Ramón Orraca March 23, 2023

Metaverse: Network Requirements and Roadmap

To begin, some basic concepts will be covered. Although the telecommunications and technology industries often use convoluted and abstract names, these ideas are not difficult to grasp. The discussion will start with the cloud, application programming interfaces (APIs), and mobile networks focused on 5G. After clearing these concepts an explanation of how modern mobile network architectures are constructed will be presented.

With all the jargon out of the way and a clear understanding of how these concepts interact with one another in the modern digital realm a more profound analysis focused on the technical requirements of creating a metaverse will be done, starting with the question: what is the metaverse? This analysis will tend to focus on how software developers could leverage this new technology and give a brief recount of the network requirements needed to create such a service. While uncovering these two ideas a clear picture of what mobile network operators (MNOs) might look like in the future will be presented.

Finally, towards the end of this document, the conversation will steer to less technical topics and cover business and philosophical perspectives. These ideas of how things could unfold are personal opinions and thus should be taken with a grain of salt. Nonetheless, a big effort to present the most likely scenarios will be made. The objective of this writing is to create public debate about these ideas outside the small island of knowledge that sometimes seems to surround the technology and telecommunications industries.

Uncovering the cloud, APIs, and mobile networks

Most people that live in a modern city have probably heard concepts such as the cloud and have been mesmerized by the abstractness of its name[1]. After getting one thing out of the way things will start to become much clearer: the cloud is just someone else's computer[2]. This point has been highlighted in many t-shirts and mugs, but the reality is that as a whole the cloud really turns out to be just the migration of computing into space you rent from a third party. If computing is done in proprietary hardware hosted in the owner's premises this is called on-premise equipment, but in reality, it is still just a computer and could be considered a cloud.

[1] This includes me, the author, whom to a certain degree considers himself to be a technologically savvy individual.
[2] As Parker Software (ND) points out this is a shallow understanding of the concept, but for the purpose of this writing it is enough.

The difference between these two types of clouds is important because as this concept has taken hold of the world in the last couple of years many MNOs have played around with hybrid architectures. This means that part of their infrastructure is provided by third parties and other services are computed on their own proprietary hardware. This leads to another distinction that must be considered when speaking about cloud services: private and public clouds. The difference between these is a lot easier to understand, private clouds are computing resources—servers—that are single purposely assigned to one company[3] and public clouds are servers that different companies can rent from a cloud provider at the same time.

With this basic understanding of cloud computing the second concept will be tackled, APIs. These are a set of tools and protocols used for building software applications. Generally, these services are provided by the owner of some digital infrastructure—generally software or data—that can be made available to third-party users through the internet[4]. Although this might sound like something not commonly used, billions of people daily use these services when consuming even the most basic forms of internet-based content.

Lastly, mobile networks will be explained. To get a hold of this concept it is important to understand how digital communications work, this comes down to a mix of electromagnetic frequencies and fiber optic cables. To explain this process consider a scenario where a cellphone user in Mexico City using AT&T is sending a WhatsApp message to another cellphone user in Sydney using Vodafone. It is important to note that for the purpose of this example, both users are using their cellular data, they are not connected to the internet via WiFi. The communication process could be broken down into seven steps:

1. The cellphone user in Mexico City hits send, at this moment the user's cellphone antenna sends the message as a stream of bits to the nearest cellular antenna. The cellphone antenna, depending on the technology through which it's connected to the network, can use different frequencies but assuming the use of 5G it could be using something between 800 and 3,500 MHz.
2. Once the cellular antenna receives the user's payload—the WhatsApp message—gets converted to beams of light to be sent through the fiber optic backbone of the network.

[3] On-premise equipment is a private cloud, but third parties can also provide private clouds. More information upon this distinction can be found in Khillar S. (2022).
[4] This services don't always work via HTTP requests—an internet connection—, they can also work on a more local level to provide the consumer an abstraction layer to use other services.

3. When information is sent through the fiber cable the first stop it will reach is generally the carrier's network core, this is basically a data center where the user's MNO—in this case AT&T—routes network traffic. As the message can't be processed by the servers living inside this data center, the message needs to be routed to WhatsApp's data center.
4. Once the message reaches WhatsApp's data center the message is captured in a database and then forwarded to the receiving user in Sydney[5].
5. Same as when the message was sent the final stop the data will make before getting to the receiving user will be this user's network core, which is a data center controlled by the MNO which the individual in Sydney has a contract with—in this scenario Vodafone.
6. From the Vodafone network core the message is routed towards the cellular antenna nearest to the receiving user and there the information gets converted into radio frequency once again to be sent to the receiving user's cellphone antenna.
7. Once the receiving user's cellphone receives the information, this is processed and displayed on the application where the content ought to be consumed.

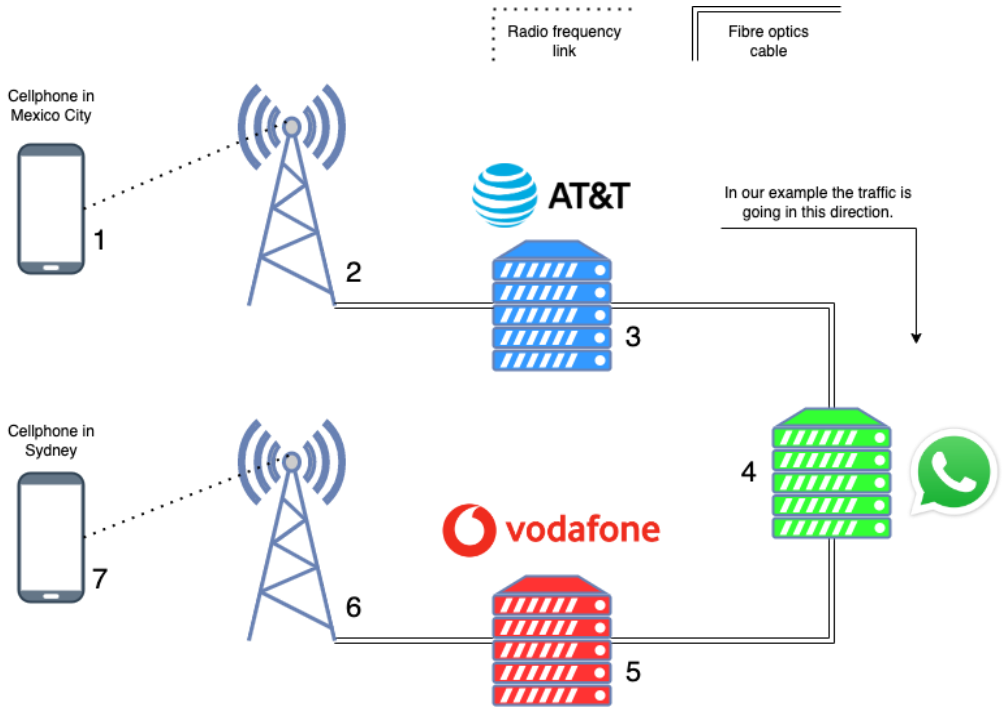

Figure 1. Very high-level example of how a mobile network works when sending a WhatsApp message.

[5] This is not all that happens, to really understand what WhatsApp does you could read the *WhatsApp Encryption Overview (Technical white paper)* explains in detail how end-to-end encryption works and a bunch of other cool things. Google the title and it'll appear, the link for this resource is quite ugly so I won't write it down.

Modern mobile network architectures

With this high-level understanding of cloud computing, APIs, and mobile networks; an effort can be done to understand how these things currently interact to create a modern mobile network. The first thing to get out of the way is the underlying architecture of the network, it all stays the same as in our WhatsApp example except for the network's core. In current times the core has begun a virtualization process that allows MNOs to more efficiently control their OSS (Operation Support System), BSS (Business Support System), and IT workloads.

What virtualization means in this context is creating a containerized infrastructure within the server, this is a more technical topic, but what it basically means is simulating smaller computers within the real hardware that exists in the data center[6]. These smaller virtual computers can be managed in clusters through services such as Kubernetes and give the MNO much more flexibility when making changes to the infrastructure; this is a huge step towards network efficiency. Before, changes needed to be done in a more systematic way as a single machine managed many network operations through a Command Line Interface (CLI), but now ephemeral containers can be scaled through software to meet dynamic traffic demands[7].

Before using containers and microservices, MNOs used Virtualized Network Functions (VNFs) that ran as Virtual Machines (VMs) inside their hardware[8]. However, with the deployment of 5G newer technologies started being used and this led to what some in the industry call the telco cloud. This means managing the network's core with more modern technologies that have led VNFs to evolve and become Cloud-native Network Functions (CNFs).

The difference between a regular cloud and the telco cloud is that the latter is focused on running more restrictive network functions and essential business applications that require more reliable operations. A good example explained in Red Hat (2023) is how virtual radio access networks (vRANs) and open RAN require a real-time environment that extends out to the edge[9]

---

[6] As explained in Google Cloud (ND) beautifully: "Converting one physical server into multiple virtual servers allows organizations to use processing power and resources more efficiently by running multiple operating systems and applications on one partitioned server."

[7] In the industry's lingo these are called Software Defined Networks (SDNs) because you manage them through software and don't need to do any physical changes to your infrastructure.

[8] Red Hat (2023) does an incredible job in explaining all of these ideas. Going even more into the past, what VNFs did was take functions that were traditionally handled by specific hardware—such as routers and load balancers—and move them to virtual, software-based equivalents.

[9] In networks the closer something is to the end user, the more this thing would be considered to be on the edge. An interesting shift that is also happening within the industry is bringing the network's core closer to the end user, this avoids travelling longer distances that could clutter the network.

of the network and meets more stringent requirements that are beyond the capabilities of the typical cloud. This cloud can also take advantage of public cloud capabilities and build hybrid cloud environments. Another difference is that the regular cloud has fixed physical boundaries, but telco clouds cross data centers, central offices, and even edge locations.

What is the Metaverse?

Having cleared the introduction and understanding how data is served to end users an analysis of the central topic of this writing begins, starting with answering what is actually meant when saying the word metaverse. Giving a precise definition to this concept is probably impossible for many experts consider it to be different things. For simplicity, it will be considered a digital fully immersive 3D world in which humans can interact as if in a video game. Inside this space, people could take the form of any avatar they want to be, travel to surreal locations, and perform things that in the real world would be impossible.

For the moment it would be best to avoid the philosophical debate surrounding the metaverse. However, this is important and will be considered towards the end of this document, for now, the focus will be more on the technical side of things. An important consideration is how software developers will use this new platform and how they will create things to integrate with these services. Another important thing to consider at this point is the technical requirement the network will need; how much bandwidth does connecting to one of these digital worlds require?

Technical Requirements of the Metaverse

The metaverse is a technology that is still in diapers, there is little understanding of how things will work, and basic development standards were arguably set in place less than a year ago[10]. This makes the technology uncertain but cements important foundations for its future development. An important organization in this standardization process is Khronos Group[11], this organization created the OpenXR standard for creating and deploying virtual and augmented reality (VR/AR) applications across a wide range of hardware platforms. This last point is of utmost importance because a common API to develop VR/AR applications is needed for the

[10] The Metaverse Standard Forum (MSF) was announced on June 21, 2022 and its aim is to "foster interoperability standards for an open metaverse".
[11] This is a non-profit focused on creating open standards for graphics, multimedia, and parallel computing. The organization was founded in 2000 and has since become a leading authority in the development and promotion of open standards for the computing industry.

metaverse to work in a free and open way; this is also key in creating a development ecosystem in which innovation can occur outside hardware provider silos.

Understanding that standardization is one of the main drivers of new technologies is important. As the world adopts the metaverse success will probably come down to two things: (1) is there a sound business model surrounding these projects and (2) are there clear guidelines to how developers—which at the end of the day are just regular people with technical knowledge—can use and deploy new products. If a consistent ecosystem is created in which knowledge transfer is simple the metaverse is sure to thrive as long as the economics of it make sense.

Another key player in the adoption of this new industry which is expected to grow to $5 trillion by 2030[12] is the telco industry. It is responsible for delivering the ever-increasing bandwidth required for many of these applications and allowing the services to work with the extremely low levels of latency required to avoid motion sickness in the VR consumer[13]. To achieve this many of the aforementioned mobile network architectural innovations are required, but one thing that for the most part has been ignored and that will now play a key role is the adoption of network APIs.

These APIs are fairly new and have been used to automate and abstract some network administration controls, a good example would be updating a service. With a network API, the update of 100 network devices can be more efficient, it is tedious to configure or update devices one by one through the use of a CLI. The novelty with this APIs is that a new project led by the Global System for Mobile Communications Association (GSMA), a non-profit industry organization that represents the interests of mobile network operators worldwide, recently launched a new open-source network API standardization project called Open Gateway[14] with the intention to allow third-party developers from outside the telco industry access to network functionality.

Another organization backing this development is The Linux Foundation, an important non-profit that is taking charge of the API definition, development, and testing through an internal project

[12] This estimation was extracted from Boreham (2022), according to other resources I've read the number seems about right.
[13] In a keynote during the Barcelona 2023 Mobile World Congress (MWC) Steve Alexander, CTO of Ciena, argues that the latency ought to be under 10ms in order to avoid motion sickness. You can find this keynote in the references as MWC GSMA (2023).
[14] This proposal is very recent, the official announcement of the project was released on February 2023 during the Barcelona 2023 MWC.

called CAMARA[15]. Through the foundation and its collaboration with more than 20 leading MNOs from around the world, a clear path to building a universal industry standard is feasible. In total Open Gateway launched with eight APIs[16]:

- **SIM Swap:** checks the last time that the SIM card associated with a mobile number has changed. The response may be a timestamp for a defined period—i.e. the last 24 hours.
- **Quality On Demand:** allows an application to request a level of quality for its traffic flows. Quality may be defined in terms of latency, jitter, or throughput. The API response confirms whether the network can fulfill the request and may offer an alternative quality.
- **Device Status:** checks if a device is connected to the network and/or is roaming.
- **Number Verify:** requests the seamless authentication of the mobile device by the mobile network. The mobile network confirms if the authentication was successful.
- **Edge Site Selection and Routing:** allows an application to discover the nearest Edge-Cloud node for a device to connect to.
- **Number Verification (2FA):** delivers a short code to the mobile device via SMS.
- **Carrier Billing (Check Out):** allows an online merchant to request payment from the user's mobile operator. The API responds with payment status and related details. The payment amount is then added to the user's phone bill and funds are paid to the merchant by the mobile operator.
- **Verify Location:** allows an application to check if a mobile device is in proximity to a given location. The API request contains the location to be checked and the mobile number; the response indicates whether the location is within a predefined radius of the last known location of the Mobile Station International Subscriber Directory Number (MSISDN).

With this variety of APIs and the ones still to come in the not-too-distant future developers are sure to create new AR/VR applications that could start the development of a metaverse. Examples of these types of use cases with the existing APIs could be the use of Edge Site Selection and Routing along with the Quality On Demand to first identify the nearest cloud and then request the network a minimum quality of service (QoS) to create a connection. With these two validations, the connection of a VR application could guarantee the user receives enough resources to avoid the common shortfalls of these systems: too much latency that causes the user motion sickness.

[15] You can check out the project's GitHub repository (https://github.com/camaraproject), not all the API code lives here, but documentation for all APIs does appear here.
[16] The definitions of these APIs are basically copied word by word from GSMA Future Networks (ND).

Business Analysis of the Metaverse

Having cleared the technical hurdles that must be accomplished to create the metaverse, the discussion will now drift and go on to analyze less technical topics. To start things off the business analysis will be done, here there are a lot of contributing players as highlighted by Boreham (2022) and they all play fundamental roles in turning this into a reality. What follows is a list of some of the areas that need synergetic collaboration to make this happen.

- **Hardware manufacturers:** there are a lot of different businesses—i.e. Meta and Microsoft—doing this development and giving them clear guidelines to align their products with the industry makes their work scalable.
- **Software solutions:** as with any piece of hardware, what gives these products real value are the programs you can run within it. In the case of the metaverse, these could be avatars, worlds, objects, or any other thing a user could consume in the digital realm.
- **Graphic development engines:** the videogames that currently exist are built with robust game engines—i.e. Unity and Unreal Engine—that make the creation and rendering of graphics more efficient[17]. To build immersive experiences that extend reality we need these as well[18].
- **Networking capabilities:** this up till now has been the focus of the writing, most things involved here have already been covered.

At a high level, it could be argued that these are the key areas involved in developing the metaverse. As with many new technologies—and as highlighted by Mark Zuckerberg[19]—the creation of this environment will not be simple or cheap. Huge economic commitments are needed for the field to develop, but all-in-all the feasibility of the products could be—and be skeptical about this as it is my personal opinion—guaranteed. Some of the brightest minds in current human civilization have set their target on this project and thus an efficient product is sure to be achieved.

---

[17] In a panel discussion seen in MWC Barcelona (2023) Vueling's Head of Innovation, Alex Corretgé, mentioned that the creation of these worlds is one of the biggest pain points of creating a metaverse and that generative AI technologies could play an important role in this arena.

[18] A company that seems to be set to take a leading role in this area is NVIDIA, it recently launched a service called Omniverse that offers developers a chance to collaborate on 3D models. These 3D models follow a standard, the Universal Scene Description (USD) that was invented by Pixar.

[19] As mentioned in Vanian (2022) Meta CEO Mark Zuckerberg plans to lose money during the creation of the metaverse, but expects this is "going to provide greater returns over time".

All things considered, this is a paradigm shift in the way users consume digital content and thus the future is hard to predict. Notwithstanding, another topic that is ought to be mentioned is the creation of Brain-Computer Interfaces (BCIs). As much as these gadgets could simply improve the user experience by giving higher sensing fidelity, there is also a remote possibility of this technology supplanting the aforementioned developments[20].

Utopic Analysis of a Future Containing a Metaverse

Finally, the conversation will turn toward the philosophical debate surrounding this development and how the world could turn out to be in the not-too-distant future. The first thing that should be considered in this section is a simple question around which a personal philosophical analysis will follow: how does the ideal world you want to live in look like in 10 years? This is definitely a question that needs a lot of deep thinking to truly begin to answer, but in short, my ideal vision could be described as a world in which a leveled playing field gives equal opportunity to people in all corners of the world. Based on this utopic idea—and I think this is a fundamental requirement for humanity to prosper—a portrait of the future will be laid out.

Technology, in my opinion, is the single most important resource for improving living standards in a fast and sustainable manner. Considering this and the creation of digital worlds in which people could experience greater levels of comfort while interacting with their loved ones I think would give the metaverse a positive impact. For starters this could create an immersive and accessible educational experience on par with those found at the best schools around the world, wouldn't it be awesome to get an explanation of how gravity works from Newton himself? More so, this could also create whole new economies by which the economic pie of the world grows and in which resource allocation could be done in a more efficient and just manner.

As a whole I consider this technology to be the natural next step of human civilization and look forward to a future in which it plays an increasing role in our daily lives. As far off as this future could sound I think it is closer than many people think and that its impact could be a lot more positive than negative. Let's not forget that by nature technology is neutral and that it is human beings that in the end could decide to make this evil. However, I consider this to be less of a possibility in the long term and I'm confident that humanity will make this work toward a better and more just world.

---

[20] This would mean a metaverse constructed on nothing but the thoughts of an individual which would definitely upset one of the key features of the metaverse: social interaction. As highlighted by Meta "the metaverse is the future of social media" and removing the social part of the product could be considered as something completely different, but still apt for some markets—think of solo vs multiplayer gaming.

References

1. Parker Software (ND). *The Cloud is Just Someone Else's Computer… or is it?* March 20, 2023. Parker Software, URL: https://www.parkersoftware.com/blog/the-cloud-is-just-someone-elses-computer-or-is-it/
2. Khillar S. (2022, August) *Difference Between Private Cloud and On-Premise*. March 20, 2023. Difference Between, URL: http://www.differencebetween.net/technology/difference-between-private-cloud-and-on-premise/
3. Google Cloud (ND) *What is a Virtual Server?* March 20, 2023. Google Cloud, URL: https://cloud.google.com/learn/what-is-a-virtual-server/
4. Red Hat (2023, February) *What is telco cloud?* March 20, 2023. Red Hat, URL: https://www.redhat.com/en/topics/cloud-computing/what-is-telco-cloud/
5. Marr B. (2022, March) *A Short History of the Metaverse*. March 21, 2023. Forbes, URL: https://www.forbes.com/sites/bernardmarr/2022/03/21/a-short-history-of-the-metaverse/
6. Metaverse Standrds Forum (ND) *The Metaverse Standards Forum FAQ*. March 21, 2023. Metaverse Standards Forum, URL: https://metaverse-standards.org/faq
7. The Khronos Group (ND) *About The Khronos Group*. March 21, 2023. The Khronos Group, URL: https://www.khronos.org/about/
8. The Khronos Group (2021, September). *OpenXR Auggie Awards Submission* [Video]. March 21, 2023. YouTube, URL: https://www.youtube.com/watch?v=PxPIr_C5s7k/
9. Boreham J. (2022, August) *7 of the World's Top Metaverse Companies (2022 List)*. March 22, 2023. The Metaverse Insider, URL: https://metaverseinsider.tech/2022/08/08/7-of-the-worlds-top-metaverse-companies-in-2022/
10. MWC GSMA (2023, March) *Building Metaverse Ready Networks* [Video]. March 20, 2023. MWC Barcelona, URL: https://www.mwcbarcelona.com/agenda/session/building-metaverse-ready-networks/
11. Muhungu V. (2023, January) *A guide to network APIs and their use cases*. March 21, 2023. TechTarget, URL: https://www.techtarget.com/searchnetworking/tip/A-guide-to-network-APIs-and-their-use-cases/
12. GSMA Future Networks (ND) *GSMA Open Gateway APIs*. March 21, 2023. GSMA, URL: https://www.gsma.com/futurenetworks/gsma-open-gateway-api-descriptions/
13. Blackman J. (2023, February) *Major Telcos Move to Open Network APIs for Developers to Drive Innovation*. March 21, 2023. RCR Wireless News, URL: https://www.rcrwireless.com/20230227/5g/major-telcos-move-to-open-network-apis-to-developers-to-drive-innovation-revenues/
14. Wooden A. (2023, February) *GSMA Explains its Strategy for Network API Standards*. March 21, 2023. Telecoms.com, URL: https://telecoms.com/520216/gsma-explains-its-strategy-for-network-api-standards/
15. NVIDIA (ND) *Universal Scene Description*. March 22, 2023. NVIDIA, URL: https://www.nvidia.com/en-us/omniverse/usd/

16. Vanian J. (2022, October) *Meta plans to lose even more money building the metaverse while its ads business shrinks*. March 22, 2023. CNBC, URL: https://www.cnbc.com/2022/10/26/meta-plans-to-lose-even-more-money-building-the-metaverse.html/