Engineering and Technology Journal 40 (08) (2022) 1006- 1013

Engineering and Technology Journal
Journal homepage: https://etj.uotechnology.edu.iq

An Enhanced Interface Selectivity Technique to Improve the QoS for the Multi-homed Node

Haider W. Oleiwi [a]*, **Nagham Saeed** [b], **Heba L. Al-Taie**[c], **Doaa N. Mhawi** [d]

[a] Department of Electronic and Electrical Engineering, Brunel University London, London – UK.
[b] School of Computing and Engineering, University of West London, London – UK.
[c] Information and Communication Technologies Center, Ministry of Construction and Housing, Baghdad – Iraq.
[d] Department of Computer Systems Techniques, Middle Technical University, Baghdad – Iraq.
*Corresponding author Email: Haider.Al-Lami@brunel.ac.uk

HIGHLIGHTS

- The paper introduces a reliable system, providing a sufficient solution for the associated nodes during hand-offs.
- It investigates different QoS mechanisms, deploying each mechanism into various interfaces, and overall network performance when nodes switch between available interfaces.
- It compares overall performance and feasibility of QoS mechanisms with the single-homed and multi-homed networks/nodes (site/host multi-homing) fluctuating resource availability.

ARTICLE INFO

Handling editor: **Ivan A. Hashim**

Keywords: Multi-homing; QoS; Interface Selection; Best-effort; DiffServ; IntServ; IntServ-DiffServ

ABSTRACT

The user's hand-off is still an arguable issue that many mobile communication systems face, especially with the exploded growth of users and internet-based applications. Hence, there is a critical need for adequate quality of service (QoS) to meet the stringent requirements. This paper aims to study the overall performance and feasibility of several QoS mechanisms with the single-homed and multi-homed networks/nodes fluctuating resource availability. It investigates the adaptability of multi-interfaced multi-homed techniques to enhance the essential governing parameters, i.e., throughput, end-to-end latency, processing time, and jitter. Moreover, the paper introduces an interface selectivity technique for the multi-homed node to adopt the optimal interface, which offers the best services to explore the enhancements of the overall network performance. The overall results show how the introduced mechanism managed to keep the communication going on the multi-homed node. Furthermore, the results show that site multi-homing provides a better overall end-to-end latency over host multi-homing as it supports the entire network.

1. Introduction

For simultaneous internet ubiquity, reliable communication is required; therefore, various techniques and equipment were invented [1][2]. Hence, integration between the technologies is required to achieve the targeted objective. Usually, the communication paths will be directed to another interface due to connection losses or changes in network status. Researchers proposed many technologies to utilize available resources, meaning to make the best use of the bandwidth (BW) available [3][5]. Several techniques were suggested to adopt the best protocols based on the connectivity type or user's priorities [5]. The network's performance is highly based on its interfaces which require various resources with different costs. There is always a trade-off between the users' required QoS and the cost-effectiveness. The interface performance changes depending on the accessing ranges. In the wireless communication networks, the associated users nominate the best available interfaces and their suitability according to specific conditions, e.g., mobility and condition change [6]. The user equipment (UE) can adopt the best interface/s to obtain the best network resources and maintain its QoS. On the other hand, Internet traffic rates are growing rapidly globally with a wide variety of internet-demanding applications. To overcome the limitations compelled by multimedia applications and maintain high QoS, the network, end systems, and users should process successful handed-over techniques. The networking QoS mechanisms provide the required tools to manage and control resources efficiently. Hence,

http://doi.org/10.30684/etj.2022.133066.1165
Received 18 February 2022; Accepted 9 April 2022; Available online 15 May 2022
2412-0758/University of Technology-Iraq, Baghdad, Iraq

resources management [7] is important to enhance the required services for data-hungry applications, explode the number of users and balance the simultaneous network-demanding rates with resource availability. This paper is organized as follows; in the next section, we discussed the related literature, following it up with the design methodology section. Then we showed and discussed the results in section 4, and finally, we concluded the research findings in section 5.

2. Related literature

Single-homing technique [8] was the first Internet-access technique approved with which the single-homed network communicates with only one Internet Service Provider (ISP) to access all the targeted ends. Due to limited resources, the network will deliver poor performance, e.g., the scarcity of end-to-end routes due to high demands. Later, the multi-homing technique [9] was proposed to present a reliable system with better performance in delivering the required services. Figure 1 depicts multi-homing architecture. It is worth noting that the end node can be linked to multiple ISPs to establish reliable internet access [11][11].

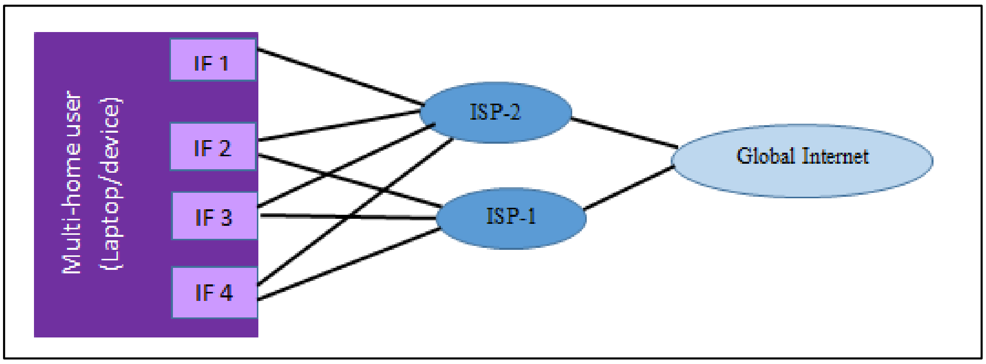

Figure 1: Multi-homing architecture

Multi-homing users associate with multiple ISPs via multiple networks demanding various services. However, the user compares the available services provided by multiple ISPs in terms of cost-effectiveness, security, and QoS, prioritizing the best ISP. In case of connection failure or insufficiency of the internet provider, the node will keep its ongoing internet access connection using another associated internet provider alternatively. The multi-homing technique has associated mechanisms with providing alternative routes upon connection failure by redirecting traffic to an available connection and has the required mechanisms to select the best route whenever more than one route is available [12]. This strategy provides load-balancing with the possibility of distributing the traffic onto the available number of associated ISP links, e.g., the system administrator can prioritize the important traffic by linking it with a certain interface and registering it to a preferable ISP. However, achieving a stable connection with a smooth hand-off is essential. Multi-homing is classified into; host multi-homing, with which the host has several network interfaces, and site multi-homing, with which the entire network has redundant paths [13]. In conclusion, multi-homing is becoming more preferred for the networks and the end nodes. The multi-homing technique enables the communication networks to deliver highly qualified services, improve the speed [14] and enhance the stability of services to the nodes [15]. It reveals the multi-homing practicability and its capability in avoiding connection failure, providing user-reachability, and selecting the right ISP [16]. Multi-homing can be utilized with the mobile IP to obtain reliable and scalable connectivity and achieve the required internet ubiquity, leading to enhancing the communication network performance. Hence, mobile IP was proposed to support the Internet's host mobility, and it has both IPv6 and IPv4 protocols. The home address addresses the home gateway as a home agent, while the visiting gateway is a foreign agent [17]. Thus, the multi-homing concept provides an added value by registering the visiting agents as home agents at the repeatedly visited destinations.

3. Design methodology

One of the Internet's most distinguishing features is its networking technology diversity. Therefore, it is arguable whether the Internet can supply an ultimate end-to-end QoS. If the prevalence of the QoS-capable technology reaches a sufficient degree, this implies that the core internet may be able to provide a certain level of service. It is worth noticing that there are many network solutions at the network's edges. QoS can be characterized as a set of precisely specified metrics such as data loss, latency, jitter, and network resource utilization linked to the sensation or notion of quality that a network user has. The most difficult aspect of defining QoS as a function of the measures and the human factor is defining it as a function of both. In general, when we describe networks, QoS indicates that a user of a service obtains a predetermined network's resources, delivering the users' packets to the destinations within the given parameters and performance limitations [18]-[21]. Because of the current software improvements and the emergence of new services with increased commercial activities, QoS and Class of Service (CoS) [24] are supposed to be added to the Internet. Below is a classification for multi-home technologies:

3.1 Differentiated Service (diffserv)

It is a set of technologies that enable ISPs to provide various types of services to various customers and related traffics. The differentiated service (DiffServ) is designed to provide a modular solution to IP QoS for various applications. Its protocols are designed to allow scalability and service recognition on the Internet without requiring a per-flow state or signaling at each hop [25][27]

3.2 Integrated service (Intserv)

The rise of various spectrum-hungry or latency-sensitive applications necessitates the availability of adequate QoS or other network performance assurances. Hence the integrated service (IntServ) was proposed [28]. The adopted resource reservation protocol (RSVP) with IntServ is an example of this service. The IntServ mechanism has proposed several service types; however, only two were defined: a) An assured service with a guaranteed scale of BW, a definite end-to-end latency restriction, and no lining-up losses for the traffic's corresponding packets. b) A controlled-load service that offers no quantitative association assurances but strives to supply the traffic with a service quality comparable to a lightly laden network.

3.3 Intserv-diffserv

The telecom community adopts the assumption that IntServ and DiffServ mechanisms cannot solely support a multiple services network architecture [29]. As a result, a proposal was made to merge the two mechanisms, employing the IntServ at the network's edge and DiffServ within the core network. The most used reference model for supporting the IntServ-DiffServ collaboration in the state-of-the-art involves a DiffServ area in the center of two IntServ-supported regions, as illustrated in Figure 2.

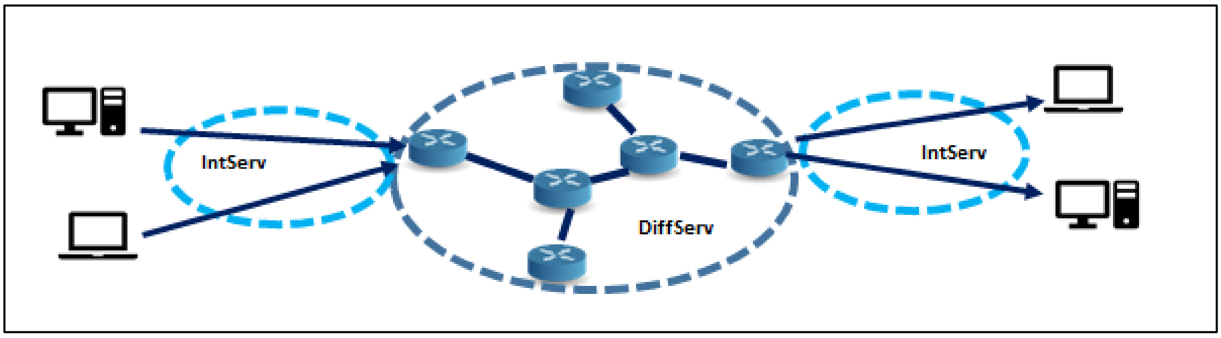

Figure 2: IntServ-DiffServ architecture

The work in this paper thoroughly investigates the OoS for these three services in several simulation scenarios. In our previous work [30], we compared wireless communication models with IntServ, DiffServ, and IntServ-DiffServ services and discussed the difference in their performance. In this paper, we proceed to evaluate QoS mechanisms thoroughly based on communication performance improvement under multi-homed networking and fluctuating resource availability and how to merge these mechanisms within the communication network to ensure the delivery of the optimal end-to-end QoS to the users. We studied the main QoS parameters to evaluate the overall network performance, i.e., the throughput of producing packets, end-to-end latency, packet processing time at intermediary nodes, and disconnecting jitter. The implementation is as follows: The correspondence node (CN), represented by the laptop and PC in figure 2, sends information to the multi-homed network or the multi-homed node over the core network. The received traffic performance will be investigated concerning single or multi-homed destinations. In both cases, the QoS will be carried out within the network; traffics of best-effort (no QoS guarantees), DiffServ, IntServ, and IntServ-DiffServ are all options. One case considers the destination has a single interface and is single-homed (router or node). The other case scenarios will have the destination a multi-homed router (i.e., site multi-homing) or a node (host multi-homing) with multiple interfaces to connect with the CN and compare the overall results. The multi-homing scenarios are implemented as; the multi-homed end-node is connected to several interfaces, and the link goes down every five seconds. This scenario allows the handover analysis to the communication network. As a result of the link breaking down, the node needs to switch from one link to another to keep the communication going. The links were set with different QoS's, starting from the best-effort link to the DiffServ only link, the IntServ link, and finally the IntServ-DiffServ link. The introduced mechanism of interface selectivity in this paper considers the QoS offered by each interface. The proposed mechanism gives the node the ability to maintain the communication going on the multi-homed node along with the hand-off between the access points. Moreover, the mechanism keeps the throughput at an acceptable level as much as possible and reduces the overall end-to-end latency to as minimal as possible. The interface(s) selectivity considered its influential parameters based on the path characteristics that the targeted interface(s) are connected to. The coming section explains the feasibility of multiple interfaces with the multi-homing, demonstrating the benefits of this strategy to increase communication reliability and improve network performance.

4. Simulation results and Discussion

The simulation results are based on the Network Simulator (N2). As mentioned previously, the simulation results will compare both the site multi-homing versus the single-homing scenario and the host-Multihoming versus the single-homing scenario. Simulation time was 32 s, whereas a longer time was set for jitter examinations to achieve the best accuracy. The dedicated interfaces were assumed for each mechanism in multi-homing scenarios.

4.1 Single homing Vs. Site multi-homing

This case investigated two communications that took place. The first is between the CN with a single-homed and best-effort destination (a router with one interface). The second is with CN with a multi-homed router (i.e., the site Multi-homing), which has multiple interfaces to communicate with the CN. The router is connected to the other nodes in the network, and it is responsible for the node registration while the network moves from one point to another. Similarly, when one of the connections fails, the site multi-homed destination is switched to the most adequate associated link of the four mechanisms' links to communicate with the CN. The results for the performance parameters are shown below:

4.1.1 Throughput of Generating packets at CN

The results in Figure 3 show the producing packets' throughput at the CN against the simulation time in single homing and site multi-homing scenarios. It shows the graphs for single-homed with a best-effort destination (a router with one interface) and site multi-homed with various mechanisms destination (a router with multiple interfaces). Both graphs begin with the best-effort technique. The two scenarios begin with the best effort; then, the link breaks down after 5 seconds. As illustrated in Figure 3, there is a noticeable difference in the network performance when the connection drops at second 5, demonstrating the behavior of the two scenarios. In the single-homed, the connection stayed down for 25 seconds, after which the destination must register and receive acknowledgment (i.e., link recovery) from every two intermediatory nodes, resulting in the next link recovery taking about 32 seconds. However, with the site multi-homing, we observe that the destination can redirect its communication to other paths when the connection fails, resulting in a highly reliable connection guiding to high performance. Additionally, we observe a distinct throughput value every 5sec, as the router switches among various interfaces with different QoS mechanisms every 5 seconds. Thus, the throughput for the site multi-homing network was better than the best-effort network.

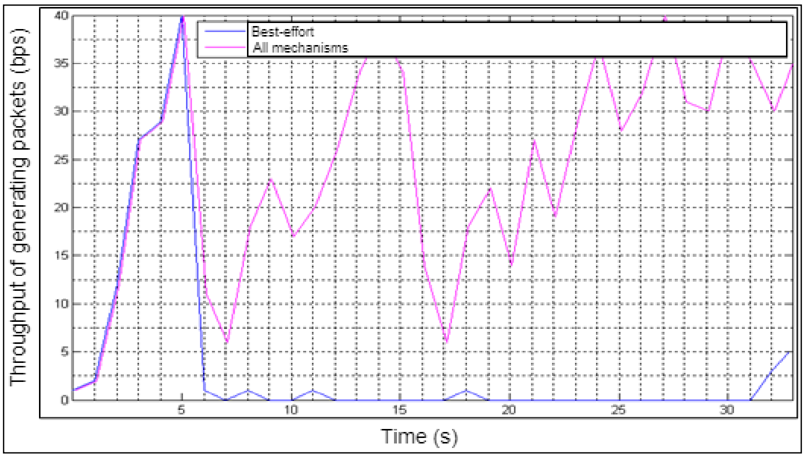

Figure 3: Throughput of generating packets at CN Vs. time

4.1.2 Jitter

Figure 4 shows the variation in the time delay between when a signal is transmitted and when it's received over the network connection for the two scenarios through simulation time. Both cases show the same start of the simulation jitter, but when the initial connection fails, the jitter jumps in the case of the single-homed scenario, as shown in Figure 4, around time 100 sec. However, the jitter stays around the same values in the case of the multi-homed router, as the router can switch to another interface. Hence, the jitter for the site multi-homing network was better than the best-effort network.

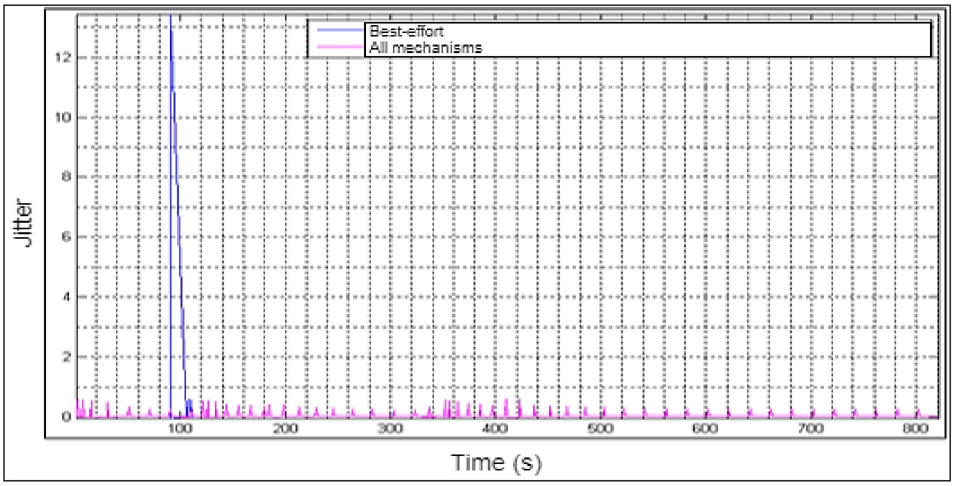

Figure 4: Simulation time Vs. jitter

4.1.3 End-to-end latency

Figure 5 shows the end-to-end latency over the simulation time for the two proposed scenarios. Similarly, the two scenarios show the same start in the first 5 seconds, as they both use the same interface. However, after t= 5 sec, the single-home case shows a steady end-to-end delay as the CN keeps trying to reach the router with no reply (i.e., it reaches the last point where the connection was on before). This is an indication of ineffective engagement in the communication process. Whereas the site multi-homed router, after t=5 sec, continued to engage with the communication process showing different variations in the end-to-end delay and some edges every 5 seconds as it moves from one access point to another. But, the overall advantage of keeping the communication going makes it a much better choice than the single-homed scenario.

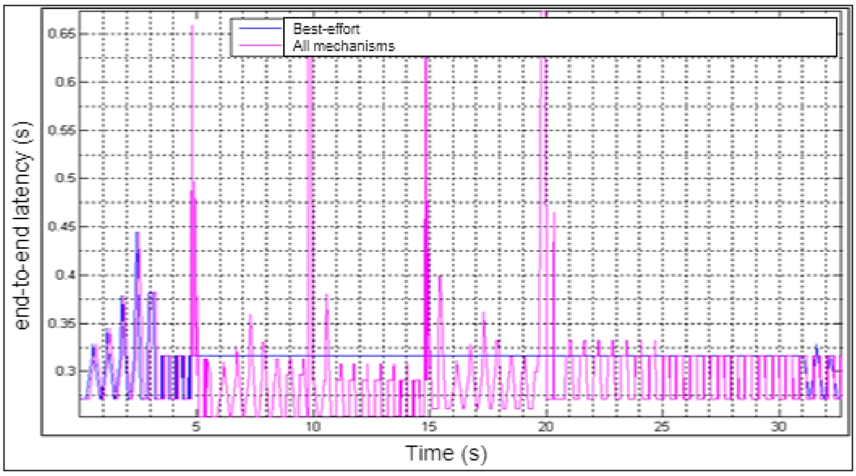

Figure 5: End-to-end latency

4.2 Single homing vs. Host multi-homing scenarios

In this section, the performance of the CN communication with the single-homed node and multi-homed node (i.e., host multi-homing) was investigated. The same parameters examined in the previous section will be examined in this section. In this case, the destination has multiple interfaces to communicate with the CN.

4.2.1 Throughput of generating packets at CN

Figure 6 depicts the various throughput values of the two scenarios. The simulations start with best-effort QoS. After 5 seconds, the connection is cut off and stays off up to 25 seconds in the single-homed case. The destination requires links registration and recovery to maintain the connection with the CN; thus, the communication starts again after approximately 12 seconds. However, the multi-homed node can switch among different interfaces to preserve the communication with the CN. The result shows that the node managed to keep the communication going along with the entire time. Although the figure shows the throughput drops while the node moves from one access point to another (i.e., from one link to another with different QoS’s), the node maintains ongoing communication with the CN with minimum cost.

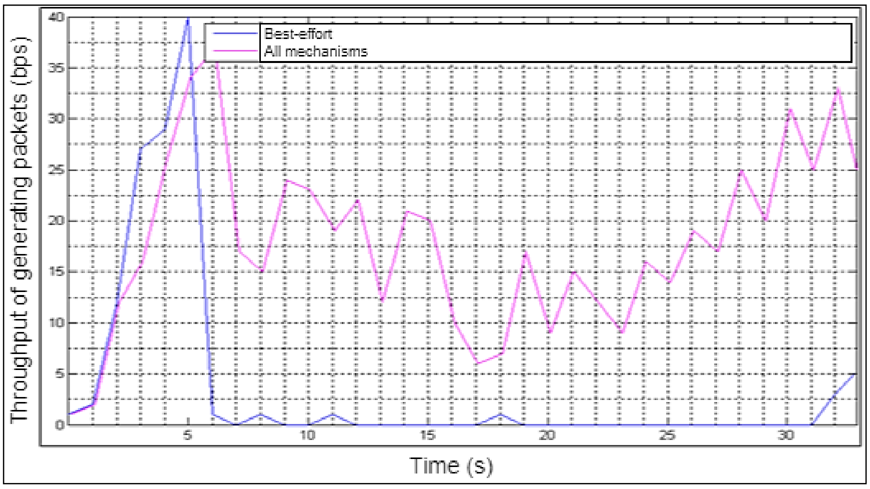

Figure 6: Throughput of generating packets at the CN Vs. time

4.2.2 Jitter

Figure 7 illustrates the difference between the simulation jitter in the single-homed and multi-homed cases. As discussed previously, the multi-homed host shows better (i.e., steady) jitter over the simulation time, as it managed to switch between different interfaces according to which one is available. However, for the second time, the single-homed host shows a jump in the simulation jitter when the node lost its connection (i.e., the interface failed or cut off). After that, the node will lose communication until the link is up again after 20 seconds.

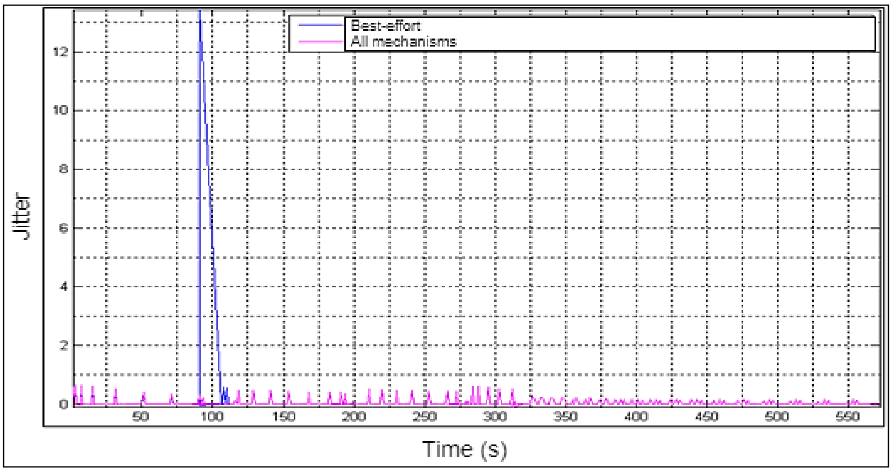

Figure 7: Simulation event time Vs. jitter

4.2.3 End-to-end latency

Similarly, figure 8 depicts the end-to-end latency and how the multi-homed node with IntServ, DiffServ, and IntServ-DiffServ mechanisms maintains ongoing communication with the CN. However, there are some edges due to the handover from one access point to another. Moreover, the single-homed node loses communication after the 5th second as the link goes down. The end-to-end latency in the single-homed case remains constant until the links are on again and the nodes start the communication all over again, around the 32nd second of the simulation time.

The noticeable impact of these parameters on the overall network performance; the results are comparable to the finding mentioned previously, explaining how the various mechanisms perform regarding processing, latency, distances, system throughput, and jitter.

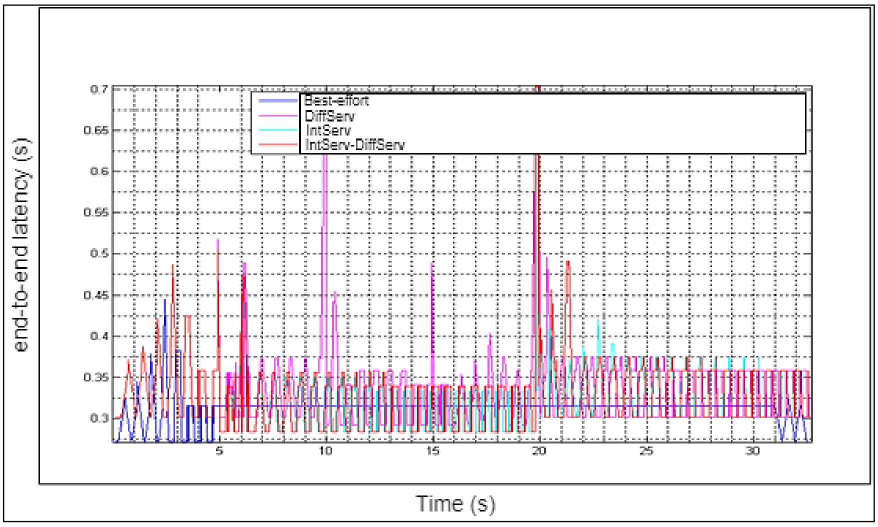

Figure 8: End-to-end latency

5. Conclusion

Multi-homing technology presents a remarkable enhancement for overall communication performance. Therefore, it is extremely useful to study the performance of the multi-homed networks, as it represents the current wireless communication networks. However, there is still an urgent need for comprehensive studies to address the weak points, state the required procedures, and develop a decent communication system to meet the essential requirements with adequate performance. This paper thoroughly studied different QoS mechanisms; best-effort, DiffServ, IntServ, and IntServ-DiffServ. It studied the effects of deploying each one of them into various interfaces and how the overall network performance would be increased if the node managed to switch between them according to their availability. The paper compares two multi-homing scenarios (i.e., site multi-homing and host multi-homing) with the single homing scenario. Finally, the overall results show how the switching mechanism defined in this paper managed to maintain ongoing communication between the CN and the multi-homed node, showing how the network's overall performance was improved almost perfectly.

Author contribution

All authors contributed equally to this work.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

References

[1] I. El-Dessouki , N. Saeed, Smart Grid Integration into Smart Cities, IEEE International Smart Cities Conference (ISC2), Manchester, United Kingdom, (2021) 1-4.https://doi.org/10.1109/ISC253183.2021.9562769

[2] A. Anwar, N. Saeed ,P. Saadati, Smart Parking: Novel Framework of Secure Smart Parking Solution using 5GTechnology, IEEE International Smart Cities Conference (ISC2), Manchester, United Kingdom, (2021) 1-4. https://doi.org/10.1109/ISC253183.2021.9562776

[3] H. W. Oleiwi, H. Al-Raweshidy, Cooperative SWIPT THz-NOMA / 6G Performance Analysis, Electronics, 11 (2022) 873. https://doi.org/10.3390/electronics11060873

[4] H. W. Oleiwi, N. Saeed, and H. Al-Raweshidy, Cooperative SWIPT MIMO-NOMA for Reliable THz 6G Communications, Network, 2 (2022) 257-269. https://doi.org/10.3390/network2020017

[5] N. H. Saeed, M. F. Abbod, H. S. Al-Raweshidy, O. Raoof, Intelligent MANET routing optimizer, 2008 5th International Conference on Broadband Communications, Networks and Systems, London, UK, (2008) 359-365. https://doi.org/10.1109/BROADNETS.2008.4769107

[6] N. H. Saeed, M. F. Abbod , H. S. Al-Raweshidy, IMAN: An Intelligent MANET routing system, 2010 17th International Conference on Telecommunications, Doha, Qatar, (2010) 401-404. https://doi.org/10.1109/ICTEL.2010.5478779

[7] H. Azarhava, J. Musevi Niya, Energy Efficient Resource Allocation in Wireless Energy Harvesting Sensor Networks, IEEE Wireless Commun. Lett., 9 (2020) 1000-1003. https://doi.org/10.1109/LWC.2020.2978049

[8] M. Kolberg, E. H. Magill, M. Wilson, Compatibility issues between services supporting networked appliances, IEEE Commun. Mag., 41 (2003) 136-147. https://doi.org/10.1109/MCOM.2003.1244934

[9] O. Raoof, H. Radhi, H. S. Al-Raweshidy , Z. Jerjees, Dynamic interface/network selection mechanism approach for multi-homed wireless nodes, 2009 5th IEEE GCC Conference & Exhibition, Kuwait, Kuwait, (2009) 1-4, https://doi.org/10.1109/IEEEGCC.2009.5734251

[10] M. Ismail, W. Zhuang, Decentralized Radio Resource Allocation for Single-Network and Multi-Homing Services in Cooperative Heterogeneous Wireless Access Medium, IEEE Trans. Wireless Commun., 11 (2012) 4085-4095. https://doi.org/10.1109/TWC.2012.091812.120329

[11] M. Niraula, T. McParland, Aviation Safety Service IPV6 Based Air-To-Ground Communication: Multi-Homing Challenges, 2019 Integrated Communications, Navigation and Surveillance Conference (ICNS), Herndon, VA, USA, (2019) 1-5. https://doi.org/10.1109/ICNSURV.2019.8735276

[12] X. Wang, M. Jia, Q. Guo, I. W. -H. Ho, J. Wu, Joint Power, Original Bandwidth, and Detected Hole Bandwidth Allocation for Multi-Homing Heterogeneous Networks Based on Cognitive Radio, IEEE Trans. Veh. Technol., 68 (2019) 2777-2790. https://doi.org/10.1109/TVT.2019.2892184

[13] P. Bellavista, A. Corradi , C. Giannelli, Differentiated Management Strategies for Multi-Hop Multi-Path Heterogeneous Connectivity in Mobile Environments, IEEE Trans. Netw. Serv. Manage., 8 (2011) 190-204. https://doi.org/10.1109/TCOMM.2011.072611.100066

[14] H. Adhari, T. Dreibholz, M. Becke, E. P. Rathgeb, M. Tüxen, Evaluation of Concurrent Multipath Transfer over Dissimilar Paths, 2011 IEEE Workshops of International Conference on Advanced Information Networking and Applications, Biopolis, Singapore, (2011) 708-714. https://doi.org/10.1109/WAINA.2011.92

[15] L. Zheng, X. Zhang, S. Zhang, X. Chen, Research on Multi-path Network in Cloud Computing Based on SCTP, 2021 8th IEEE International Conference on Cyber Security and Cloud Computing (CSCloud)/2021 7th IEEE International Conference on Edge Computing and Scalable Cloud (EdgeCom), Washington, DC, USA, (2021) 30-35, https://doi.org/10.1109/CSCloud-EdgeCom52276.2021.00016

[16] Z. Jerjees, H. Al-Raweshidy, A Novel Mechanism to Select Better Multi-homed MIPv6 Networks, 2008 The Second International Conference on Next Generation Mobile Applications, Services and Technologies, Cardiff, UK, (2008) 136-141. https://doi.org/10.1109/NGMAST.2008.58

[17] B. Feng, H. Zhang, H. Zhou ,S. Yu, Locator/Identifier Split Networking: A Promising Future Internet Architecture, IEEE Communications Surveys & Tutorials, 19 (2017) 2927-2948. https://doi.org/10.1109/COMST.2017.2728478

[18] Q. -D. Vu, L. -N. Tran, M. Juntti, E. -K. Hong, Energy-Efficient Bandwidth and Power Allocation for Multi-Homing Networks, IEEE Trans. Signal Process., 63 (2015) 1684-1699. https://doi.org/10.1109/TSP.2015.2399863

[19] T. Shuminoski, T. Janevski, Lyapunov Optimization Framework for 5G Mobile Nodes with Multi-Homing, IEEE Communications Letters, 20 (2016) 1026-1029. https://doi.org/10.1109/LCOMM.2016.2540622

[20] R. Liu, M. Sheng , W. Wu, Energy-Efficient Resource Allocation for Heterogeneous Wireless Network with Multi-Homed User Equipments, in IEEE Access, 6 (2018) 14591-14601. https://doi.org/10.1109/ACCESS.2018.2810216

[21] M. Khan, M. Jamali, QoS optimization-based dynamic secondary spectrum access model, Trans. Emerg. Telecommun. Technol., 29 (2018) e3455, https://doi.org/10.1002/ett.3455

[22] N. Yeadon, F. García, D. Hutchison, D. Shepherd, Filters: QoS support mechanisms for multipeer communications, IEEE Journal on Selected Areas in Communications, 14 (1996) 1245–1262. https://doi.org/10.1109/49.536366

[23] L. Costa, F. Lima, Y. Silva, F. Cavalcanti, Radio resource allocation in multi-cell and multi-service mobile network based on QoS requirements, Comput. Commun., 135 (2019) 40-52, https://doi.org/10.1016/j.comcom.2018.12.007.

[24] M. Ismail, W. Zhuang, A Distributed Multi-Service Resource Allocation Algorithm in Heterogeneous Wireless Access Medium, IEEE Journal on Selected Areas in Communications, 30 (2012) 425-432. https://doi.org/10.1109/JSAC.2012.120222

[25] I. S. Pesántez-Romero, G. E. Pulla-Lojano, L. F. Guerrero-Vásquez, E. J. Coronel-González, J. O. Ordoñez-Ordoñez, J. E. Martinez-Ledesma, Performance Evaluation of Hybrid Queuing Algorithms for QoS Provision Based on DiffServ Architecture, Lect. Notes Netw. Syst., 216 (2021) 333–345. https://doi.org/10.1007/978-981-16-1781-2_31

[26] Z. Zhang, Y. Wu, Iterative Rank-Two Transmit Beamforming Design for QoS-DiffServ Multi-group Multicasting Systems, 2018 IEEE 4th International Conference on Computer and Communications, Chengdu, China, (2018) 114-118. https://doi.org/10.1109/CompComm.2018.8780898

[27] S. Gan Chaudhuri, C. S. Kumar, R. V. RajaKumar, Validation of a DiffServ based QoS model implementation for real-time traffic in a test bed, 2012 National Conference on Communications, Kharagpur, India, (2012) 1-5 . https://doi.org/10.1109/NCC.2012.6176841

[28] M. Vaezi, Y. Qi, X. Zhang, A Rotation-Based Precoding for MIMO Broadcast Channels with Integrated Services, IEEE Signal Process. Lett., 26 (2019) 1708-1712. https://doi.org/ 10.1109/LSP.2019.2946088

[29] J. Liu, Design and Implementation of Vo IPQoS Model Combining IntServ and DiffServ Based on Network Processor IXP2400, 2021 7th Annual International Conference on Network and Information Systems for Computers, Guiyang, China, (2021) 60-64. https://doi.org/10.1109/ICNISC54316.2021.00019

[30] H. W. Oleiwi, H. L. Al-Taie, Comparative Investigation on Different QoS Mechanisms in Multi-homed Networks, Iraqi J. Ind. Res., 9 (2022) 1-10. https://doi.org/10.53523/ijoirVol9I1ID141