the wireless network.
- In view of the complexity & diversity of an Institution, the network should be managed by the institution and not by outsourcing.
- The transmission media technologies & standards, bandwidth capacity, network architecture and full redundancy at the core level, all work in order to ensure a network's scalability, reliability, fault tolerance, security and adaptability.
- Security has been a top barrier in providing network services.
- The network should have a disaster recovery plan for data networking.

In view of these findings and the objectives set by National Mission on Education through ICT (NMEICT) Ministry of Human Resource Development (MHRD) Government of India, to provide an efficient 'one stop solution to whole of the academic community' in the country, it was thought prudent to have a quantitative estimate of performance and efficiency of ICT networks on the University campuses located in Western Himalayan region of India. In this context, there are variety of methods available alongwith some optimization solutions like that of Barrett (2010) [3], to boost the network performance and efficiency. However, the methods range from empirical where "rule of thumb" is subjective offering little mathematical rigor, to those using complex mathematics, like stochastic modeling and queuing theory. The latter methods are problematic and tricky to understand and conceptualize.

A much simpler and relevant approach of 'Bandwidth Nodes (B- Nodes)' was presented by Cikara et al. [4] for a hypothetical network system, a couple of years ago. It is a high level bandwidth-centric abstraction used to decouple and simplify the complexity of a particular technology. In this approach various devices can be

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modeled as individual nodes or as a collection of nodes describing the overall functioning & interactions between the sub-systems and the operating environment. The approach demonstrates, to a first approximation, that the efficiency of B-Nodes can be obtained as a product of all efficiencies contained within that segment of the network system. This B-Node theory allows the performance and efficiency of a network to be easily and quickly determined. Interestingly, to the best of authors' knowledge, not much work has so far been done on the real network systems within the framework of this simple B-Node approach. We plan to take it up in this technical paper, in reference to different university campuses in the Western Himalayan region of India.

With the installation of Optical Fibre Networks (OFB) with suitable architectural design, on different university campuses, the motivation of the present work has been to evaluate the efficiencies of various networks using B-Node theory and perform experiments on a real network system within the spirit of this theory.

The three fold objectives of the present work are,

- Study and analyse the efficiency of networks of different university campuses of the region using the parameters/ values given by Cikara et al, Table I, and the technical details of switches given in Table II.
- Using the philosophy of the B- Node approach, carry out experiments to find performance and efficiency of the real network on the campus of H.P.University, Shimla.
- This experimental data was analysed, discussed and compared with that given by Cikara et al.

## II. BASICS OF B- NODE THEORY

Cikara et al (2006) used a hypothetical network for which they developed a simple technique of 'B-Nodes', by reducing the total network into different individual abstractions for calculating efficiency, to a first approximation. They found the efficiency parameters in respect of different important abstractions like Internet Protocol version 4 (IPv4), end to end device (PC- PC), switches (L-II and L-III) and the multi layer core switch in the network system, which are summarized in Table I.

TABLE I

EFFICIENCY PARAMETERS FOR VARIOUS B-NODES IN THE NETWORK (CIKARA ET AL, 2006).

| Efficiency parameter for various B-Nodes | | |
|---|---|---|
| $e_{IP}$ | eipv4 | 0.9493 |
| $e_{pc-pc}$ | PC-PC | 0.9978 |
| $e_{LII}$ | LII Switch | 0.9997 |
| $e_{LIII}$ | LIII Switch | 0.6683 |
| $e_{cs}$ (assumed at highest end) | Core Switch (Multilayer) | 0.6683 |

$e_{iP}$= Efficiency of IPv4, $e_{pc-pc}$ = Efficiency of PC to PC communication, $e_{i\ II}$ = Efficiency of layer- II switches, $e_{i\ III}$ = Efficiency of Layer- III switch. $e_{cs}$ = Efficiency of core/ multiplayer switch taken at higher end.

Using these values, the net efficiency, e, of the complete network system can be obtained as a multiplication of respective efficiencies, $e_i$ of different abstractions (Table II.), where i denotes the number of abstractions i.e.

$$e = \Pi_{i=1}^{n} e_i. \qquad (1)$$

## III. METHODOLOGY

The methodology consists of the following steps:

- The universities located in the Western Himalayan Region of India are those spreading over the state of Himachal Pradesh and Jammu & Kashmir. There are mainly seven universities located in this region out of which six ICT based universities are selected purposely.
- B-Node approach has been a simple method, to a first approximation, to find out the efficiency of the network, in the form of multiplication of individual nodes' (the main network components as abstractions) efficiencies, which Cikara et al has presented as parameters for such abstractions. This method is used to find the efficiency of the network, which is supposed to be quite instructive.
- In view of the fact that network data handling capacity can be calculated once the throughput of the core switch, efficiency of the network, and number of users are known. It may be taken as the simple empirical way of finding the performance. This is what has been done in this paper

- Finally, it was decided to consider an actual network architecture, and find the experimental efficiency of various nodes (abstractions) within the procedural framework of B-Node theory, of a real system. For this, the network of H.P.University is chosen as a typical case, in the universities of Western Himalayan region of India.
- Since the efficiency experiment depends on several parameters (say coupling parameters) present in the network, this dependence has been estimated approximately.

## IV. Technical Summary Of Campus Networks' Architecture

In the past, the academic community in this Western Himalayan region had been facing challenges in respect of an efficient internet connectivity supported with Optical Fibre Backbone (OFB), for accessing the latest/ advanced material for research. Around the year 1999, on the recommendation of the IT Task Force set up by Government of India, University Grants Commission (UGC) decided to provide complete connectivity through VSAT/ Leased line (broadband services) to all the Indian Universities under UGC-Infonet Scheme through Information Library Network of India (INFLIBNET), connecting all the libraries of the country. This decision was implemented within the next five years, almost in all the universities funded by the UGC. Thus, with the availability of efficient network connectivity on all the different campuses of the region, the dream of full fledged ICT facility became a reality for accessing more than 4000 national and international e-journals online [5], to all the users. Further, under the NMEICT and National Knowledge Network (NKN) program of MHRD (Government of India), all the Universities got an additional boost, upgrading their ICT networks, in recent years.

Consequently, all the six universities of the region procured and commissioned an efficient network architecture, by including the following essential elements:

- Effective Star Topology, transmission media, high power core switch (CS) and routing switches.
- Sufficient Internet bandwidth capacity and the security.

These details have already been presented earlier [6-8] by the authors. However, the relevant summary of the throughput, the functional bandwidth, the active components of the network and the users of the ICT facility, is given in Table II.

Table II

PRESENT STATUS OF BANDWIDTH, THROUGHPUT, ACTIVE COMPONENTS OF THE NETWORK AND INTERNET USERS IN DIFFERENT UNIVERSITIES OF THE REGION.

| S.No | Name | Throughput of Core switch (Gbps) | Bandwidth in 2010. | Active components and user details |
|---|---|---|---|---|
| 1. | H.P.University, Shimla | 96 | 10 Mbps(1:1) (NKN) | Layer II – 26, Layer III- 3, Multilayer (Core switch)- 01, user 900 |
| 2. | Jammu University, Jammu | 64 | 30 Mbps(1:1) + 10 Mbps.(NKN) | Layer II – 40, Layer III (Core switch)- 01, user 900 |
| 3. | NIT Hamirpur | 512 | 64 Mbps(1:1) + 1 Gbps (NKN) | Layer II – 100, Layer III (Core switch)- 03, user 3000 |
| 4. | JUIT, Solan | 56 | 12 Mbps(1:1) + 1 Gbps (NKN) | Layer II – 75 Layer III (Core switch)- 01, user 2500 |
| 5. | Agricultural Univ. Palampur | 12.8 | 2 Mbps (1:1) | Layer II – 10, Layer III (Core switch)- 01, user 450 |
| 6. | Horticultural Univ. Nauni, Solan | 24 | 4 Mbps(1:1) | Layer II – 08, Layer III (Core switch)- 01, user 300 |

The important features of the most crucial part of the network architecture features like throughput, will be utilized in calculating the efficiency of the network.

## V. Performance & Efficiency Of Networks

The calculation of performance efficiency, using B- node theory, of networks laid in Tier II or Tier III (different number of layers) in various universities, has been taken up in two steps.

- Once the maximum throughput of the core switch is known, the data handling capacity/ user has been calculated and presented in Table III. In this process we have used the efficiency parameters of Cikara et al, to determine the total efficiency of the campus networks.
- It was further tempting to attempt finding the experimental values of efficiencies of different abstractions as shown by Cikara et al, on a real functional network system, by selecting a typical case of the network architecture on the campus of H.P. University, Shimla,India. These experimental values are presented in Table IVa.

### *A. Data- handling Capacity per User*

We have calculated the actual user data handling capacity in a particular network using the values of the throughput (Table II) and the efficiency parameters (Table I), which are presented in Table III, and also graphically in Fig.1.

Table III

ACTUAL THROUGHPUT, EFFICIENCY AND DATA HANDLING CAPACITY PER USER OF THE NETWORK IN DIFFERENT UNIVERSITIES.

| S.No | HPU | Jammu Uni | NIT | JPU | Palampur | Nauni |
|---|---|---|---|---|---|---|
| Tier system | III* | II** | II | II | II | II |
| Theoretical Throughput (T)/ Backplane of Switch in (Gbps) | 96 | 64 | 512 | 56 | 12.8 | 24 |
| Efficiency (e) of The network as per B- Node theory (in %) | 42.29 | 63.28 | 63.28 | 63.28 | 63.28 | 63.28 |
| Actual User Data (D) Handing Network capacity (Gbps) D= (E*T)/100 | 40.60 | 40.49 | 323.99 | 35.44 | 8.10 | 15.19 |
| No. of users (U) | 900 | 900 | 3000 | 2500 | 450 | 300 |
| Data Handing Network Capacity per user= (D/U)*1024 (Mbps) | 46.19 | 46.08 | 110.59 | 14.51 | 18.43 | 51.84 |

*Efficiency Tier III= $e_{ip}*e_{pc-pc}*e_{LII}*e_{LIII}*e_{cs}$ and ** efficiency Tier II= $e_{ip}*e_{pc-pc}*e_{LII}*e_{LIII}*e_{cs}$

The figure illustrates that National Institute of Technology

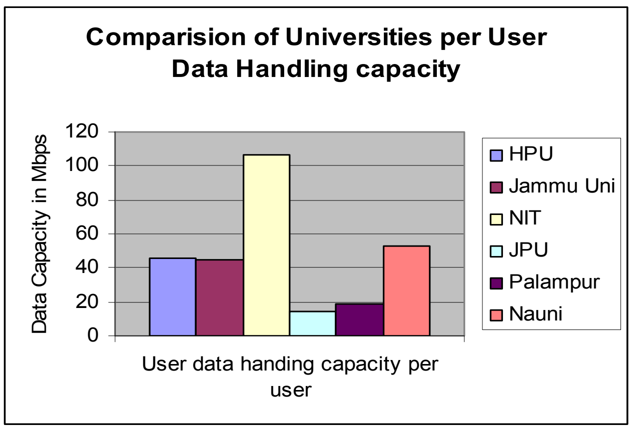


Fig. 1. Data Handling Network Capacity per user of different universities

(NIT), Hamirpur is having the highest data handling capacity per user, with a value of 110.59 Mbps, followed by Horticulture University (HU), Nauni (51.84 Mbps), H.P.University, Shimla (45.5%), Jammu University, Jammu (45%), Agriculture University, Palampur (18.8%) and then J.P University, Solan (14.2%). Interestingly, NIT Hamirpur, is having good network data handling capacity even after having a large no of users on the campus, whereas Nauni stands next even after having obsolete model of the core switch having a very low backplane of 24 Gbps. The J.P. University, Solan, which is one of the best technical universities, found to be lowest in network data handling capacity per user.

### B. *Efficiency Measurement on a Real Network system of H.P. University, Shimla.*

The experiment of efficiency measurement has been accomplished in two phases. In the first phase, simple isolated segments, like PC-CS-PC etc, were picked up, the bandwidth of the respective output was measured and presented in Table IVa.

For this experiment, Jperf v.2.0.2 [9] (a graphics version of iperf), software tool has been used for measuring TCP and IPv4 values between two end points of different segments in the network.

The use of software tool 'Jperf' between two endpoints is as simple as choosing Server node on one endpoint and Client node on the other. Jperf is just a front end to Iperf, which performs the same tests and is interpretable with Iperf. The capabilities and features of this tool (Iperf/ Jperf) are as follows:

- The values are adjustable in Jperf for Buffer Length, Window Size and Maximum Segment Size (MSS)
- It can check the impact of the changes on throughput/ bandwidth.
- There is an option available for handling different protocol like Transmission Control Protocol (TCP)/ Internet Protocol (IP), User Datagram Protocol (UDP), etc.
- It can work with IPv4/ IPv6.
- It allows optimization of the network for file transfer capability.

Here, TCP/ IPv4 system has been considered. The isolated segment wise efficiencies are presented in Table IVa.

TABLE IVa

Experimental segment wise efficiency.

| Segment | A Theoretical Maximum (Mb/s) (Cikara et al) (I) | B Experimental output (Mb/s) (II) | (E) Segment-wise efficiency (%) E= B/A *100 (III) | Remarks (Dependent on factors) (IV) | Efficiency of Nodes from Cikara et al (V) |
|---|---|---|---|---|---|
| PC-PC | 949.3 | 877.1 | 92.39 | Configuration of PC's | 99.78 |
| PC-LII-PC * | 949.3 | 380.4 | 40.07 | LII 100 Mbps speed. (Limitation) | 99.97 |
| PC-LIII-PC | 949.3 | 790.6 | 83.28 | LIII 1000 Mbps speed. | 66.83 |
| PC- CS -PC | 949.3 | 866.8 | 91.30 | CS 1000 Mbps speed | 66.83 |

These segment wise efficiencies are compared with those of Cikara et al, in Fig 2.

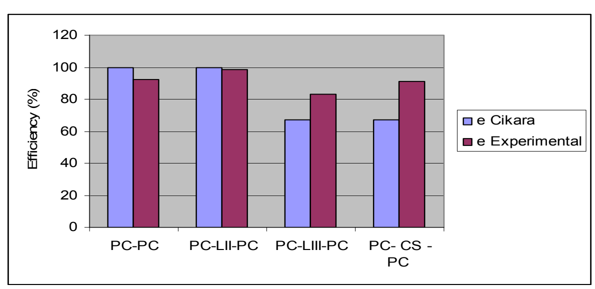


Fig. 2. Comparison of efficiencies, segment wise experimental values vs those of Cikara et al.

It may be pertinent to mention before drawing any conclusion out of the comparative analysis that most of the active & passive components on the campus network of the H.P. University, are having the Gbps capacity except the LII switch which has the capacity 100 Mbps only. In star topology, when LII is being used in the circuit (in series) then the following equation [10], becomes effective:

$$B_{circuit} = \text{Min}\{B_1, B_2, B_3\ldots B_n\} \quad (2)$$

Where $B_{circuit}$ is the effective bandwidth and $B_n$ corresponds to the Bandwidth of nth component of the network system.

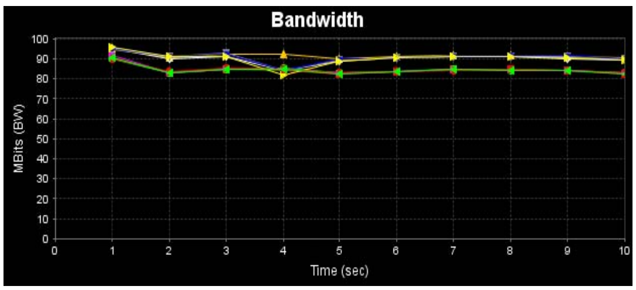


Fig. 3. Bandwidth vs. Time curve for the segment PC-CS-PC. This is a one of the data graph received from the communication between two end points i.e. PC-CS-PC through Jperf software tool. These lines represent different data streams.

In Fig. 3, experimental values of bandwidth for a typical case of PC- Core Switch- PC, are presented, which clearly depicts that bandwidth between two end points comes out to be 866.8 Mbps, same as given in Table IVa. The analysis goes as follows:

- Last two segments in Fig. 2 i.e. PC-LIII-PC and PC-CS-PC, reveal higher value of efficiencies as expected, because of higher processing capacities/ speed of devices as compared to those used by Cikara et al.
- PC-PC component is less than Cikara et al due to PC- dependent factors.
- PC-LII-PC is found to be less than Cikara et al due to a mixed link capacity (in 1 Gbps LAN Cards and 100 Mbps LII switching), where eq. (2) plays its role effectively.
- A 'negative bandwidth' [10] (decrease in bandwidth), was observed after the processing took place.
- In principle, all the components of the network should be of the same link capacity for a reasonable comparison. The mixing of nodes with different capacities is bound to lower the efficiency of the circuit in the network [11].

From Table IVa, component wise efficiencies may be calculated which are given in Table IVb

Table IVb

EXPERIMENTAL VALUE OF EFFICIENCY, COMPONENT WISE.

| S.NO | Component | Experimental Maximum efficiency (Mb/s) |
|---|---|---|
| A | PC-PC | 0.9239 |
| B | Core switch (7750 3 COM) | 0.9883 |
| C | Layer III (5500 3 Com) | 0.9013 |
| D | L-II ( 4400 3 Com) | 0.4007 |

Phase two is concerned with the experimental measurement of the efficiency on a respective segment of the real network (placed at different information outlets) connected through CAT6 at the Campus of H.P.University, Shimla. These values are presented in Table IVc (III Column).

Table IV c

COMPARISON OF EFFICIENCIES OF SEGMENT ON REAL NETWORK, EXPERIMENTAL VS THEORETICAL.

| Segment | Eq.(1) from B-node Theory (I) | Experimental Efficiency from eq (1) & from Table IVb. (II) | Experimental Efficiency for the entire segment on real network (III) | Relative error due to the coupling factor in real network (II-III)/III |
|---|---|---|---|---|
| PC-CS- PC | A*B | 0.9130 | 0.8465 | 0.0784 |
| PC- CS-LIII-PC | A*B*C | 0.8228 | 0.8061 | 0.0207 |
| PC-CS-LIII-LII-PC | A*B*C*D | 0.3297 | 0.3279 | 0.0054 |

The analysis of experimental efficiencies (B-Node approach vs Actual observed), based on the Table IVc, is given below:

- It is pertinent to mention that the values obtained in column II and III, are quite comparable, proves that B node theory is also applicable for real functional networks.
- However, the relative error, given in the last column, in the expected vs. actual efficiency on a particular segment, using Jperf 2.0.2, software tool, is found to be around 5%. This difference may be attributed due to the coupling factors linking different abstractions/ nodes through which the data is passing.
- The role of LII appears as a bottleneck in whole of this experiment, may be because of its non- compatibility. That's why efficiency is very quite low compared to LIII and CS.

## VI. CONCLUSIONS

This paper presented a comparative study of performance, efficiency and utilization of the bandwidth in terms of data handling capacity per user in the university environment of Western Himalayan region of India.

Further, the experimental efficiency (component wise) has been determined for a typical case of real, functional network system of H.P. University, Shimla, which has been compared with that obtained from the B-Node theory. The findings of this work are as follows:

- The B-Node theory may be effectively used as a measure of performance & efficiency, to a first approximation, of the real functional networks.
- Efficiency of the network with a particular architecture design is found to depend mainly on throughput, different level switches in various tiers, PC- PC link, the internet protocol (IP, LII & LIII) and finally on the number of users on the campus. The universities should try to optimize the efficiency of their network system [11].
- In order to have the maximum efficiency, link capacity of all the active and passive components of the network system should have consistent values i.e. Gbps or higher, and must be compatible with each other.
- Mixing different link capacities of various components is bound to decrease the efficiency of total network system.
- The difference in the expected efficiency (as per the B-Node theory) and the actual values of a real network system is found to depend upon different coupling factors involved in the actual network segments/components.
- B-Node theory may be very helpful in evaluating options before procuring efficient & reliable, secure & compatible 'Nodes' for an efficient network.

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