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Assessing IPv6 Readiness and Adoption in Palestine, A Case Study with Strategic Recommendations

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Abstract— **This research examines the current state of IPv6 adoption in Palestine, comparing it to the global and regional adoption trends, particularly in Arab countries. While the global IPv6 adoption rate exceeds 45%, and Arab countries average 12.79%, Palestine remains at a negligible adoption rate. Through a mixed-method approach that includes experiments, technical analysis, and stakeholder interviews, the study highlights the readiness of end-user devices for IPv6, primarily due to international compliance standards. However, significant challenges exist within Internet Service Providers (ISPs) and large enterprises in Palestine, such as dual-stack resource demands, insufficient technical expertise, and lack of customer demand. This paper underscores the urgent need for a national strategy, stakeholder collaboration, and increased awareness to accelerate IPv6 transition in Palestine. Recommendations are made to address these obstacles and position Palestine for future compatibility in the global internet ecosystem.**

Keywords: Ipv6 adoption, IPv6 Challenges, IPv6 Readiness, Palestine, ISPs, enterprises, end user.

I. Introduction

Despite having active internet connections, many users in Palestine and across the Arab world find themselves unable to access modern websites and services—particularly those reliant on IPv6. This growing limitation is not due to firewalls or access restrictions, but rather stems from a deeper infrastructural issue: the inadequate adoption of the IPv6 protocol in developing regions.

As more global platforms and service providers shift toward IPv6-only networks, countries that lag in IPv6 deployment risk digital exclusion. Over time, this could result in widespread service inaccessibility, economic disadvantages, and reduced opportunities for innovation, education, and communication.

If no action is taken, users in Palestine—and similar developing nations—may find themselves increasingly disconnected from the evolving digital landscape. The urgency of this issue underscores the importance of identifying the root causes of IPv6 adoption delays and developing targeted strategies to overcome them.

This research aims to investigate the systemic barriers to IPv6 adoption in Palestine, assess the technical readiness of stakeholders, and propose a strategic roadmap to ensure that the country can fully participate in the global internet ecosystem.

In the realm of data networking, specifically at the third layer of the OSI model [1], two fundamental protocols exist: IPv4 and IPv6. IPv4, introduced in the early 1980s, was designed to connect multiple sites using a 32-bit addressing system, allowing for approximately 4.295 billion unique addresses.

As the demand for internet connectivity grew and the internet became a cornerstone of modern life, its significance expanded globally. Recognizing this, the Human Rights Commission declared on June 27, 2016, that internet access is a fundamental human right, comparable to essential needs such as food, clothing, housing, and education [2].

Over time, the pool of IPv4 addresses began to deplete, and the Internet Assigned Numbers Authority (IANA) has already exhausted its supply [3][4]. This shortage has become particularly evident with the rise of the Internet of Things (IoT) and the growing reliance on the internet in all areas of life, including education, healthcare, government, financial services, and more. This reality is widely recognized.

To address this issue, it became essential to develop a new protocol capable of accommodating additional addresses. This vision was realized in 1995 with the introduction of the IPv6 protocol. One of its key features was the expansion of the address size from 32 bits to 128 bits. With 128 bits, IPv6 offers an immense address range of 3.4e+38, or 34 followed by 37 zeros. To put this into perspective, every square meter on Earth could have a share of 6.6e+23 addresses. Can you imagine the scale of this number?

In addition to expanding the range of addresses, IPv6 was designed to be more efficient than its predecessor, IPv4, by eliminating secondary and optional fields in the header and improving routing and quality of service. These enhancements bring several advantages to the IPv6 standard over IPv4 [5]:

- Enhanced multicast capabilities
- Removal of NAT overhead
- Smaller IP header size, improving transmission efficiency
- Automatic configuration, reducing the load on DHCP servers
- Improved Quality of Service (QoS) by prioritizing specific applications for better network efficiency
- Built-in IPSec security, offering end-to-end encryption for communications
- Mobility support, allowing mobile devices to seamlessly transition between networks without losing their Internet connection

For these reasons and more, the online world has gradually begun transitioning from the IPv4 protocol to the IPv6 protocol. The pace of this adopting can be tracked using many sources.

One of the most effective methods to measure IPv6 adoption among internet users is through statistics provided by globally popular websites. Google's data on IPv6 adoption among its users [6] and Facebook's user statistics [8] offer valuable insights. These statistics cover the period from September 2017 to the end of 2024 see figure 1 and 2.

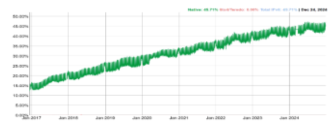

Figure 1: Google's IPv6 adoption statistics 2017-2024

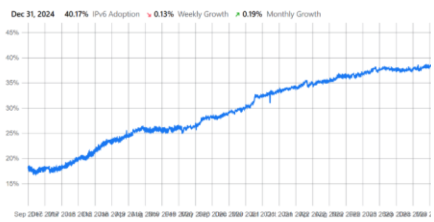

Figure 2: Facebook's IPv6 adoption

adoption by Google users until writing this paper was 45.71%, and Facebook users showed an adoption percent 40.17%.

Why start from September 2017? Facebook's IPv6 adoption data became available starting that year, while Google's data has been accessible since September 2008.

According to these statistics, countries around the world are steadily transitioning to IPv6.

What about our region" Arabic countries" are we adopting at the same rate of the word?

A deeper analysis of these statistics, based on data from individual countries, whether through Google [7] or Facebook [9] statistics, provides further insight.

The IPv6 adoption rate for Arab countries, was determined based on Google's and Facebook statistics by treating each Arab country as a single unit cluster, regardless of the number of connections (as obtaining this data was not feasible). The results illustrated in the following charts:

According to Google's statistics, the IPv6 adoption rate for Arab countries stands at 12.79%, significantly lower than the global average of 45.71%. Similarly, Facebook's data shows an adoption rate of 11.62% for Arab countries, compared to the global average of 40.17% see figure 3.

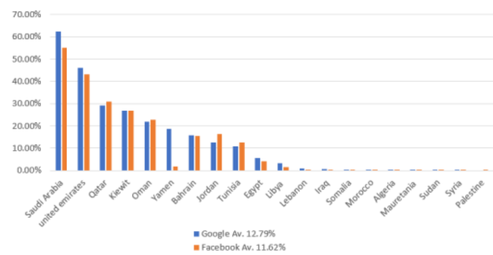

Figure 3: IPv6 Adoption percentage at Arab countries

According to Google's statistics, the IPv6 adoption rate for Arab countries stands at 12.79%, significantly lower than the global average of 45.71%. Similarly, Facebook's data shows an adoption rate of 11.62% for Arab countries, compared to the global average of 40.17% see figure 4.

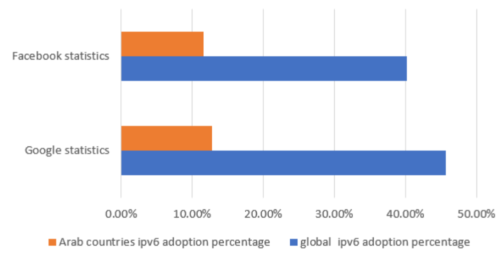

Figure 4: IPv6 Adoption percentage at Arab countries compared to the global word

However, most of Arab countries, have a significantly lower adoption rate compared to world rate especially the developed countries. As integral members of the global internet community, we should be keeping pace with this transition. Yet, while the world moves toward IPv6 we lag even further behind, widening the gap in this critical technological shift.

This slowdown places us at the back of the line in the IPv6 adoption process, potentially leading to a stage where many countries achieve full IPv6 adoption and decide to disable the IPv4 protocol. At that point, we would face a limited timeframe to switch, causing disruptions to internet services.

As IPv4 usage diminishes, many global service providers and critical websites will reassess their operations to maintain IPv4 alongside IPv6. Eventually, this will drive them to phase out IPv4 entirely. Before that day arrives—likely sooner than expected—it is crucial to implement strategies to accelerate the IPv6 adoption at our countries.

Experience and history clearly demonstrate that the adoption of new technologies to address the limitations of existing ones follows a predictable progression. Initially, the old technology remains dominant, and hybrid solutions are introduced to bridge the gap, enabling a smooth transition for users. However, this phase is temporary. As the adoption of the new technology accelerates, hybrid solutions gradually decline, eventually giving way to a full transition to the modern technology.

This can be exemplified by the transition from HTTP to HTTPS [10].

Consider what happened to websites that failed to transition from HTTP to HTTPS. These sites became marginalized, with many web browsers no longer supporting them. At best, users receive a warning when attempting to access them.

Research by Everett Rogers (2003) [18] established a foundational theory on the diffusion of innovation within social systems. A significant insight from his study is that organizations undergo a process of innovation-decision similar to individuals. This process starts with acquiring initial knowledge about an innovation, followed by forming an attitude toward it, deciding whether to adopt or reject it, implementing the innovation, and ultimately confirming the decision see figure 5.

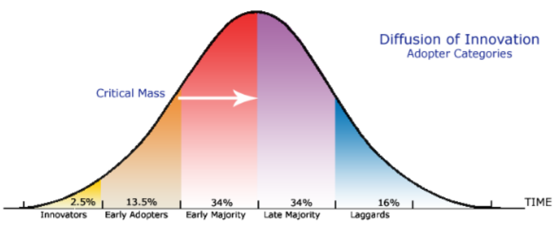

Figure 5: Diffusion of Innovation Adopter Categories

Potential adopters progress through these stages based on their level of innovativeness, with not all adopters embracing an innovation simultaneously. As a result, the adoption of innovation typically follows a normal bell-shaped distribution curve over time, as illustrated in Figure 5.

Based on Google's global statistics [6]:

The world surpassed the first stage “"innovators"” of IPv6 adoption in early 2014 when the global transition rate exceeded 2.5%, and the next stage “early adopters” began.

By the mid-2017, the second stage “early adopters” was surpassed, marked by an adoption rate surpassing 16%= 2.5+13.5. and the third stage began.

By the end of 2024, the global rate reached 45.71%, signaling that we are so close the end of the third stage. This marks the conclusion of the dominance of IPv4 and the beginning of the era of IPv6 dominance see figure 6.

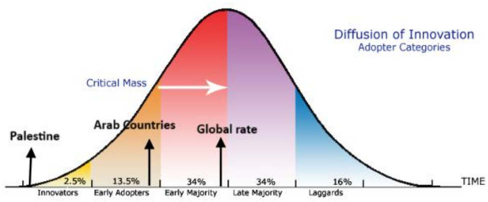

Figure 6: Diffusion of Innovation Adopter comparison

As for our Arab countries, the current IPv6 adoption rate is 12.79%, indicating that we are still in the second stage.

What about Palestine? The rate is almost zero! We are still “Innovators”

Palestine, unfortunately, ranks among the countries with the lowest IPv6 adoption rates in both the Arab world and globally. For this reason, it was selected as deliberate sample study to investigate the reasons behind this slow adoption. As a Palestinian researcher born, raised, and working in Palestine for over two decades in the field of computer networks, I am well-acquainted with its environment, making it easier to identify the causes of this delay and propose effective solutions to accelerate the adoption to IPv6. Additionally, since Palestine shares many similarities with the broader Arab world, it serves so far as a representative sample for the challenges faced by other Arab countries.

The motivation behind this research stems from the widening gap between developed and developing countries in adopting the IPv6 protocol. As the world transitions to IPv6, countries that fail to adapt risk being left behind in digital connectivity, with profound implications for education, commerce, communication, and national development. Palestine's particularly low adoption rate, approaching zero, raises concerns about future internet access and competitiveness. This research is driven by the urgency to understand why IPv6 adoption is lagging in Palestine and how this challenge can be addressed in a practical, scalable manner.

This research makes several key contributions:

A. It provides a comprehensive assessment of IPv6 readiness in Palestine by examining both end-user devices and Internet Service Providers (ISPs).
B. It identifies technical, infrastructural, and organizational barriers to IPv6 adoption specific to Palestine and similar developing countries.
C. It includes practical experiments and surveys to validate the current state of IPv6 readiness, making the findings grounded and actionable.
D. It proposes a set of strategic recommendations tailored to policymakers, ISPs, and enterprises to facilitate a smoother and faster transition to IPv6.
E. It positions Palestine as a representative case study for other Arab countries, making the research applicable to broader regional and global contexts.

II. Related Work

A survey of previous studies on the transition to IPv6 in Palestine was conducted, and only one research paper on this topic was found: Analyzing the IPv6 Deployment Process in Palestine [21].
This paper, conducted four years ago, examines IPv6 deployment in Palestine, highlighting slow progress due to low customer demand, infrastructure limitations, and costs. Of the surveyed ISPs, only one had started deploying IPv6, while others planned to do so within 1-5 years. Partial readiness was reported with some dual-stack networks and IPv6-capable tools. Notably, the study relied solely on a questionnaire to gather results, without using empirical tools or practical testing.
Several studies on the global transition to IPv6 were also reviewed to understand the ongoing processes worldwide and to attempt to relate them to the situation in Palestine.
"IPv6 Diffusion Milestones: Assessing the Quantity and Quality of Adoption" [19]
This paper analyzes IPv6 adoption progress, highlighting milestones and challenges. IPv6 was developed to address IPv4 limitations, but adoption has been slow due to costs, technical hurdles, and limited immediate benefits. Global adoption surpassed the critical 20% threshold in 2018, with full adoption projected by 2026. However, performance issues persist, as IPv6 often exhibits longer load times and incomplete implementations compared to IPv4. Quality disparities stem from reliance on IPv4-based systems and insufficient IPv6 deployment strategies. To ensure successful adoption, organizations must address these issues and invest in improving IPv6 performance and compatibility.
Another paper was reviewed Modeling IPv6 adoption from biological evolution" [20]
This paper addresses the challenges and dynamics of transitioning from IPv4 to IPv6, noting the limited global adoption of IPv6 despite its necessity due to IPv4's limitations. It introduces a novel approach to analyzing IPv6 adoption using a biological analogy, comparing the process to evolutionary dynamics. Key aspects include the use of concepts such as "survival of the fittest" and evolutionary stable strategies to model the competition between IPv4 and IPv6.
Also, several technical references from online sources were utilized to enrich the research and to connect these practical findings to serve the objectives of this study.

III. Methodolgy

The readiness for IPv6 adoption in Palestine needs to be assessed using two main components, end-users and ISPs "the internet structure".

A. *End-users readiness cheching for IPv6 adoption Methodolgy*

For end-users, it is essential to analyze their readiness for IPv6 adoption by evaluating their needs and the compatibility of their equipment.
The transition to IPv6 primarily revolves around understanding the needs, benefits, and challenges faced by the end-user. In Palestine, the requirements and readiness of end-users align closely with those of users worldwide, as the devices and services utilized by Palestinian users are largely similar to those used globally.
The end-user plays a central role in the transition process, as their needs drive the adoption of IPv6. All internet capabilities are ultimately directed toward serving the end-user, with companies and institutions focusing on satisfying this user, who is the primary source of revenue and the foundation for the continued operation of the global network.
End-user component can be categorized as follows:

- End user Devices: Devices directly used by end-users to access internet services, such as computers, mobile phones, printers, cameras, and Internet of Things (IoT) devices.
- End user Services: online services like web services.

The key questions arise in this adoption: Are these devices and services ready for IPv6? Beyond adopting new technology.
An inventory survey of the majority of devices used by end-users will be conducted, and the compatibility of their operating systems with IPv6 will be assessed using technical documentation from device manufacturers and operating system providers.
Practical experiments will also be performed to test the use of the IPv6 protocol as a means of connection between devices within the local network and also connection between end devices and Internet services. The results of these tests will be evaluated and compared with those obtained using the IPv4 protocol.

B. *ISP readiness cheching for IPv6 adoption*

Understanding the structure of the Internet is crucial to identifying the requirements for transitioning to IPv6. Based on this understanding, we can assess the availability of these requirements, determine what is lacking, analyze why it is unavailable, and devise mechanisms to address and fulfill these needs.

Basically, the internet structure consists of three hieratical ISP layers, Tier 1, 2 and 3.

The end users basically connected to the Tier 3, Tier 3 is connected to Tier 2 or Tier1 and Tier 2 connected to backbone Tier 1 these connections are called IP transit. Connection between tiers in the same level is available for backup and shortest path choices for the routing process and these connections are called Peering [11] see Figure 7

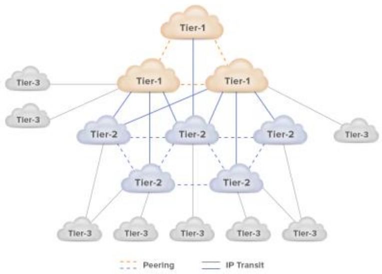

Figure 7: IP Transit and the Tiers of Transit Providers

The Internet infrastructure in Palestine should be analyzed using this model to understand its characteristics and dynamics. This approach will provide a clear and comprehensive overview, aiding in the study of this case. The methods to be employed to achieve this goal are as follows:

- A survey will be conducted to compile a comprehensive list of ISPs within Palestine. A structure of any internet network in a country primarily relies on internet service providers (ISPs) and enterprises that hold registered domains and IP addresses (both IPv4 and IPv6). These entities serve as the main providers of IPv4 and IPv6 services in any country.
- Once this list is obtained, a technical study will be conducted to evaluate the readiness of these service providers and enterprises via checking global BGP records for IPv6 adoption using technical BGP investigation tools.
- Contacting the customer support teams of ISPs in Palestine through phone calls to determine which providers offer IPv6 routing services to their customers.
- Interviews will be arranged with the technical administrators managing these ISPs and enterprises to gain deeper insights into their preparedness for IPv6 adoption. These discussions will explore the motivations driving the adoption and the challenges or obstacles hindering it.

Building on the previous two steps, a clearer understanding of the strengths and weaknesses in Palestine's IPv6 adoption process will emerge. The findings can largely be extrapolated to other countries in the Arab world and nations with similarly low IPv6 adoption rates.

Develop a working mechanism and recommendations for the relevant stakeholders (Ministry of Communications, Internet Service Providers, and enterprises) to overcome these challenges. The goal is to accelerate the transition to IPv6 in Palestine and generalize this experience to similar countries.

IMPLEMENTATION AND RESULTS

Unfortunately, IPv4 and IPv6 protocols are not compatible to work together. However, fortunately, both protocols operate at the third layer of the OSI model [1], which provides two key advantages:

- Minimal Impact on Other Layers: The transition to IPv6 has no direct effect on the lower layers, especially the physical media layer, nor on the upper layers, particularly applications. This means that, in most cases, there is no need for significant investment in renumbering network media or upgrading applications used by end-users.
- Software-Based Layer: The third layer is implemented through software, specifically in the operating systems of devices, rather than hardware. This means that upgrading from IPv4 to IPv6 primarily involves updating the operating systems on devices, not their hardware “mostly”. This simplifies the transition process, as the focus shifts to software upgrades rather than costly hardware replacements.

Testing the IPv6 Adoption readiness of end-user devices using survey methods.

We did a survey in order to categorized the types of end-user devices and the operating systems that manage them, to subsequently explore their compatibility with IPv6.

- PCs and Laptops: Operating systems such as Windows, Unix, and macOS.
- Mobiles and Tablets: operating systems like Android and iOS.
- Other Terminal Devices: Devices such as printers, cameras, use specialized firmware.

After surveying the operating systems managing the above devices, it was found that most of those produced in the least fourteen years support IPv6 (Dual Stack [12]).[13][14][15] see table 1.

Table1: Operating systems IPv6 adoption

	Operating system/device	First version supports IPv6	Release date
1	Windows desktop	Windows XP with SP1	September 9, 2002
2	Windows server	Windows Server 2003	April 24, 2003
3	Linux	Linux kernel 2.6 including Red Hat (Desktop or WS 3.0 or later and Enterprise (RHEL) 5.2 or later), Mandrake 8 or later, Fedora 9 or later, and CentOS 7 or later systems.	17 December 2003
4	MAC OS	Apple Mac OS X v10. 3 "Panther"	October 24, 2003
5	Android	Android 4.0 Ice Cream Sandwich	October 19, 2011
6	IOS	iOS 4.1	September 8, 2010

This readiness is largely due to regulations established by U.S. authorities. Since 2014 [5], laws have required manufacturers of end-user devices to ensure their products and operating systems are compatible with IPv6.

Most operating systems used by end-users in Palestine and worldwide are adhere to these regulations. These include Windows, macOS, Unix, Linux, Android, IOS, and the firmware systems of peripheral devices such as printers and cameras.

Thus, our devices have been prepared for the transition to IPv6 many years ago.

Testing the IPv6 Adoption readiness of end-user devices using Experiments.

- **Experiment 1: Testing Dual Stack [12] Functionality for end user devices in local network "PC, printer, and IP camera"**

1. Purpose of Experiment 1

The purpose of this experiment is to evaluate the dual stack functionality of a PC connected to a printer and an IP camera. The devices are configured in the same VLAN and are assigned both IPv4 and IPv6 addresses.

2. Device Specifications of Experiment 1

2.1 PC Specifications

- System Model: HP Z6 G4 Workstation
- Processor: Intel(R) Xeon(R) Silver 4114 CPU @ 2.20GHz, 2195 Mhz, 10 Core(s), 20 Logical Processor(s)
- Installed Physical Memory (RAM): 32.0 GB
- Operating System: Microsoft Windows 11 Pro
- Camera Surveillance Software: iVMS 4200 (Version: v2.8.1.4)

- IPv4 Addresses**:** 192.168.14.95/24 (Manual),192.168.1.55/24 (Manual)
- IPv6 Address**:** 2001:abcd::1/64 (Manual)

2.2 Printer Specifications

- Model: HP LaserJet Enterprise MFP M631
- Firmware Version: JS124050147
- IPv4 Address: 192.168.14.21/24 (DHCP)
- IPv6 Address: 2001:abcd::5/64 (Manual)

2.3 IP Camera Specifications

- Model: DS-2CD1T43G0-I
- Firmware Version: V5.7.4 build 220509
- IPv4 Address: 192.168.1.64/24 (Manual)
- IPv6 Address: 2001:abcd::6/64 (Manual)

3. Experiment Methods of Experiment 1

3.1 Printer Tests

3.1.1 Printer Configuration using IPv6:

- Navigate to Windows settings, select "Add Printers."
- Choose "Add a printer using an IP address or hostname."
- Set device type to "TCP/IP Device" and enter the IPv6 address: 2001:abcd::5.
- Install the appropriate driver and finish the setup.
- **Result:** A test paper was printed successfully.

3.1.2 Printer Configuration using IPv4:

- Repeat the above steps using the IPv4 address: 192.168.14.21.
- **Result:** A test paper was printed successfully.

3.1.3 Both printers are now configured—one via IPv4 and the other via IPv6.

3.2 Camera Tests

3.2.1 IP Camera Configuration using iVMS 4200:

- Configure both IPv4 and IPv6 addresses on the IP camera.
- Open the iVMS software, navigate to "Device Management."
- Add a device:
  - IPv4 Setup:
    - Nickname: ipv4 cam
    - Address: 192.168.1.64
    - Port: 8000
    - Enter username and password.
  - **IPv6 Setup:**

    Repeat the above steps using

    - Nickname: ipv6 cam
    - the address 2001:abcd::6

3.2.2 Live View Configuration:

- Access the "Live View" section in iVMS.
- Drag and drop both configured cameras into the live view field.
- **Result:** Both cameras displayed the same picture and quality, functioning properly under both IPv4 and IPv6.

4. discussion of Experiment 1

The dual stack [12] functionality was successfully demonstrated with both the printer and the IP camera. The configuration and performance of devices under IPv4 and IPv6 addresses were consistent and effective. Both printers were able to print test papers successfully using both protocols, and both cameras provided live view with the same quality and performance.

- **Experiment 2: Comparison of IPv4 and IPv6 Performance over internet connection**

1. Purpose of Experiment 2

A computer was connected to an Internet Service Provider supporting both IPv6 and IPv4 (Dual Stack). Through this ISP, the computer accessed websites and services that supporting both protocols using IPv6 and IPv4. The connections were monitored using various tools based on the ICMP protocol, such as ping and tracert, and nslookup . Wireshark used as a data-sniffing tool. The results obtained from both protocols were compared.

A Dual stack [12] ISP environment and Google's website (www.google.com) and windows machine were chosen as the test sample due three of them support dual stack. The tests were performed under controlled conditions to ensure accuracy and minimize external factors.

2. Using Tool 1: show ip configuration

The ipconfig command was used to show the IPv4 and IPv6 configuration on windows machine, see figure 8.

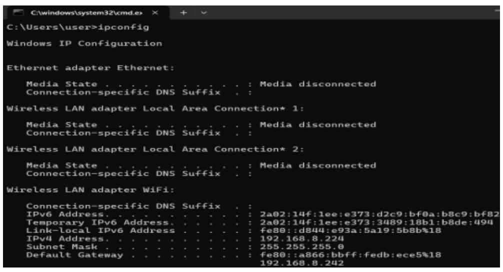

Figure 8: ipconfig results

PC IPv4 address: 192.168.8.224 /24 by DHCP

PC IPv6 address: 2a02:14f:1ee:e373:d2c9:bf0a:b8c9:bf82 /64 by DHCP

3. Using Tool 2: Domain Name Resolution

The nslookup command was used to resolve the domain name "www.google.com" to its respective IP addresses. This identified the IPv4 and IPv6 addresses associated with Google, *see figure 9*.

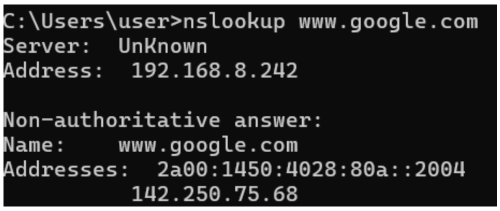

Figure 9: nslookup results

4. Using Tool 3: Ping Test (Round-Trip Time)

To measure the round-trip time (RTT) for reaching Google using both IPv4 and IPv6.

The ping command was executed simultaneously for both addresses IPv4 and IPv6 to reduce the influence of external factors. A total of 637 ping requests were sent, *see figure 10*.

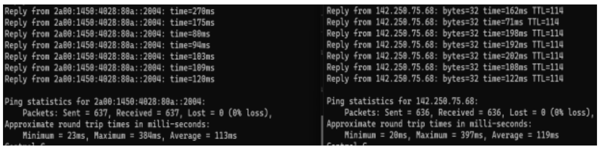

Figure 10: ping to google results for both ipv4 and ipv6

See table 2

Table2:IPv4 Vs IPv6 Ping Results

Protocol	Average RTT	Packet loss
IPv4	113ms	0%
IPv6	119ms	0%

See table 3

Table3:IPv4 Vs IPv6 Header

Feature	IPv6 Packet Header	IPv4 Packet Header
Header Complexity	Simpler and smaller	Larger and more complex
Fragmentation	None	Present

IPv6 demonstrated a slightly better average RTT compared to IPv4, with no packet loss for either protocol.

5. Tool 4: Traceroute Test (Hop Count)

To determine the number of hops required to reach Google using both protocols.

A tracert command was executed simultaneously for both addresses to reduce the influence of external factors, *see figure 11*.

Figure 11: ping to google results for both ipv4 and ipv6

Both IPv4 and IPv6 required the same number of hops to reach Google.

This indicates that the packets likely traversed the same routers configured with Dual Stack technology.

6. Tool 5: Packet Analysis Using Wireshark

6.1 To compare the packet headers of IPv4 and IPv6 when accessing Google.

Capturing IPv6 Packets:

With Dual Stack enabled, Wireshark was used to capture packets during access to Google.

Both endpoints preferred IPv6 for communication, *see figure 12*.

```
Internet Protocol Version 6, Src: 2a02:14f:1ee:e373:3489:18b1:b8de:494, Dst: 2a00:1450:4028:80a::2004
    0110 .... = Version: 6
  > .... 0000 0000 .... .... .... .... .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
    .... 1001 1100 0011 0010 1100 = Flow Label: 0x9c32c
    Payload Length: 1380
    Next Header: TCP (6)
    Hop Limit: 254
  > Source Address: 2a02:14f:1ee:e373:3489:18b1:b8de:494
  > Destination Address: 2a00:1450:4028:80a::2004
    [Stream index: 3]
```

Figure 12: IPv6 captured packet using wireshark

6.2 Capturing IPv4 Packets:

To capture IPv4 packets, IPv6 was disabled on the Windows ope

rating system used for the experiment.

The google page was reloaded, and the IPv4 packet was captured using Wireshark, *see figure 13*.

```
Internet Protocol Version 4, Src: 192.168.8.224, Dst: 142.250.75.68
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
  > Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
    Total Length: 40
    Identification: 0x21aa (8618)
  > 010. .... = Flags: 0x2, Don't fragment
    ...0 0000 0000 0000 = Fragment Offset: 0
    Time to Live: 128
    Protocol: TCP (6)
    Header Checksum: 0x355f [validation disabled]
    [Header checksum status: Unverified]
    Source Address: 192.168.8.224
    Destination Address: 142.250.75.68
    [Stream index: 10]
```

Figure 13: IPv4 captured packet using wireshark

7. Discussion of Experiment 2

The experiments reveal that IPv6 offers several advantages over IPv4, including:

- Better average RTT (lower latency).
- Simpler and more efficient packet headers.
- No fragmentation, improving performance.

However, the hop count remained identical for both protocols, indicating that the ipv6 and ipv4 packets traveled on same path with same routers equipped with dual stack capabilities. These results emphasize the readiness of worldwide networks to adopt IPv6 and the benefits it provides for future scalability and performance.

B. Understanding the structure of the Internet in Palestine.

A survey of the licensed Internet Service Providers (ISPs) in Palestine was conducted. The best source for this information is the Palestinian Ministry of Communications, as it is the authority responsible for issuing licenses to ISPs. The information was obtained through their official website [16].

It was found that there are eight licensed Internet Service Providers (ISPs) in Palestine.

The next question is: how can their readiness for transitioning to the IPv6 protocol be assessed?

The following methods were used to address this question:

1. Utilizing BGP tools to analyze network readiness.

2. Requesting IPv6 services from ISPs through telephone calls to customer support.

3. Conducting interviews with technical staff at each ISP.

1. Using network tools such as BGP tools https://bgp.tools/

BGP Tools: are utilities and platforms used to monitor, analyze, and manage the behavior of the Border Gateway Protocol (BGP), which is the protocol responsible for routing data between autonomous systems (ASs) on the Internet. These tools are essential for network administrators, engineers, and researchers to understand and optimize internet traffic, assess routing policies, and ensure efficient connectivity.

Any ISP wishing to adopt to IPv6 must first acquire ownership of a range of IPv6 addresses. These addresses must then be globally announced using the Border Gateway Protocol (BGP) to enable routing traffic to and from global networks.

Each Internet Service Provider (ISP) has at least one unique identifier, known as an AS number (Autonomous System number), which is used to announce its networks to the external world via the BGP protocol.

Using the website https://bgp.tools/, we accessed the list of AS numbers associated with Palestine [17] to identify which ISPs have a range of IPv6 addresses announced to other ISPs globally. The results were organized and presented in the following table:

Table 4: Palestinians ISPs BGP ipv6 results

	ISPs in Palestine	AS	Ipv6 BGP advertise	Ipv6 prefixes	Size of prefix	Tier provide level	Prefix status	ISP Registered on	IPv6 BGP Registered on
1	Paltel	12975	yes	2a00:d2c0::/32	65536 /48's	Ties 1	Active, Allocated under RIPE	19 Aug 2002	6 Jun 2023
2	Al Zaytona	197350	NO	-----	-----	-----	------	7 Jan 2011	Not yet
3	Mada	51407	yes	2a04:940::/29	524288 /48's	Tier 1	Active, Allocated under RIPE	16 Aug 2010	4 Feb 2013
4	Together	42013	yes	2a0b:4d40::/29	524288 /48's	Tier 2	Active, Allocated under RIPE	21 Jun 2017	22 Jun 2017
5	Bnet	47253	No	-----	-----	-----	------	26 May 2008	Not yet
6	CoolNet	12754	yes	2a00:4e80::/32	65536 /48's	Tier 1 and Tier 2	Active, Allocated under RIPE	11 Nov 2009	27 Apr 2011
7	Gimzo	51336	No	-----	-----	-----	------	27 Jul 2010	Not yet
8	zone	52145	No	-----	-----	-----	------	7 Jan 2011	Not yet

The table 4 shows that four out of eight Internet Service Providers in Palestine have reserved IPv6 address ranges, which have already been announced to the global network using the BGP protocol.

Regarding to enterprises (large companies, banks, universities) all of them don't have ipv6 network announced to the global network using the BGP[17].

2. A phone calls to the customer support for the four Internet Service Providers that announce their IPv6 address ranges via BGP was contacted to request IPv6 services. The response from all of them was that the service is currently unavailable, with no estimated timeline provided for when it might become available.
3. The next step involved arranging interviews with the technical personnel of the ISP and enterprises to understand why they have not decided to offer IPv6 services to their customers. The following conclusions were drawn:

Regarding to responses from technical administrators of ISPs about the lack of transition to IPv6:

- Dual Stack hardware Challenges: Transitioning to IPv6 requires running Dual Stack on all routers of the ISPs. The issue is that some of these devices do not support this feature, necessitating their replacement. For devices that do support it, enabling Dual Stack consumes additional resources, requiring further investment to maintain the same performance levels.
- Configuration Effort Challenges: Beyond the hardware challenge, there is the additional burden of configuring these devices to be ready for the transition. This requires investment in both time and human resources.
- Customer Demand: The vast majority of customers do not request IPv6 services, making the investment in transitioning to IPv6 seem unjustified from a business perspective.

Regarding to responses from technical administrators of enterprises about the lack of transition to IPv6:

- **No Compelling Reason for Transition**: They see no substantial reason to transition to IPv6, as NAT (Network Address Translation) has effectively solved the problem of IPv4 address shortages. However, they acknowledged that NAT adds a burden on the edge routers connecting the organization to the Internet Service Provider.
- **Concerns About Network Stability**: There is a fear of network instability during the transition to IPv6. Their current network stability is the result of years of accumulated effort and investment in IPv4. Transitioning to IPv6 poses a risk to this stability and introduces additional burdens that they prefer to avoid at this stage.
- **Security Challenges**: Transitioning to IPv6 could make it easier for external entities to establish connections to many internal addresses that were previously hidden "private ipv4 address" due to NAT. Converting these addresses to "global IPv6 unicast addresses" would expose the internal network, increasing the risk of external attacks. This would place an additional burden on the enterprise's network security teams.
- **Lack of IPv6 Support from ISPs**: A significant obstacle is that ISPs in Palestine do not provide IPv6 routing services to their customers. This forces enterprises that was believe in ipv6 adoption to create alternative solutions, such as tunneling. For example, one of the enterprises experimented with routing IPv6 traffic through an IPv6 packet-over-IPv4 tunnel[12] *"This explains the IPv6 adoption percentages related to Palestine reported by platforms like Facebook"* [9]. However, this solution added complexity and burdens to the routing process, leading the organization to abandon the approach and continue and forget about ipv6 adoption.

IV. Discussion of Results

A. End-User Device readiness for IPv6 adoption

Since 2014, U.S. regulations have mandated that end-user devices and operating systems be IPv6-compatible. Most operating systems used by end users in Palestine, the Arab world, and globally are U.S.-based, including Windows, macOS, Unix, Linux, Android, and iOS. This compliance extends to peripheral devices such as printers and cameras.

As a result, devices in Palestine are ready for IPv6 transition, a fact supported by practical experiments.

B. Internet Service Providers (ISPs)

The study revealed that 4 out of 8 ISPs in Palestine have held IPv6 address allocations for years and they announce these addresses globally via the BGP protocol, indicating some awareness of the importance of IPv6. Additionally, the Palestinian Ministry of Communications, along with universities and banks, also holds IPv6 address allocations. However, these addresses are not announced via BGP, as Palestinian ISPs do not provide IPv6 routing services. To date, ISPs and most organizations do not offer IPv6 services to their customers. The main reasons include:

1. **Increased Load on Devices**: Running a dual-stack system increases the burden on devices, necessitating additional resources and significant budgets.
2. **Human Resource Costs**: Configuring devices for IPv6 requires specialized personnel, adding to operational expenses.
3. **Lack of Demand**: There is no strong customer demand for IPv6 services leading to a lack of urgency for the transition.

V. Recommendations

National Vision and Transition Plans

A unified national vision is essential for transitioning to IPv6, implemented through phased plans with a clear timeline. If organizations are left to view the transition from a narrow perspective, the overall internet infrastructure in Palestine will suffer both short-term and long-term consequences. It is recommended to enact laws from relevant authorities to encourage stakeholders to plan for the IPv6 transition, similar to countries that have legislated such policies and achieved significant adoption rates. The key stakeholders include:

- Ministry of Communications, in collaboration with ISPs.
- Ministry of Education and Higher Education, coordinating with universities, schools, and educational institutions.
- Palestinian Monetary Authority, working with banks and financial institutions.

Workshops can be held to facilitate collaboration among these entities.

Awareness and Training

Network specialists in Palestine need to be educated about the importance of IPv6 transition and its potential benefits despite the existing challenges. Technical training courses can be organized to prepare these specialists for the transition, as they are the key decision-makers in implementing IPv6.

Global Incentives

Global organizations that rank institutions, such as the QS World University Rankings can include IPv6 transition as a criterion. This can incentivize institutions to adopt IPv6 as a means to improve their global standing, motivating them to take proactive steps toward the transition.

By implementing these recommendations, Palestine can effectively navigate the challenges of IPv6 adoption and align its infrastructure with global standards.

VI. Conclusion

The transition to IPv6 is no longer a matter of preference but a necessity for ensuring the future scalability, security, and functionality of the internet. While global adoption rates have steadily increased, reaching significant milestones, Palestine remains far behind with an adoption rate approaching zero. This stark contrast highlights the critical challenges faced by the country, including a lack of ISP readiness, insufficient customer demand, and resource-intensive infrastructure upgrades required for dual-stack implementation.

Despite these challenges, the study reveals that end-user devices in Palestine are largely IPv6-ready due to compliance with international standards. Additionally, a few ISPs and large organizations in the country have reserved IPv6 address blocks and even announced them via BGP, demonstrating foundational awareness of IPv6's importance. However, these efforts remain largely unutilized, underscoring the need for coordinated action.

To address these barriers, a national strategy must be developed that unifies stakeholders, including ISPs, government agencies, educational institutions, and financial organizations. This strategy should include awareness campaigns, technical training, and incentives to foster a gradual yet structured transition to IPv6. Furthermore, aligning with global standards and leveraging international incentives could accelerate the adoption process.

Without immediate action, Palestine risks further isolation in a digital landscape increasingly dominated by IPv6. By implementing the recommendations outlined in this research, the country can begin its journey toward a modern, scalable, and competitive internet infrastructure.

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