mCast: An SDN-based Resource-Efficient Live Video Streaming Architecture with ISP-CDN Collaboration

Ahmed Khalid, Ahmed H. Zahran
and Cormac J. Sreenan

Mobile and Internet Systems Laboratory (MISL)
Department of Computer Science
University College Cork (UCC), Cork, Ireland
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Presented by: Ahmed Khalid

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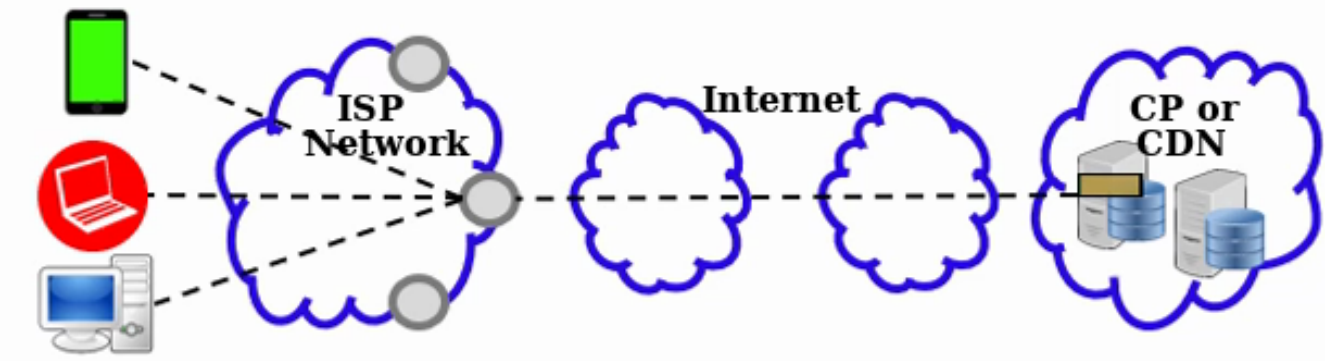
Overview

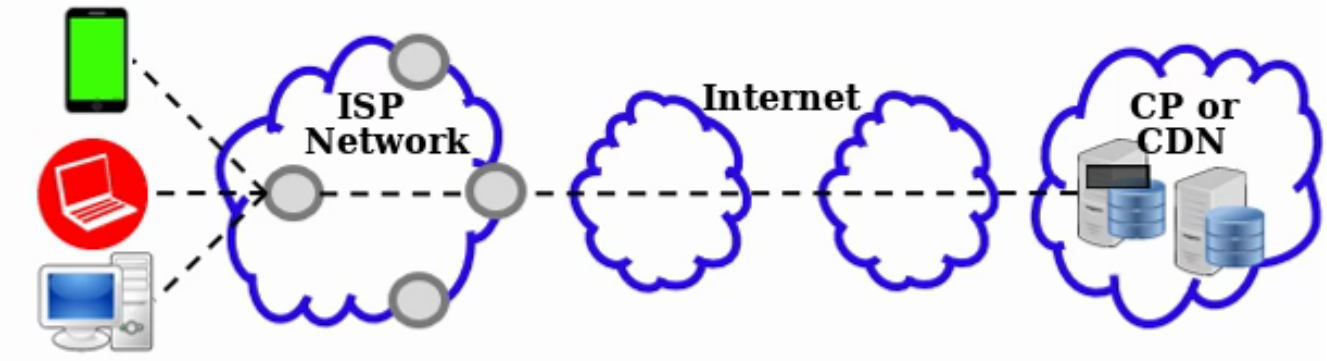
Overview

In a Nutshell..

IP unicast is used to deliver live video streams to thousands of clients



IP Multicast can save resources but can not pass through the Internet



Our architecture mCast enables inter-domain multicast and saves network and system resources for both ISPs and CDNs

Why Is IP Multicast Not Used?

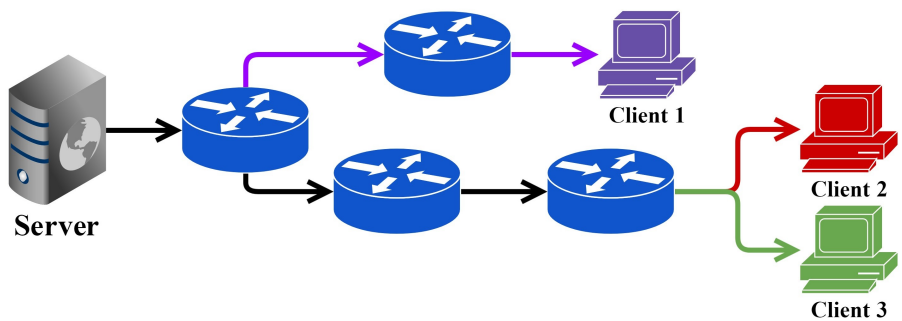
Lacks features essential for a business model of a CDN, such as:

- Billing policies and client authorization
- Group management
- Data and user privacy

Near impossible for ISPs to manage inter-domain IP multicast:

- Hard to achieve traffic and admission control
- Rigid and static routing algorithms

- High CAPEX/OPEX



What about P2P?

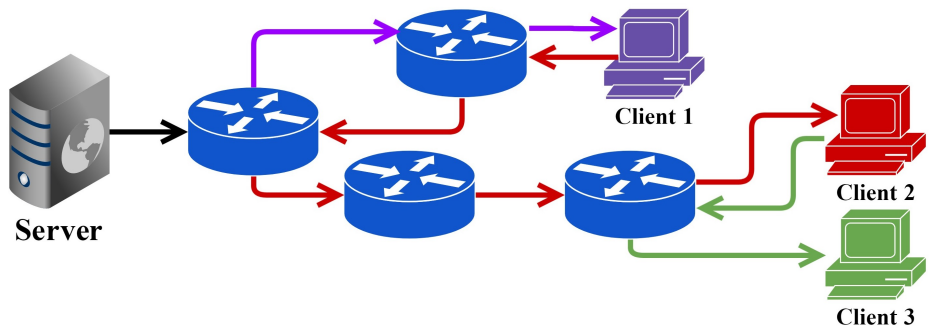
- Peer-to-Peer systems use Application Layer Multicast (ALM)
- Peers form an overlay topology and share streams

- Reduces the load on content servers but increases start-up delays

Further deteriorates situation for ISPs:

- Additional inter-domain and intra-domain unicast flows
- Even more bandwidth consumption than IP unicast

- Better solution needed



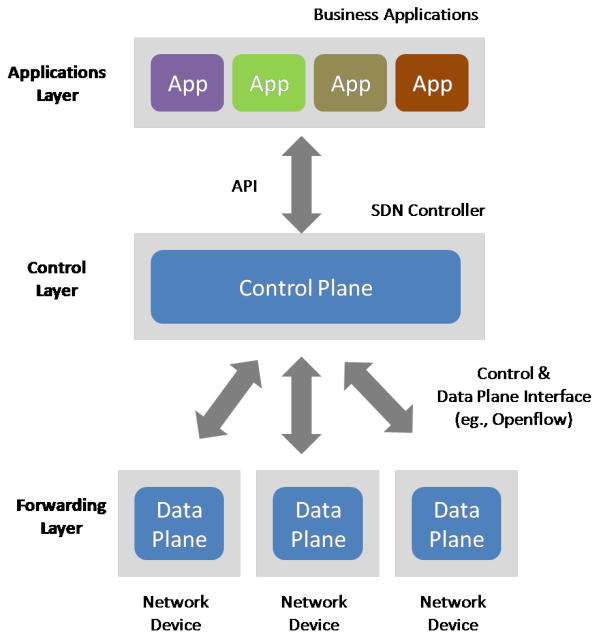
What Can SDN do?

Software-Defined Network (SDN):

Separates the control plane from the data plane

The global view of SDN can make the delivery of traffic very efficient

The flexible control of SDN solves the deployment issues of IP multicast



The centralized control of SDN:

Can help ISPs manage the traffic flows across their domain

Contribution of Paper

An Internet architecture for live streaming that provides:

- Reduced inter-domain and intra-domain traffic for ISPs and CDNs
- A dynamic and scalable mechanism for multicast tree construction
- Transparent delivery of video streams to clients

A framework for:

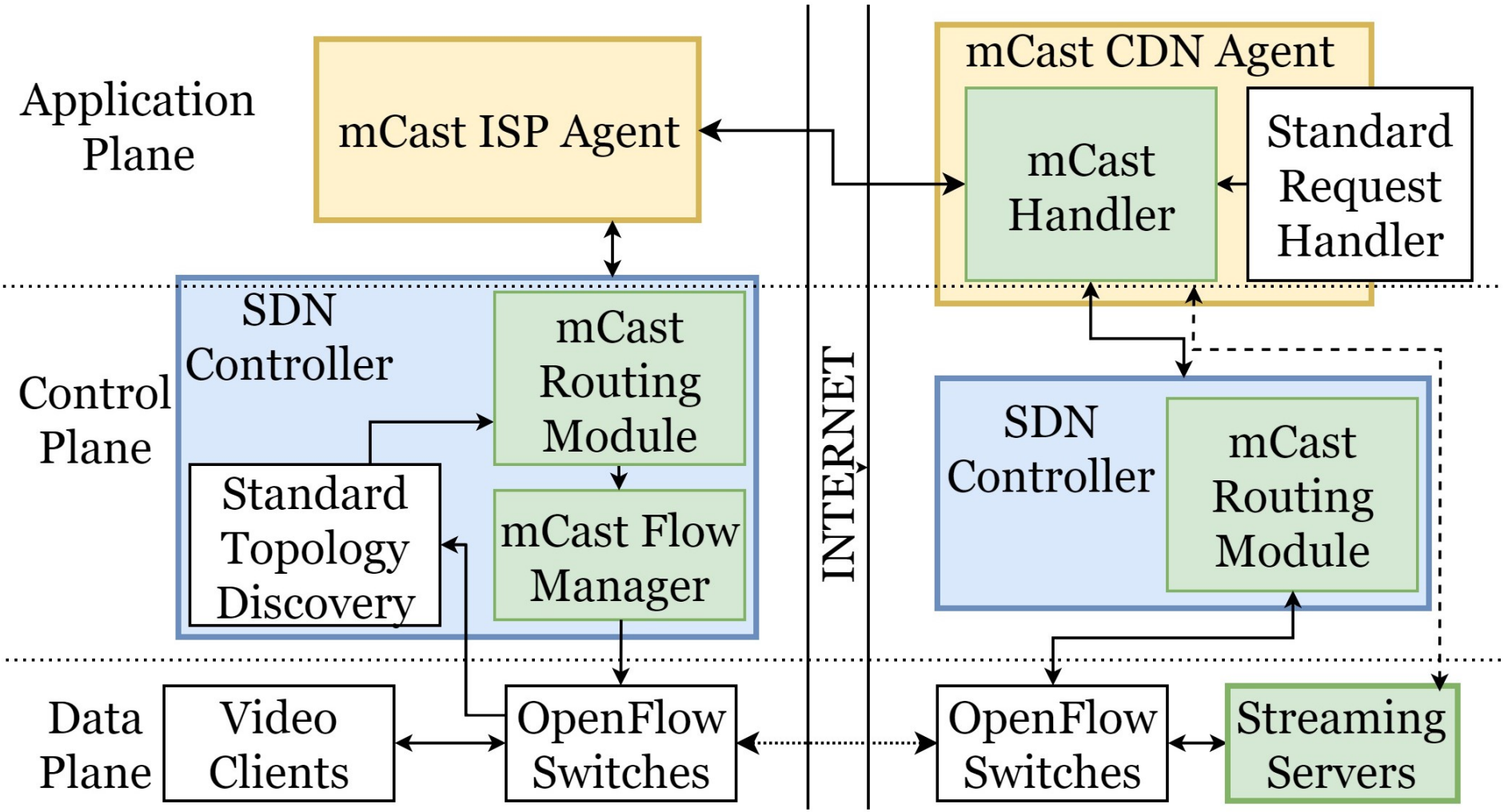
- Communication between SDN controllers of ISPs and CDNs
- Maintaining full control of CDNs over their clients

- A cost-based decision model to help CDNs decide when switching to mCast will be profitable

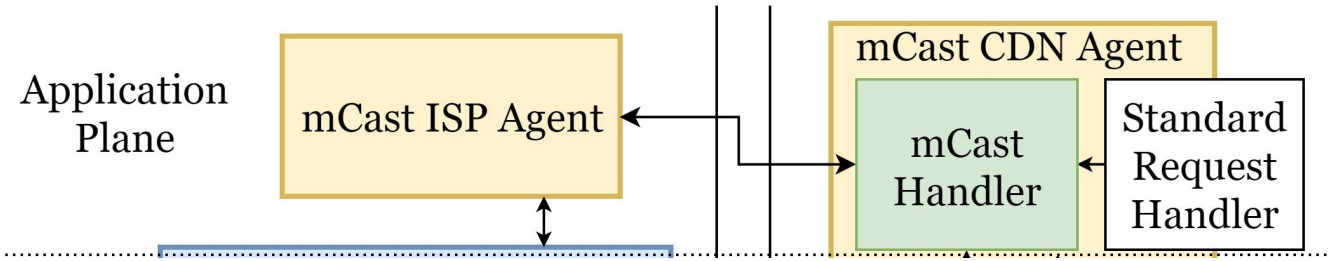
- An evaluation platform to compare the performance of SDN-based multicast architectures or algorithms

Overview

Design Overview



Components in Application Plane



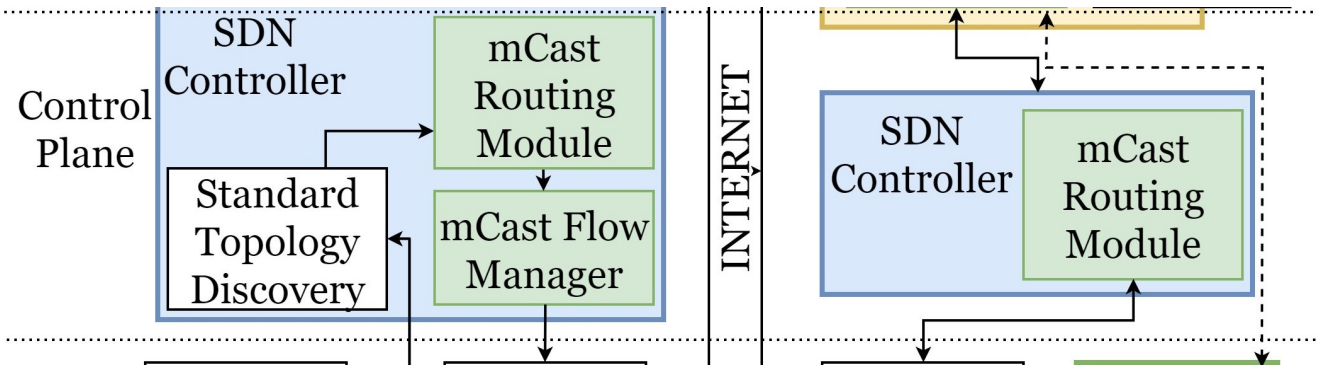
mCast ISP Agent

- Plays a passive role and does not trigger mCast
- Interfaces with CDN to receive session aggregation requests
- Orchestrates multicast operations
- Creates identifier for the mCast stream

mCast CDN Agent

- Gathers information from Standard Request handler
- Identifies clients that can be served with mCast
- Performs multicast management functions
- Triggers mCast based on the output from decision model

Components in Control Plane



mCast ISP Routing Module

- Probes Topology Manager to get a graph of network
- Creates multicast trees

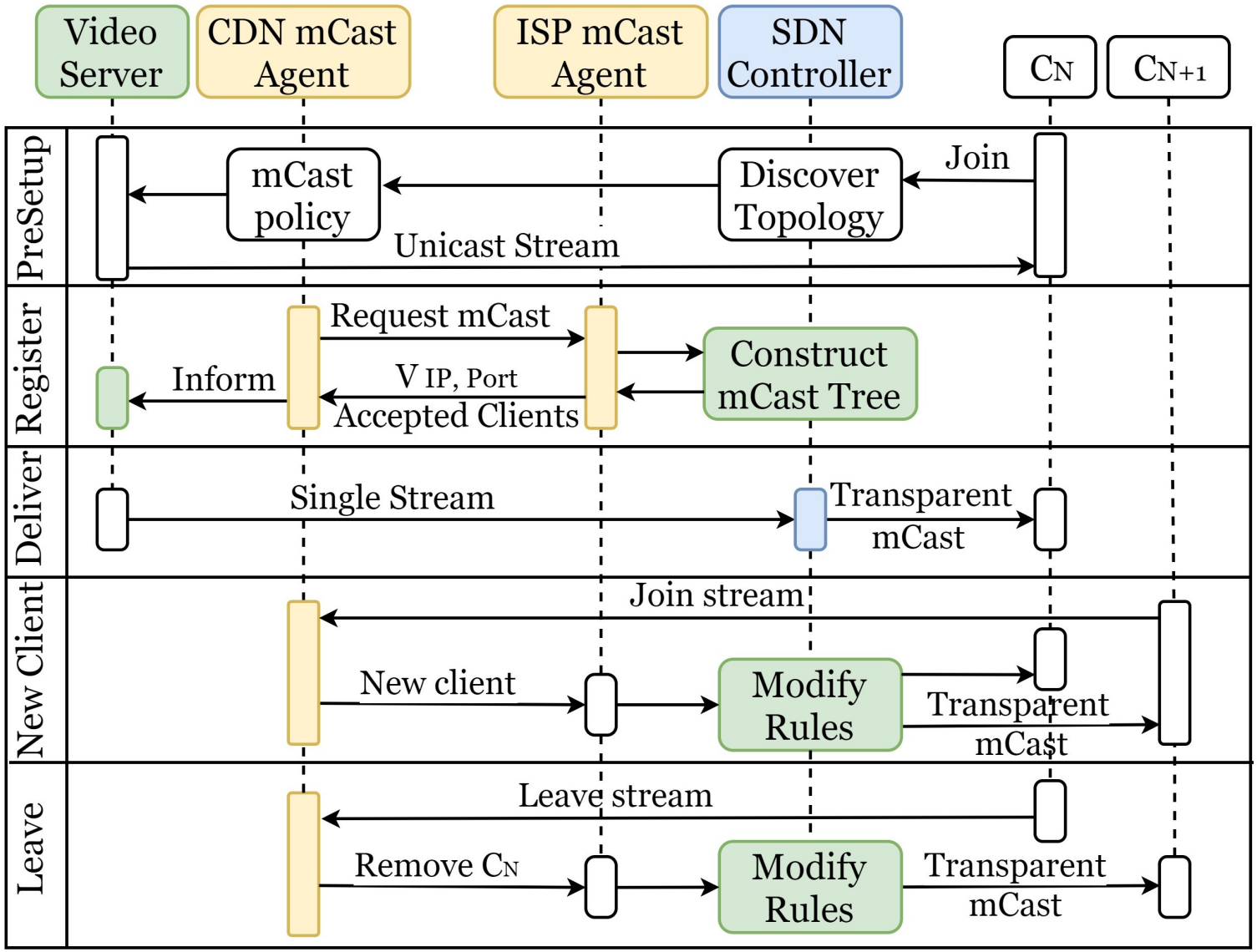
mCast Flow Manager

- Installs mCast entries with higher priority than IP unicast
- Installs transparency rule on egress switches

mCast CDN Routing Module

- Forwards content requests of clients to the request handler for authentication
- Consults mCast CDN Agent before proceeding with the default routing

An Example of Message Exchanges



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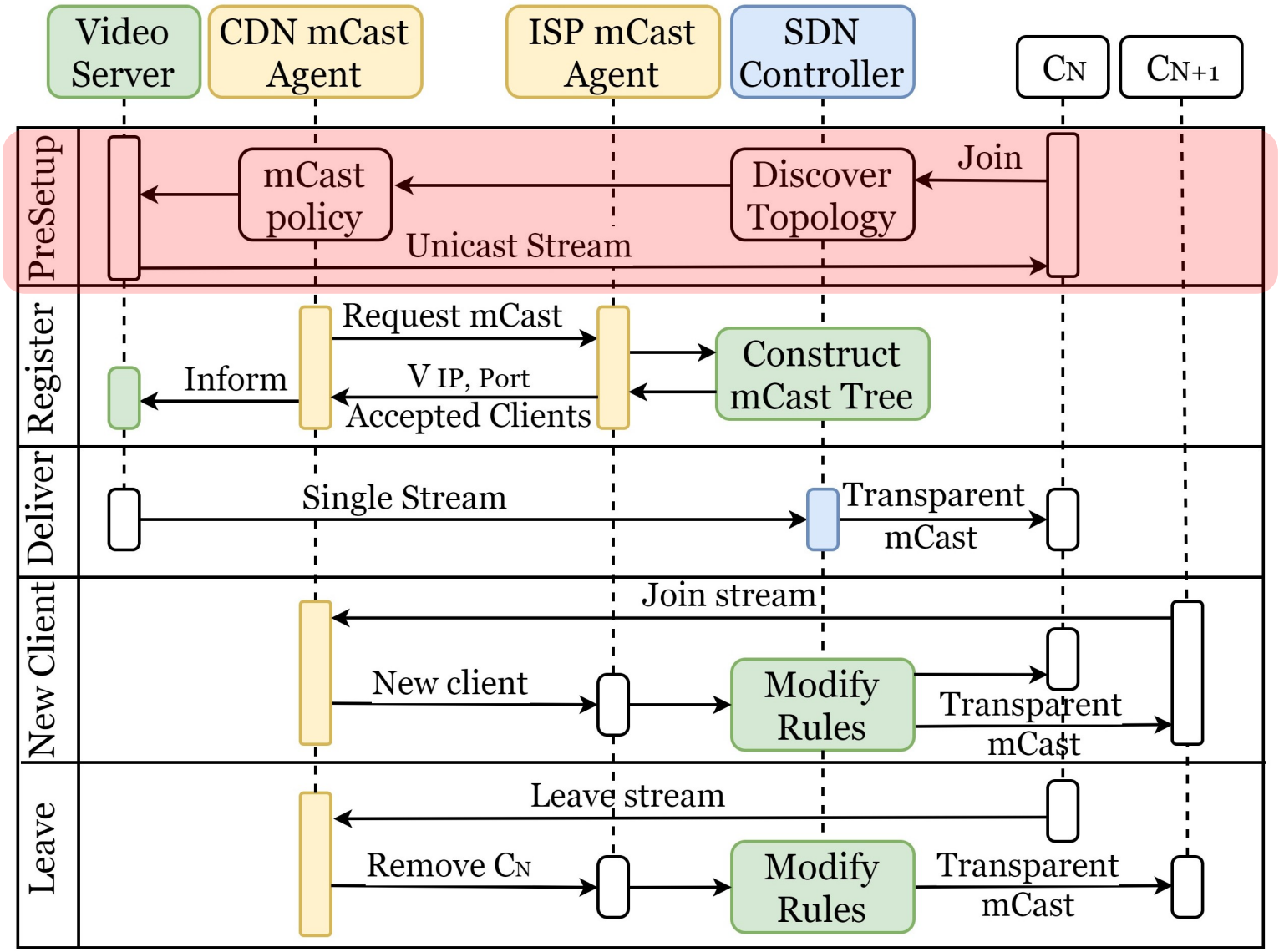

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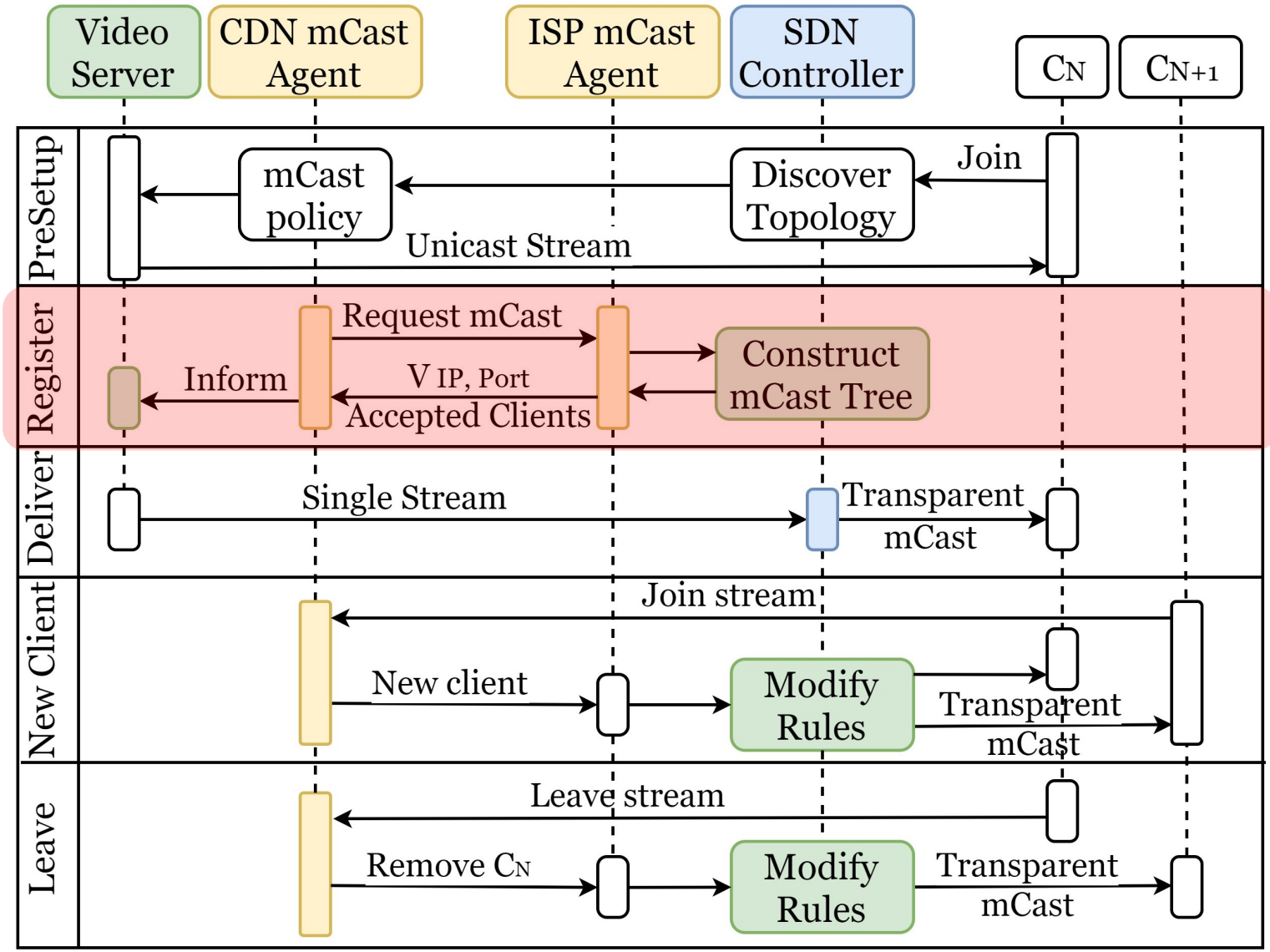

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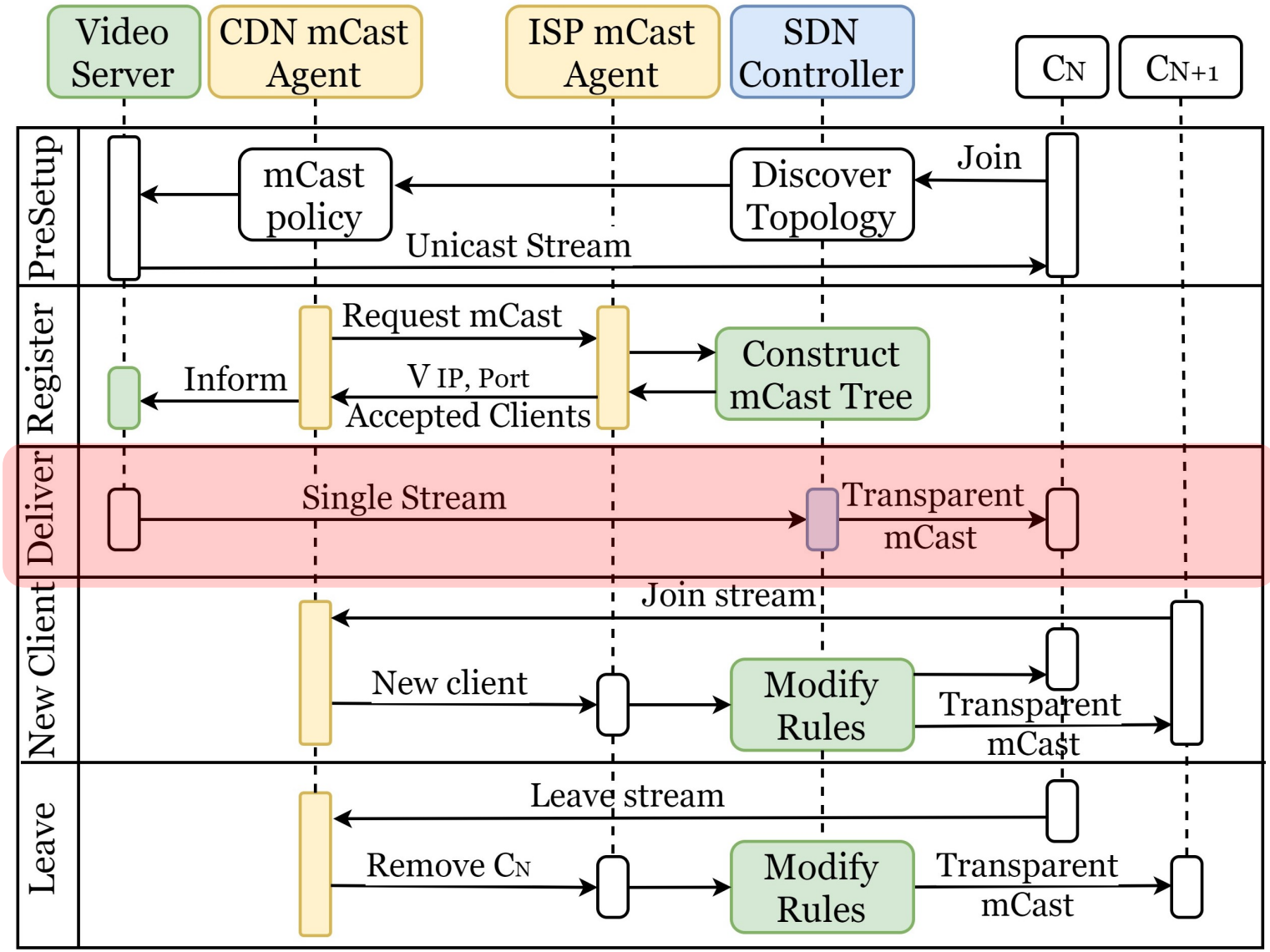

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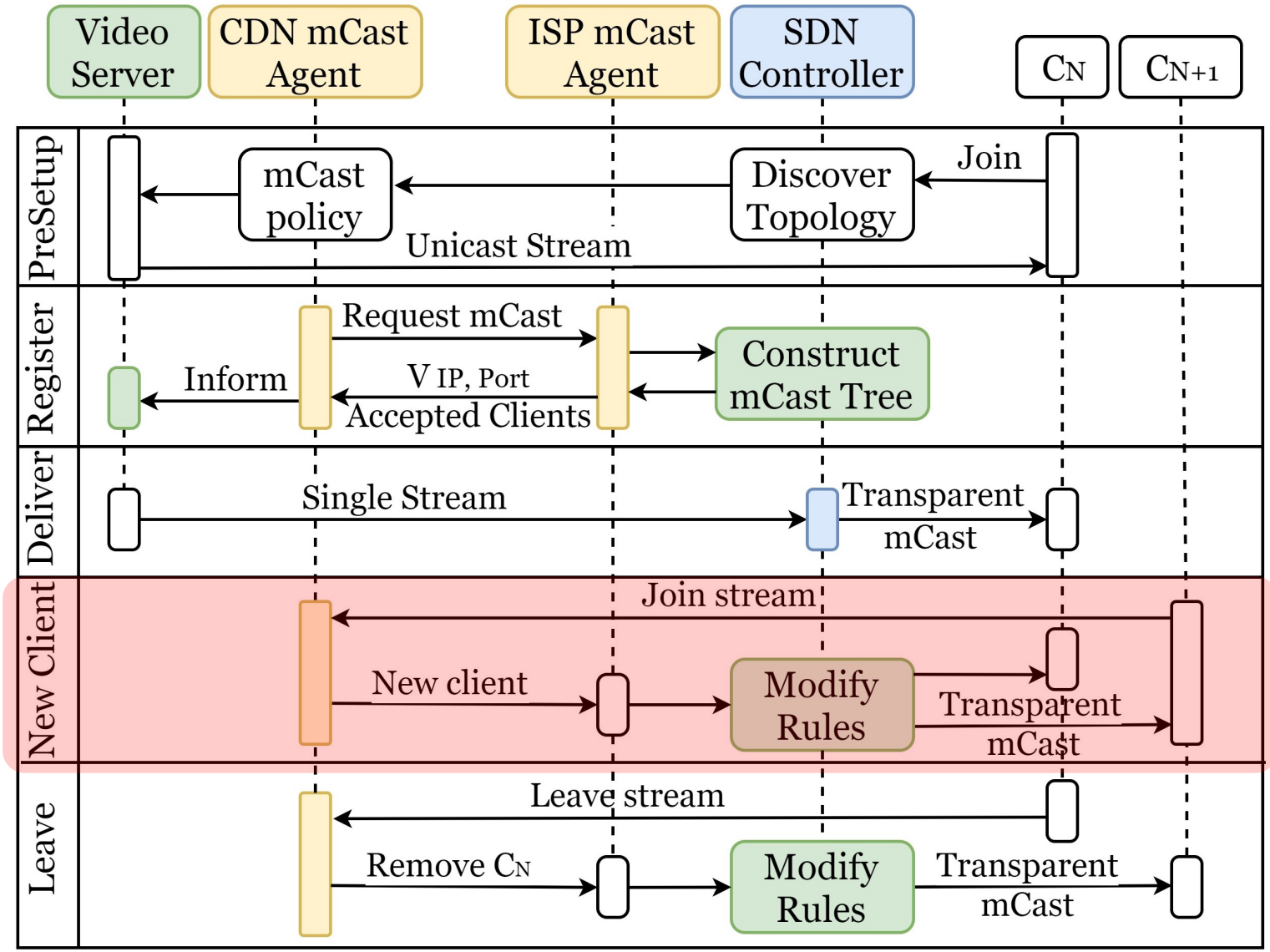

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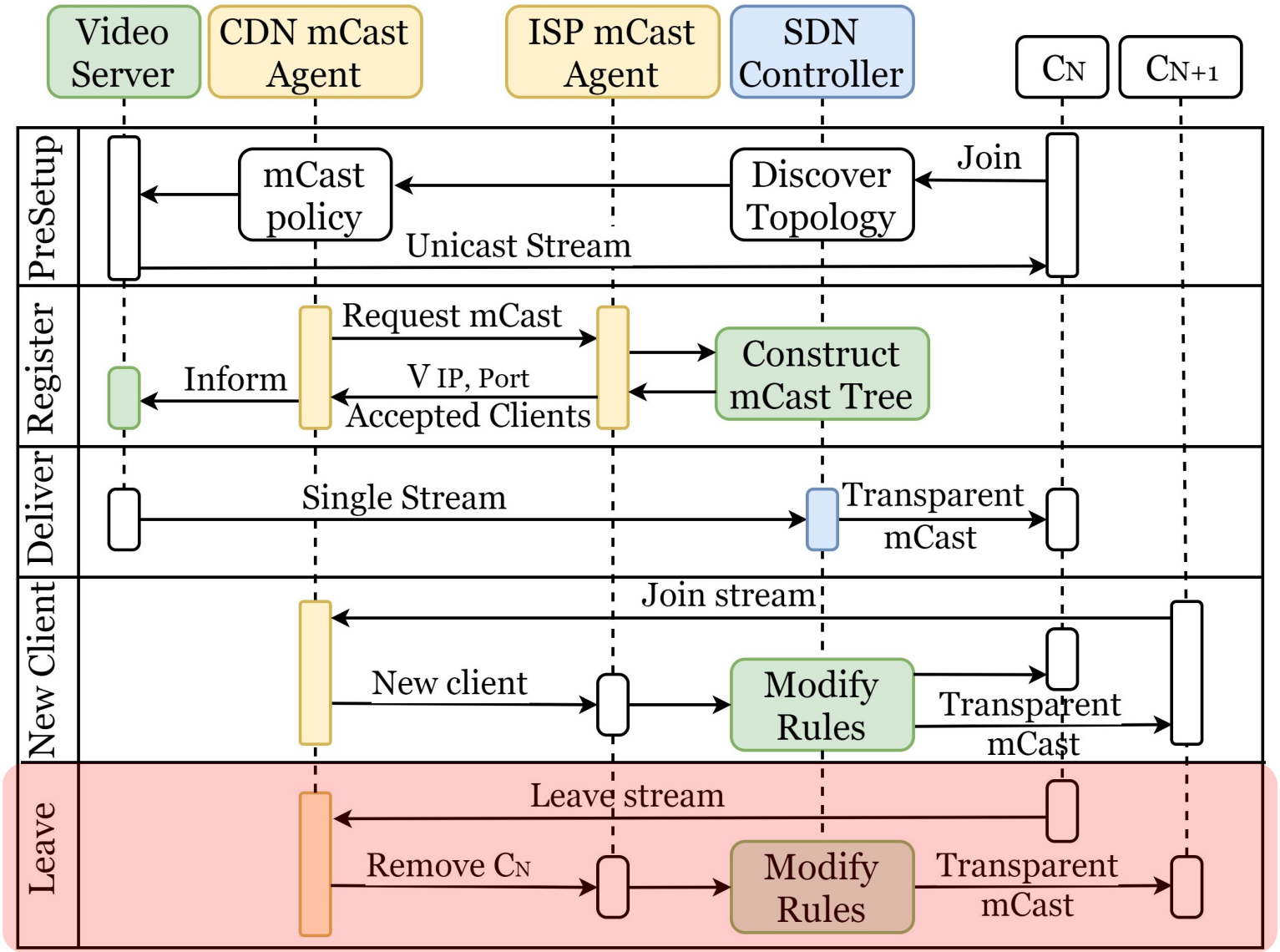


Overview

Importance of the Decision Model

- Complimentary contribution to mCast architecture
- ISPs and CDNs are economically driven:
  - ISPs will charge CDNs for availing mCast service
  - CDNs would want to minimize the cost to serve a stream to clients

The decision model:

- Identifies various cost factors
- Presents the cost factors in quantifiable mathematical equations
- Informs CDNs when switching to mCast will reduce the total cost to serve a stream

Cost Factors

Power Consumed to serve a stream to N clients:

$$P(N) = P_{max}\left(0.7\left\lceil\frac{N}{N_o}\right\rceil + 0.3\frac{N}{N_o}\right)$$

P_{max} = power consumed by a server when fully utilized
N_o = maximum number of clients that a server can serve

Bandwidth Consumed to serve a stream to N clients:

$$B(N) = max\left(\alpha N B_i S_T, \frac{V_C S_C N B_i}{\sum X_i Bi}\right)$$

α = factor to avoid large queuing delays
B_i = average bit-rate of channel i, X_i = a client watching channel i
V_T = transit volume; V_C = commit volume
S_T = unit price for V_T; S_C = unit price for V_C

Problem Formulation

Cost to server N clients with IP Unicast:

$$U(N) = P_{max}\left(0.7\left\lceil\frac{N}{N_o}\right\rceil + 0.3\frac{N}{N_o}\right) + \frac{V_C S_C N B_i}{\sum X_i Bi}$$

Cost to server N clients with mCast:

$$M(N) = U(1) + C\frac{1-r^N}{1-r}$$

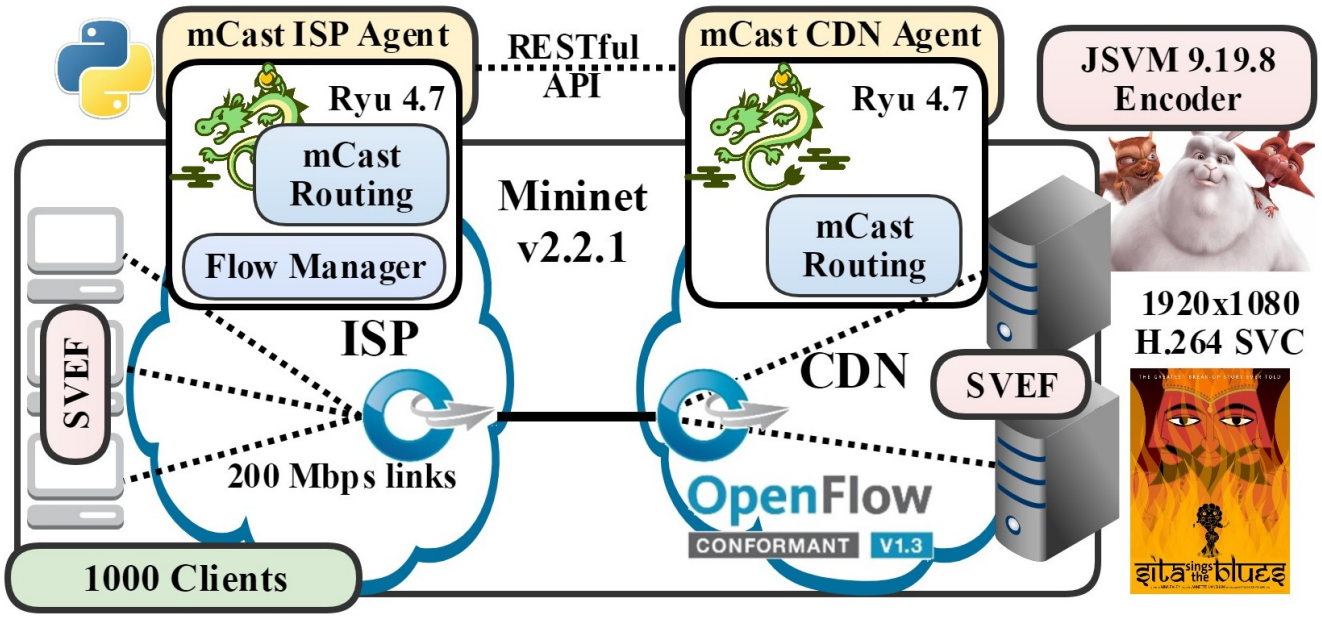
C = initial cost that ISP charges CDN for providing mCast service
r = ratio for decreasing cost of every new client

Find Number of clients for which:

$$M(N) < U(N)$$

Overview

Testbed



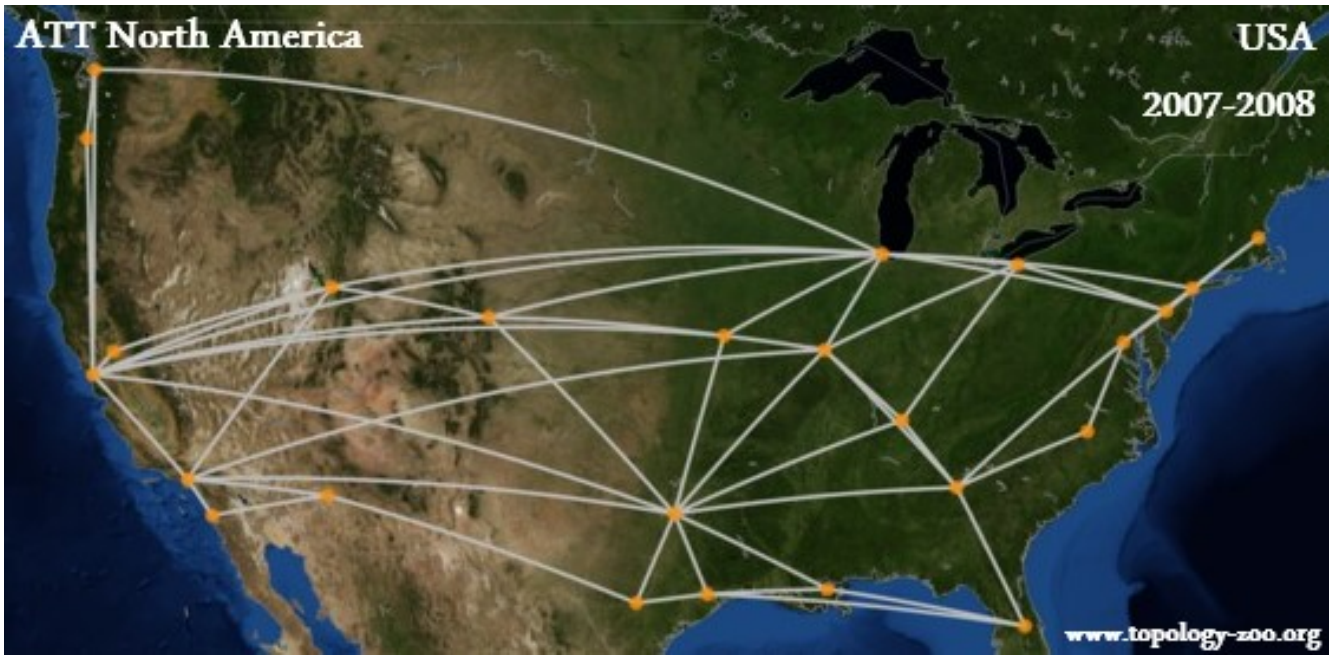
JSVM to encode videos and SVEF to stream and receive

- Two videos: Big buck bunny (bbb) and Sita sings the blue (sstb)
- 1920x1080 HD resolution, 9 minutes, GOP = 8, frame rate = 25fps
- Number of clients: 200, 400, 600, 800, 1000

Ryu for SDN controllers and Mininet for network emulation

- Results are averaged over 5 runs of experiment

ISP Topologies from Topology Zoo Database



Mesh topology

STAR topology

Performance Metrics

Network performance

- Total link utilization in the ISP network
- Percentage of packets dropped in the network

Video quality

- Average start-up delays
- Amount of lost video frames

Overhead

- Number of OpenFlow rules

Understanding the Results

- Less than 600 clients: The system (Open vSwitch, Servers) is not overloaded
- More than 600 clients: mCast continues to work fine whereas IP Unicast overloads the system

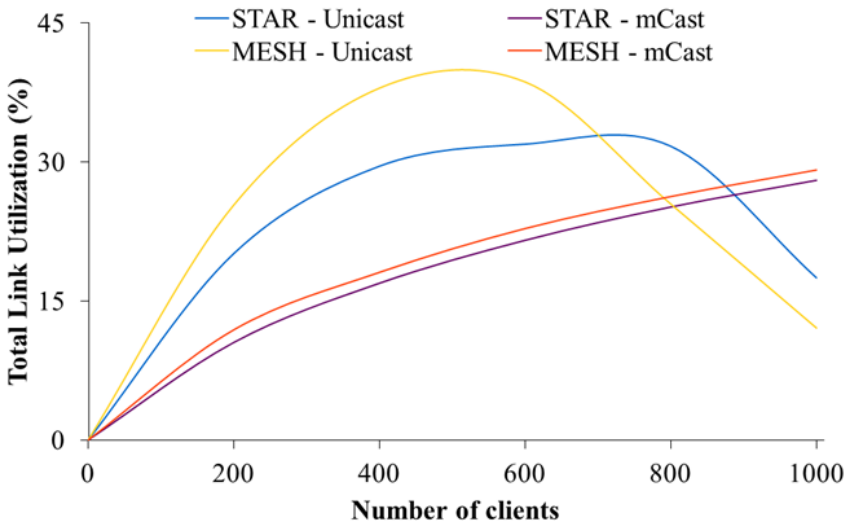
Number of client-connection failures due to system overload

Clients	STAR Topology		MESH Topology	
	Unicast	mCast	Unicast	mCast
200	0	0	0	0
400	0	0	0	0
600	56	0	191	0
800	470	0	677	0
1000	844	0	938	0

Link Utilization and Packet Losses

By avoiding any unnecessary packet duplication, mCast:

- Reduces link utilization
- Avoids network congestion
- Eliminates network losses



Link Utilization (%) vs Clients

Clients	STAR Topology		MESH Topology	
	Unicast	mCast	Unicast	mCast
200	0.33	0	0.37	0
400	3.41	0	5.62	0
600	23.56	0	13.02	0
800	1.33	0	5.61	0
1000	0.64	0	1.15	0

Percentage of network packet loss (%)

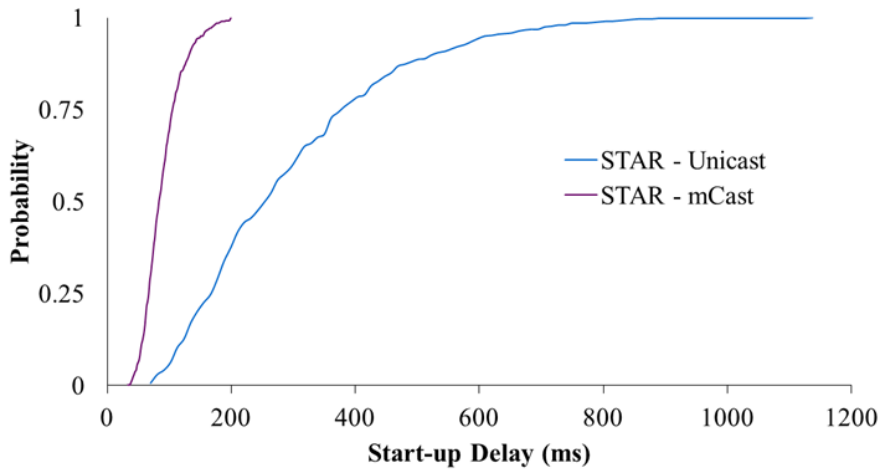
Video Quality: Video Frame Loss and Start-up Delays

When using mCast:

- No lost, delayed or un-decodable frames
- Decreased start-up delays
- Clients experience better quality of video delivery

Clients	STAR Topology		MESH Topology	
	Unicast	mCast	Unicast	mCast
200	1.22	0	1.38	0
400	5.98	0	9.10	0
600	38.78	0	22.91	0
800	2.52	0	9.10	0
1000	1.75	0	3.88	0

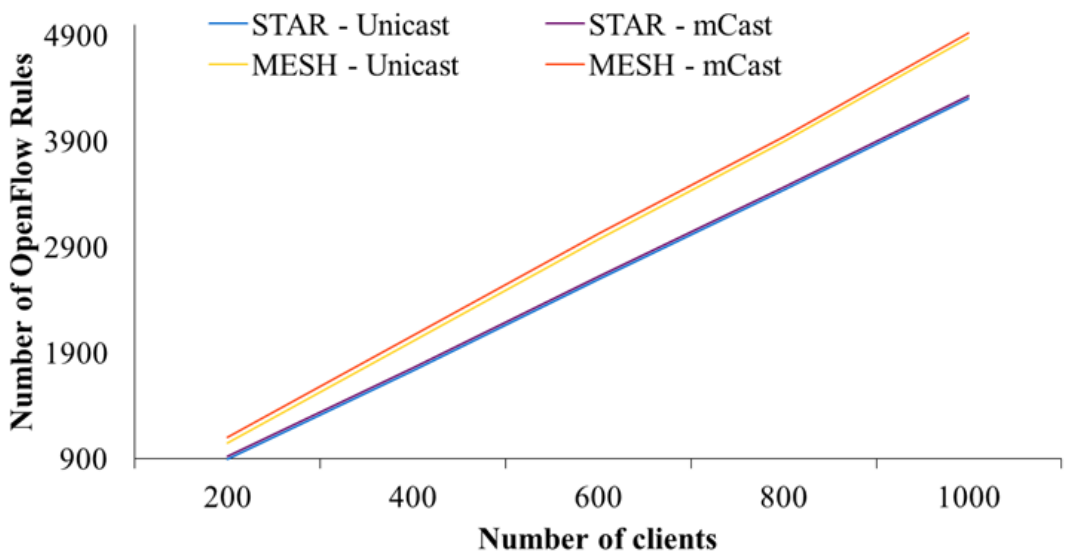
Percentage of Video Frame Loss (%)



CDF of start-up delays for 600 clients

Overhead Due to mCast

- Each stream adds only one rule per switch participating in mCast



Number of OpenFlow rules vs Number of clients

- Number of OpenFlow messages can increase in mCast depending on user behavior and frequent channel switching or clients leaving

Overview

Related Work That Utilizes SDN

- Improving mechanism of IP Multicast
  - Example: Fast failure recovery for IP multicast trees [SAINT'12]
  - Issues such as handling inter-domain traffic remain unaddressed

SDN-based frameworks and architectures

- Lcast [EJCN'14]: creates a router overlay to connect hosts across domains
- SDM [JNSM'15]: enables ISPs to support resource-efficient P2P streaming

- Elaborate multicast routing algorithms
  - The SDN controller receive network statistics from all network nodes and construct efficient paths [TNSM'15]
  - Complimentary to our work and can be implemented in mCast

Summary

- IP multicast cannot handle inter-domain traffic and lacks features essential for the business model of CDNs

- We proposed a novel architecture for live streaming that merges the flexibility and control of SDN with efficiency of multicast to save resources for both ISPs and CDNs

- We proposed a decision model that can help CDNs to choose when switching to mCast can save resources

- We implemented mCast on an evaluation platform and showed its feasibility, robustness and gains against IP unicast

Future and On-going Work

- Designing algorithms and mechanism for quick and efficient channel switching
- Supporting reliable mCast using forward error correction (FEC) or a reliable UDP protocol
- Designing a mechanism for optimizing and reconstructing multicast tree with clients joining and leaving dynamically
- Handling personalized advertisement
- Stretching mCast in wireless networks from the core, to the access and on to the clients

Questions??

Ahmed Khalid

An Internet Infrastructure for Video Stream Optimization (iVID) Project

Mobile and Internet Systems Lab
University College Cork,
Cork, Ireland

a.khalid@cs.ucc.ie

Check out the iVID datasets and software

mCast:	Evaluating SDN-based multicast architectures
MiniNAM:	A network animator for Mininet
D-LiTE:	A platform for evaluating DASH in a simulated LTE network
D-LiTE-ful:	A platform for DASH SDN offloading in LTE
DASH Datasets:	Trace and stream-based, AVC (H.264) and HEVC (H.265). QoE metrics: PSNR and VQM
SAP:	Stall-Aware Pacing for DASH in Cellular Networks

http://www.cs.ucc.ie/misl/research/current/ivid/

Please come see my demo in the next session

"Prototyping and Evaluating SDN-based Multicast Architectures for Live Video Streaming"