The Cloud, Powered by UNIX

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***Abstract*—In 1969, at AT&T's Bell Laboratories, a team led by computer scientists Ken Thompson and Dennis Ritchie created the first version of UNIX for use as a time-sharing computer system. Later on, students and professors at the University of California at Berkeley would expand UNIX into the Berkeley Software Distribution, or BSD for short. UNIX inspired free and open source operating systems such as FreeBSD and Linux and was the basis of Apple's Mac OS. [1]**

***Index Terms*—unix, cloud, server, web, service, freebsd, linux, iaas, caas**

I. Introduction

UNIX is ubiquitous in the cloud. Roughly 80% of websites are hosted on UNIX-based servers, with over 40% of those using Linux [2]. UNIX-based operating systems (OSes) are commonly used in the cloud as they are typically free, open source, resource-efficient and have a powerful command-line interface (CLI) [3].

Fig. 1. FreeBSD, a popular UNIX-based operating system. [4]

II. Advantages and Disadvantages of UNIX

UNIX-based OSes are an attractive and popular choice for the cloud due to their free and open source nature, flexibility and powerful CLI [3].

A. Advantages of UNIX

UNIX-based OSes have several advantages [3]:

- **Portability**
  - They can run on a large number of different hardware platforms.
  - They are written in C, a popular low-level programming language.
- **Memory Usage**
  - They are very memory-efficient.
  - They handle virtual memory well.
- **Powerful CLI:** The CLI comes with a variety of powerful commands that can save a lot of time over having to perform several mouse clicks in a graphical user interface (GUI).
- **Everything as a File:** Several device interfaces are exposed as file-like objects, making them quick and easy to work with, especially in the CLI.
- **Security:** They use UID and GID for user permissions, which control file access.
- **Free and Open Source:** They are typically free and open source, allowing anyone to audit and contribute to them.

B. Disadvantages of UNIX

Unfortunately, UNIX-based OSes have downsides [3]:

- **Not Beginner-Friendly:** They can be have a high learning curve.
  - Most system administration on UNIX-based OSes is done via commands, of which there are many, which users will have to memorise to work efficiently.
  - Some commands have functions that are different to what their name implies.
  - Some commands have syntax that's different to most, adding extra nuances that users must familiarise themselves with.
- **Lack of driver support:** Some devices may not have open-source drivers, official drivers or any drivers at all for these OSes.

III. Useful UNIX Tools

UNIX-based OSes come with tons of useful commands [3]. Here are some listed by [5]:

- **curl:** This command connects to and downloads content from a given URL, making it useful for testing API-endpoints.
  - For example, it can check if they respond to requests, show the HTTP response code (200 for OK, 500 for Internal Server Error, etc.) or even test if a domain name resolves.
  - 'jq' can be used to print an APIs JSON response in a more readable format, with line breaks and indentation. For example: `echo '{...}' | jq`, where `{...}` is a long JSON object.
- **tail:** Outputs the last few lines of a file, which is useful for checking the most recent lines in a logfile.
  - By default, the last 10 lines are printed, but this can be changed with the `-n` argument.

  - `-f` causes `tail` to "follow" the file, showing new lines being written to it in real time.
- **grep:** Shows lines of a file with content that matches a given regex pattern. Useful for searching through log files and can even be used with command output that's piped into it.
- **ps:** Shows running processes and their details such as:
  - The user it's running under.
  - Process ID.
  - Parent process ID.
  - Time it was started.
  - Time it was running for.
- **env:** Sets and prints environment variables and their values.
- **lsof:** Shows opened files and what processes are using them, this includes device interfaces exposed as file objects. Similar to `netstat`, `lsof` can be used to check ports that are being listened to and by what process.
- **nslookup:** Queries domain names, seeing where they lead to or if they're working properly.
- **history:** Shows the users command history. All shells will have a variant of this command.

IV. IaaS V.S. CaaS

There was 2 popular ways of offering UNIX-based hosting: Infrastructure as a Service (IaaS) and Container as a Service (CaaS) [6].

A. Infrastructure as a Service

Infrastructure as a Service (IaaS) is a cloud computing model where vendors provide access to hardware that customers can manage through the internet and host online services such as web applications, data storage or any server software they desire. This hardware is hosted and maintained by the vendors. IaaS allows for businesses to deploy online services without having to invest in their own hosting infrastructure. Virtualisation is typically used to isolate and split the host hardware into smaller virtual machines [6].

The benefits of IaaS are [6]:

- Businesses don't have to expend as much effort in managing, maintaining and expanding their servers, as vendors handle most of it.
  - Most vendors have very high uptime guarantees. For example, DigitalOcean and AWS's instances and Google Cloud's zones guarantee 99.99% uptime, and Google Cloud's instances guarantee 99.5% uptime.
- Because hardware resources are allocated via virtualisation, scaling up or down is a lot faster and can be done via software (i.e. through a web portal or vendor provided CLI).
- It replaces large upfront infrastructure costs and replaces them with a more palatable subscription fee.

B. Container as a Service

Container as a Service (CaaS) is a cloud computing model that involves applications being deployed as containers, rather than via a traditional UNIX application install. These containers also provide isolation from the host system and other containers. Containerised applications run on the host OS instead of utilising virtualisation. CaaS runs on top of IaaS [6].

The benefits of CaaS are [6]:

- Isolation without requiring a separate OS per instance, as containerised applications still run on the host OS, versus a virtual machine per isolated application. This saves on:
  - Processing Power
  - Memory
  - Storage Space
  - Startup Times (for an isolated application)
- Consistent environment for the application within. This reduces the likelihood of unexpected behaviour caused by different environments.

C. IaaS V.S. CaaS

- Due to the fact that CaaS runs on top of IaaS anyway, IaaS is more hardware efficient and less complex.
  - Is it essentially a virtualisation of a basic UNIX-based system, meaning that it is not much different to managing one, reducing complexity.
  - The lack of containerisation on top of IaaS means less overhead.
- CaaS provides isolation without having to have an OS for each isolated application, reducing hardware usage.
- CaaS applications come with their container, and therefore, a consistent environment, instead of hoping that the OS environment they're running on is compatible.

References

[1] E. Gregersen *et al*. "UNIX — Definition, Meaning, History, & Facts." Britannica. https://www.britannica.com/technology/UNIX (accessed Sep. 9 2023)

[2] "Usage statistics of Unix for websites." W3Techs. https://w3techs.com/technologies/details/os-unix (accessed Sep. 9 2023)

[3] J. Rehman. "What are advantages and disadvantages of UNIX operating system." IT Release. https://www.itrelease.com/2021/03/what-are-advantages-and-disadvantages-of-unix-operating-system (accessed Sep. 9 2023)

[4] FreeBSD Foundation, FREEBSD_Logo_Horiz_Pos_RGB. 2016. Accessed: Aug. 9, 2023. [Photo]. Available: https://freebsdfoundation.org/about-us/about-the-foundation/project/

[5] R. Wang. "20 Linux commands every sysadmin should know." Opensource.com. https://opensource.com/article/17/7/20-sysadmin-commands (accessed Sep. 9 2023)

[6] J. Clark. "CaaS vs IaaS — What's the difference?" Back4App. https://blog.back4app.com/caas-vs-iaas-whats-the-difference (accessed Sep. 9 2023)

Unix Comunication Report

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I. Introduction

Linux and Unix has became increasingly popular in the cloud computing industry. More providers are offering Linux and Unix services to their clients. It is becoming such a useful tool the providers themselves are even utilising it for their own infrastructure when delivering services as they need to ensure high availability for their clients. What is causing this upward trend for Linux and Unix in the cloud computing market.

II. Cloud Computing

Cloud computing allows for system resources to be delivered to a user over the internet quickly and relatively cheaply, only paying for what you use. Companies recognised the advantages to this system, allowing for a quick, scalable development environment that doesn't require specialised resources to set up and maintain. These resources can be divided up into three different services that a company may offer. One of these is platform as a service (PaaS). Over the past ten years PaaS has become increasingly more popular as cloud computing has become more accessible. PaaS provides hardware, an operating system and databases via the cloud leaving the user to control what applications will be run on the system. Infrastructure as a service (IaaS) provides the physical hardware and networking connections for the end user, meaning that the user has to provide everything above on the stack, this includes the OS and applications.

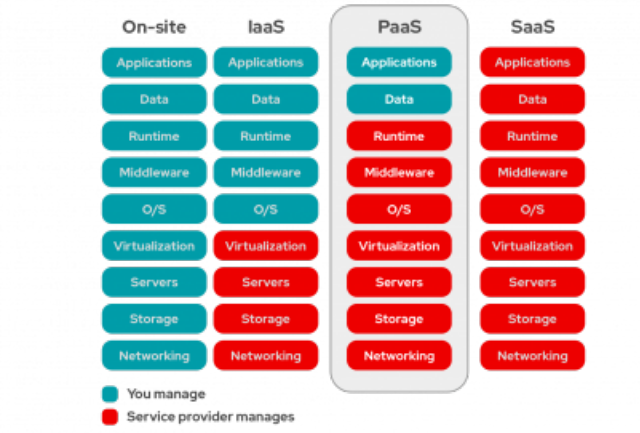

Fig. 1. IaaS and PaaS stack
[1]

PaaS is highly scalable and requires less upkeep on the systems. IaaS is extremely flexible, allowing for purchasing of resources as required and gives the client control of their infrastructure as they choose what servers and processing power they need. Both services have security concerns with the vulnerability of a business data when utilising PaaS or for IaaS being susceptible to vulnerabilities introduced through the use of VM's.

The two largest players in the cloud computing space are AWS and Azure, "AWS holding 33% of market share, Azure having 22% respectively as of 2022" [2]. AWS began in 2006 though was very primitive to what most cloud computing platforms offer today. Most of AWS utilizes a custom Linux OS called Amazon Linux. This has since been updated to Amazon Linux 2023 a cloud computing centered version optimised for Amazon's EC2. Microsoft Azure started in 2010. It offers services at all three levels and was developed to run on Windows OS at the start. Azure since 2015 has begun to even run more of its infrastructure on Linux when they announced Azure Cloud Switch (ACS) which was built on Linux stating that "running on Linux, ACS is able to make use of its vibrant ecosystem" [3]. In 2017 40% of VM's for Azure were running Linux while now "more than 50% of all Azure compute cores are Linux" [4]. In 2018 Scott Guthrie Microsoft executive VP of cloud computing said during an interview "Native Azure services are often running on Linux," Guthrie added. "Microsoft is building more of these services. For example, Azure's Software Defined Network (SDN) is based on Linux." [5] Even a company that began offering cloud services using its own closed software has begun to transition in all aspects of their business to support open-source Linux OS. This is because the customers that they are serving are wanting to use open-source software such as Linux. With the largest competitors transitioning it begs the question why are so many people utilising Linux software?

III. Advantages

A. Licensing Costs

One reason is licensing costs, since Linux began it has been offered for free and prohibited from commercial distribution. This means both Linux distributions are free for personal and company use though they may charge for support under enterprise agreements. This means when choosing IaaS or PaaS that are utilising some form of Linux it's always going to be less as they can only charge for extra services on top such as Tech-support or cost of running the hardware. This leads to an overall decrease in cost for end users. Red Hat Enterprise Linux is an example of a distribution that offers support plans to clients. It offers many different plans but in this instance let's compare plans from Microsoft and RedHat for datacentre see fig 2. At the minimum Windows is cheaper but this licence only works for one user and is limited to 16 cores, increasing cores incurring price increase, as well as each additional user

incurs a $38 fee. There is no pricing increase for red hats support on how many cores it is offering support to. Meaning the difference between the two only increases as the number of compute cores increase.

		Year 1	Year 2	Year 3	Year 4	Year 5	Total	Delta
	License	Support						
Red Hat		$2,499	$2,499	$2,499	$2,499	$2,499	$12,495	
Windows	$8,055	$1,525	$1,525	$1,525	$1,525	$1,525	$15,680	25%

Fig. 2. License and Support cost over 5 years
[6]

A similar trend continues when looking at cloud services. AWS, Google and Microsoft all offer both Windows and Linux options for PaaS. Over a year depending on the provider, it is possible to pay a increase of 16%-27% extra for any instance running a Windows OS using 2 cores (Fig 3). This percentage increase only gets larger as you increase the number of cores to the plan.

Provider	Reserved Instance Type	1 Year Red Hat Linux	1 Year Windows	Windows Premium
AWS	m5.large	$1,060	$1,340	26%
Google	n1-standard-2	$1,108	$1,283	16%
Microsoft	D2 v3	$1,034	$1,313	27%

Fig. 3. Annual Cloud Subscription 2 vCPU
[7]

B. Stability and Security

Linux based systems provides more advantages than just cheaper costs, it is historically more stable and more secure platform which is very important for critical infrastructure or applications you can't afford to have go down. This stability comes from not having to restart to apply updates, and its community approach means that lots of bugs can be found and fixed before they may have a chance to interrupt your service. Its secure nature comes from a number of features it offers such as highly customisable access control able to control who can do what and even set up independent environments such as jails that are totally quarantined from other parts of the system. Additionally, the community support that helps finds bugs also helps find and fix potential security flaws before they can be exploited and are fixed since there are so many eyes on it that its not common for these exploits to be used.

C. Open-Source and Scalable

This open-source nature of Linux allows for a high level of versatility meaning the end user can change to newer technologies adopt even, whole new infrastructure while not being tied into a specific vendor that may not offer the latest supports for newest technologies. It allows end user more choices meaning its likely they will find the perfect solution for what they need. It also means Linux is highly scalable, Linux like Unix was designed to be easily portable across different processor types. This is why it is the basis for so many different operating systems like android and it continues to work even though phone processors architecture is different than desktop processors. Combine this with its community support from independent developers to industry it is likely some version of a distro will work on whatever new processor architecture will be in use in the future.

IV. Disadvantages

A. Steep Learning Curve

Opting to run your infrastructure or platform on a Linux or Unix system does have draw backs that should be considered. For both environment the major hurdle is the required knowledge to mange and use these systems. If you're running these systems and not knowledgeable it could lead to weaking some of its advantages such as security. It is important to know what updates your working distro may have pending and if it's needed for your use. Documentation for Unix explicitly can be lacking and requires an understanding on how best to put into practice what documentation does exist. This disadvantage can be largely mitigated with paying for support but not all distros offer support plans so it's important to plan appropriately.

B. Driver and Application Support

Another disadvantage is that not all hardware or software can run on a Linux or Unix system. For clients with PaaS cloud service this will likely impact what programs they are able to run. An example is Visual Studio wont work on a Linux platform. Some applications are able to work after adding a compatibility layer between the system and the application like Wine, but this may not always work if it is a niche application.

V. Network Services Available

A. SONiC

The customisability of Linux like systems leads to lots of innovation and the ability to offer network services. A technology which was mentioned earlier SONiC is an innovation that is hoping to allow for the continued improvement of switches while still able to use the same software no matter the vendor or how many different switches may make up a node. "SONiC is the first solution to break monolithic switch software into multiple containerized components" [8] which is the ethos behind many Unix and Linux systems giving them the ability to be compartmentalised. Lots of networking hardware use proprietary API's and most configuration is done on the console by network engineers. SONiC uses the Debian

Linux distro to run though could be changed to run on any distro that would be needed. This also allows for a cloud network infrastructure to be fully run on open-sourced software utilising, Open Network Linux for controlling the hardware, SONiC in the middle then an open-sourced management tool like Kubernetes or Docker manager clients containers. It's community of partners is growing and in 2022 was moved to be managed by the Linux foundation, features are being added by these partners meaning that no matter the needs it is likely that SONiC will have features that would be useful and if it doesn't they can be added.It is still relatively early for SONiC but as of October 2022 their is already one company that is set them self's up offering support for SONiC users like Red Hat do for their own version of Linux. This should further promote the move to utilising this technology in the industry.

B. Lighttpd and FreeBSD

When delivering services its important to try and minimise the impact of all other applications running on a system apart from what you want it to be doing. Open-sourced OS's allow for this with the ability to customise what is mandatory to be running. As you get closer to the backbones of any service being web servers or databases you want the equipment to be highly specific for the task. An example of this is Lighttpd which was is a web server purposely designed to have low memory and CPU footprint while still delivering high speeds. Netflix built a CDN called Open Connect, part of this CDN utilises a customised version of FreeBSD that runs on their content caches [9]. In the cloud it is important that you are maximally using your resources for your compute tasks. Running software on top of your IaaS that may be inefficient could be resulting in much higher cost for your business and why Linux and Unix can be so important with ensuring your resources are being used well.

C. Network Monitoring Tool

An open-source monitoring tool that can be utilised is OpenNMS which is an enterprise level monitoring tool designed for service monitoring, event management and data collection. It was designed to be able to work on diverse systems and is designed for easy implemntation of extra features if the user needs. It does require java to be able to execute and PostgreSQL database. Larger companies also offer monitoring for Linux as well like SolarWind though these are not free open source software and requires licensing to use.

VI. Containers in Cloud Computing

As we have seen lots of infrastructure utilises Linux and Unix to run their infrastructure and some people may be hesitant that when migrating to cloud system that is running on Linux that their applications, they require for development may not work the same. There is a solution called containers. "Containers are packages of software that contain all of the necessary elements to run in any environment" [10]allowing for further compartmentalisation at and application level. This allows for the piece of software to be completely unaware of the host OS or the infrastructure that is delivering the processing power. Unlike a VM which is virtualising an OS before running the application requiring resources, containers only have the software and related libraries for it to work. Containers are less resource intensive to run which is important for cloud computing when you are paying for your compute costs.

With the use of container tools as Docker and Linux Containers users are able to regain control of the OS giving more customisation and control. It allows PaaS services to be able to develop for different architectures without needing to have a host running the required architecture or OS.

VII. Conclusion

It is clear to see that Linux and Unix are supplying the backbone to many cloud computing services. The benefits for open-source development style outweigh the downsides for these companies. The major competition has over the past 10 years have taken steps to not only offer Linux services but helping to develop fully open-sourced tools that will benefit all. With the continual acceptance of Linux in the enterprise space it is only a matter of time before more every day applications begin to be developed explicitly for Linux likely to cause more home users to eventually switch.

REFERENCES

[1] R. Hat. Types of cloud computing. [Online]. Available: https://www.redhat.com/en/topics/cloud-computing/public-cloud-vs-private-cloud-and-hybrid-cloud

[2] C. Griffiths. The latest cloud computing statistics. [Online]. Available: https://aag-it.com/the-latest-cloud-computing-statistics/#:~:text=AWS%20had%20the%20largest%20market,all%20other%20companies%20at%2035%25

[3] M. Azure. Microsoft showcases the azure cloud switch. [Online]. Available: https://azure.microsoft.com/en-us/blog/microsoft-showcases-the-azure-cloud-switch-acs/?ranMID=24542&ranEAID=TnL5HPStwNw&ranSiteID=TnL5HPStwNw-jwTkNwQ2Nq0fDezNbB4f9A&epi=TnL5HPStwNw-jwTkNwQ2Nq0fDezNbB4f9A&irgwc=1&OCID=AIDcmm549zy227_aff_7593_1243925&tduid=%28ir__p1iqsdhhdskfdxkomicaezceuu2xb0z0pj1ms0f300%29%287593%29%281243925%29%28TnL5HPStwNw-jwTkNwQ2Nq0fDezNbB4f9A%29%28%29&irclickid=_p1iqsdhhdskfdxkomicaezceuu2xb0z0pj1ms0f300

[4] ——. Linux virtual machines in azure. [Online]. Available: https://azure.microsoft.com/en-au/products/virtual-machines/linux#:~:text=Select%20your%20preferred%20distribution%20with,Azure%20compute%20cores%20are%20Linux.

[5] S. Vaughan-Nicholos. Linux now dominates azure. [Online]. Available: https://www.zdnet.com/article/linux-now-dominates-azure/

[6] K. Leoni. Linux vs windows - a cost comparison. [Online]. Available: https://www.heroix.com/blog/linux-vs-windows-a-cost-comparison/

[7] ——. Linux vs windows - a cost comparison. [Online]. Available: https://www.heroix.com/blog/linux-vs-windows-a-cost-comparison/

[8] Y. Khalidi. Sonic: The networking switch software that powers the microsoft global cloud. [Online]. Available: https://azure.microsoft.com/en-us/blog/sonic-the-networking-switch-software-that-powers-the-microsoft-global-cloud/

[9] J. Looney. Netflix and freebsd: Using open source to deliver streaming video. [Online]. Available: https://papers.freebsd.org/2019/fosdem/looney-netflix_and_freebsd/

[10] G. Cloud. What are containers? [Online]. Available: https://cloud.google.com/learn/what-are-containers