PENERBIT UMT
Menjana Khazanah Ilmuwan

JMSI
Journal of Mathematical Sciences and Informatics

SIMULATION OF WIRELESS ESTIMATION BANDWIDTH FOR NETWORK TECHNOLOGY

WAN AEZWANI WAN ABU BAKAR[1*], CHE MUHAMMAD FAIZUL CHE WAIL[2*] AND MUSTAFA MAN[3]

[1]Pusat Asasi Sains dan Perubatan UniSZA (PUSPA), Universiti Sultan Zainal Abidin, Gong Badak Campus, 21030 Kuala Nerus, Terengganu, Malaysia; wanaezwani@unisza.edu.my. [2]Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin, Besut Campus, 22200 Besut, Terengganu, Malaysia; sl3706@putra.unisza.edu.my. [3]Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia; mustafaman@umt.edu.my

Corresponding author: wanaezwani@unisza.edu.my

ARTICLE INFO	ABSTRACT
	Wireless estimation bandwidth is used in path selection for a network environment. To access the internet, a typical user shares the same bandwidth that has been provided by the Internet Service Provider (ISP). The scenario worsens when a few of the users access multimedia content on the Internet which requires high bandwidth at the same time. This research could be enhanced in other different network environments, such as wired and mobile phone environments, and represents an analysis of ready bandwidth using a few wireless bandwidth estimation tools, which are WBest, Pathload, IGI MRTG, PRTG and PTR. This paper attempts to design and develop a detection mechanism for wireless estimation bandwidth to estimate an available bandwidth through several sending of injection traffic packets to the server. In this paper, we measured available bandwidth with WBest. Then we analysed the estimation measurements prior to 2 simulations done on Wireless Mode 11 Mbps 802.11b and Wireless Mode 54 Mbps 802.11g. Three different percentages of packet injection (0%, 25%, 50%) were tested on Wireless Mode 54 Mbps 802.11g. The results accuracy shows that the 50% packet injection performs the least available bandwidth compared to the injection of 0% and 25% of packets.

©Penerbit UMT

INTRODUCTION

The internet is an international network that comprises of multiple services and resources. Information and communication technologies are the Internet's basic pillars. Wireless Internet is prevalent in home and other public places. Especially for middle developing countries, there remains persistent challenges with regards to access mechanisms. Access still suffer from the available bandwidth issues. This is the main problem because the available bandwidth is usually not enough to meet the demands of users. This situation will make the network performance slow and congested. The normal WLAN network relies on IEEE 802.11 and HiperLAN network by ETSI that are grouped under Wireless Fidelity (Wi-fi) alliance. The IEEE 802.11 and Wi-fi are used interchangeably. A typical WLAN network consists of an Access Point (AP) in the middle while number of stations (STAs) are connected to AP [1-2]. However, problems can be overcome without the need to increase the wireless network bandwidth to the Internet. There is one alternative to handle this situation, which requires users to manage their usage of the Internet. In order to handle these constraints, this study came up with the

idea of monitoring the local network bandwidth usage, which is also called network awareness. Users note the current bandwidth usage on local networks and manage the usage to get better performance.

RELATED WORKS

The review of literature is done by focusing on three major bandwidth measurement tools, namely Variable Packet Size (VPS), Packet Pair/Train Dispersion (PPTD) and Trains of Packet Pairs (TOPP), to estimate capacity and available bandwidth in individual hops and end-to-end paths and followed by a few networks monitoring on traffic-based classification.

Network Awareness

There are three types of network monitoring i.e., Active Monitoring (AM), Passive Monitoring (PM) and Hybrid Monitoring (HM). AM is the approach that is based upon the capability of two mechanisms. First, the test packets injection into the network and secondly, sending of packets to servers and applications, and later, following the packets within traffic and measuring the service obtained from each network. This would create extra traffic, but that traffic or its parameters are artificial. The volume and other parameters of the introduced traffic are adjustable and able to obtain significant measurements. The PM is a passive approach on special-purpose devices, such as a sniffer, or they can be turned into routers, switches or end-node hosts to control the traffic. The Simple Network Monitoring Protocol (SNMP) is the device that does not include traffic on the network for the measurements. Thus, PM is preferable than AM because only the actual user's packets are measured. The HM is a combination of active monitoring and passive monitoring. This scheme is deemed to provide a better solution by combining the advantages of these two methods. The HM would reduce the traffic by active probe but accuracy [2-3]. A pervasive computing means a paradigm shift from computer to embedded technology devices with powerful connectivity. With the combination of current technologies of wireless computing, Internet coverage and artificial intelligence, it could create an unobtrusive (readily available) environment.

Bandwidth Estimation Techniques

Three major techniques for bandwidth measurements for capacity and available bandwidth estimation, either in individual hops or end-to-end paths, are Variable Packet Size (VPS), Packet Pair/Train Dispersion (PPTD), Trains of Packet Pairs (TOPP). VPS measures capacity of each hop along a path. It measures the RTT from the source to each hop of the path as a function of the packet size. VPS probing forces the TTL (time to live) field of the IP header to expire probing packets at a particular hop. The source of probes receives an ICMP 'time-exceeded' error message from the routers along the path, when the probing packets expire [2]. Meanwhile, PPTD is the measurement of end-to-end path capacity. The source sends back-to-back multiple packet pairs of the same size to the receiver. This applies that spacing between the packet pairs is verified through the bottleneck link and preserved by the link of another higher-bandwidth [3-4]. While in TOPP, it estimates the available bandwidth of the network path by sending many packets at gradually increasing rates from source to sink. It measures the rate of sent packet pairs (offered rate) and also the rate at the receiver [4-5]. This method is analogous to SLoPS.

Table 1: Techniques of bandwidth measurement and metric

Technique	Estimate
VPS	Capacity of individual hops
PPTD	End-to-end capacity
SLoPS and TOPP	End-to-end available bandwidth

Bandwidth Estimation Tools

To monitor network band width metrics, many tools employing different principles, techniques and algorithms have been developed. The main purpose of this section is to describe various bandwidth measurements metric and explain different types of bandwidth estimation methodologies. This section also aims to present previous work done on available bandwidth estimation tools and their methodologies. Table 2 shows an example of several bandwidth measurement tools. Each tool applies different estimation methodologies.

Table 2: Available bandwidth estimation tools and methodology [5]

Tool	Author	Measurement Metric	Methodology
pathchar	Jacobson	Pre-hop Capacity	Variable Packet Size
clink	Downey	Pre-hop Capacity	Variable Packet Size
pchar	Mah	Pre-hop Capacity	Variable Packet Size
bprobe	Carter	End-to-End Capacity	Packet Pairs
nettimer	Lai	End-to-End Capacity	Packet Pairs
pathrate	Dovrolis-Prasad	End-to-End Capacity	Packet Pairs & Trains
sprobe	Saroiu	End-to-End Capacity	Packet Pairs
cprobe	Carter	End-to-End Available-bw	Packet Trains
pathload	Jain-Dovrolis	End-to-End Available-bw	Self-Loading Periodic Streams
IGI	Hu	End-to-End Available-bw	Self-Loading Periodic Streams
pathChirp	Ribeiro	End-to-End Available-bw	Self-Loading Periodic Streams
treno	Mathis	Bulk Transfer Capacity	Emulated TCP throughput
cap	Allman	Bulk Transfer Capacity	Standardized TCP throughput
ttcp	Muuss	Achievable TCP throughput	TCP connection
Iperf	NLANR	Achievable TCP throughput	Parallel TCP connections
Netperf	NLANR	Achievable TCP throughput	Parallel TCP connections

Wireless Bandwidth Estimation Tool: WBest

WBest is the tool designed for applications with faster time convergence but lower intrusiveness, like multimedia streaming. WBest operates on packet dispersion techniques to provide capacity and available bandwidth details using a two-step algorithm. At the first step, a packet pair technique will estimate the wireless network effective capacity whereas in the second step, the packet train scheme will calculate the achievable throughput before inferring its available bandwidth [5-6]. Table 3 summarizes the research gap of tools estimation bandwidth and Table 4 outlines the estimated available bandwidth median for 30 evaluations run on four bandwidth estimation tools (IGI-PTR, PathChirp, Pathload, WBest and RT-WABest (the variance of WBest)). The 'ground truth' indicates the exact available bandwidth.

Table 3: Research gap Wireless Estimation bandwidth tools

Author Research	Platform	Tools Evaluation	Strength	Weakness
Hu (2003)	Linux, Solaris, NetBSD	WBest	• Detecting available fraction of the effective capacity. • Mitigate estimation delay and the impact of random wireless channel errors.	• No significant changes of conditions in two steps of the WBest algorithm. • No overflow in the path.
Shriram (2005)	Linux	Pathload	• Analyzes available bandwidth on a path to a high degree of precision.	• Quite intrusive and hence does not really suit cellular networks.
Botta,Michaut (2005)	Linux	PathChirp	• Uses packet interarrival times to determine maximum bandwidth.	• Results in a large deviation due to the probing bit-rate; frequently has drastic changes.
Gupta (2009)	Linux	IGI	• Transmits packet trains with a growing time gap. • Evaluates relationship with the competing traffic.	• Less competing traffic where light traffic induces since smaller number of probing gaps.
Yang (2017)	Linux, Solaris, NetBSD	RT-WABest	• Low intrusiveness. • Short convergence time. • Improves the percentage of accuracy.	

Table 4: Estimated available bandwidth (Median, In Mbps)

Case	IGI/PTR	PathChirp	Pathload	WBest	Ground truth
0	8.11	30.15	6.78	28.47	28.94
1	8.74	28.89	6.81	23.24	24.39
2	10.06	27.59	6.91	15.76	20.52
3	1.92	5.00	1.95	1.01	0
4	1.12	14.50	1.69	0.00	0
5	9.99	26.91	7.07	22.87	24.50
6	9.62	26.98	6.78	14.56	-
7	1.48	5.00	1.10	0.00	0
8	0.66	11.97	0.92	0.00	0
9	6.89	25.60	6.47	13.26	16.26
10	0.67	5.72	0.99	0.00	0
11	0.59	9.95	0.48	0.00	0
12	0.77	12.73	1.06	0.00	0
13	5.18	16.79	5.99	13.99	15.26

The articles in [7-9] work on a high-speed testbed at the San Diego Supercomputer Centre on OC-48 and GigE paths in real-world networks. Available bandwidth estimation tools, such as Abing, PathChirp, RT-WABest, WBest, and Spruce, were tested and the result were compared. The results show that WBest is the most accurate tool under the conditions of our experiments, since we could not get the RT-WABest for testing during the simulation period [10-12]. Experiments and analytical evaluation are executed on the available bandwidth estimation tools in a controlled environment. The model based on a network of M/M/1 queues was included to have an analytical reference to compare the performance of state-of-the-art estimation bandwidth tools such as WBest, IGI, and Spruce. The WBest was recognized as accurate but slow in convergence [12-14].

Measuring bandwidth means focusing into both wired and wireless networks. A few characteristics were identified from the bandwidth measurement perspective. The differences between available bandwidth were measured [15-16] between a simple and light-weight tool called Spruce together with IGI and Pathload. Using Multi-Router Traffic Grapher (MRTG) to compare data, the experiment found that Spruce gives better accuracy compared to Pathload and IGI [17].

A work by [18] looks at end-to-end bandwidth with Iperf with Web100. The work is to investigate whether the TCP heap (Web100) can measure the exact accuracy of end-to-end bandwidth although with less bandwidth circle. The results show that Iperf using Web100 was able to finish even in slow-start and calculate the actual end. This means how much data was dispatched in 1 sec. The purchase of bandwidth rates differs by less than 10% when compared to Iperf with regards to 20 seconds. They conclude that the financial savings within bandwidth was up to 94% and financial savings of visitors was near to 92% [19]. For a broadband network, it requires a modification technique for capacity and the available bandwidth estimation based on endpoint measures. The focus has primarily been on setting where the constrained link can be modelled as a point-to-point link with a well-defined bandwidth, serving packet in FIFO. For example, in a cable modem link and 802.11 based wireless network, the possible mechanisms such as token bucket rate regulation, schedule packets in a non-FIFO manner and support for multiple distinct rates could be considered [20].

PROJECT METHODOLOGY

The project methodology (as shown in Figure 1) consists of 9 phases i.e., planning, information gathering, determining the tool requirement, installation and configuration, source code modification, data transfer, web development, result analysis and finally, the documentation.
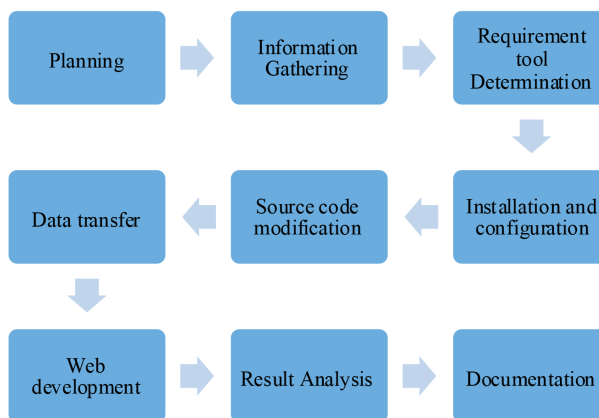

Figure 1: Project methodology

Planning is the most important thing before starting a project. All information and requirements must be identified to ensure that planning can be done successfully. Therefore, this phase requires the researcher to define goals and objectives of this project as milestones in order to complete it. All objectives must be taken into consideration to make sure that it can be achieved successfully. Furthermore, this phase also needs the researcher to do a feasibility study and determine any possible constraints regarding the research topic. The main idea is to give a brief overview to the researcher about how the project that is going to be developed.

The second phase is information gathering. Similar projects, case studies and white papers that contain information related to the project are reviewed. Some of the information is gathered from electronic as well as non-electronic mediums. It is important to have a better understanding and in-depth knowledge about the project to avoid misunderstanding. The resources for data collection are accumulated from a variety of electronic media and non-electronic media.

The third phase is installation and configuration of selected Wireless Bandwidth Estimation tools WBest and NUTTP for packet injection. WBest has two executable files called wbest_snd and *wbest_rcv*. The first file, wbest_snd works on the sender while wbest_rcv is on the receiver. To start the WBest estimation, *wbest_rcv* is initiated on the receiver and followed by *wbest_snd* on the sender. The standard operating procedure for installation processes starts with unpacking the WBest package at both sides (receiver and sender). Second, change the directory. Third, run the commands (*execute. /configure.*) and finally, run the command *execute make.*

The fourth phase is source code modification, where it describes how the process of the algorithm of WBest to work. Process of WBest is depicted in Figure 2.
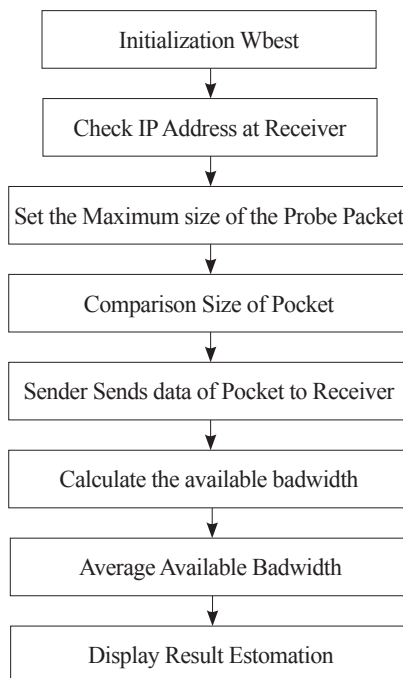

Figure 2: WBest processes

The fifth phase is to transfer the results into the MySQL database for the implementation into web-based development as in the sixth phase. Then, the overall results that are viewed through the web could be analyzed in real-time analytic mode. Lastly, the documentation is include into the dissertation prior to final presentation during viva voce.

EXPERIMENTATION

Experimentation is done in hardware with the specifications of Ubuntu 10, Acer Aspire 4920 with Intel® Core™ 2 Duo CPU T5550 @ 1.83Ghz on 400 front bus speed. The level 2 cache is of standard type with 160GB hard disk and 2GB SDRAM memory. The Network Interface Card is Broadcom Netlink ™ Gigabit Ethernet and Mobile Intel® GMA X3100 chipset display cards. The list of software requirements for simulation purposes are depicted in Table 5.

Table 5: Software specification for simulation purposes

Operating System	Window XP/Win 7
	Ubuntu v12
Wireless Bandwidth Estimation Tool	WBest
Monitoring Tool	MRTG
Injection Packet	Nuttcp
Web Application	Wamps
	Php
	Adobe Photoshop CS8
	Macromedia Dreamweaver
Database	MySQL

a. ***Simulation 1***

The testing is done using Wireless Mode 11 Mbps 802.11 b. The objective is to show the result of median available bandwidth of WBest in mode 11 of 802.11 b. The design of physical topology includes two computers, and one router, as illustrated in Figure 3.
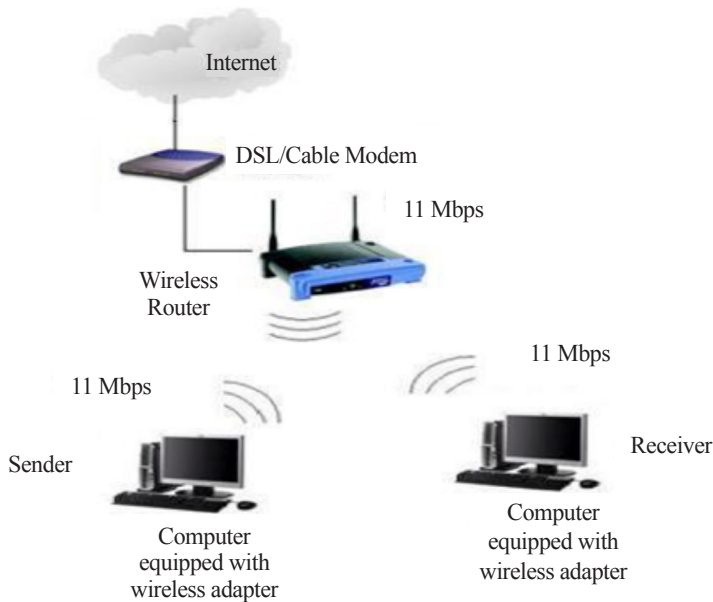
Figure 3: Physical topology of Wireless Mode 11 Mbps 802.11 b

The results of running simulation 1 is tabulated in Table 6, where the first device is Computer 1 as a sender and device 2 refers to Computer 2 as a receiver, while device 3 is a router.

Table 6: Network connection for each device in Wireless Mode 11 Mbps 802.11 b

Item	Device	Specification
1	Computer 1: Sender	11 Mbps
2	Computer2: Receiver	11 Mbps
3	Router	11 Mbps

b. Simulation 2

The testing is done using Wireless Mode 54 Mbps 802.11 g. The objective is to show the median available bandwidth of WBest in a Wireless Mode 54 Mbps 802.11 g. Figure 4 shows the design of physical topology and device use in this experimentation and the topology includes two computers and one router. The network connection for each device in 54801MBps and Fast Ethernet environments is shown in Table 7.
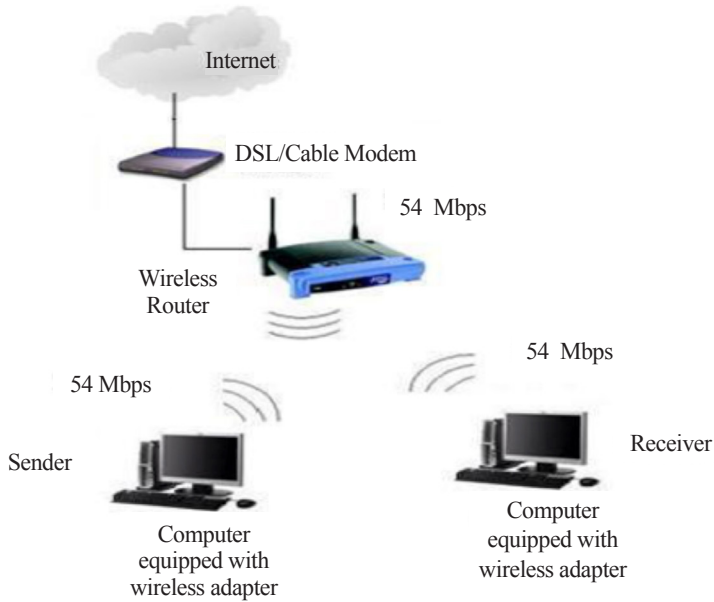
Figure 4: Physical topology of Wireless Mode 54 Mbps 802.11 g

Table 7: Network connection for each device in Wireless Mode 11 Mbps 802.11 b

Item	Device	Specification
1	Computer 1: Sender	54 Mbps
2	Computer 2: Receiver	54 Mbps
3	Router	54 Mbps

RESULTS AND DISCUSSION

From the analysis results, it can be concluded that estimating available bandwidth using WBest is suitable for various types of wireless network environments. It shows the estimation of available bandwidth by bandwidth detection is accurate since the results estimation are close to real value available bandwidth. To study the sensitivity of network-aware delivery to the accuracy of Bandwidth Detection Mechanism (modified WBest) in realistic scenarios (exhibiting varying degrees of bandwidth volatility), we have conducted the following experiment as illustrated in Table 8.

Table 8: Simulation result of median available bandwidth in Wireless Mode 54 Mbps 802.11 g
done on Friday, 2ⁿᵈ July 2021

No.	Available Bandwidth using 0% Traffic Injection (Mbps)	Available Bandwidth using 25% Traffic Injection (Mbps)	Available Bandwidth using 50% Traffic Injection (Mbps)
1	15.42	10.47	9.38
2	16.89	10.46	9.20
3	15.12	9.48	8.19
4	15.48	11.78	6.32
5	16.01	8.74	8.01
6	15.85	9.11	8.50
7	16.42	9.56	9.60
8	15.86	10.68	9.45
9	14.33	10.10	9.74
10	16.39	10.65	9.81
11	16.01	11.78	6.05
12	15.15	10.40	7.75

Figure 5 shows the 3 different packet injections of 0%, 25% and 50%. The graph is plotted showing the available bandwidth of different packet injections into minutes allocation. The more packets are injected, the less available bandwidth is allocated.
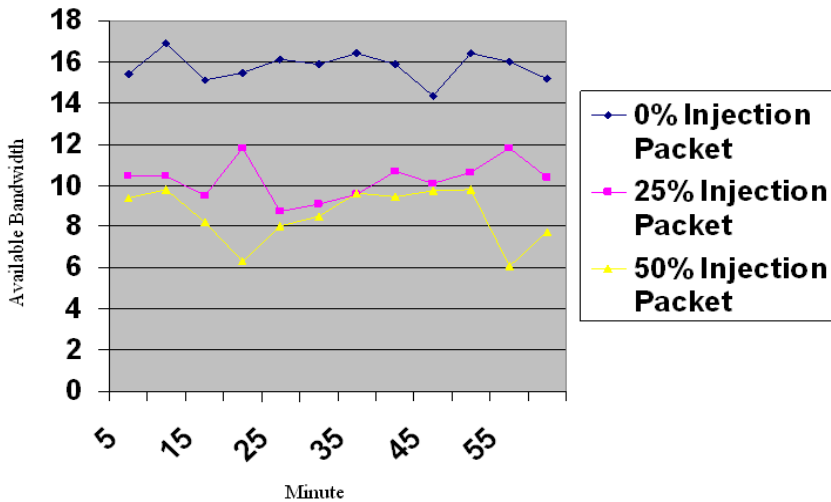

Figure 5: Wireless bandwidth detection mechanism in Wireless Mode 54 Mbps 802.11 g Environments

Both simulations are done using Nuttcp tool traffic injection packet and Wireless Bandwidth estimation tool (WBest). From the results gained, it yields that there was a significant improvement on the internet wireless network or multimedia application performance in IEEE 802.11 wireless network. The solution of Wireless Bandwidth estimation is designed for fast, non-intrusive, accurate estimation of available bandwidth in IEEE 802.11 wireless network and can be used by the streaming multimedia application to improve the wireless network.

CONCLUSION

Bandwidth estimation measurement produces a significant impact on wireless network conditions such as other traffic contention as well as adapting the rate. Thus, inaccurate estimates may cause high and varying convergence times and intrusiveness. A few available tools might be impractical for applications running over a wireless link, such as streaming media, that require fast, accurate, non-intrusive bandwidth estimates. But the result is in contrast to WBest. Based on our experimentation, WBest is found to consistently provide a quickly available bandwidth estimation, with lower intrusiveness over three different packet injection conditions. To provide effective bandwidth related information, WBest should be configured to use the same packet size as the application.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

ACKNOWLEDGEMENTS

REFERENCES

[1] S., Banerji & R. S., Chowdhury. (2013). On IEEE 802.11: Wireless LAN Technology. arXiv preprint arXiv:1307.2661. *International Journal of Mobile Network Communication & Telematic (IJMNCT)*, *3*(4).

[2] M. X., Gong, B., Hart & S., Mao. (2015) Advanced wireless LAN technologies: IEEE 802.11 ac and beyond. *GetMobile: Mobile Computing and Communications*, *18*(4), 48-52.

[3] C., Jinwei, K. M., McNeill, D., Zhang & J. F., Nunamaker. (2004). An overview of network-aware applications for mobile multimedia delivery. *Proceedings of the 37th Annual Hawaii International Conference on System Sciences* (pp-10). IEEE. doi: 10.1109/HICSS.2004.1265689

[4] J. Hui & J. A. Smith. (2020). *U.S. Patent No. 10,587,720*. Washington, DC: U.S. Patent and Trademark Office.

[5] O. Ayodeji, A., Aderounmu, O., Obembe & F., Ogwu. (2006). An efficient host-to-host available bandwidth estimation scheme.

[6] A. Ferrari, M. Cantono, B. Mirkhanzadeh, Z. Lu, A. Shakeri, C. Shao, C., & V. Curri. (2018). *A two-layer network solution for reliable and efficient host-to-host transfer of big data.* 20th International Conference on Transparent Optical Networks (ICTON) (pp. 1-4). IEEE.

[7] R. Prasad, C. Dovrolis, M., Murray & K. C. Claffy. (2003). Bandwidth estimation: Metrics, measurement techniques and tools. *IEEE Network*, *17*(6), pp. 27-35.

[8] G. P. Jesi & G. Mazzini. (2020). *Banda Calculus: A tool for bandwidth estimation in broadband network infrastructures*.

28th International Conference on Software, Telecommunications and Computer Networks (SoftCOM) (pp. 1-5), IEEE.

[9]   M. Li, M. Claypool & R. Kinicki. (2006). Packet dispersion in IEEE 802.11 wireless networks. *Proceedings of 31st IEEE Conference on Local Computer Networks* (pp. 721 – 729).

[10] T. Yang, Y. Jin & Y. Chen. (2017). RT-WABest: A novel end-to-end bandwidth estimation tool in IEEE 802.11 wireless network. *International Journal of Distributed Sensor Networks*, *13*(2), 1550147717694889.

[11] A. Shriram, M. Murray, Y. Hyun, N. Brownlee, A. Broido & M. Fomenkov. (2005). Comparison of public end-to-end bandwidth estimation tools on high-speed links. In *International Workshop on Passive and Active Network Measurement* (pp. 306-320), Berlin, Heidelberg: Springer.

[12] T. Yang, J. Yuehui, C. Yufei & J. Yudong. (2017). RT-WABest: A novel end-to-end bandwidth estimation tool in IEEE 802.11 wireless network. *International Journal of Distributed Sensor Networks*, *13*(2), 1550147717694889.

[13] E. Goldoni & M. Schivi. (2020). End-to-end available bandwidth estimation tools, an experimental comparison. In *International Workshop on Traffic Monitoring and Analysis* (pp. 171-182). Berlin, Heidelberg: Springer.

[14] C. D. Guerrero & M. A. Labrador. (2006). Experimental and analytical evaluation of available bandwidth estimation tools. *Proceedings of 31st IEEE Conference on Local Computer Networks* (pp. 710-717). IEEE.

[15] F. Ciaccia, I. Romero, O. Arcas-Abella, D. Montero, R. Serral-Gracià & M. Nemirovsky. (2020). Sabes: Statistical available bandwidth estimation from passive TCP measurements. *IFIP Networking Conference (Networking)* (pp. 743-748). IEEE.

[16] A. Johnsson. (2005). *Bandwidth measurements in wired and wireless networks*. Department of Computer Science and Electronics, Mälardalen University.

[17] W. Shi & G. Chen. (2021). Research on bandwidth allocation strategy of train communication network based on time division multiplexing. *Procedia Computer Science*, *183*, (pp. 448-455).

[18] J. Strauss, D. Katabi & F. Kaashoek. (2003). A measurement study of available bandwidth estimation tools. *Proceedings of the 3rd ACM SIGCOMM conference on Internet measurement*. (pp. 39-44).

[19] A. Tirumala, L. Cottrell & T. Dunigan. (2003). Measuring end-to-end bandwidth with Iperf using Web100. *Proc. of Passive and Active Measurement Workshop (PAM)*.

[20] K. Lakshminarayanan, V. N. Padmanabhan & J. Padhye. (2004). Bandwidth estimation in broadband access networks. In *Proceedings of the 4th ACM SIGCOMM Conference on Internet Measurement* (pp. 314-321).