

A photograph of a long, straight path lined with large, mature trees, leading towards a bright horizon. The trees are lush green and have thick, gnarled trunks. The path is a reddish-brown color and runs down the center of the image. The background is a bright, hazy landscape with a clear sky.

# TreeDN: Tree-based CDNs for Live Streaming to Mass Audiences

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# Problem Statement

- With live audiences exploding combined with increasing bitrates (4K/8K/AR), are we at an inflection point?
  - NFL Thurs Night FB on Amazon Prime (10-15M streaming viewers)
  - NFL Sunday Ticket on YouTubeTV
  - 2023 Cricket IPL Final- 32M concurrent streams
- Live Streaming is not the same as On-Demand Streaming
  - Expectations for low latency means shorter playout buffers
    - < 10s to match traditional broadcast TV, much less for micro-betting
  - Join rates are vastly different
    - Smooth/predictable for on-demand, ~ step function for live events



# Mass Audience Live Streaming AR

Is this possible with today's Internet???



# Network-Based Replication

- Multicast has been fairly successful in some places
  - Financials, Video Distr, VPN SPs, some enterprises
- Internet Multicast- not so much...
  - So what went wrong?

# The Problems with Internet Multicast

1. “All or Nothing” Problem
    - Every L3 hop (router/fw) between source and destination must be multicast-enabled
  2. “It’s Too Complex” Problem
    - Perceived benefit not worth the cost of deploying and operating
  3. “Chicken and Egg” Problem
    - No multicast audience because no multicast content, and vice versa
- Good News: Network Replication technologies are now available to address these problems

# TreeDN: Tree-based CDNs

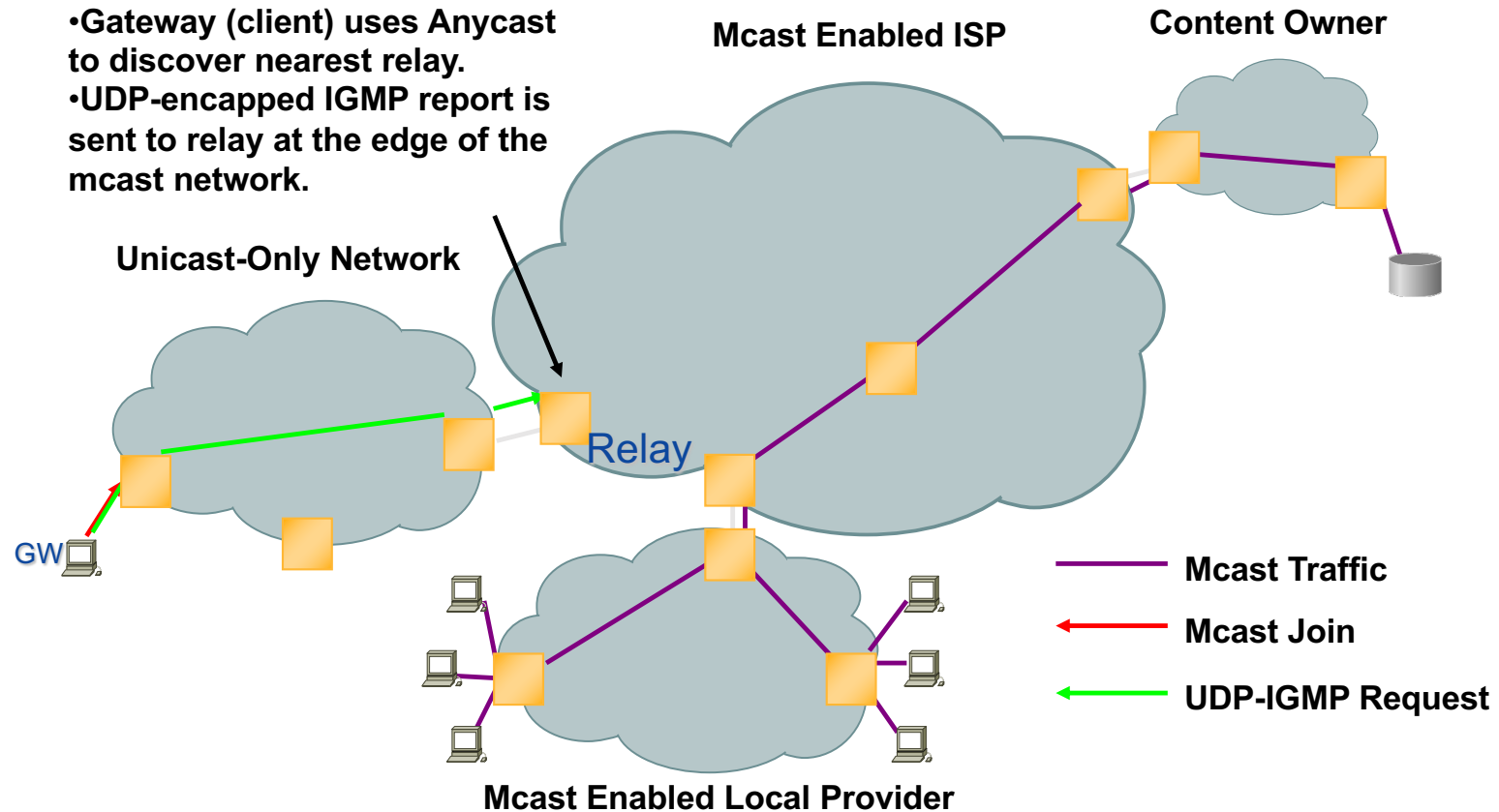
- Leverages native + overlay concepts to deliver service to end users even where parts of the network don't support multicast
  - Native (On-Net): SSM
  - Overlay: AMT (RFC7450)
- Incremental Deployment
  - Multicast-enabled parts of network enjoy benefits, unicast-only parts are tunneled over
  - Most importantly, end users receive the service (eg, no dependency on last mile provider)

# TreeDN Components

- Native (On-Net): SSM
  - SSM vastly simplifies multicast deployment, solves the "It's too complex" problem
  - Usually PIM-SSM, but could also use mLDP, GTM, BGP-MVPN, BIER, SR-P2MP
- Overlay: AMT (RFC7450)
  - Dynamically-built tunnels in host/app "hop over" unicast-only parts of network
  - Simplifies "last mile"- can avoid wifi and other in-home issues
  - Solves the "All or Nothing" and "Chicken & Egg" problems
  - Could also use LISP or any other overlay networking technologies

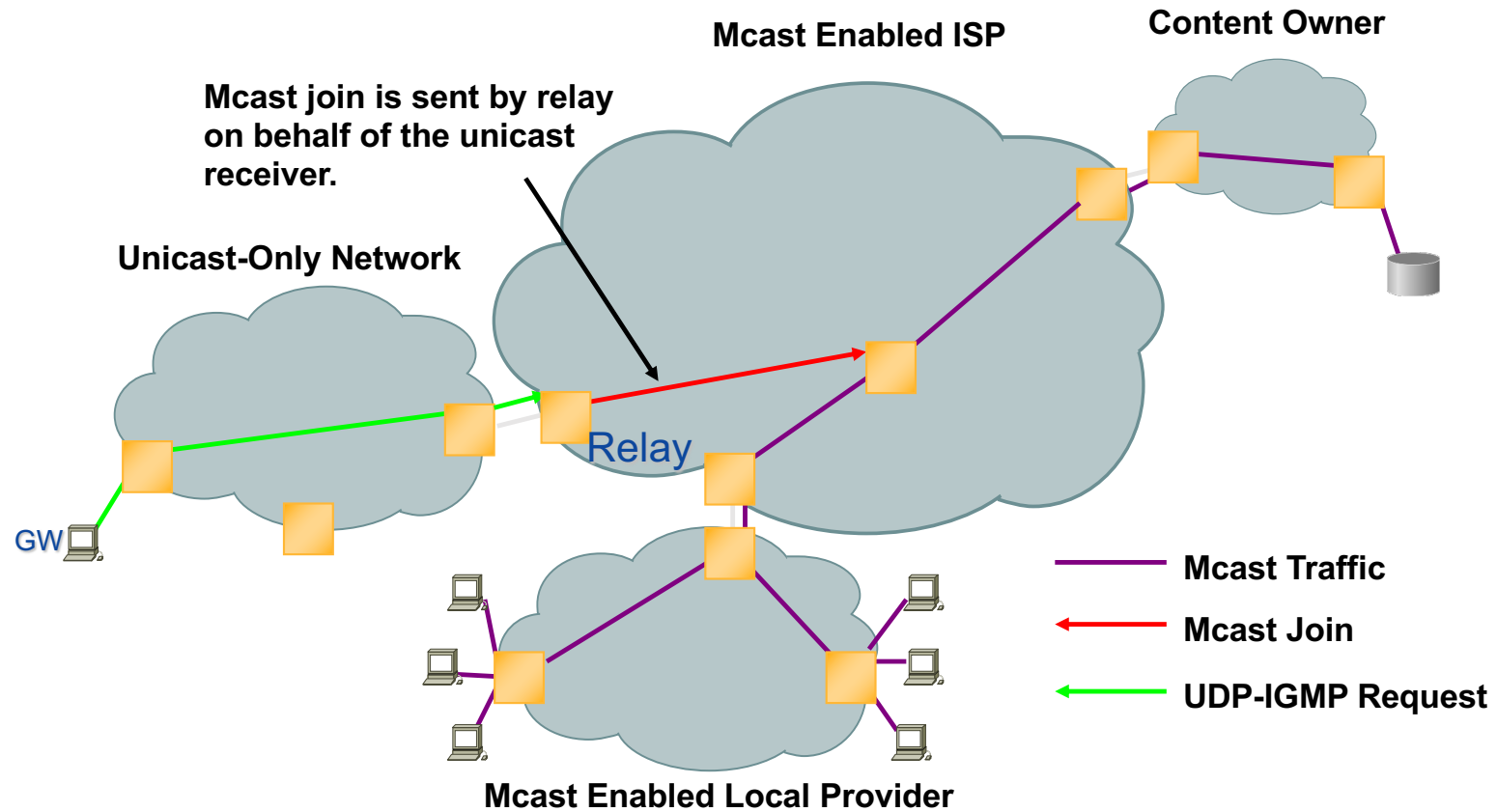
# AMT- How it works

- Gateway (client) uses Anycast to discover nearest relay.
- UDP-encapped IGMP report is sent to relay at the edge of the mcast network.

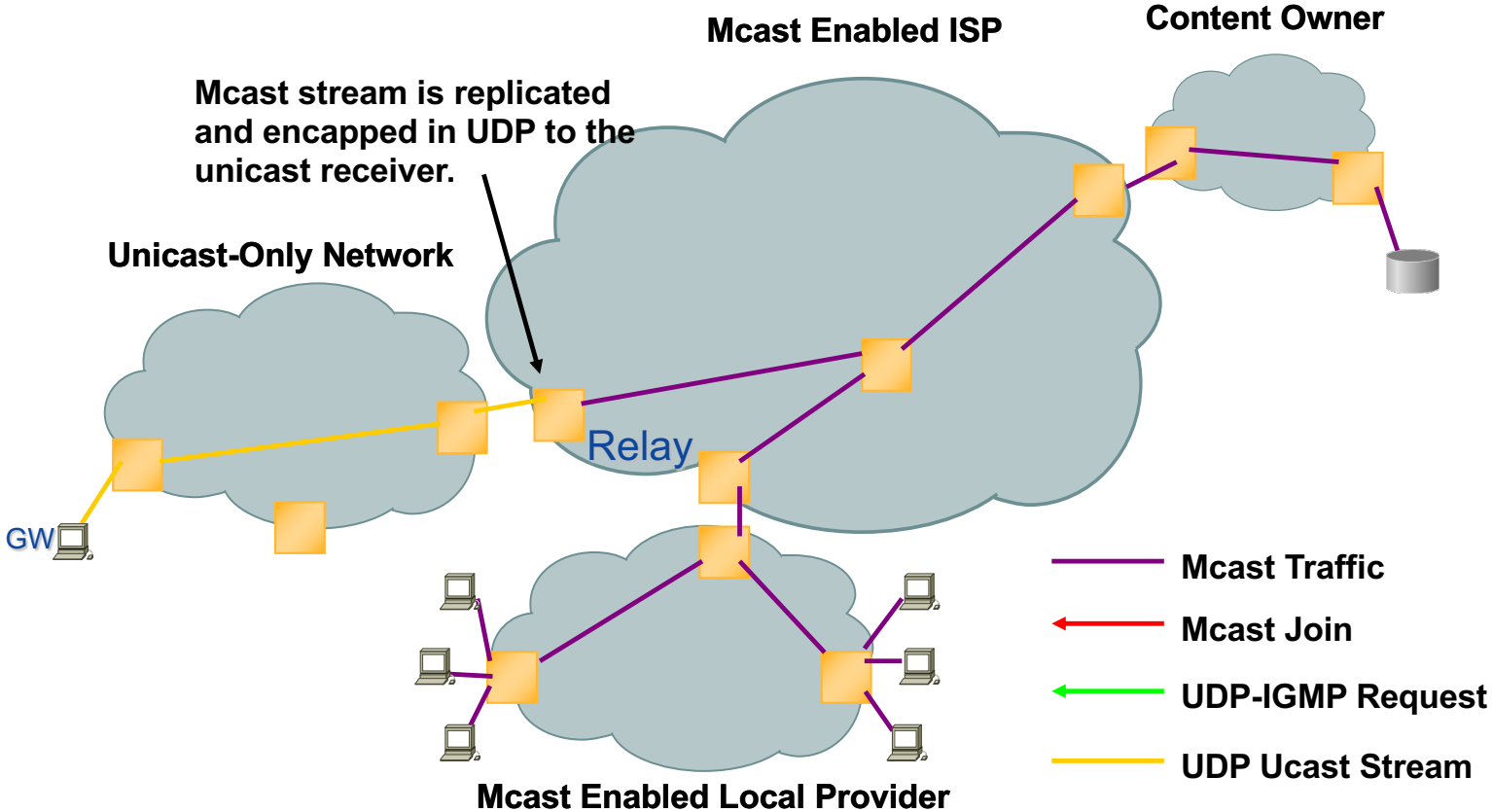




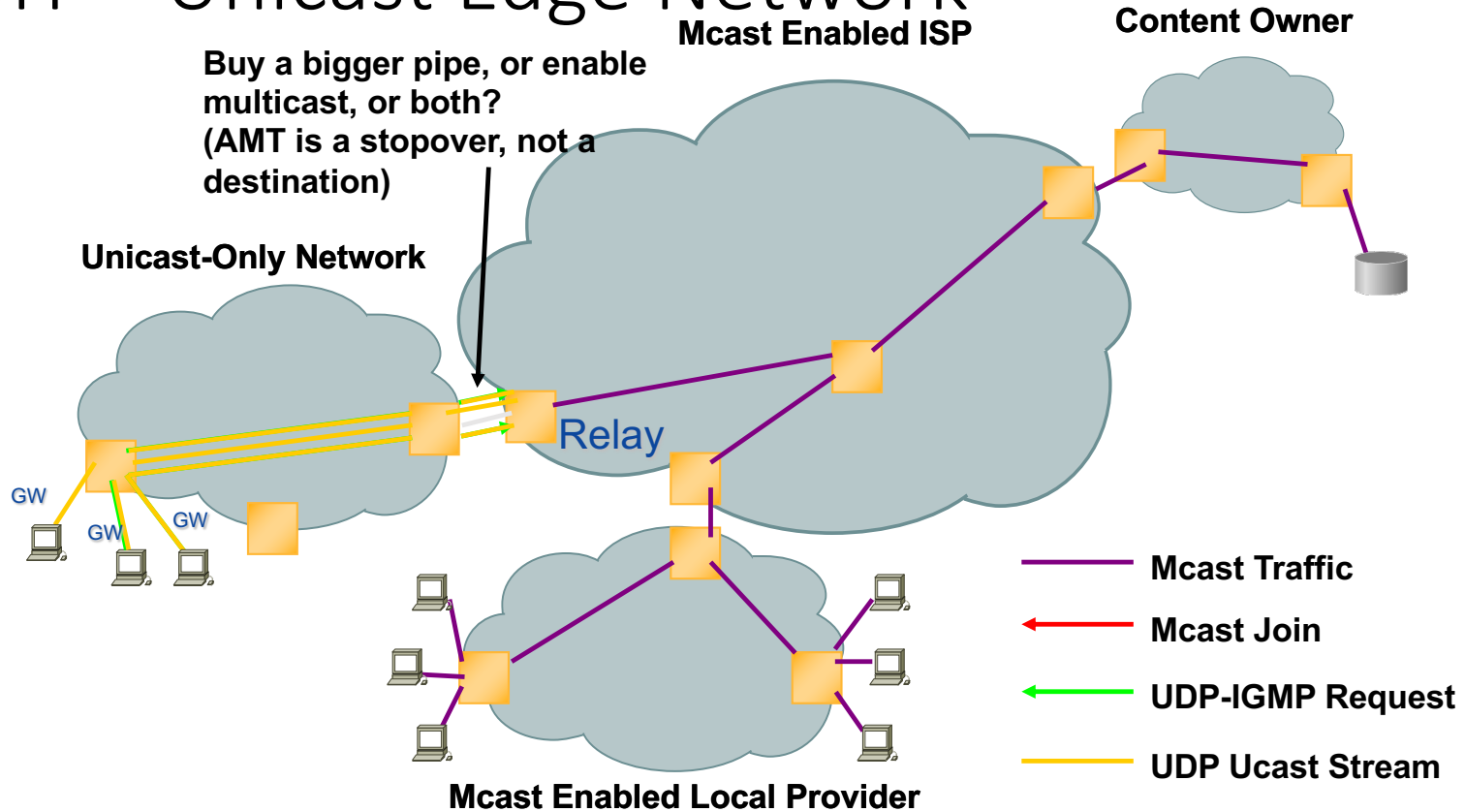
# AMT – Unicast Edge Network



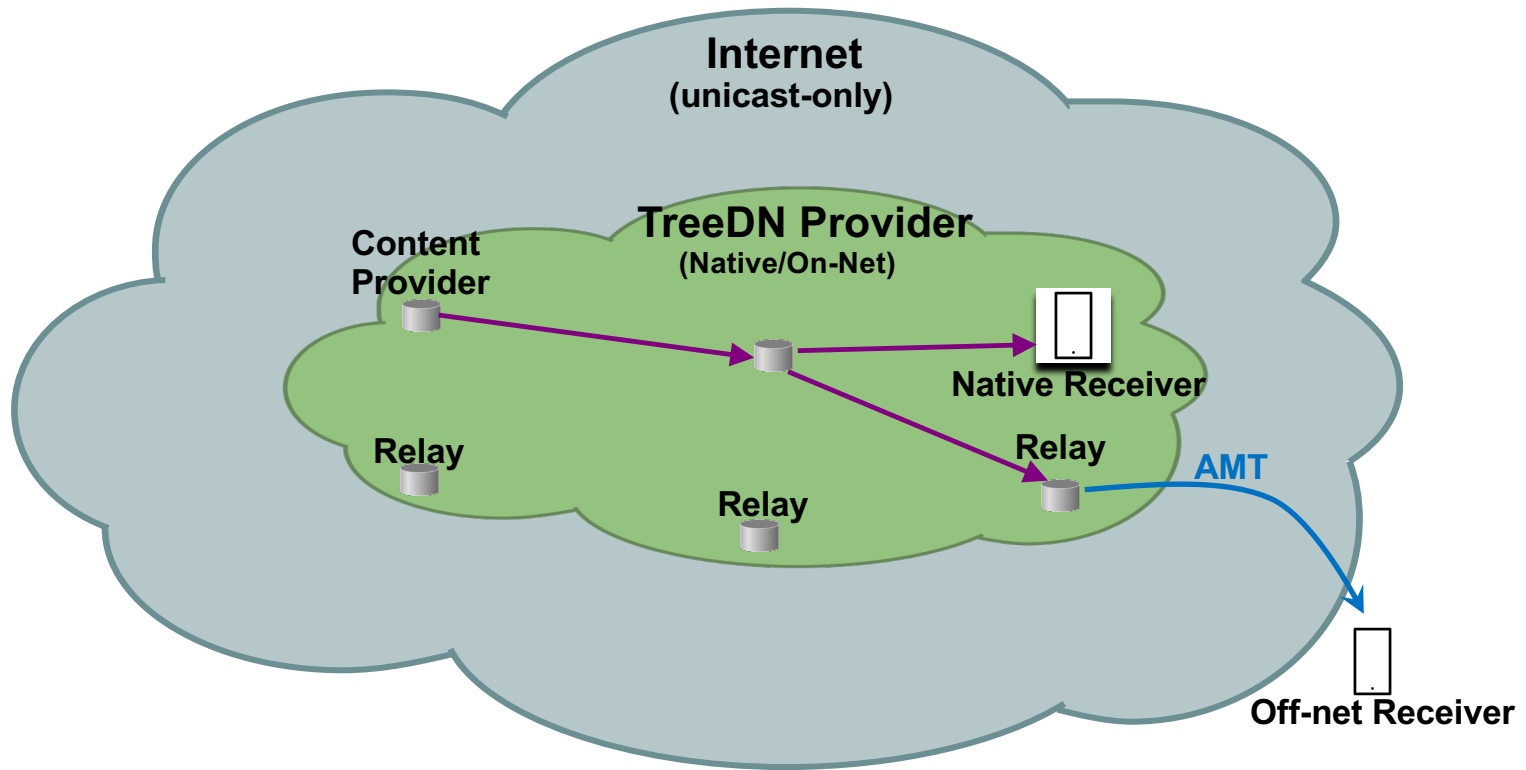
# AMT – Unicast Edge Network



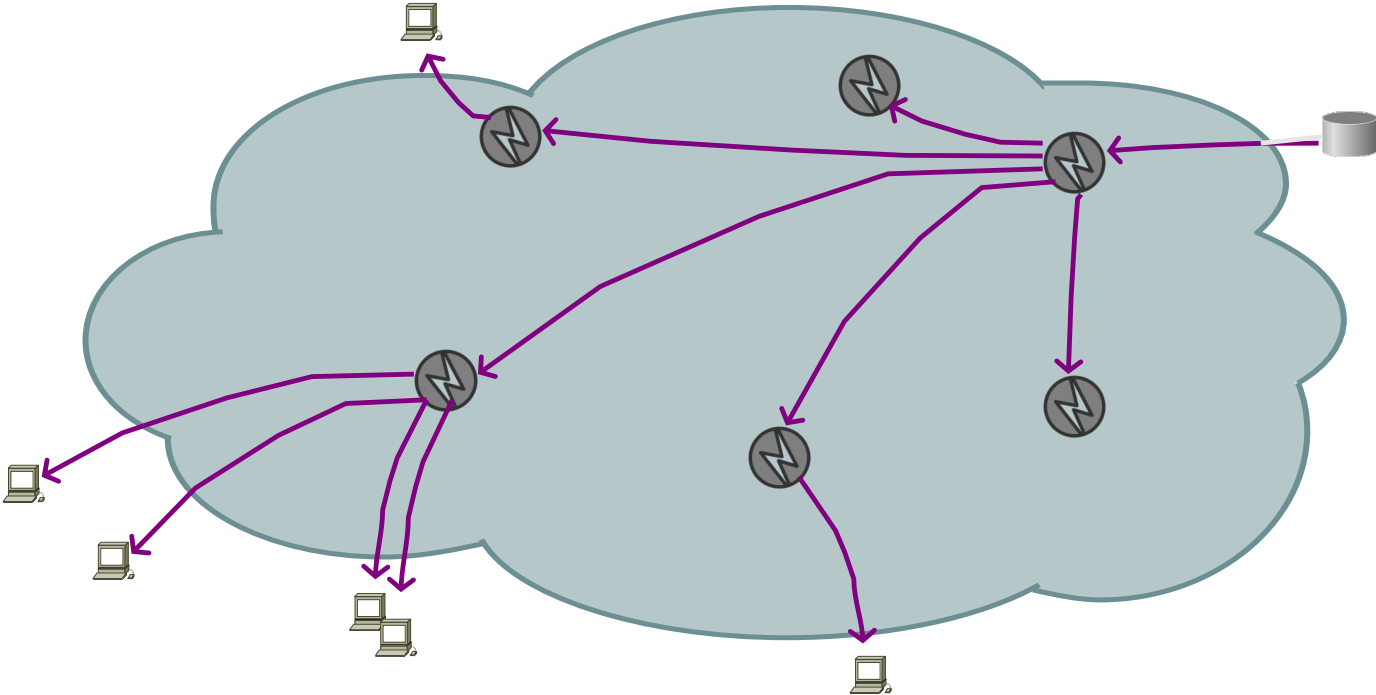
# AMT – Unicast Edge Network



TreeDN= SSM + AMT

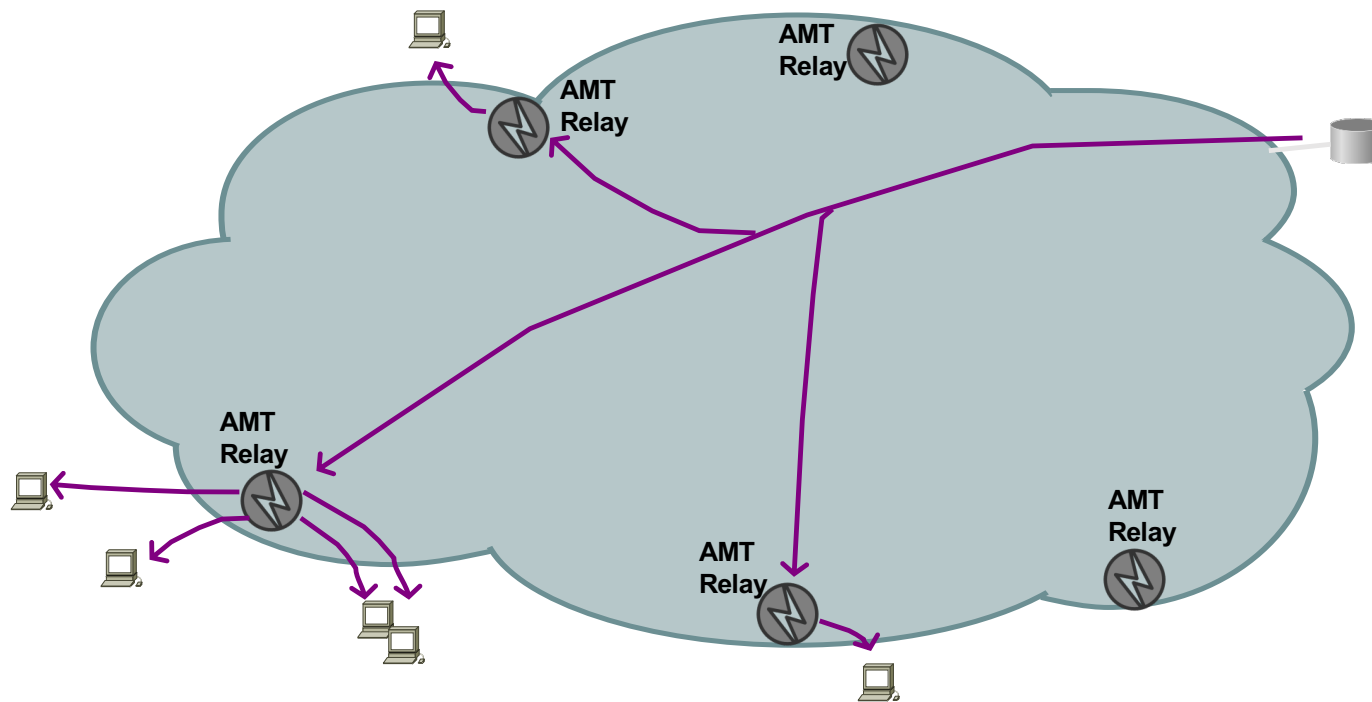


# CDN's without Multicast



# CDN's with Multicast: TreeDNs

- TreeDN: Tree-based CDN Architecture for Mass Audience Live Streaming
- If deployed on existing network infra (CDN-on-a-Chip): \$0 capex
  - ... and maybe \$0 opex, too
  - Open, standards-based solution with mature protocols and minimal coordination with CP



# Use Cases/Applicability

- Any multi-destination content
  - Live streaming (audio/video/AR/telemetry)
  - Large File SW Updates (eg, OS updates)

# TreeDN Benefits

- More efficient network utilization
  - Delivers existing live streaming content at an order of magnitude lower cost
  - Scales to makes new content viable (eg, AR livestreaming to mass audiences, microbetting)
  - Sustainability/Green Networking
- Allows SPs to offer new Replication-as-a-Service (RaaS)
  - At potentially zero additional cost to deliver service (if existing infra support AMT)
  - Open, standards-based architecture with widely available protocols
  - Far less coordination between CP and CDN
    - No need for data storage, protection, key management- CDN just forwards packet
- Addresses fundamental problems with network replication on Internet
  - Incremental deployment, overlay networking, mcast over WIFI
- Democratizes and decentralizes content sourcing
  - Is it healthy for the Internet (and society) that a small handful of companies control nearly all content distribution?



# Summary: Crossing Supply/Demand Curves for Live Streaming on the Internet

- Demand: exploding livestream audience sizes + increasing bitrates (4K/8K/AR)
- Supply: network-based replication is easier and more available than ever
- TreeDN describes a CDN model optimized to address the increasing strain of live streaming on the network, and enables new types of content delivery

# TreeDN and DVB-MABR

- TreeDN can extend M interface to reach any host on the Internet
  - M interface no longer bounded to walled-garden networks
- TreeDN Overlay (AMT) can be used anywhere there is a multicast discontinuity (First/Middle/Last Mile)
  - Last Mile use case solves biggest business needs
  - First/Middle Mile use case is possible also, but less compelling (other solutions exist)
- TreeDN + DVB-MABR: Perfect Together
  - TreeDN addresses L3 connectivity, MABR covers everything else (L4 and up)

# References

- TreeDN Internet Draft:
  - <https://datatracker.ietf.org/doc/draft-ietf-mops-treedn/>
- TreeDN in action:
  - <https://menu.treedn.net/>