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A Comparative Investigation on Different QoS Mechanisms in Multi-Homed Networks

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Abstract

The current wireless communication system in Iraq faces several challenges during users' handoff, especially with the fast growth of users and demands. This is also a global issue; therefore, quality of service (QoS) measures have rapidly become more important and developed over the years. The complexity of communication between diverse applications and underlying QoS architectures leads to these deployment problems, which decreases the utility of QoS provisioning. This paper studies different QoS aggregation mechanisms in order to improve the overall operational efficiency of the multi-homed node. The main QoS mechanisms, i.e., IntServ, DiffServ, best-effort, and IntServ-DiffServ were investigated and compared thoroughly. Furthermore, it focuses on the multi-homed network that aims to develop a scalable system with better performance, reliability, and optimized communication networks. In this paper, multi-homed network enhancements are carried out with the comparable site and host multi-homing. The results show how the IntServ-DiffServ has achieved the best overall performance compared to the other mechanisms as it combines the advantages of the IntServ and DiffServ mechanisms. Another important finding was that the multi-homing managed to keep the communication going on the multi-homed node, whereas the site-multi-homing gave a better overall end-to-end latency over the host-multi-homing.

1. Introduction

Recently, various types of equipment are marketed with a wide variety of techniques, aiming to provide all the required support to the communication field for simultaneous internet ubiquity [1] [2]. This requires integrating more than one technology to achieve the targeted objective [3] [4]. Due to connection losses or network status, the communication redirects the path using another interface. Several technologies were merged to utilize the available resources, e.g., bandwidth (BW), and to adopt the best technology based on the connectivity type or user's priorities. The network interfaces have various resources and costs, whereas they perform differently with diverse accessing ranges. The associated users may decide to nominate several best interfaces of the available network's interfaces and their suitability, especially with wireless communication networks, i.e., mobility and condition change [5]. The user equipment (UE) can adopt the best interface or interfaces according to its QoS to obtain the best network resources. Internet is globally encountering exploded traffic rates with a wide variety of internet-demanding applications, which need to be delivered to end systems, networks, and end-users such that they can handle while satisfying the constraints imposed by the multimedia applications. The QoS mechanisms present the required networking tools to manage and control network resources efficiently. The resources management enhances the required services to the data-hungry applications and the exploded number of users, balancing the simultaneous network-demanding rates with the availability of resources. This will make use of the trade-off between the users' required QoS and the cost-effectiveness [6], [7].

To the best of the author's knowledge, neither multi-homing nor its applications have been deployed in Iraq yet. This comparative study provides a good direction for finding the optimal networking scheme, participating in the optimization of communication systems.

2. Experimental Procedure

Multi-homing

The foundational Internet-access technique was single-homing, with which the single-homed network adopts one internet service provider (ISP) to access all the targeted ends. The network will deliver poor performance due to limited resources, e.g., the scarcity of end-to-end routes due to high demands. The multi-homing technique develops a reliable system with better performance, providing the required services [8]. Figure 1 depicts multi-homing architecture. Furthermore, multi-homing enables the communication networks to deliver highly qualified services, and improve the speed and stability of services to the nodes. It reveals the capability of avoiding connection failure, providing user-reachability, multi-homing practicability, and ISP selection. 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.

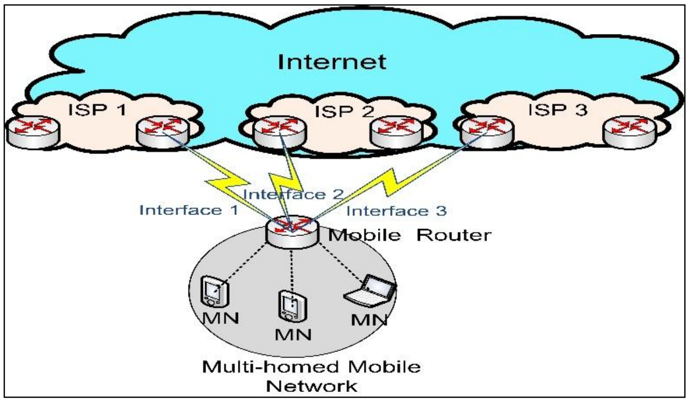

Figure (1). Example of Multi-homing technique.

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 [9], [10]. Multi-homing is becoming more preferred for the networks and end nodes; the end node can be linked to multiple ISPs to establish reliable internet access. 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. Besides, this strategy provides load-balancing with the possibility of distributing the traffic onto the available number of associated ISP-links.

Furthermore, the multi-homing technique has associated mechanisms to provide 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. However, it is essential to achieve a stable connection with a smooth handoff. 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.

This paper is organized as follows; in the next section, we discuss the Quality of Service (QoS) mechanisms, comparing the obtained results of using IntServ and DiffServ, to discuss the idea of adopting these models. Then, we proceed to discuss QoS mechanisms thoroughly on the basis of 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 optimal end-to-end QoS to the users.

Quality of Service Mechanisms:

The current internet in Iraq cannot assure strength or stability to the QoS; thus, it is logically arguable whether the internet can supply an ultimate end-to-end QoS. The diversity of networking technology on the internet is one of its most distinguishing features[11][15]. If the prevalence of 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 is a multitude of 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 that are 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 [17][19].

A) 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 DiffServ is designed to be organized to provide a modular solution to IP QoS goals for a variety of applications [20] [20][21]. Its protocols are intended to enable scalable service recognition on the internet without requiring a per-flow state or signaling at each hop.

B) Integrated Service (IntServ):

Because of current software improvements and the emergence of new services with increased commercial activities, QoS and Class of Service (CoS) are supposed to be added to the internet [22]. The rise of various spectrum-hungry or latency-sensitive applications necessitates the availability of adequate QoS or other network performance assurances. The resource reservation protocol (RSVP) [23] is used in the IntServ proposal to do this. The IntServ mechanism has proposed several service types; however, only two of them were defined:

1. 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.
2. A controlled-load service that offers no association quantitative assurances but strives to supply the traffic with a service quality that is comparable to a lightly laden network.

C) IntServ-DiffServ:

The telecom community adopts the assumption that IntServ and DiffServ mechanisms cannot support a multiple services network architecture. 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. Edge routers (ER) and border routers (BR) are the interface networks devices between the two areas. As illustrated in Figure (2), the ER is close to the DiffServ areas, whereas the BR is within the DiffServ area.

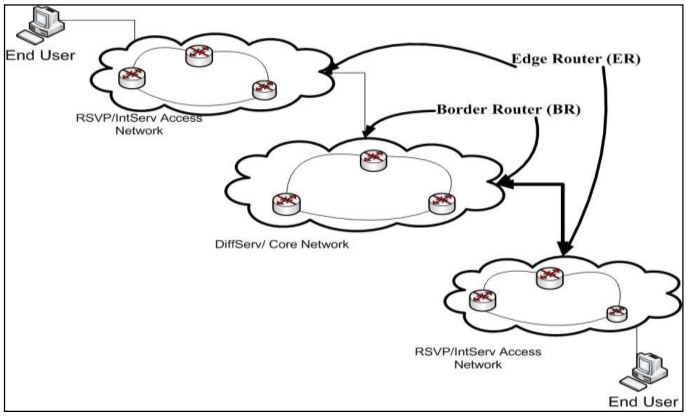

Figure (1). IntServ-DiffServ architecture.

The simulation results are based on the Network Simulator (NS2) [24][25]. The simulation scenarios are implemented as follows; the correspondence node (CN) sends information to the multi-homed network or the multi-homed node over the core network (Figure 2). The received traffic performance will be investigated, concerning single or multi-homed destinations. In both cases, the QoS is going to be carried out within the network; traffics of best-effort (no QoS guarantees), DiffServ, IntServ, and IntServ-DiffServ are all options. On the one hand, the destination has a single interface and is single-homed (router or node). The destination, on the other hand, will be 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. These scenarios are implemented as; the end-node is connected to several interfaces (i.e., in the case of the multi-homed node) and the link goes down every five seconds. As a result, the node needs to switch from one link to another in order to keep the communication going. The links are of different QoS's, starting from best-effort link to DiffServ only link, then IntServ link, and finally IntServ-DiffServ link.

This paper studies the main 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.

3. Results and Discussion

A) QoS mechanisms with site multi-homing

Case 1: investigating the communication that takes place between the CN and the multi-homed Router (i.e., the Destination), 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.

A1: Throughput of generating packets at CN:

It studies the producing packets' throughput at the CN against the simulation time. Figure (3) shows the same start with all the mechanisms' links, starting with the best-effort; then the link breaks down after 5 seconds, and the packet will either continue to use its link once recovered, or redirect the packet into another mechanism's link, with each link performing differently, as follows: The best-effort traffic is still down (shows a sharp drop) after 5 seconds, pending for link recovery and register again, so it will be recovered after 32 seconds. The IntServ and IntServ-DiffServ traffic show better starting results, whereas DiffServ delivers lower throughput at the early starting time. When connection failure occurs again at 20 seconds, the IntServ mechanism shows a steep decline in throughput as it prepares to move to a best-effort link that takes longer to register. Thus, all other links elect to stay on the same link rather than switching to the best-effort link.

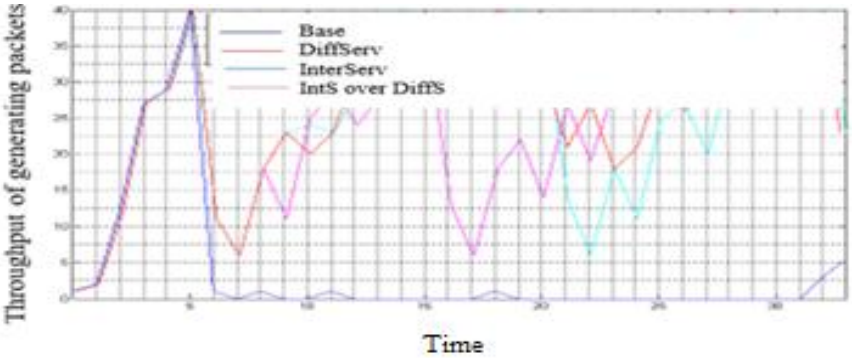

Figure (3). Throughput of generating packets at CN vs. time.

Since we adopt different policies (that is due to the DiffServ routers attempt to provide the best service to CN-to-destination packets), the DiffServ mechanism appears to have more drops than the other three mechanisms, as it shows a sharp drop at the second 15, however, the link changes its policy, causing this instant drop. In general, the DiffServ technique increases the pressure on the link as well as the CN's core, and edge queues, resulting in more drops.

A2: Simulation event time vs. jitter

The IntServ-DiffServ mechanism provides greater overall throughput than the other three mechanisms in terms of slowly dropped throughput and quick network recovery when a link fails. Figure (4) shows a clear distinction between the two cases: both cases show the identical start of the simulation jitter. However, the jitter jumps in the single-homed scenario when the initial link is disconnected.

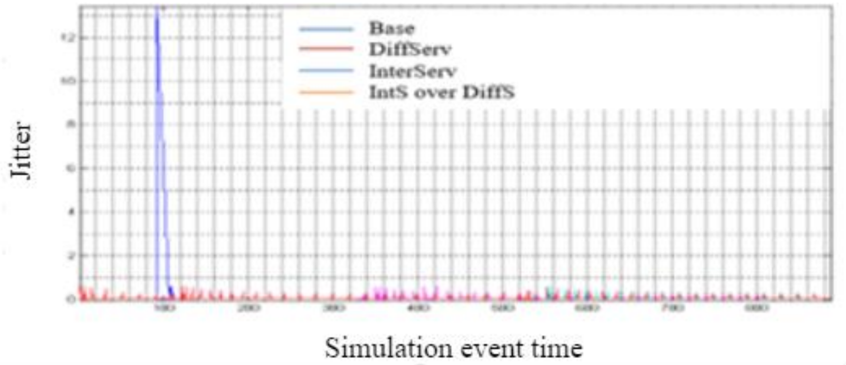

Figure (4). Jitter vs. Simulation event time.

On the other hand, the jitter stays around the same values in the case of the multi-homed router as the router has the ability to switch to another interface. All the named protocols show almost a similar simulation jitter in the multi-homed router; however, the single-homed router didn't cope with the link failure.

A3: End-to-end Latency vs. simulation event time

The multi-homed destination is associated with the four mechanisms' links, switching to the most adequate link. Figure (5) shows the end-to-end latency throughout the full time. All links started with the best-effort mechanism at first, but at the second 5, the best-effort link is turned off.

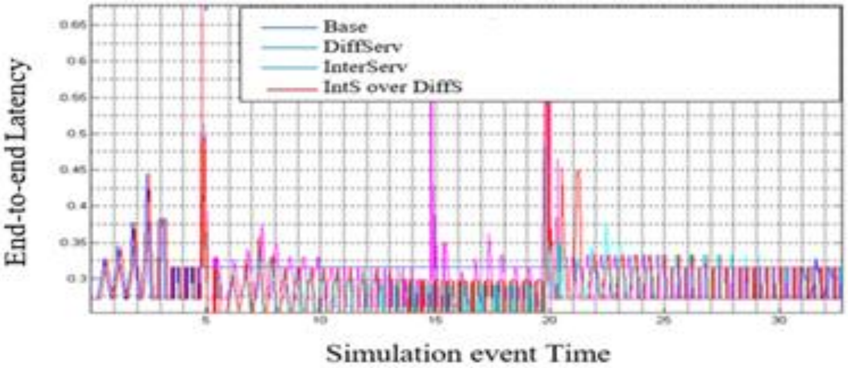

Figure (5). end-to-end Latency vs. simulation event time.

On the one hand, the DiffServ has greater latency than the IntServ and IntServ-DiffServ mechanisms, showing an instant spike when changing its link to a different policy in the second 15. However, the IntServ and IntServ-DiffServ mechanisms perform similarly during the seconds (5 - 20), whereas the IntServ shows a greater latency due to the link switching at the second 20. On the other hand, the end-to-end latency at the single-homed node stays as it is while the link is off, as the node keeps on trying to get the communication till the link is on again.

Figure (6) shows the average end-to-end latency of the various QoS mechanisms. The best-effort shows the greatest value (0.306797 sec). The DiffServ has greater latency than the IntServ and IntServ-DiffServ mechanisms (0.298318 sec). The IntServ-DiffServ reduces the end-to-end latency to (0.292232 sec), whereas the IntServ mechanism presents the shortest overall end-to-end latency during the entire implementation time (0.287273 sec).

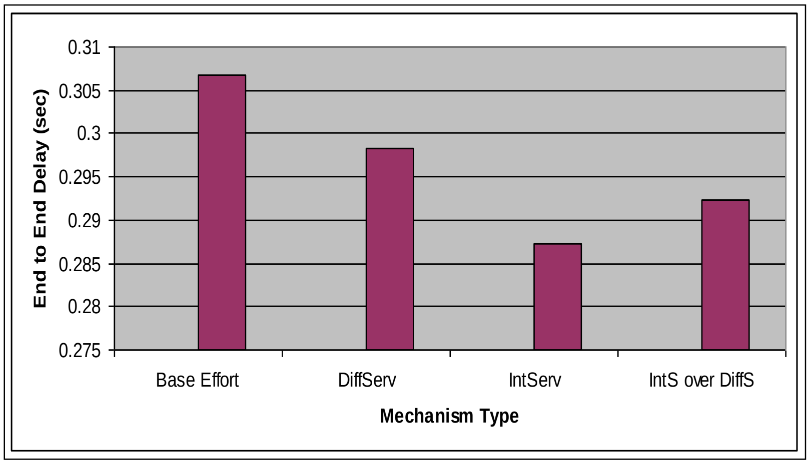

Figure (6). Average end-to-end latency.

A4: Packet processing time in intermediate nodes

Figure (7) depicts the long execution time of the best-effort mechanism at the intermediary nodes (1.611 ms), as the link goes off and the router keeps on trying to send the data to the CN. The IntServ mechanism shows a massive reduction in processing time (0.489 ms) rather than the other three mechanisms, as the IntServ mechanism is added at the edge network only.

Furthermore, the DiffServ has a slightly longer processing time (0.608 ms) than that of IntServ-DiffServ (0.572 ms), this is due to the DiffServ routers' attempt to provide the best service to CN-to-destination packets, as well as the nodes within the CN requiring a longer time to direct the packets based on their priorities to the destinations.

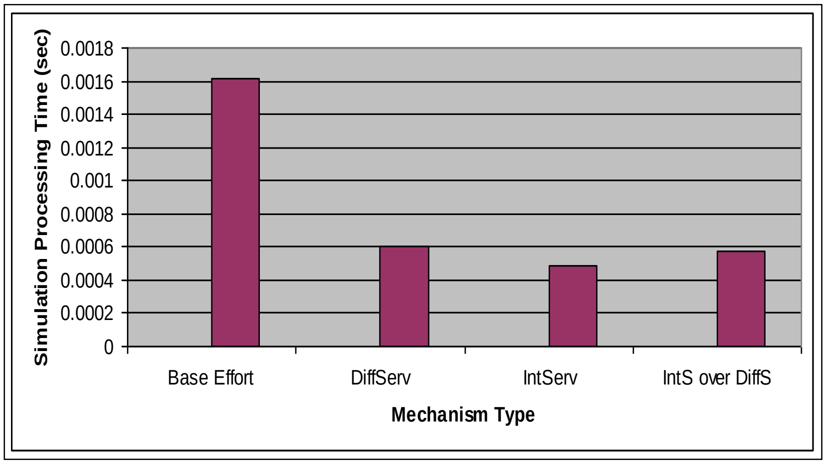

Figure (7). Average Packet processing time in intermediate nodes.

B) QoS mechanisms in a host multi-homing

Case 2: the communication happens between the CN and the multi-homed node (i.e., the destination node, which will be within the multi-homed router network). The same parameters will be studied in order to evaluate the overall performance of the node (i.e., the multi-homed node and the single-homed node) on the same network.

B1: Throughput of generating packets at CN

Figure (8) shows the noticeable impact of these parameters on the overall network performance; the results are comparable to the finding mentioned in section A1, explaining how the various mechanisms perform regarding processing, latency, distances, system throughput, and jitter.

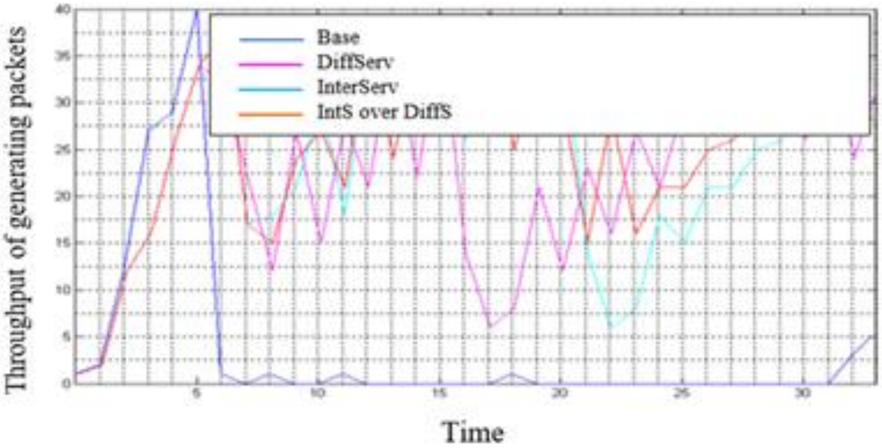

Figure (8). Throughput of generating packets at the CN vs. time.

After the 5th second, the best-effort traffic shows a sharp drop waiting for the link recovery. The performance of IntServ and IntServ-DiffServ traffic is superior; however, the DiffServ mechanism has a lower throughput in the early stages of the simulation. The DiffServ has more drops compared to the other mechanisms because it drops at the second 15 of the simulation (because the DiffServ routers try to deliver the best service to CN-to-destination packets), and the link changes its policy at that time, causing that drop. Accordingly, when compared to the other three mechanisms, IntServ-DiffServ provides the highest overall throughput in terms of a slow reduction in throughput and quick network recovery upon link failure.

B2: Simulation event time vs. jitter

Figure (9) illustrates the similarity of the results compared to the findings mentioned in section A2, explaining how the various mechanisms perform and their impact on simulation jitter. The multi-homed node shows a relatively steady jitter over simulation time as it can switch between different interfaces.

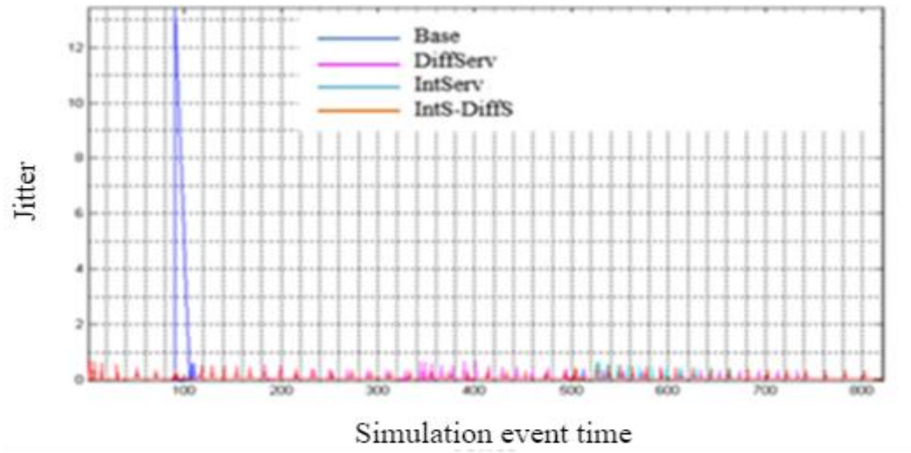

Figure (9). Jitter vs. Simulation event time.

The single-homed node, on the other hand, failed to do so. As a result, whenever the links fail, the simulation jitter increases.

B3: End-to-end Latency vs. simulation event time

Again, a similar end-to-end latency result to that in the previous section is shown in figure (10), the end-to-end latency for all the time of the host multi-homed destination switches among all mechanisms' links.

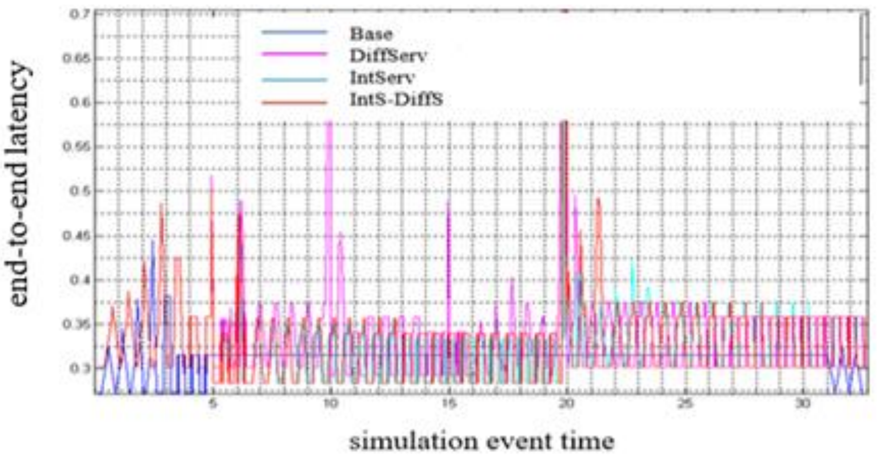

Figure (10). end-to-end latency vs. simulation event time.

The differences in host multi-homing and their effects on end-to-end latency are shown with this scenario, significantly when started. The best-effort delivers the lowest end-to-end latency, while it keeps the same failed link, waiting for the network to recover it; the latency remains studied until the link recovers the failure. When compared to other mechanisms, the DiffServ experiences the longest latency; additionally, it shows an instant spike when it changes its link to one of the other policies. The results of the IntServ and IntServ-DiffServ mechanisms are similar, whereas the IntServ shows a longer latency once it switches its link at the 20th second of simulation time.

Finally, despite the IntServ-DiffServ mechanism decreasing the end-to-end latency; the IntServ has lower end-to-end latency of the entire time than those of the DiffServ and IntServ-DiffServ mechanisms. Detailed evaluations of the end-to-end latency are shown in Figure (11).

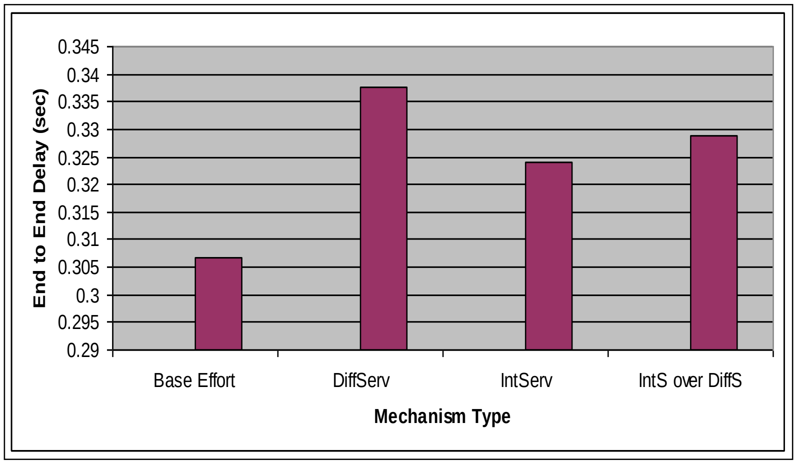

Figure (11). Average end-to-end latency

Similarly, Figure (11) depicts the end-to-end latency of the various QoS mechanisms; the best-effort has the shortest latency (0.306797 sec), whereas the DiffServ has a longer latency than the IntServ and IntServ-DiffServ mechanisms (0.337702 sec). However, the IntServ-DiffServ mechanism has the longest end-to-end latency (0.324056 sec), and the IntServ mechanism has the shortest overall end-to-end latency (0.328821 sec) compared with the other mechanisms.

B4: Packet processing time in intermediate Nodes

Figure (12) shows that the results are similar to those discussed in section A4. The host multi-homing (compared with site multi-homing) clarifies its impact on execution time; The best-effort has a similar processing time to that in section A4. The IntServ has a slight reduction in processing time to (0.47 ms), while IntServ-DiffServ has a slight reduction in processing time to (0.489 ms). The DiffServ has a slightly longer processing time (0.638 ms) as its routers attempt to deliver the best service to CN-to-destination packets. Furthermore, the nodes within the CN need a longer time for priority-based packets forwarding to the destinations. Moreover, we can see that host multi-homing has the greatest effect on processing time, specifically in the DiffServ and IntServ-DiffServ mechanisms, with the processing time reduced noticeably in the IntServ-DiffServ mechanism due to the identification of packets with their ID in the IntServ and DiffServ queues. That strategy reduces the time of packets' direction to the targeted destinations.

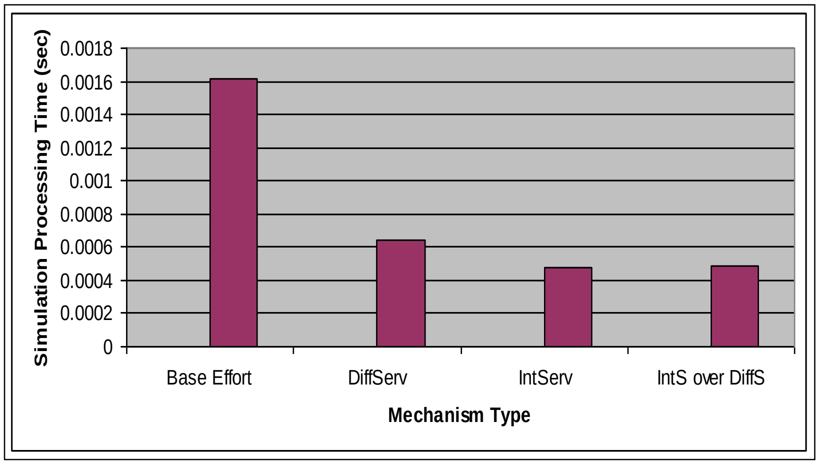

Figure (12). Average Packet processing time in intermediate nodes.

4. Conclusions

Despite the several studies for investigating and improving the multi-homed networking techniques worldwide, there is still an urgent need in Iraq for a comparative study to address the weak points and state the required procedures, developing an appropriate and decent communication system to meet the essential requirements with sufficient performance necessarily. Multi-homing technology presents a remarkable enhancement for overall communication performance. The results showed that IntServ and DiffServ were the best two mechanisms that outperform all other QoS mechanisms; they sufficiently showed the suitability for multi-homing, whereas these two mechanisms could not achieve a permanent end-to-end QoS along with all the connection time. However, the IntServ-DiffServ takes full advantage of these two mechanisms. Moreover, the IntServ mechanism might be adopted to deliver non-interrupted audio/video communications, accordingly with the DiffServ mechanism to deliver low latency and stable service to prioritized communication traffics. The best-effort provides a decent service to non-prioritized traffics, e.g., web-based and file-exchange. Aggregately, realizing all the aforementioned benefits of the best two mechanisms will explain the pivotal role of their combination strategy to form the IntServ-DiffServ mechanism.

References

[1] A. Gladisch, R. Daher and D. Tavangarian, "Survey on Mobility and Multihoming in Future Internet", *Wireless Personal Communications*, vol. 74, no. 1, pp. 45-81, 2012. Available: 10.1007/s11277-012-0898-6.

[2] I. El-Dessouki and N. Saeed, "Smart Grid Integration into Smart Cities," *2021 IEEE International Smart Cities Conference (ISC2)*, 2021, pp. 1-4, doi: 10.1109/ISC253183.2021.9562769.

[3] A. Anwar, Ijaz-ul-Haq, N. Saeed and P. Saadati, "Smart Parking: Novel Framework of Secure Smart Parking Solution using 5G Technology," *2021 IEEE International Smart Cities Conference (ISC2)*, 2021, pp. 1-4, doi: 10.1109/ISC253183.2021.9562776.

[4] A. Gladisch, R. Daher and D. Tavangarian, "Node-oriented Internet Protocol: A novel concept for enhancement of mobility and multi-homing in Future Internet," *37th Annual IEEE Conference on Local Computer Networks - Workshops*, 2012, pp. 1070-1077, doi: 10.1109/LCNW.2012.6424045

[5] N. H. Saeed, M. F. Abbod and H. S. Al-Raweshidy, "IMAN: An Intelligent MANET routing system," *2010 17th International Conference on Telecommunications*, 2010, pp. 401-404, doi: 10.1109/ICTEL.2010.5478779.

[6] R. Liu, M. Sheng and W. Wu, "Energy-Efficient Resource Allocation for Heterogeneous Wireless Network with Multi-Homed User Equipments", *IEEE Access*, vol. 6, pp. 14591-14601, 2018. Available: 10.1109/access.2018.2810216.

[7] F. YANG, Q. YANG and K. KWAK, "Energy-Efficient Resource Allocation for Multi-Radio Access in Dynamic and Heterogeneous Wireless Networks", *IEICE Transactions on Communications*, vol. 99, no. 6, pp. 1386-1394, 2016. Available: 10.1587/transcom.2015ebp3151.

[8] H. T. Karaoglu and M. Yuksel, "Effectiveness of Multi-Hop Negotiation on the Internet," *2011 IEEE Global Telecommunications Conference - GLOBECOM 2011*, 2011, pp. 1-6, doi: 10.1109/GLOCOM.2011.6133930

[9] 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 (ICNISC)*, 2021, pp. 60-64, doi: 10.1109/ICNISC54316.2021.00019.

[10] M. Niraula and T. McParland, "Aviation Safety Service IPV6 Based Air-To-Ground Communication: Multi-Homing Challenges," *2019 Integrated Communications, Navigation and Surveillance Conference (ICNS)*, 2019, pp. 1-5, doi: 10.1109/ICNSURV.2019.8735276

[11] Z. Song, X. Wang, Y. Liu and Z. Zhang, "Joint Spectrum Resource Allocation in NOMA-based Cognitive Radio Network with SWIPT", *IEEE Access*, vol. 7, pp. 89594-89603, 2019. Available: 10.1109/access.2019.2926429.

[12] Y. Tun, A. Ndikumana, S. Pandey, Z. Han and C. Hong, "Joint Radio Resource Allocation and Content Caching in Heterogeneous Virtualized Wireless Networks", *IEEE Access*, vol. 8, pp. 36764-36775, 2020. Available: 10.1109/access.2020.2974287.

[13] W. Xu, R. Qiu and X. Jiang, "Resource Allocation in Heterogeneous Cognitive Radio Network with Non-Orthogonal Multiple Access", *IEEE Access*, vol. 7, pp. 57488-57499, 2019. Available: 10.1109/access.2019.2914185.

[14] L. Costa, F. Lima, Y. Silva and F. Cavalcanti, "Radio resource allocation in multi-cell and multi-service mobile network based on QoS requirements", *Computer Communications*, vol. 135, pp. 40-52, 2019. Available: 10.1016/j.comcom.2018.12.007.

[15] H. W. Oleiwi and H. Al-Raweshidy, “Cooperative SWIPT THz-NOMA / 6G Performance Analysis”, *Electronics, MDPI*, vol. 11, pp. 873, 2022, doi:10.3390/electronics11060873.

[16] H. W. Oleiwi, N. Saeed, and H. Al-Raweshidy, “Cooperative SWIPT MIMO-NOMA for Reliable THz 6G Communications”, *Network, MDPI*, pp. 257–269, 2022, doi: 10.3390/network2020017.

[17] M. Khan and M. Jamali, "QoS optimization-based dynamic secondary spectrum access model", *Transactions on Emerging Telecommunications Technologies*, vol. 29, no. 8, p. e3455, 2018. Available: 10.1002/ett.3455.

[18] V. P. Selvan, M. S. Iqbal and H. S. Al-Raweshidy, "Performance analysis of linear precoding schemes for very large Multi-user MIMO downlink system," *Fourth edition of the International Conference on the Innovative Computing Technology (INTECH 2014)*, 2014, pp. 219-224, doi: 10.1109/INTECH.2014.6927765.

[19] N. Yeadon, F. García, D. Hutchison, and D. Shepherd, “Filters: QoS support mechanisms for multipeer communications,” *IEEE J Sel Areas Commun*, vol. 14, no. 7, pp. 1245–1262, 1996, doi: 10.1109/49.536366.

[20] I. S. Pesántez-Romero, G. E. Pulla-Lojano, L. F. Guerrero-Vásquez, E. J. Coronel-González, J. O. Ordoñez-Ordoñez, and J. E. Martinez-Ledesma, “Performance Evaluation of Hybrid Queuing Algorithms for QoS Provision Based on DiffServ Architecture,” in *Lecture Notes in Networks and Systems*, 2022, vol. 216, pp. 333–345, doi: 10.1007/978-981-16-1781-2_31.

[21] Z. Zhang and Y. Wu, "Iterative Rank-Two Transmit Beamforming Design for QoS-Diffserv Multi-group Multicasting Systems," *2018 IEEE 4th International Conference on Computer and Communications (ICCC)*, 2018, pp. 114-118, doi: 10.1109/CompComm.2018.8780898.

[22] L. Han, Y. Qu, L. Dong and R. Li, "Flow-level QoS assurance via IPv6 in-band signalling," *2018 27th Wireless and Optical Communication Conference (WOCC)*, 2018, pp. 1-5, doi: 10.1109/WOCC.2018.8372726.

[23] J. I. Agbinya, “RSVP: Resource Reservation Protocol,” in *IP Communications and Services for NGN*, 2020, pp. 151–178.

[24] N. Lin and H. Qi, "A QoS Model of Next Generation Network based on MPLS," *2007 IFIP International Conference on Network and Parallel Computing Workshops (NPC 2007)*, 2007, pp. 915-919, doi: 10.1109/NPC.2007.89.

[25] S. Gan Chaudhuri, C. S. Kumar and R. V. RajaKumar, "Validation of a DiffServ based QoS model implementation for real-time traffic in a testbed," *2012 National Conference on Communications (NCC)*, 2012, pp. 1-5, doi: 10.1109/NCC.2012.6176841.

[26] H. W. Oleiwi, N. Saeed, H. L. Al-Taie, and doaa nteesha, “An Enhanced Interface Selectivity Technique to Improve the QoS for the Multi-homed Node,” *Eng. Technol. J.*, vol. 40, no. 8, p. 0, Aug. 2022, doi: 10.30684/etj.2022.133066.1165.