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Wi-Fi Performance and Efficiency over TCP: A Study of Himachal Pradesh University Campus Network, Shimla, India

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Abstract: This paper presents the performance and efficiency of Wireless Fidelity (Wi-Fi) network implemented under the Campus Wide Optical Fiber Network (CWOFN) commissioned in Himachal Pradesh University (HPU) Shimla, India, over Transmission Control Protocol (TCP). The performance of this protocol plays a major role in deciding the deliverable Quality of Service (QOS) to network user. This work presents performance and efficiency of the various component used for Wi-Fi facility by its integration with existing CWOFN of Himachal Pradesh University. This work has been done within the framework of B- Node theory and its abstraction given by Cikara et al. (2006). Wi-Fi network has been tested on Transmission Control Protocol (TCP) using Jperf software, an end-to-end bandwidth measurement tool. It has been done in three phases: i) The various Wi-Fi network segment performances has been measured over TCP in a live environment ii) Calculation and Measurement of individual component performance using B-Node theory. iii) Identification of coupling factor by comparison and analysis of results obtained by theoretical and practical measurement. It has been found that coupling factor and end network node configuration makes a significant role in deciding the deliverable QoS to the user.

Keywords : Wireless Fidelity (Wi-Fi) , TCP, Performance, Network Efficiency, B-node theory, QoS

I. INTRODUCTION

Information and Communication Technology has emerged as an extremely important field of research and education. The growing need of ICT tools and technology has grown up to another dimension of flexibility, termed as ubiquitous computing needs. 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. Industrial and technological community

efforts to meet the non lasting demands of its users lead us to efficient environment highly suitable to the need of the research community. Optical fiber network has been treated as fastest and most reliable technology for creating a long lasting and reliable backbone for ICT infrastructure. Government of India is also taken number of initiatives such as National Knowledge Network (NKN) and National Mission on Education through Information and Communication Technology (NMEICT) to build the strong institution network backbone to support the need of education and research community. In addition to the reliable network user also have a strong demand for increased mobility, flexibility and availability of its resources without losing its connectivity. Integration of Wi-Fi with strong and reliable optical fiber backbone is answer to the demand of academic community. This integration comes up with many challenges of performance, compatibility and security. 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 link 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 network link. 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 improvements in the network system could be made by removing the bottleneck identified, which is a high level bandwidth-centric abstraction used to decouple.

Wi-Fi is a term in technology used to define the networking product comprising the need of standard defined by Institute of Electrical and Electronics Engineers (IEEE) as 822.11b. Over the last couple of years, Wi-Fi has quickly grown to become the dominant wireless LAN standard. Because it operates in unlicensed frequency bands with 2.4 Ghz, anyone can set up a WiFi network and cover an area of typically upto 100 meters with high speed wireless access over campus and able to provide internet or intranet access over Local Area Network. Unlike other wireless technologies like GSM or CDMA, WiFi has also become a universal standard. As a result, Wi-Fi components are now on a rapid cost reduction curve as volumes increase. It is widely distributed and used in many different parts of the world [4].

The coverage, capacity, density and security are identified as major challenges involved in the implementation of Wi-Fi have been addressed in a white paper by Aruba Networks [5]. The details of these challenges as per Himachal Pradesh University (H.P.U) campus network is discussed below:

- **Coverage**: H.P.U campus is located on the top of the hill in the Shimla district of Himachal Pradesh India. The campus has been built in such a way that minimum disturbance has been done with nature, so campus is densely covered with the pine trees. These pine trees are found to the major signal absorber. Second factor affecting the coverage is hilly terrain, which leads to shadow areas affecting the signal strength. Thirdly, thick wall structure of the buildings constructed in the University campus and hostel.

- **Capacity:** HPU is a state University of Himachal Pradesh, India and offering courses in both technical and physical sciences stream with campus based enrollment of roughly 5000 students and 1000 teaching and non teaching staff. Therefore a ubiquitous Network Wi-Fi facility for roughly 4000 users is required.
- **Security:** The campus of Himachal Pradesh University is widely spread due to the hilly terrain and this campus is not fully isolate. A lot of public properties are available within and around the campus. Therefore, security of network becomes important and critical consideration for the implementation of Wi-Fi facility. Major users of this facility are students, and providing services to them with reliability and security is also a big challenge.
- **Users Density:** The Himachal Pradesh University campus is scattered in a larger geographical region due to hilly terrain. So the Wi-Fi internet user's density is very low in this campus. So the Hot spot requirements are confined within buildings and not around the whole campus.

This paper presents a performance and efficiency testing of Wi-Fi implemented in the University Institute of Information Technology of Himachal Pradesh University, which is also integrated part of Campus Wide Optical Fibre Network (CWOFN). The objectives of this study covered under three phases are as given below:

- To find the overall efficiency of Wi-Fi facility available in University Institute of Information Technology in live network segment of CWOFN over TCP.
- Component wise performance of Wi-Fi equipments used over TCP using B-Node theory.
- To identify the performance bottleneck and coupling factor, if any.

II. METHODOLOGY

The steps involved in achieving the objective laid are given below:

- Campus Wide Optical Fiber 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 of Wi-Fi facility has been identified, which covers all the possible combination of component used.
- Jperf tool has been selected as a performance measurement of CWOFN over TCP protocol.
- B-Node theory has been selected as base for calculating the component and segment wise efficiency of the network.

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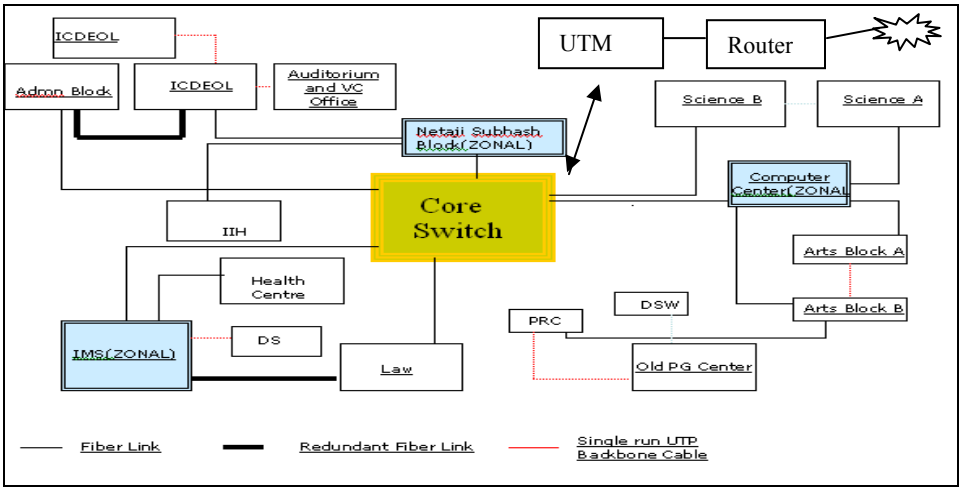
- Using the Jperf tool the measurement of each component in standalone manner is done for TCP protocol over a network link.
- Then segment wise efficiency is measured for key segment of the Wi-Fi, CWOFN over TCP.
- Then a comparison of TCP efficiency obtained through measurements and theoretical values computed using B-node theory has been presented.

III.TECHNICAL SUMMARY

3.1 Network Architecture of CWOFN, Himachal Pradesh University:

The Campus wide optical fiber network (CWOFN) of Himachal Pradesh University is having a very efficient Topology with redundancy feature and architecture design is depicted in figure 1.

Fig.1. Architectural design of H.P. University, Shimla



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:

- Core level
- Zonal level
- Edge level/ Departmental Level
- Wi-Fi access Point.

The edge level/department level is responsible for the processing the layer 2 traffic of the concerned department. For this purpose a 3 com switches i.e 4400, 10/100 mbps layer 2 has been deployed. Zonal level is responsible for handling complete inter-departmental traffic within the university campus. To get this job done university has used 3 Com switch- 5500, 10/00/1000 layer 3 device (Shown in blue colour, in Fig 1).

Core Switch 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 (Shown in yellow colour in Fig 1)

Load sharing in CWOFN has also been done on the basis of campus geography of the university. On the basis of topography 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 three layer 3 devices catering the need of respective zone.

University has also ensured the route wise and logical redundancy in the network, so as to provide uninterrupted services to their users. For inter-building backbone connectivity, Optical Fiber and CAT6 cable has been used for within building connectivity. Implementing individual Virtual LAN (VLAN) for each and every department has ensured department wise data security.

For providing the Ubiquitous ICT facility to the users, University has implemented a pilot project of integration of Wi-Fi over CWOFN facility in the University Institute of Information Technology of Himachal Pradesh University. Wireless access points of 3com make with a/b/g (maximum speed 54 mbps and nine users handling capacity on real network) compatibility has been used. The low capacity access points were used due to low density regions in the Himachal Pradesh University.

A sufficient a scope for future extension has been made in the network. Security and efficient utilization of the network has been ensured by deploying of Unified Treat management UTM Device.

3.2 B- 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 this Cikara et al (2006) has used a hypothetical network and performance values computed for UDP is given in the table 1.a below:

Efficiency parameters over TCP for

various B-Nodes, (Cikara et al, 2006).		
E ip	E ipv4	94.93 %
E pc-pc	PC -PC	99.78%
E LII	L2 switch	99.97 %
E LIII	L3 switch	66.83%

Table:1. (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.

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

$$E = {}_{i=1}\Pi^{I=n}\ E_i \quad \text{------ (1)}$$

3.3 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 [6] has been used to measure the performance of CWOFN of Himachal Pradesh University. IBM R-60 laptops have used to measure the performance of CWOFN network segments.

IV. PERFORMANCE AND EFFICIENCY OF WI-FI SEGMENT OF CWOFN

4.1. Wi-Fi performance analysis on TCP: The technical and other relevant details of CWOFN has already mentioned in section 3.1. The performance analysis of Wi-Fi facility has been done in following phases:

Component Wise Performance and Efficiency Calculation:

In this phase standalone component wise performance values has been calculated for Wi-Fi component and other values has been taken from Sharma.D, Kumar.V, 2010 Singh.V.[7]. The results have been presented in table 1(a).

Table 1 (a): Component wise efficiency and Performance of Wi-Fi			
S.No.	Component	Experimental maximum efficiency	Efficiency (%)
1	e ip	0.9239	92.39

2	e PC	0.9882	98.82
3	e Wifi	0.576	57.6
4	e L3	0.9013	90.13
5	e L2	0.9217	92.17
Note: Wi-Fi efficiency values have been calculated considering Nine concurrent Users			

Performance Measurement of Various Wi-Fi Segments:

In this phase the performance and efficiency measurement of various Wi-Fi segments over TCP has been done using Jperf tool for following Segments:

- PC-Wi-Fi-PC
- PC-Wi-Fi-L3-PC
- PC-Wi-Fi-L3-L2-PC

Experimental graphs of Jperf for these segments are given as Fig 1(a), Fig 1(b), Fig 1(c) respectively:

Fig. 1(a): Jperf PC- Wi-Fi-PC graph for TCP measurement.

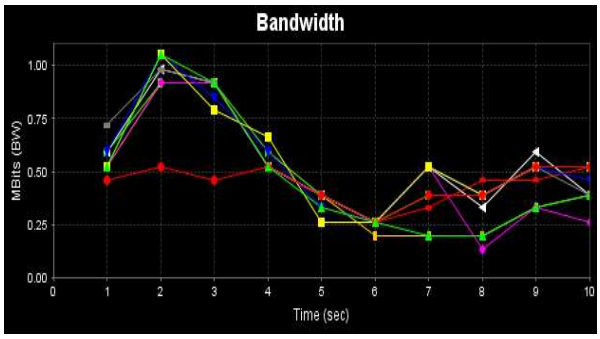


Fig. 1(b): Jperf PC-Wi-Fi-L3-PC graph for TCP measurement.

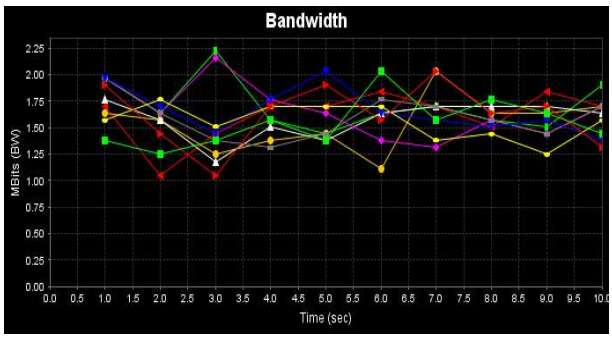


Table 1 (b): Segment wise efficiency				
S.no.	Segment (a)	Efficiency Using B - Node Theory (b)	Experimental maximum efficiency ©	Coupling factor (d)
1	PC-Wi-Fi PC	28.39788917	25.6	-2.797
2	PC-Wifi-l3-PC	25.59501751	16.4	-9.195
3	PC-wifi-l3-l2-PC	23.59092764	15.3	-8.290

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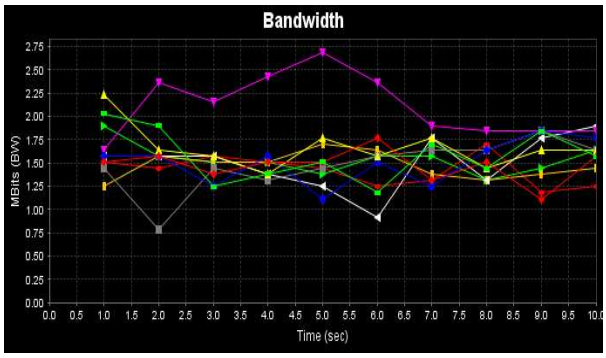

Fig. 1(c): Jperf PC-Wi-Fi-L3-l2-PC graph for TCP measurement.

Following observations can be made from the above experimental measurements:

- Following table 1(a), 1(b), it can be observed that Wi-Fi equipment performance is 57.6% and efficiency is 25.6 Mbps as compare to theoretical value of 54 Mbps claimed by a/b/g series compatible equipment.
- Wi-Fi device can be seen as a bottleneck in the performance of whole of the segments.
- The coupling factor is having a very wide range on performance and efficiency. It ranges from (2- 8) % depending upon the coupling component.
- To reduce the effect of coupling factor the component of similar configuration must be chosen. This will also help in improving the performance and efficiency of overall system.

V. CONCLUSIONS

This paper presents the performance, efficiency of the Wi-Fi segment of Campus Wide Optical Fiber Network of Himachal Pradesh University over TCP protocol. Further this paper identifies the effect of coupling of various independent on performance and efficiency by comparing the experimental values and values computed by applying B-Node theory. Conclusions of this work done are as below:

- The decision to compromise on the edge level and equipments may decrease the performance and efficiency of the overall system.
- High performance Wi-Fi devices may directly be connected with layer 3 Switch if possible, in order to reduce coupling factor introduced by L2 devices for achieving the better efficiency and performance over network.
- The B-Node theory is equally applicable on wireless network system and their results are quite comparable to the actual performance and efficiency of the system. So this theory can be used in evaluating the ICT infrastructure implementation option.

- Coupling factor also plays a very important role in deciding the deliverable services to the user therefore, precautions must be taken accordingly.
- To achieve the maximum performance and efficiency of the network, mixing of components must be chosen in such a way that all should be of same/compatible configuration and generation.

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