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# *Content Delivery Networks*

# *Overview*

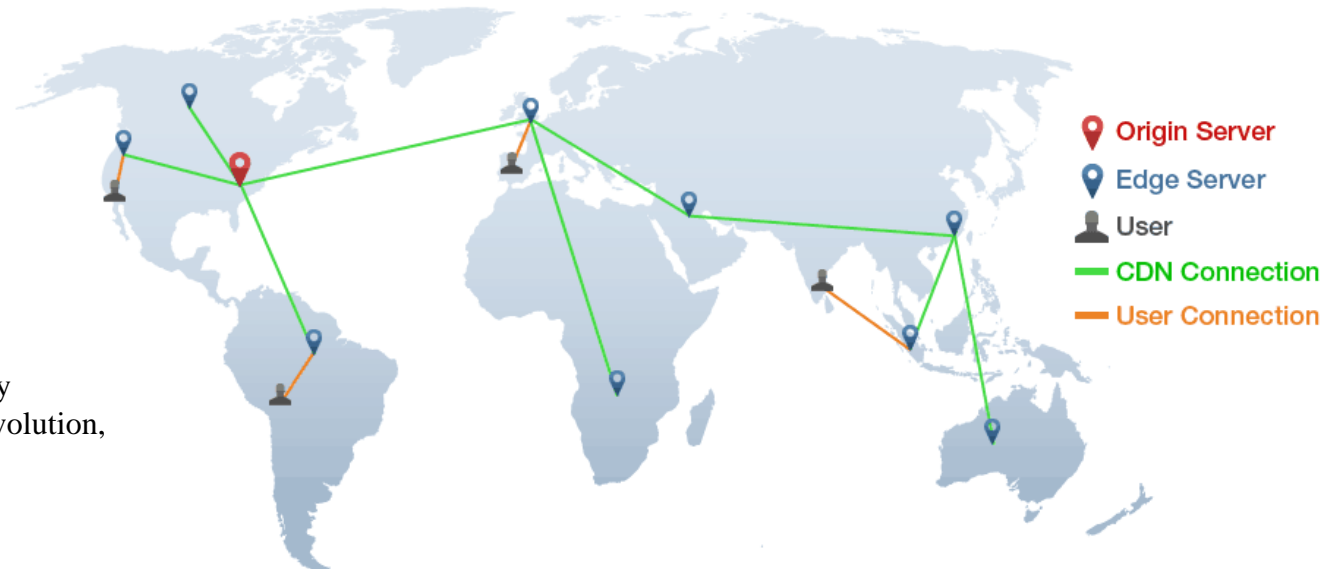
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- What is a CDN?
- Why are CDNs important?
- CDN Architecture
- How CDNs work
- CDN Examples – Google, Netflix
- Virtual CDNs

# What is a CDN?

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- Content Delivery Network (CDN)
  - Network of Edge Servers and Points-of-Presence (POP) around the globe
  - Each Edge Server resides in a POP and hosts exact copy of digital content
  - Help in improving content delivery time → bringing it closer to users
- CDN is a way to ensure that many users can consume content
  - Effective way to deliver content with high performance and reliability on global scale



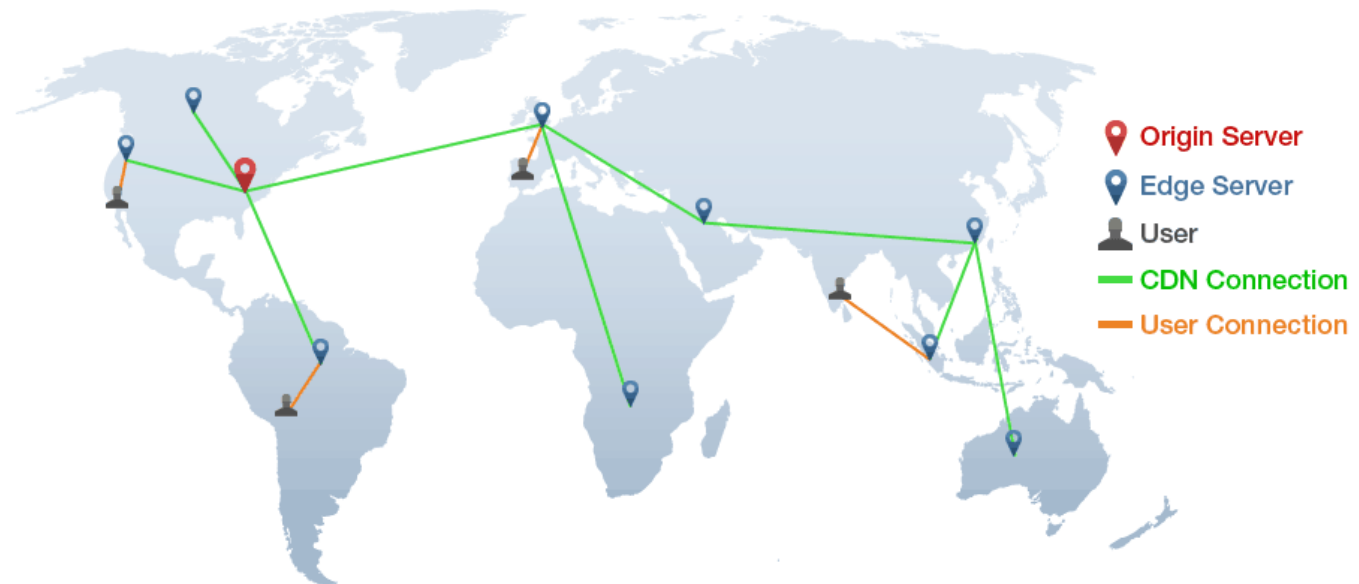
Source: Dom Robinson, Content Delivery Networks: Fundamentals, Design, and Evolution, Wiley, 2017, ISBN 9781119249887.

Source: <https://digital.com/cdn>  
[Accessed: 21<sup>st</sup> May 2021]

# What is a CDN?

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- When user makes a request it is routed to the nearest Edge Server
  - Significantly reduces latency
  - CDN allows all users, regardless of geographical location, to have fast loading content for improved experience
- At least 27.6 million websites using CDN<sup>1</sup>



<sup>1</sup> <https://trends.builtwith.com/CDN/Content-Delivery-Network> [Accessed: 21<sup>st</sup> May 2021]

## *Why are CDNs important?*

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- Let us assume you host a website at a data center in Porto
  - Without CDN → every visitor downloads content from Porto
    - That's ok if someone is visiting the website from Portugal
    - But, what if someone is visiting let's say from Japan?
- CDNs address this problem
  - They cache your content around globe
  - Even if “home” data center is in Porto, a CDN allows storage of cached version of the content at a Japan Data Center
  - Most CDN providers offer caching servers on every continent

## *Why are CDNs important?*

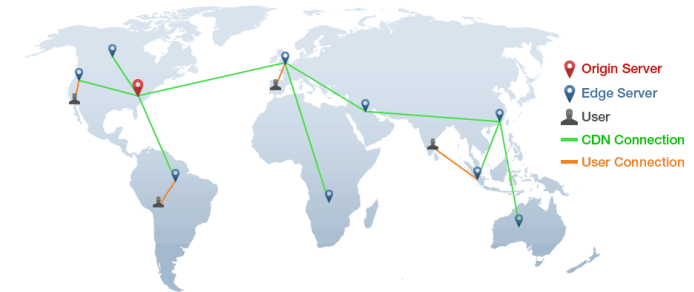
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- Speed is the keyword
  - CDN → one of best ways to speed up website for visitors around the globe
- Fast loading website → compete in today's online landscape
  - Improving your page load times can boost
    - Conversion rates<sup>1</sup> – every second decrease in page load time can increase conversion rate by 1 percentage point
    - Search engine rankings – Google publicly says that they use page load times as ranking factor
  - Studies show that 1-2 sec delay → up to 16% drop in overall customer satisfaction
    - Almost one third of users want websites to load in under a second nowadays

<sup>1</sup> Conversion rate – number of conversions divided by the total number of visitors (e.g., if ecommerce site receives 200 visitors in a month and has 50 sales, conversion rate is 25%)

# CDN Architecture – Three key components

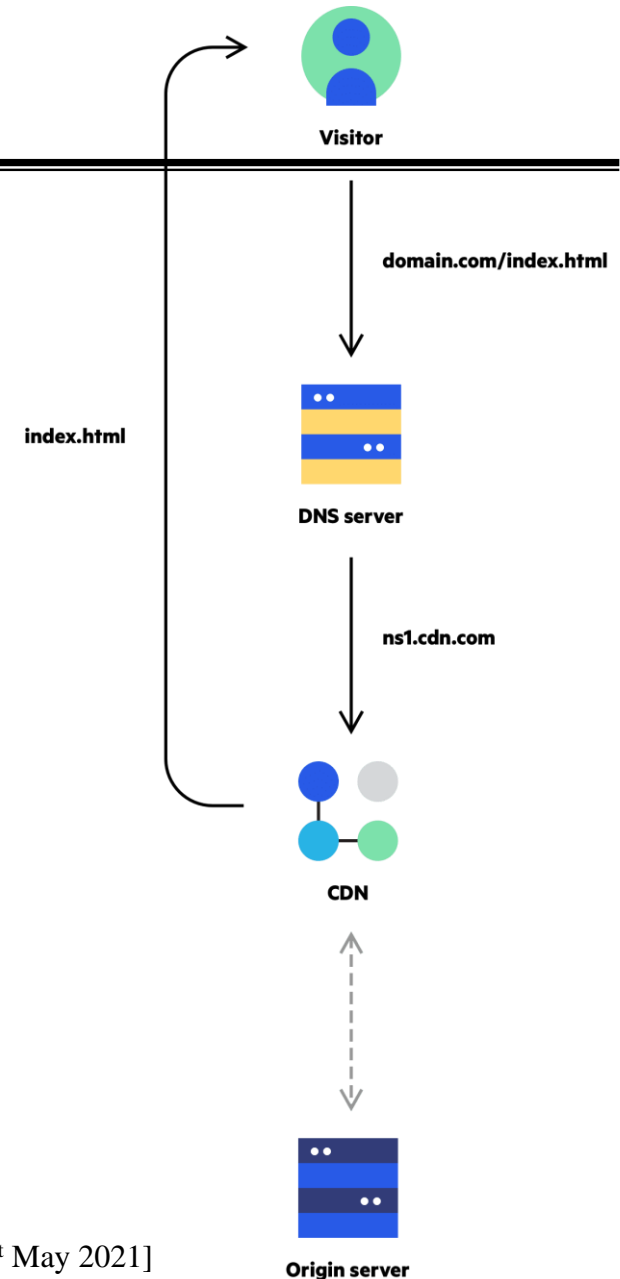
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- **Origin Server**
  - Contains original version of content cached by Edge Servers
- **Edge Servers**
  - Proxy caches that work similarly to web browser cache
  - Do not generate content → keep copy of content in cache
- **Points of Presence (POP)**
  - Geographical location where group of CDN edge servers resides
  - Strategically located data centers
  - Total number of Edge Servers at each POP vary for each CDN provider

# CDN – How it works

- CDN → default inbound gateway for all incoming traffic
- Modification to root domain DNS configurations
  - E.g., domain.com and subdomains (www.domain.com, img.domain.com)
- Root domain → change DNS A record to point to one of CDN's IP ranges
  - For each subdomain → modify its CNAME record to point to CDN-provided subdomain address (e.g., ns1.cdn.com)



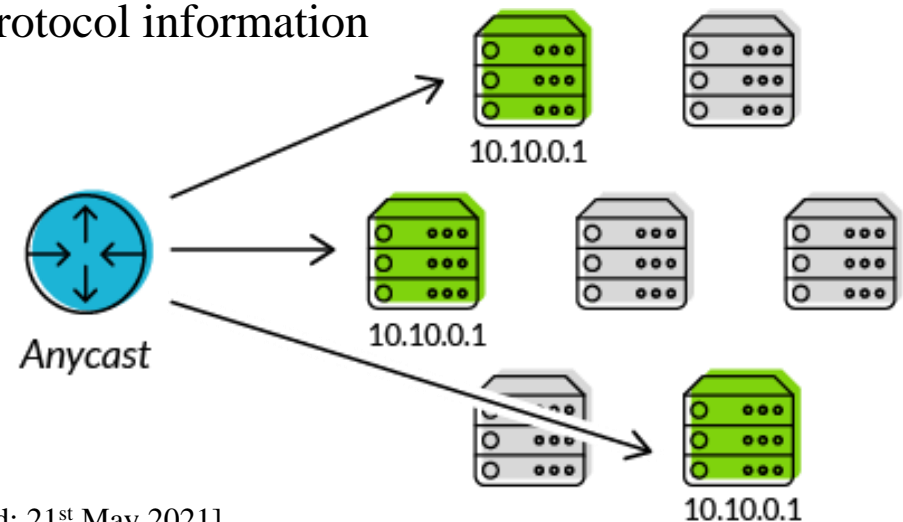
Source: <https://www.imperva.com/learn/performance/what-is-cdn-how-it-works> [Accessed: 21<sup>st</sup> May 2021]



## CDN – How it works

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- Visitor requests to any URL/resource on domain routed by DNS to one of Edge Servers
- Use of anycast routing → typically server closest to user
  - With anycast, a single address is shared by multiple servers
  - Each is valid candidate to receive request
  - The one closest in number of hops is selected
    - Taking advantage of BGP routing protocol information

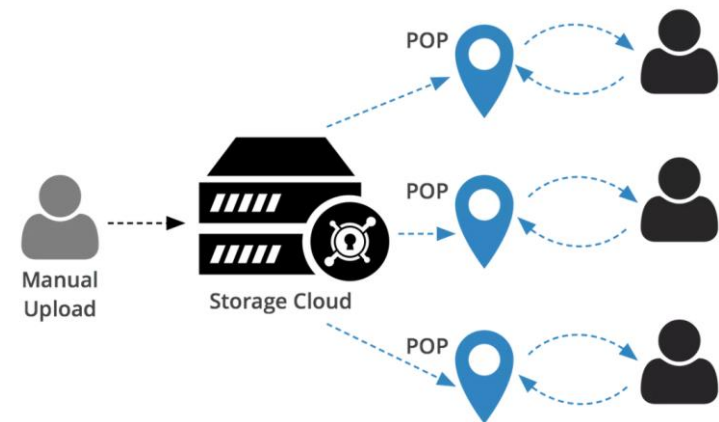
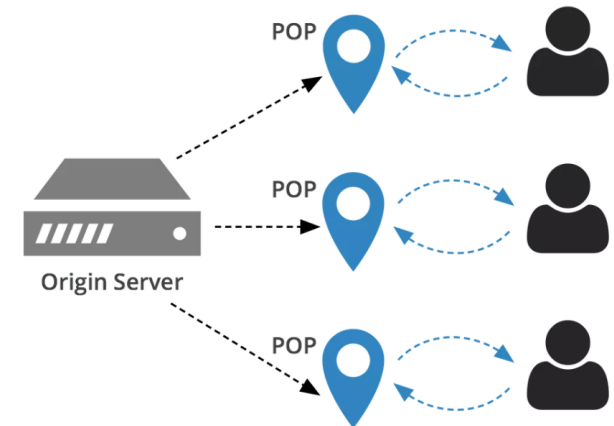


Source: <https://www.imperva.com/learn/performance/anycast> [Accessed: 21<sup>st</sup> May 2021]

# CDN – How it works

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- Pull CDN (proxy like)
  - Automatically pulls static content from Origin Server
  - Creates copy that will be served to users upon subsequent requests
  - **Drawback:** first user experiences delay
- Push CDN
  - Content uploaded proactively to Edge Servers
  - When user sends request for content, it is already there
  - **Drawback:** manual upload required



Source: <https://www.keycdn.com/what-is-a-cdn> [Accessed: 21<sup>st</sup> May 2021]

## *Some of the CDN Players*

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Source: <https://www.cdn-advisor.com/companies> [Accessed: 21<sup>st</sup> May 2021]

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## *Benefits of CDNs*

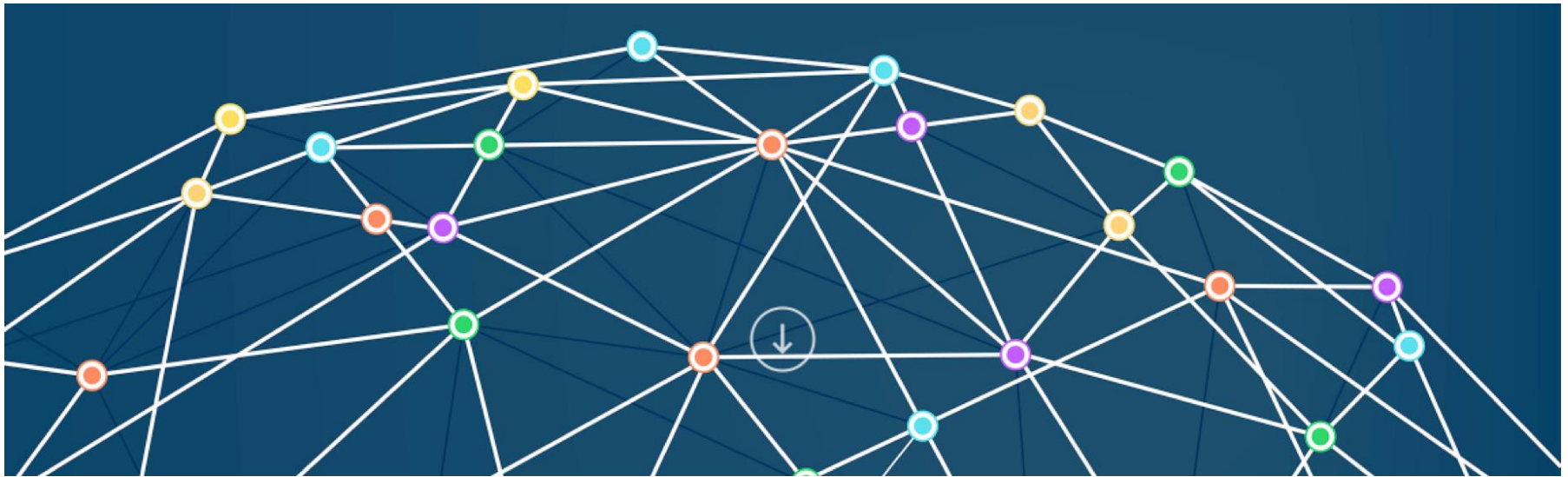
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- Improved Performance
  - No matter where in the world visitors are located
- High Availability and Redundancy
  - High number of visitors surges may be a problem
  - CDNs built to ensure your content never goes offline
    - If one server goes down or is overloaded → another existing server is used
- Improved Security
  - CDNs offer greater level of online security
  - E.g., if website is threatened by a Distributed Denial of Service (DDoS) attack → traffic will simply be redirected to different server

## *Examples of CDNs – Google*

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- Edge Network is how Google connects with ISPs to get traffic to and from users



Source: <https://peering.google.com> [Accessed: 21<sup>st</sup> May 2021]

## *Examples of CDNs – Google*

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- Process starts when user opens Google app or requests web page



Source: <https://peering.google.com> [Accessed: 21<sup>st</sup> May 2021]

## *Examples of CDNs – Google*

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- Google replies to user's request from Edge Network location that will provide lowest latency

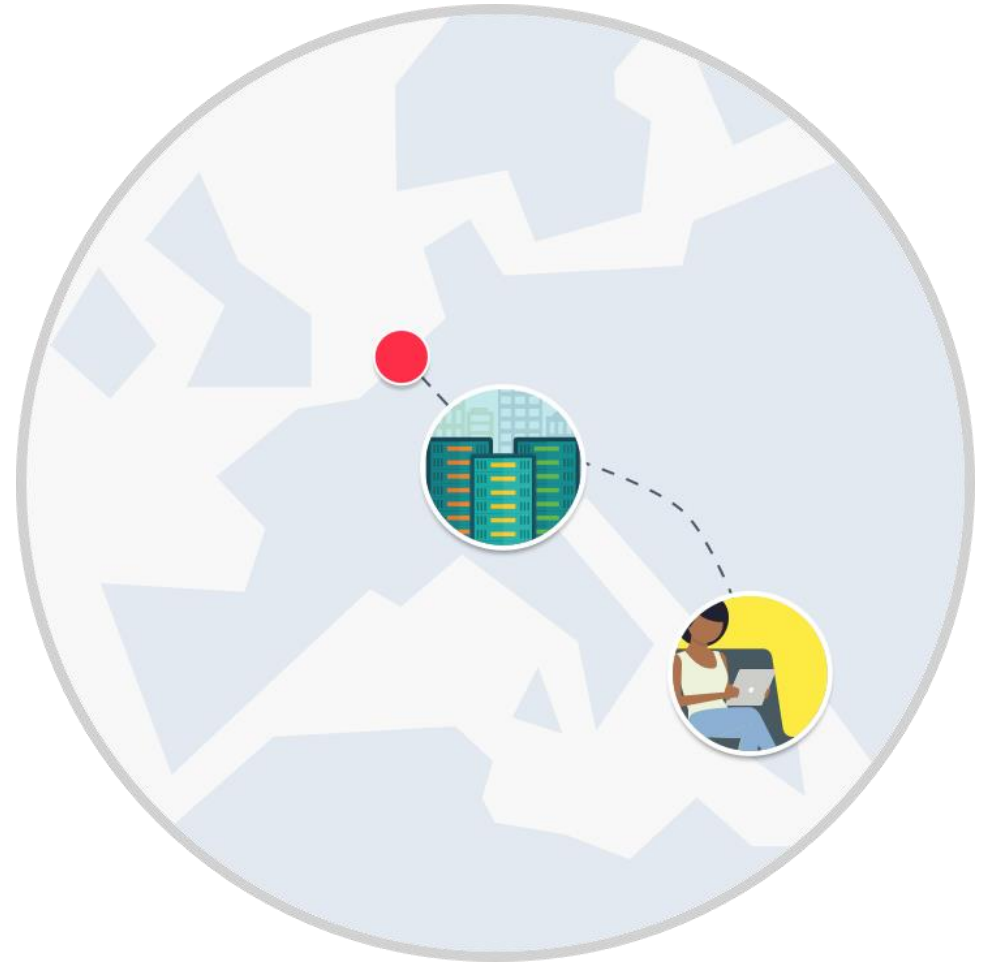


Source: <https://peering.google.com> [Accessed: 21<sup>st</sup> May 2021]

## *Examples of CDNs – Google*

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- Edge Network receives user's request and passes it to nearest Google Data Center



Source: <https://peering.google.com> [Accessed: 21<sup>st</sup> May 2021]



## *Examples of CDNs – Google*

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- Data Center generates response optimized to provide best experience for the user at that time

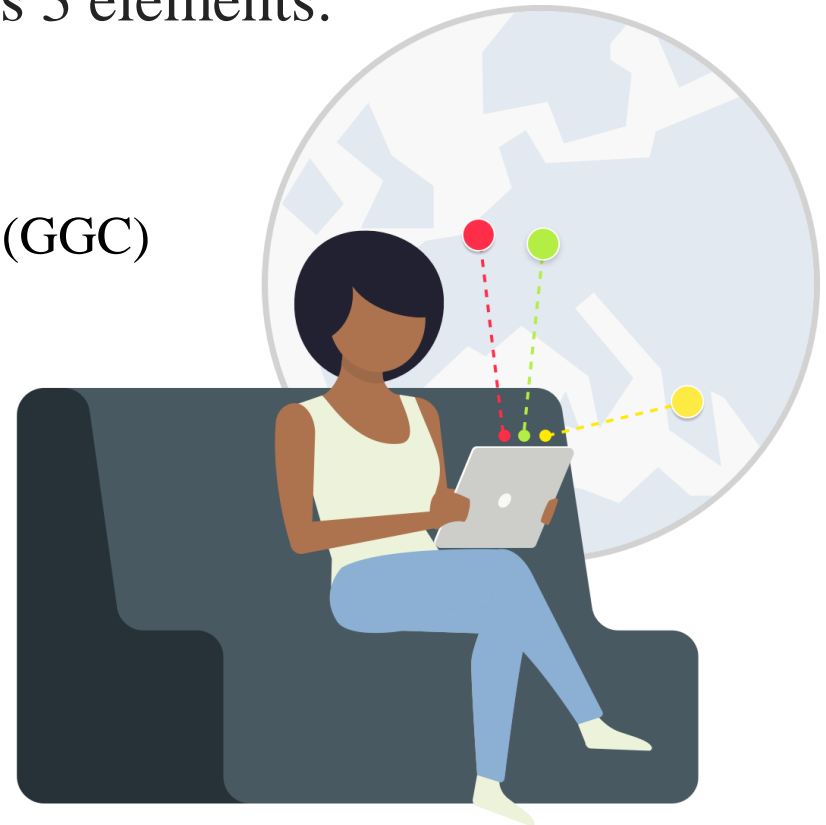


Source: <https://peering.google.com> [Accessed: 21<sup>st</sup> May 2021]

## *Examples of CDNs – Google*

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- App/browser retrieves content required
  - Content can come from multiple Google locations, including Data Centers, Edge PoPs, and Edge Nodes
- Google's network infrastructure has 3 elements:
  - Core Data Centers
  - Edge Points of Presence (PoPs)
  - Edge Nodes – Google Global Cache (GGC)



Source: <https://peering.google.com> [Accessed: 21<sup>st</sup> May 2021]

## *Examples of CDNs – Google*

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- Data Centers
  - Used for computation and backend storage
  - Located in the Americas, Europe, and Asia
  - “Heart” of Google content and services
- Data network links all data centers together
  - Content replicated across multiple sites for resilience



Source: <https://peering.google.com>  
[Accessed: 21<sup>st</sup> May 2021]

## Examples of CDNs – Google

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- Edge Points of Presence (PoPs)
  - Google's network connection to rest of the Internet
  - Present on over 90 internet exchanges and over 100 interconnection facilities around the world
  - Bring Google traffic closer to peers (e.g., Internet Service Providers)
    - Reduce their costs and providing users with better experience
- Google operates large, global meshed network
  - Connects Edge PoPs to Data Centers



Source: <https://peering.google.com>  
[Accessed: 21<sup>st</sup> May 2021]

## Examples of CDNs – Google

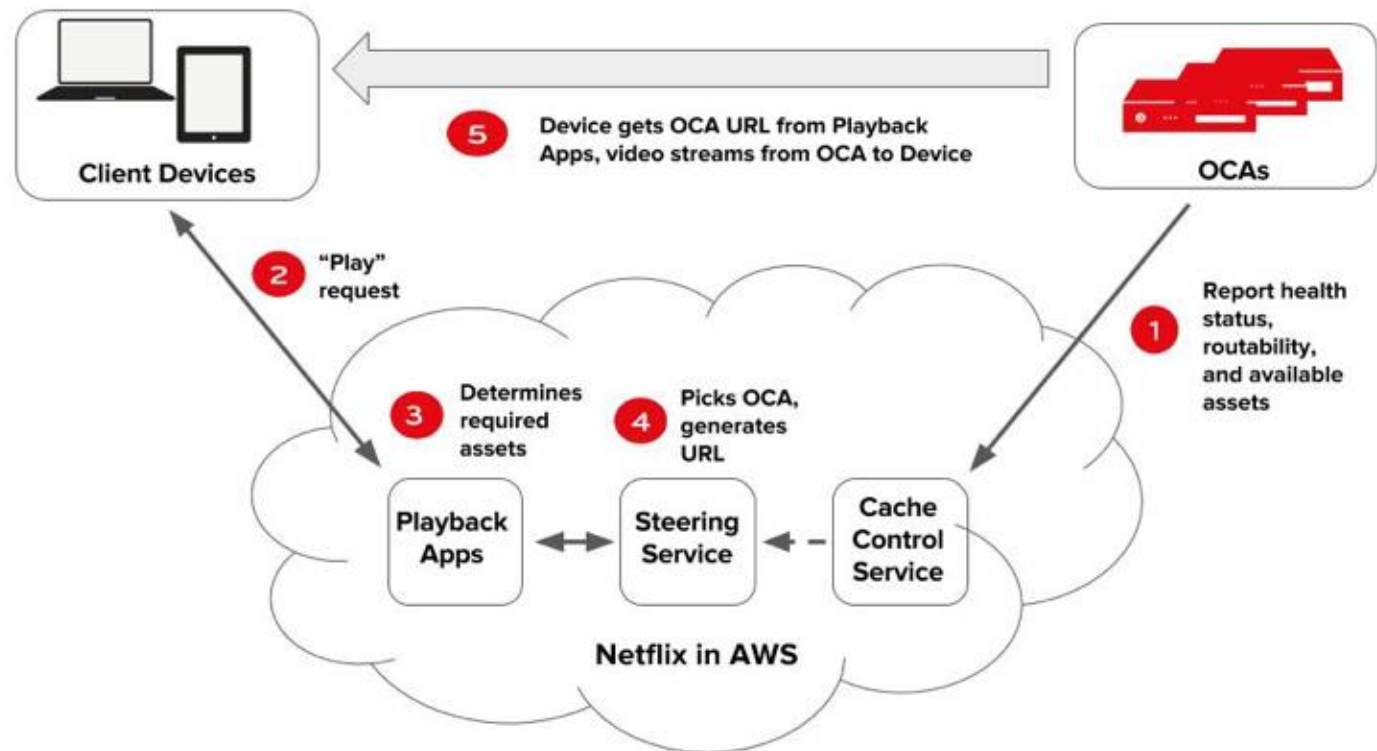
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- Edges Nodes – Google Global Cache
  - Tier of Google's infrastructure closest to users
  - Google-supplied servers inside network operators and ISPs
- Very popular static content temporarily cached on Edge Nodes
  - E.g., YouTube, Google Play
  - User requests directed to Edge Node that will provide best experience



## Examples of CDNs – Netflix

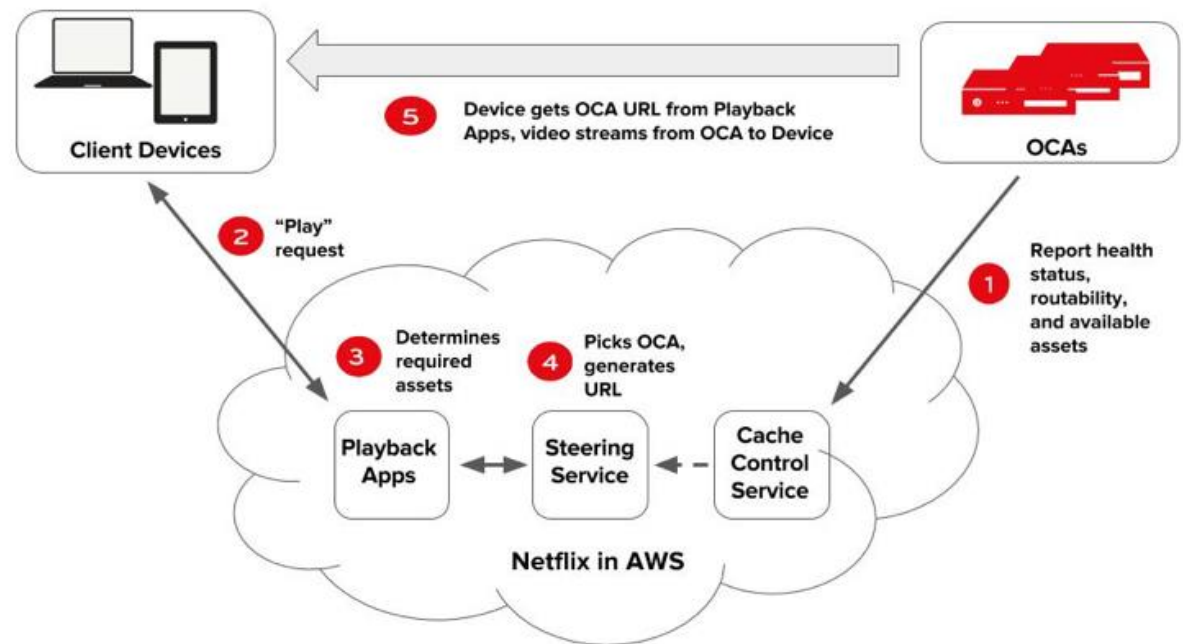
- Netflix Open Connect CDN → serves 100% of video traffic
  - ~95% traffic delivered via direct connections between Open Connect and residential ISPs the users utilize for Internet access



Source: <https://openconnect.netflix.com> [Accessed: 21<sup>st</sup> May 2021]

## Examples of CDNs – Netflix

- Open Connect Appliances (OCAs) → foundation of the service
  - Netflix provides same OCAs the company uses in their Internet interconnection locations
  - OCAs store and serve video content with sole responsibility of delivering playable bits to client devices as efficiently as possible





# CDN underlying infrastructure – submarine cables



Google **announced** yet another submarine cable project. Named Dunant, after the founder of the Red Cross, this will be the first private transatlantic submarine cable operated by a single company. This cable will run between Virginia, USA and France and is expected to be in service by 2020. While they did not announce the capacity of this cable, the **Marea cable** launched recently by Microsoft and Facebook, linking Virginia with Spain, has a capacity of 160 Tbps.



Source: <https://blog.thousandeyes.com/content-delivery-networks-under-the-sea>  
[Accessed: 21<sup>st</sup> May 2021]



## *CDN underlying infrastructure – submarine cables*

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- Major submarine cables owned or partly owned by content providers:

Cable	Landings	Content Provider
Dunant	US, France	Google
Marea	US, Spain	Facebook, Microsoft
Curie	Chile, US	Google
FASTER	Japan, US	Google
Junior	Brazil	Google
Havfrue	US, Norway, Ireland, Denmark	Google, Facebook
JUPITER	US, Japan, Phillipines	Amazon, Facebook

- Most new submarine cables being “deployed” by tech giants
  - Amazon, Facebook, Google, and Microsoft
  - By 2017 → half of total transatlantic and transpacific bandwidth demand came from content providers

# *CDN and Virtualization*

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- Virtualization at the center of current and future CDNs
  - Server and Storage Virtualization (lesson 1)
  - Data Centers and Virtual Private Networks (lesson 2)
  - SDN and NFV (lessons 3 and 4)
- CDNs need to change constantly to reflect target market demands
  - Virtualization → scalability, flexibility, availability, and performance

## Summary

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- CDN → ensure that many users can consume content
  - Deliver content with high performance and reliability on global scale
- CDN architecture composed by three key elements
  - Origin Server, Edge Servers, and Points of Presence (POPs)
- DNS and anycast routing → CDN cornerstones
- CDN may run in two modes: push and pull
- CDN benefits → performance, high availability, improved security
- Virtualization is key for CDNs