Architecture and Mechanisms for High Quality Streaming Multimedia

Tze Sing Eugene Ng

Carnegie Mellon University

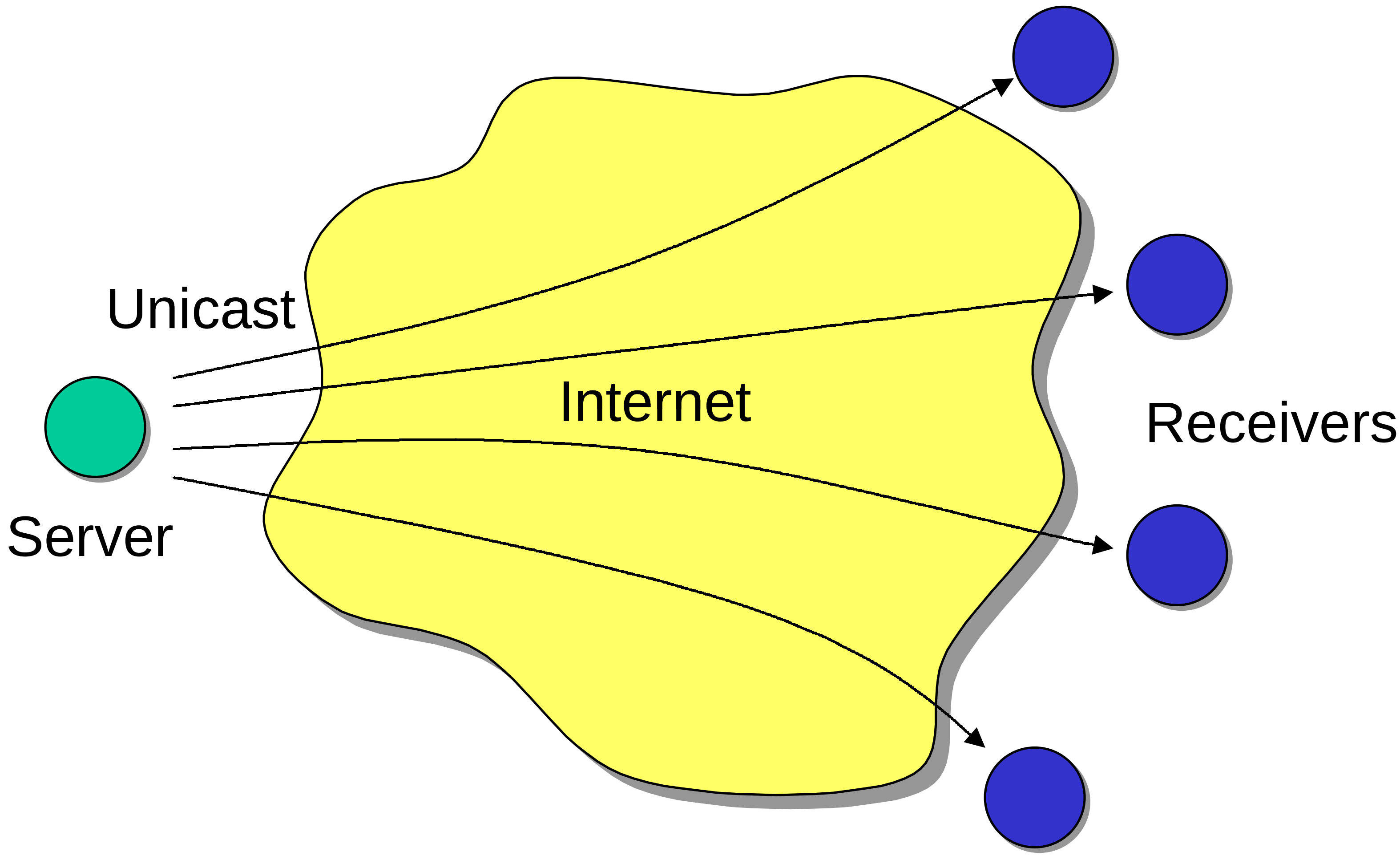
Joint work with Katie Guo, Markus Hofmann,

Sanjoy Paul, and Hui Zhang

Outline

- Motivation
- Assumptions
- Project goals
- Architecture overview
- Basic mechanisms
- Related work
- Conclusion

Current Streaming Architecture



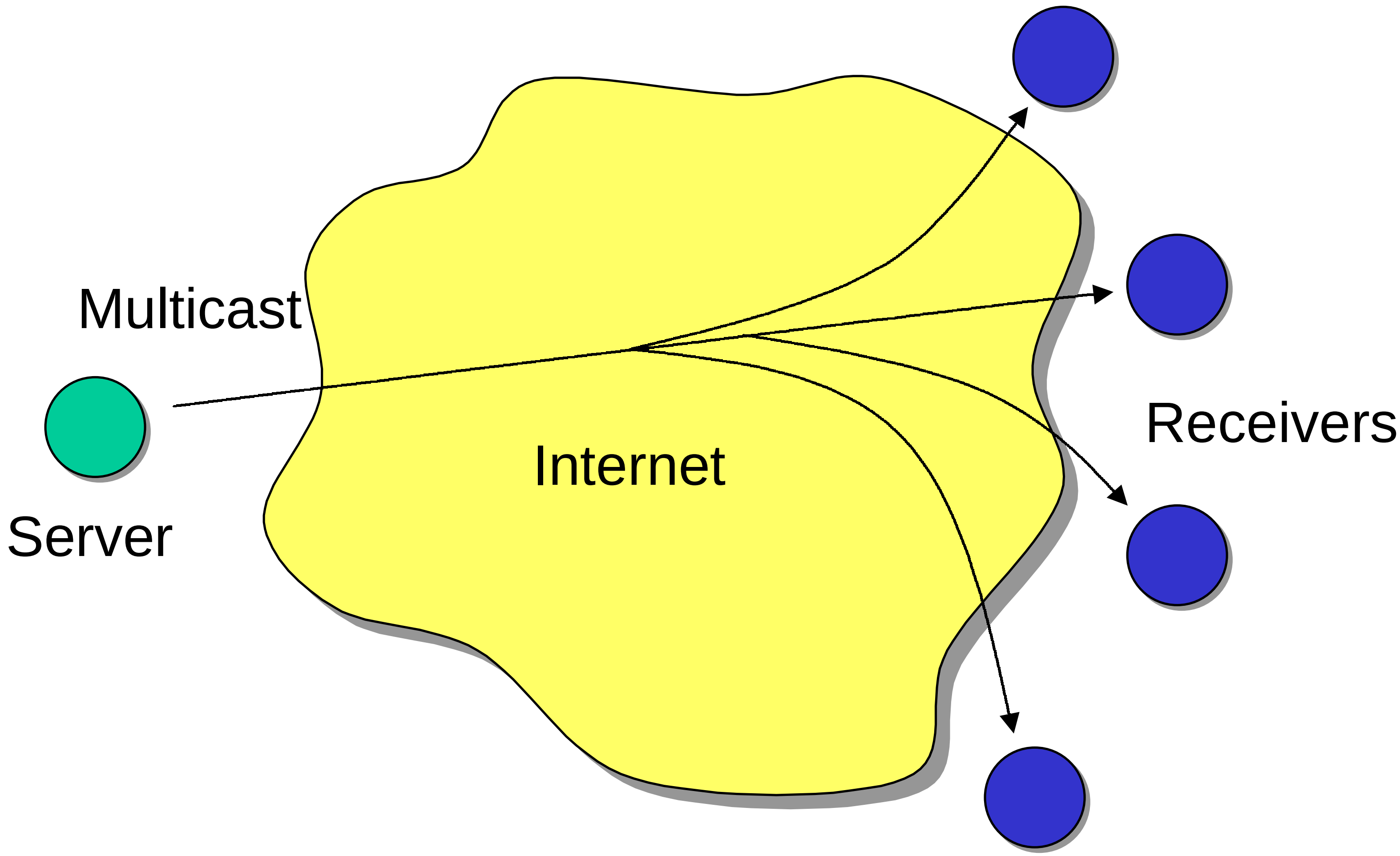
Problems with Current Architecture

- Content provider
  - Server load increases linearly with the number of receivers
- Receiver
  - High start-up latency
  - Unpredictable playback quality
  - Poor performance with VCR operations
- ISP
  - Streaming multimedia flows lead to serious network congestion problems

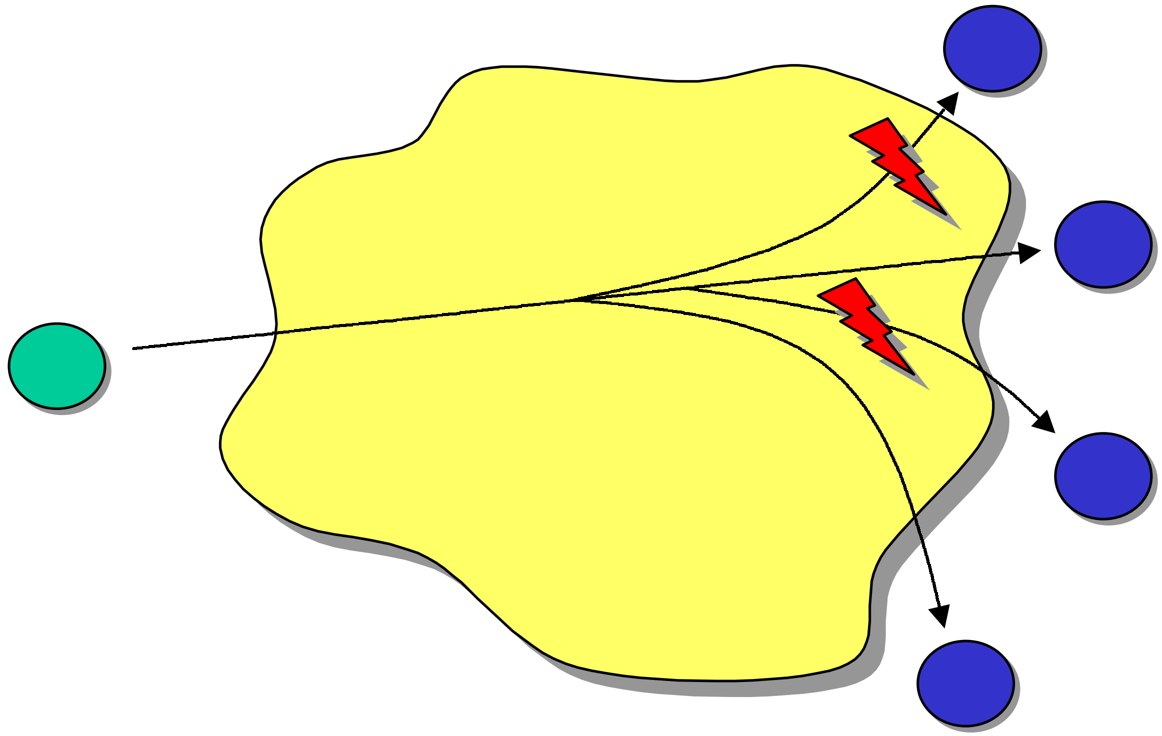
Example: News Coverage of President Clinton's Testimony

- CNN audio and video quality became unbearable for most people at around 1:00 pm on August 17
- Link to video stream removed from CNN by 1:15 pm
- Other news servers were also unreachable

IP Multicast

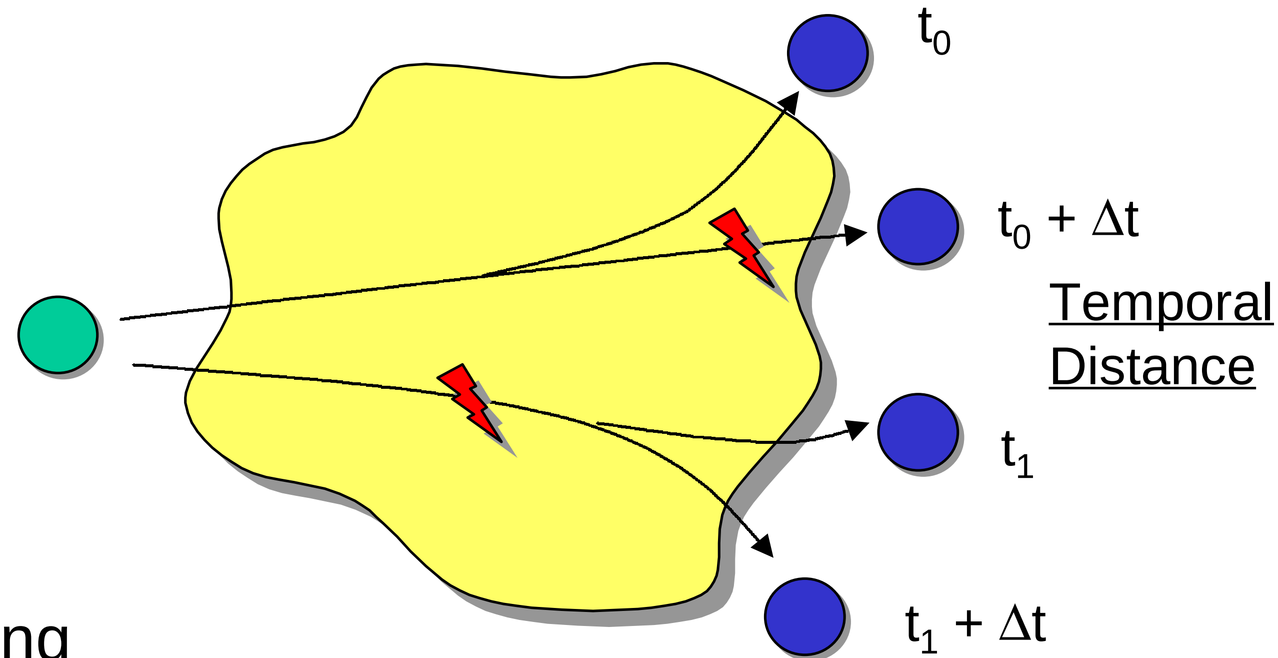


Multicast for Live Broadcast



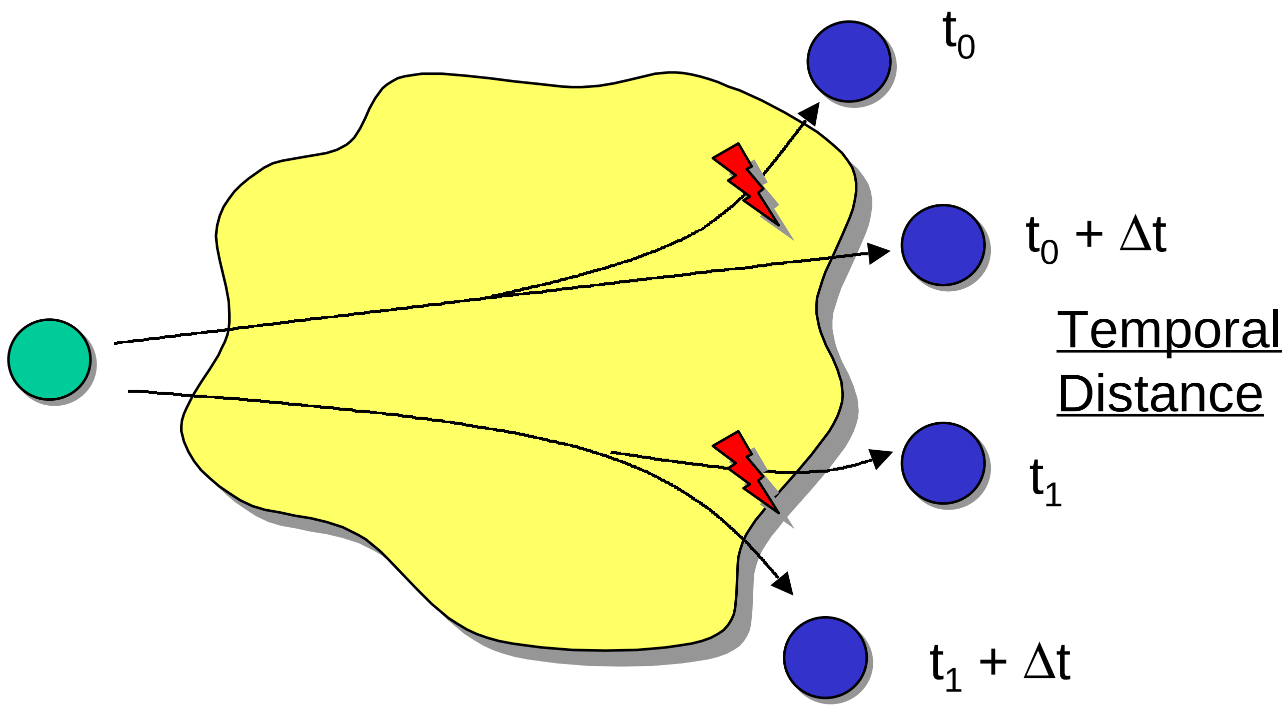
- Reduces both server load and network load
- Does not improve quality of service to receivers

Multicast for On-Demand Streaming



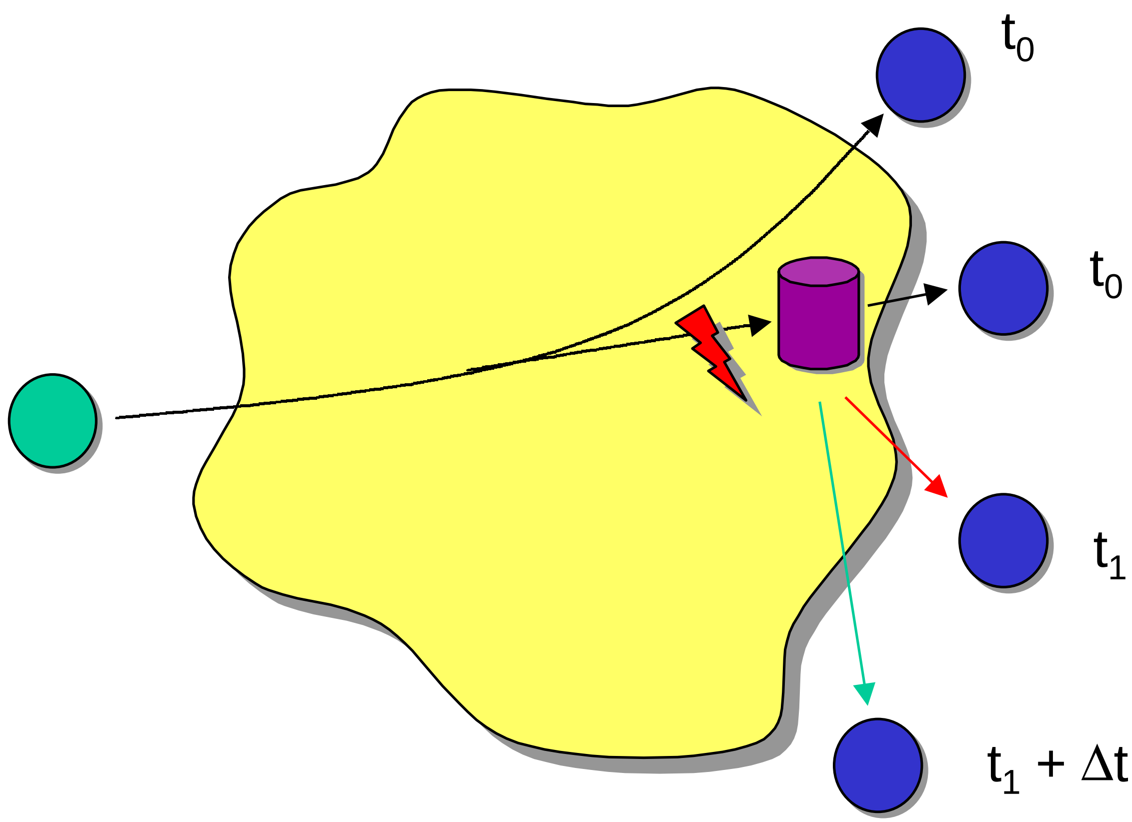
- Batching
  - Requests arriving within a time window Δt are batched together and are served by one multicast session
- Reduces both server load and network load
- Does not improve quality of service to receivers
  - Start-up latency increases

A Fundamental Problem with Multicast



- Multicast works best when receivers are homogeneous and synchronous
- In reality, receivers are heterogeneous and asynchronous

Solution: Buffer, Buffer, More Buffer



- Buffering can mask both the heterogeneity and asynchrony of receivers

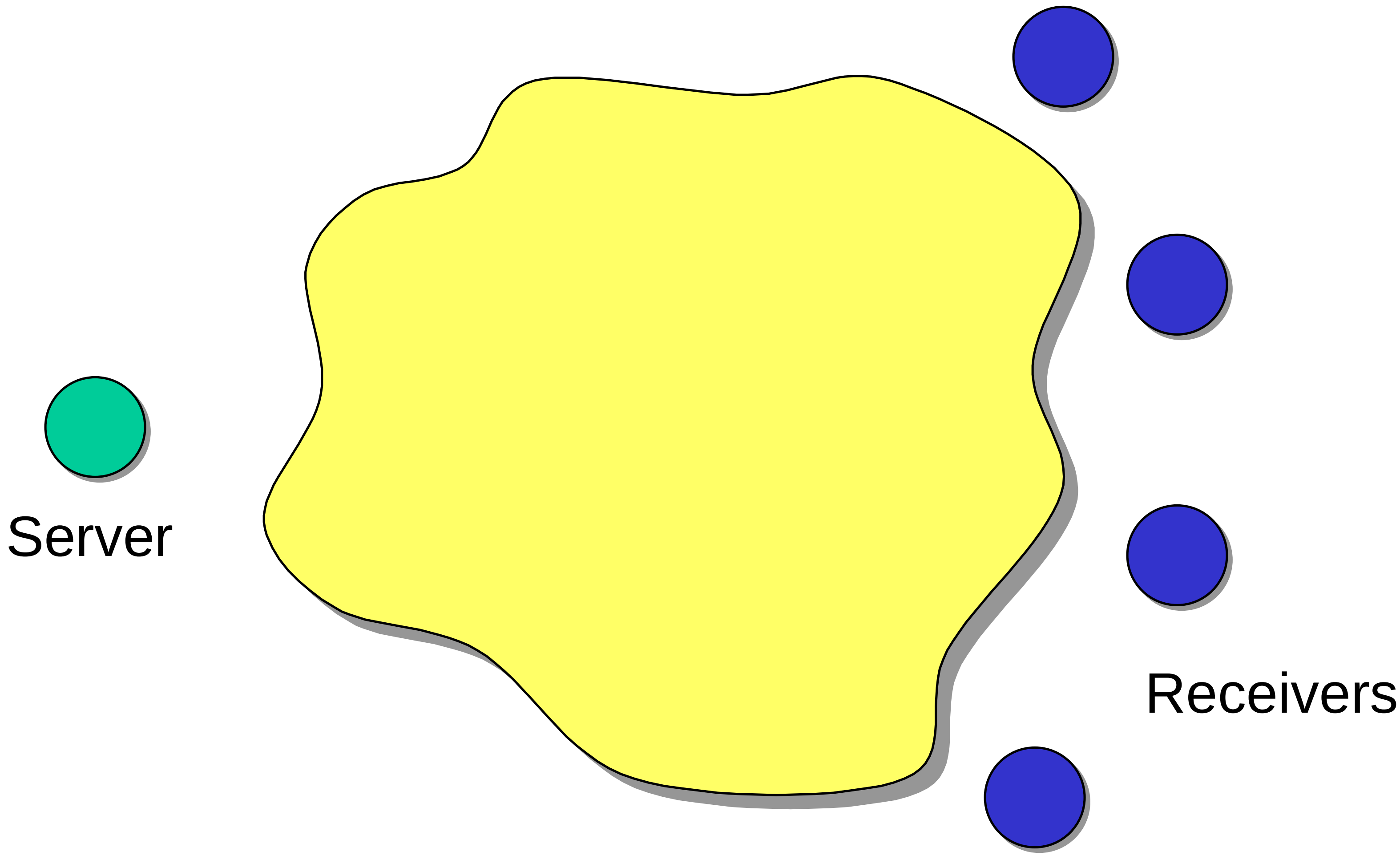
Assumptions

- Application environment
  - Live broadcasts
  - On-demand long streams
  - On-demand short clips
  - VCR operations allowed
- Network environment
  - Assume minimal QoS support
  - Can take advantage of underlying QoS if available
- Infeasible to replicate all streaming multimedia objects in their entirety

Project Goals

- Reduce start-up latency
- Improve playback quality
- Improve performance for VCR operations
- Reduce server load
- Reduce network load

New Streaming Architecture



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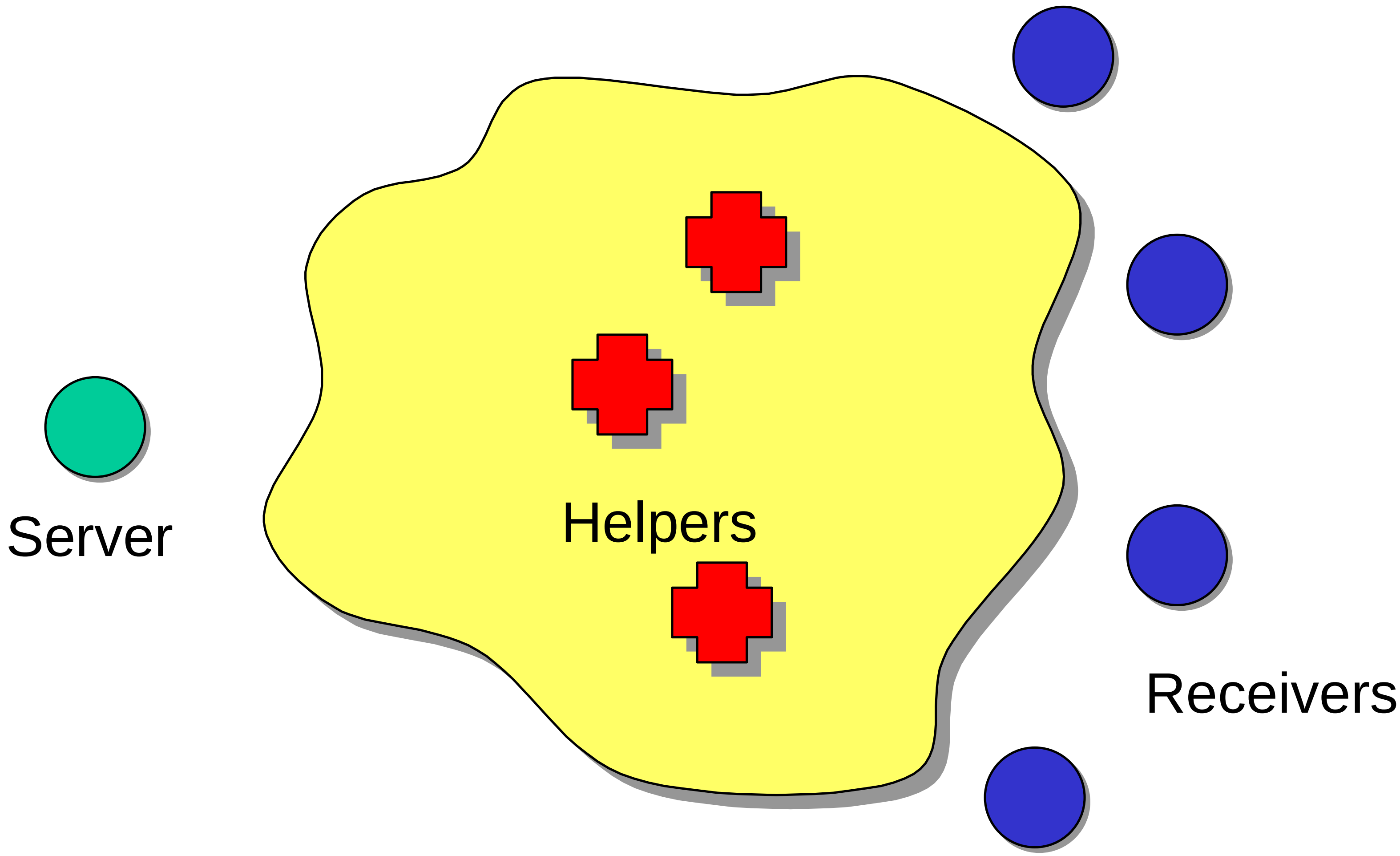
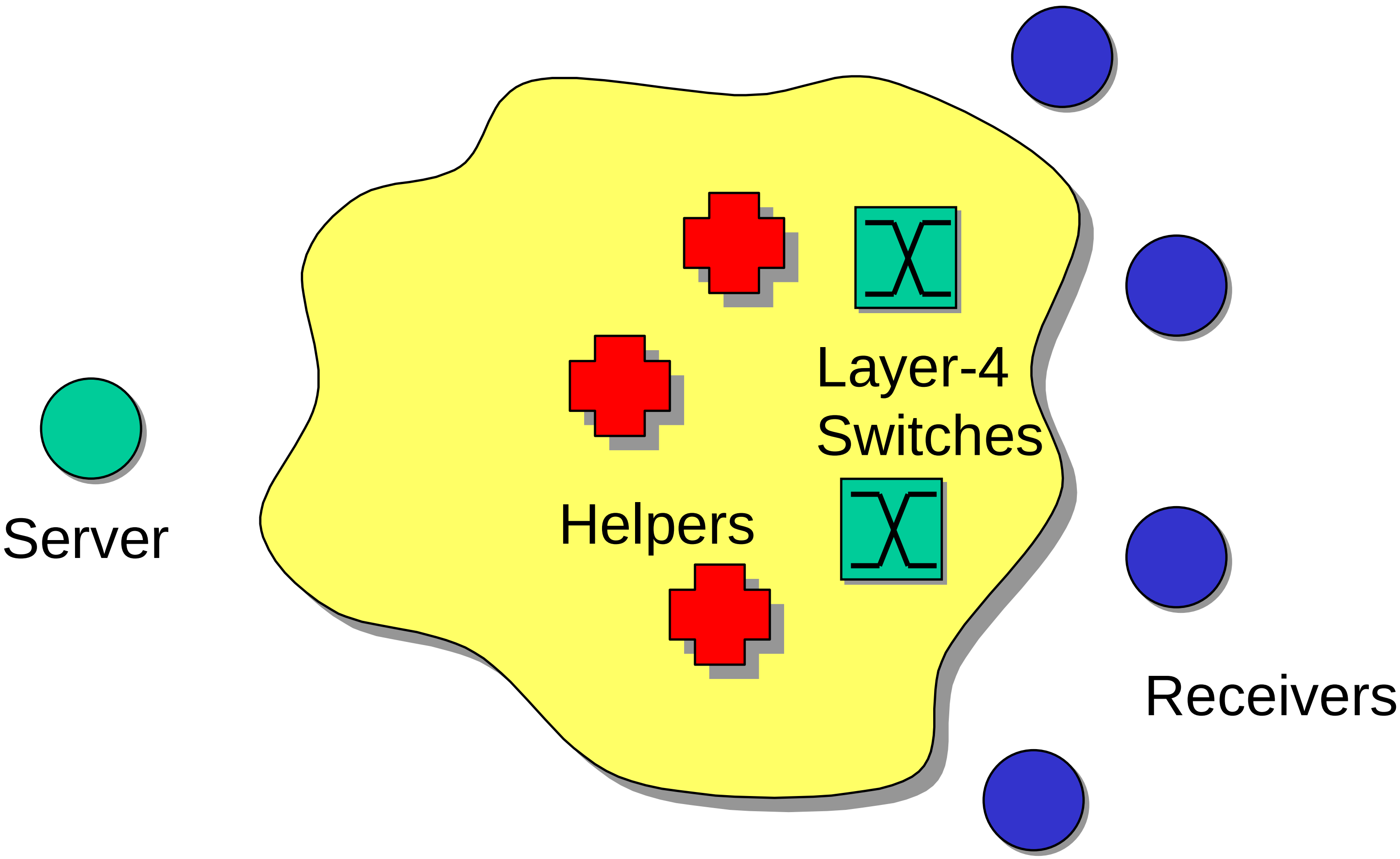
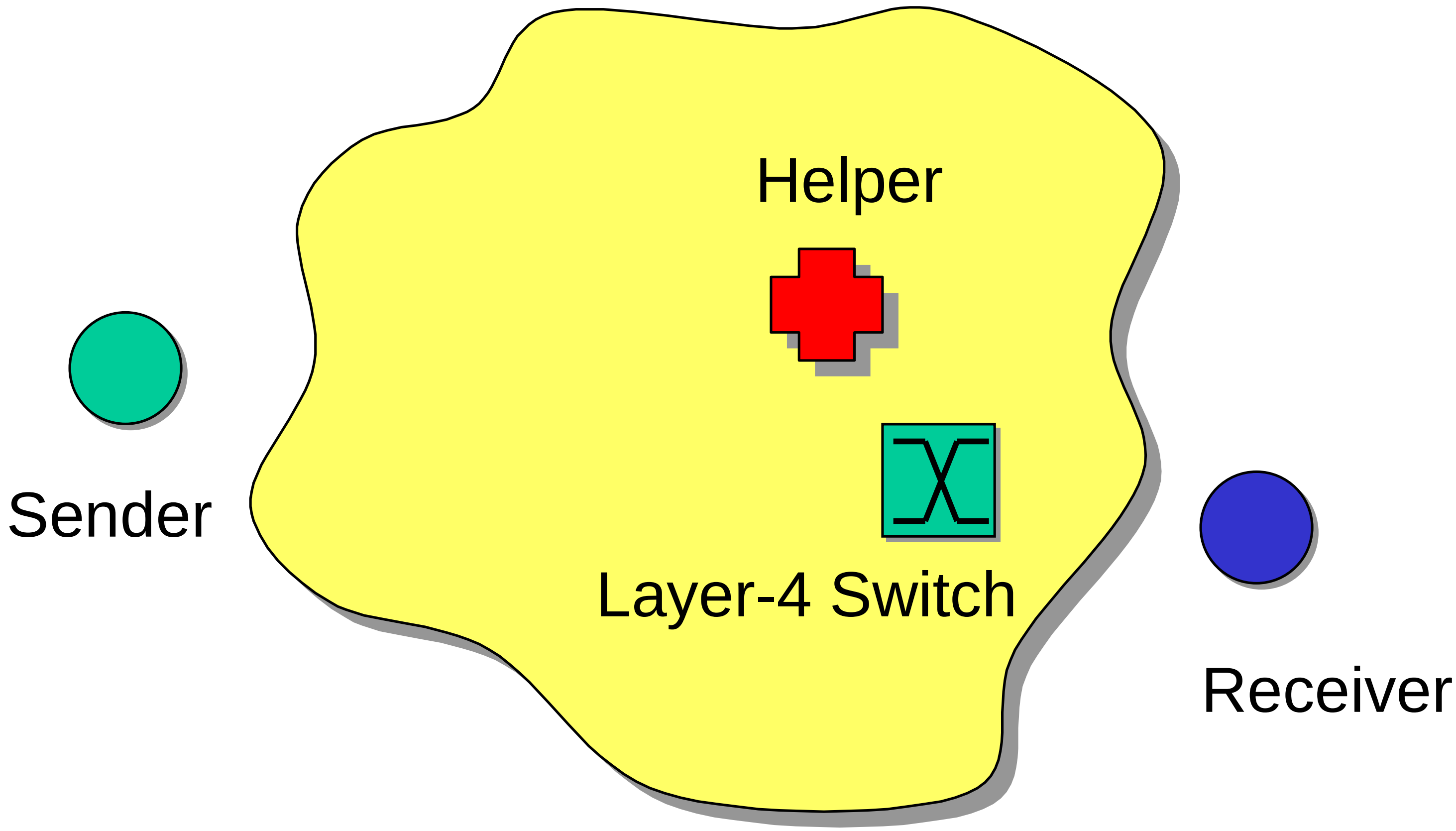


New Streaming Architecture



Transparent Operation



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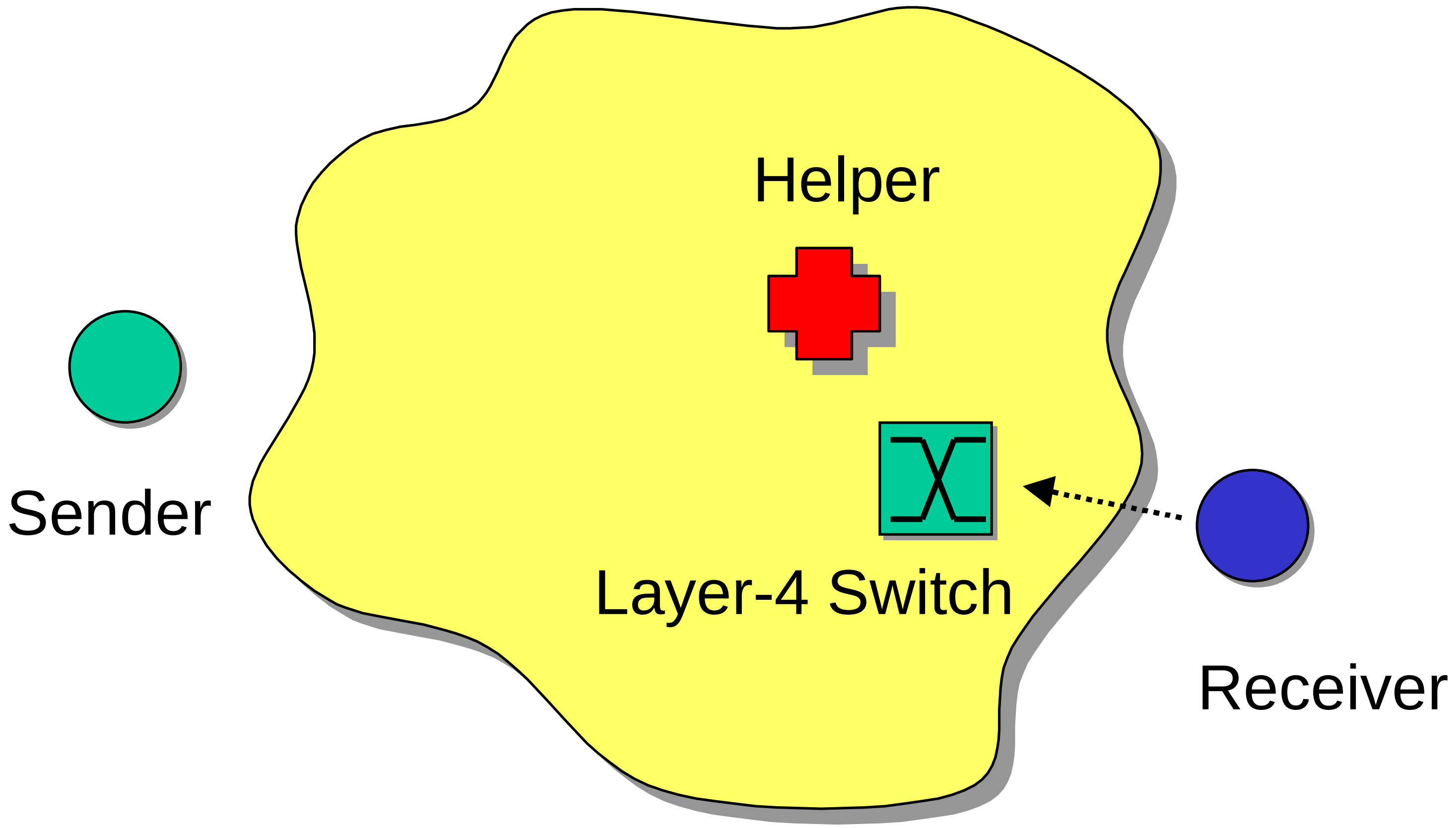

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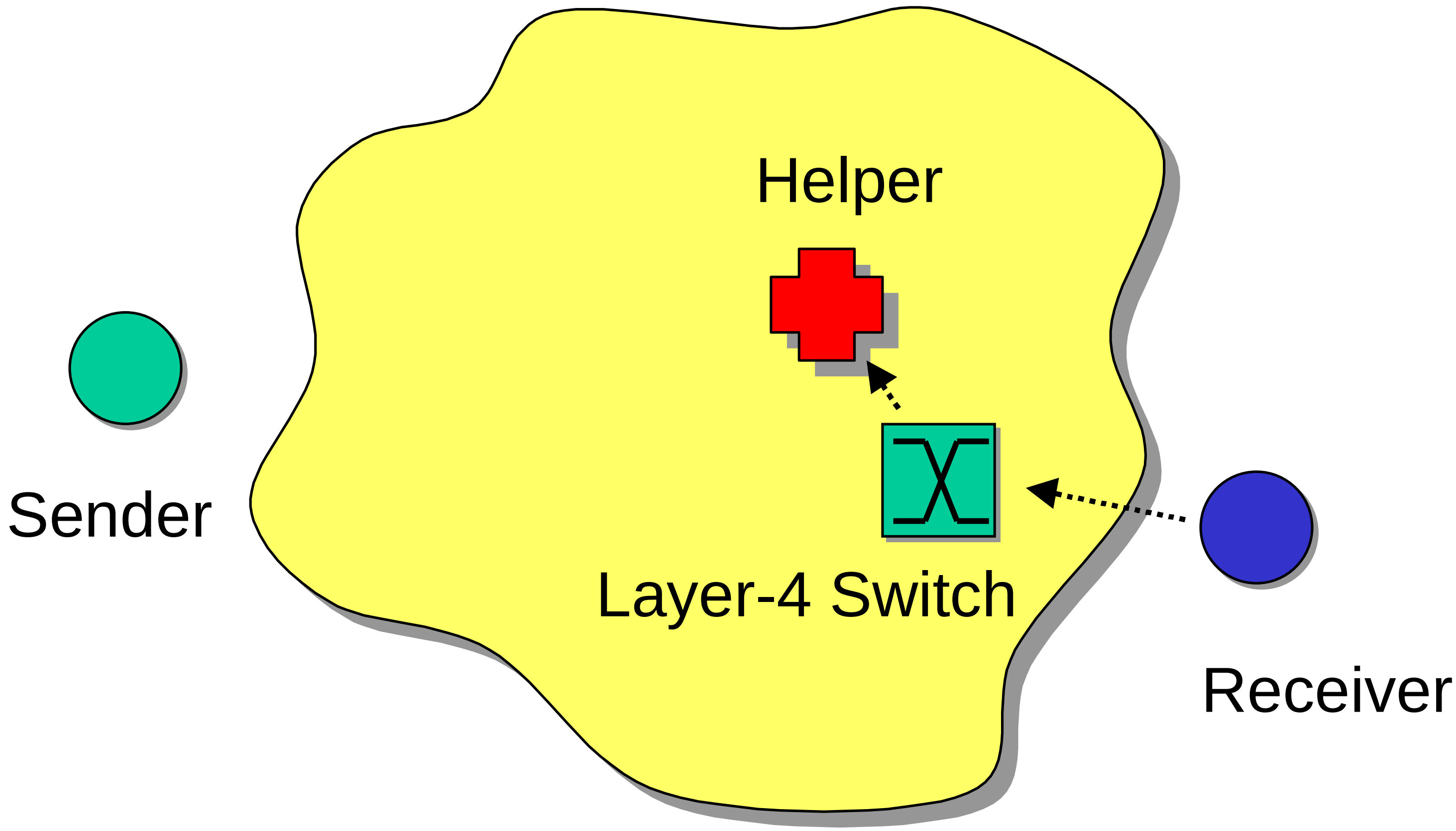

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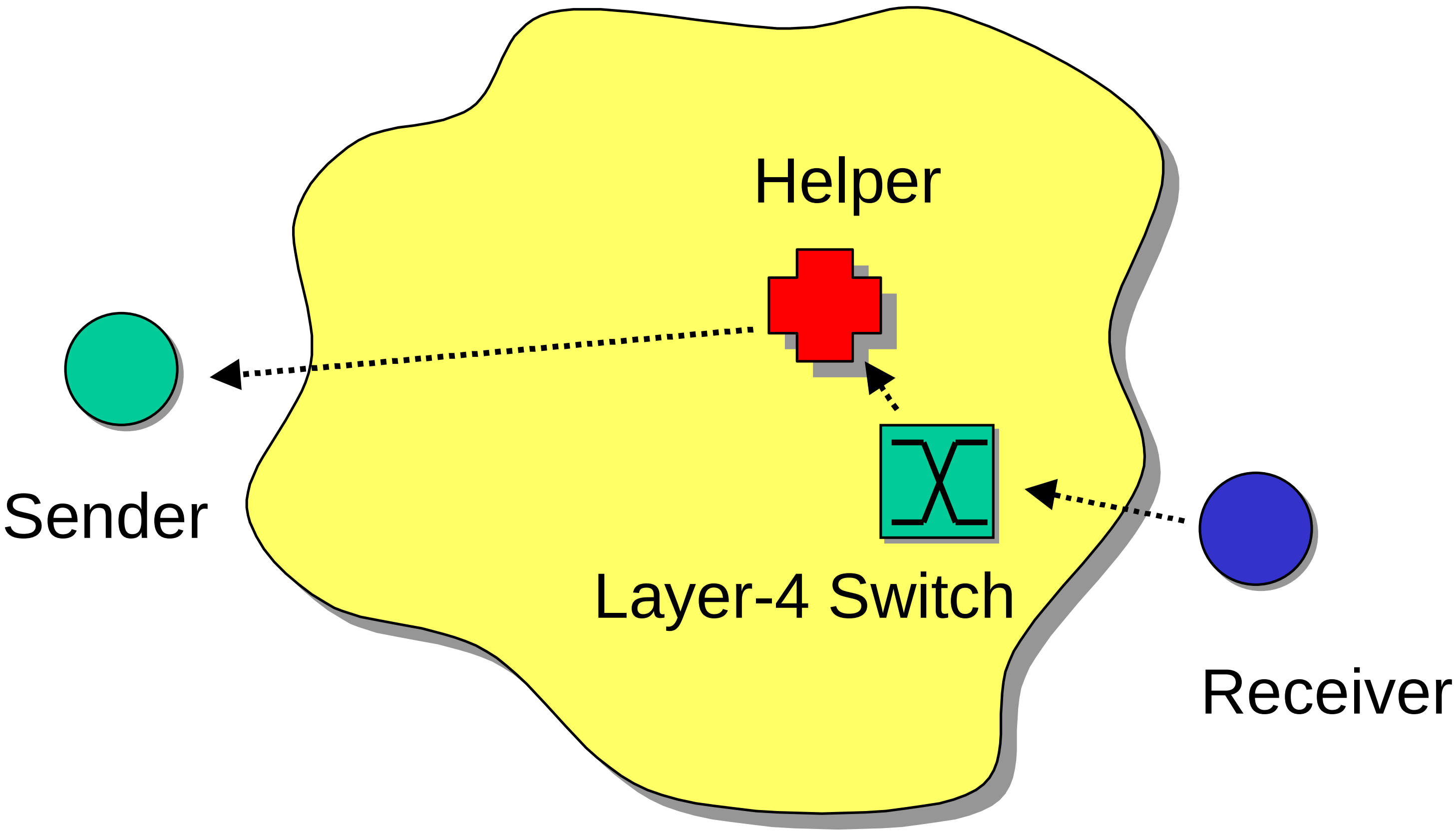

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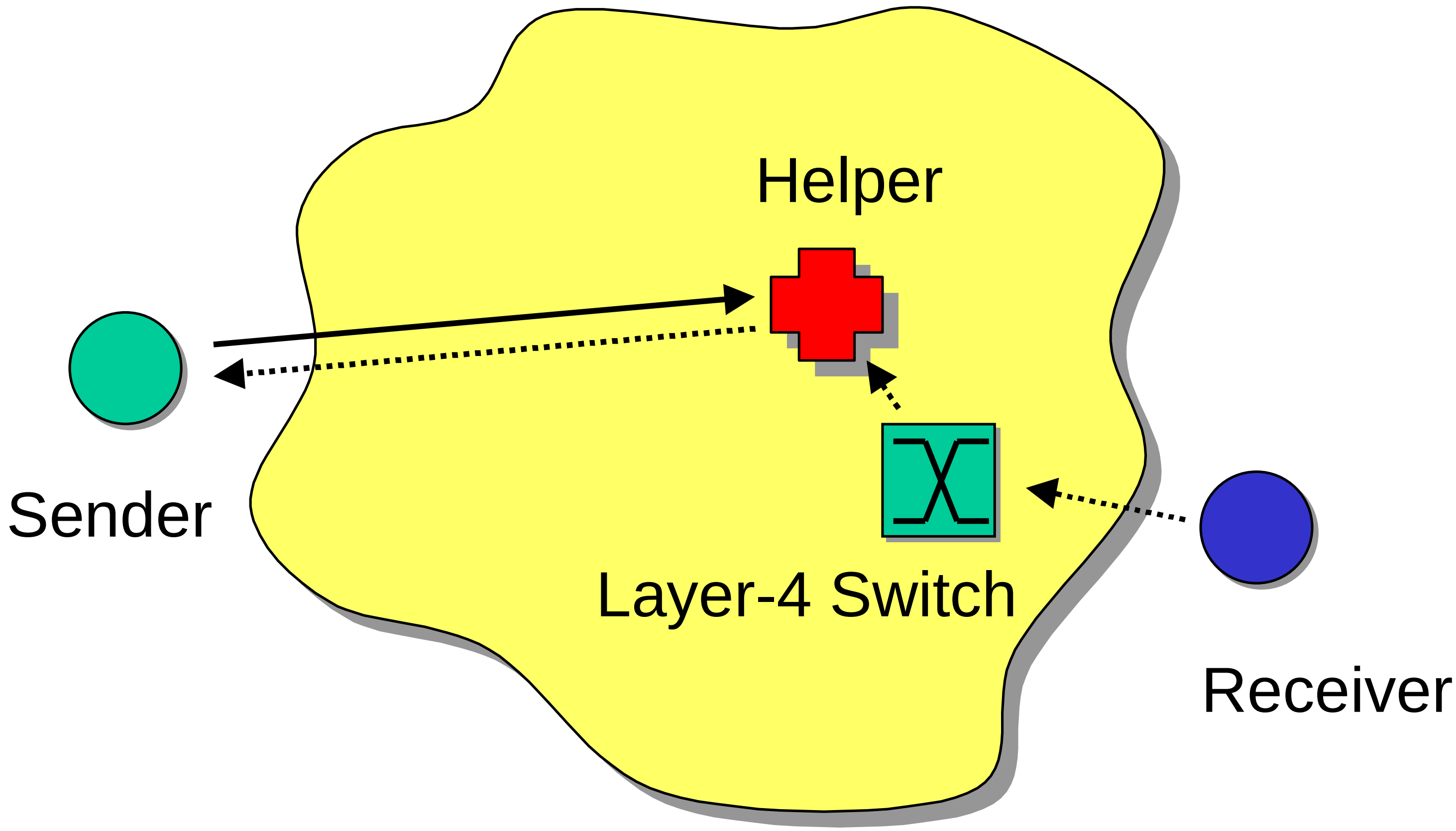

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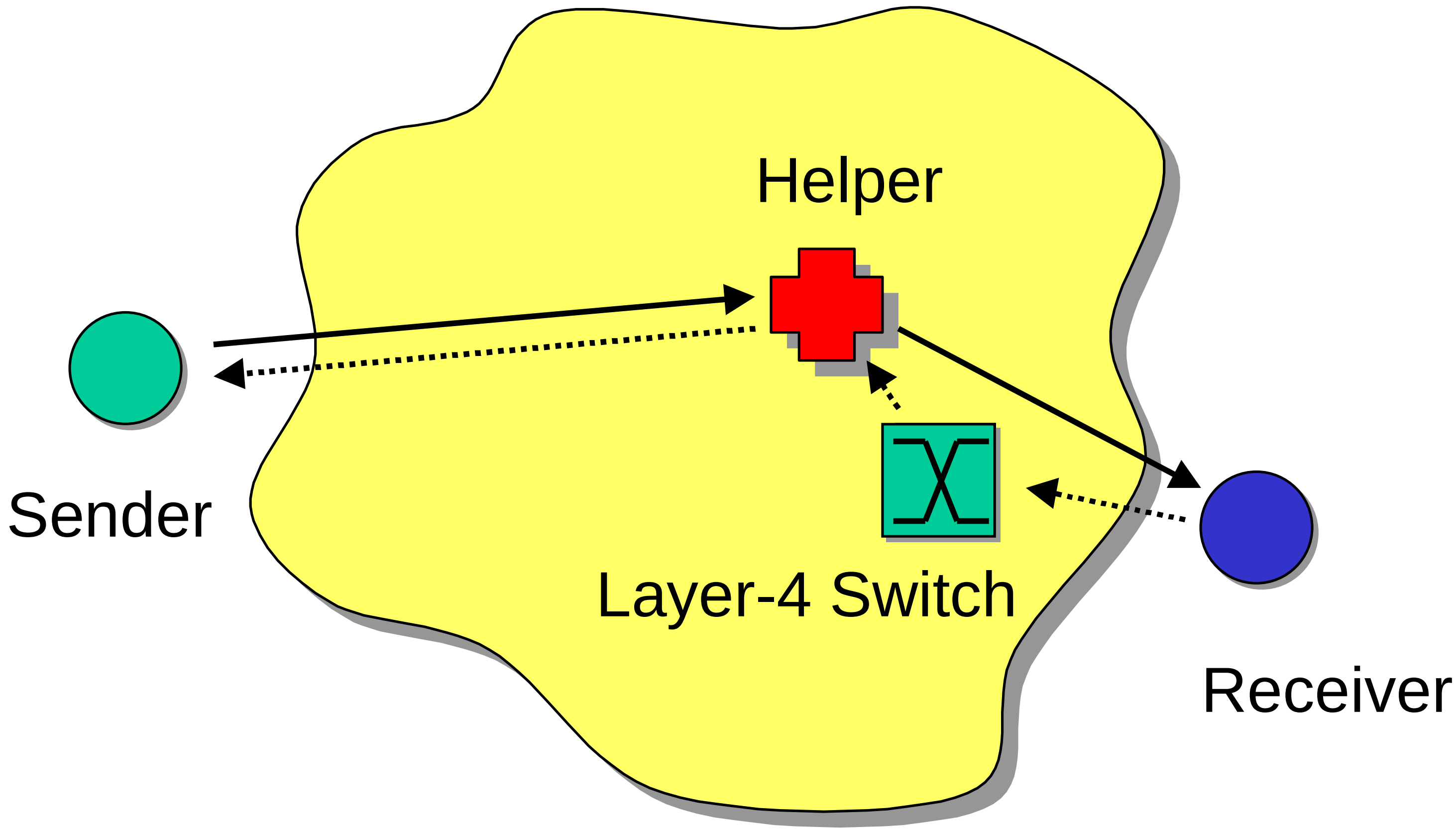
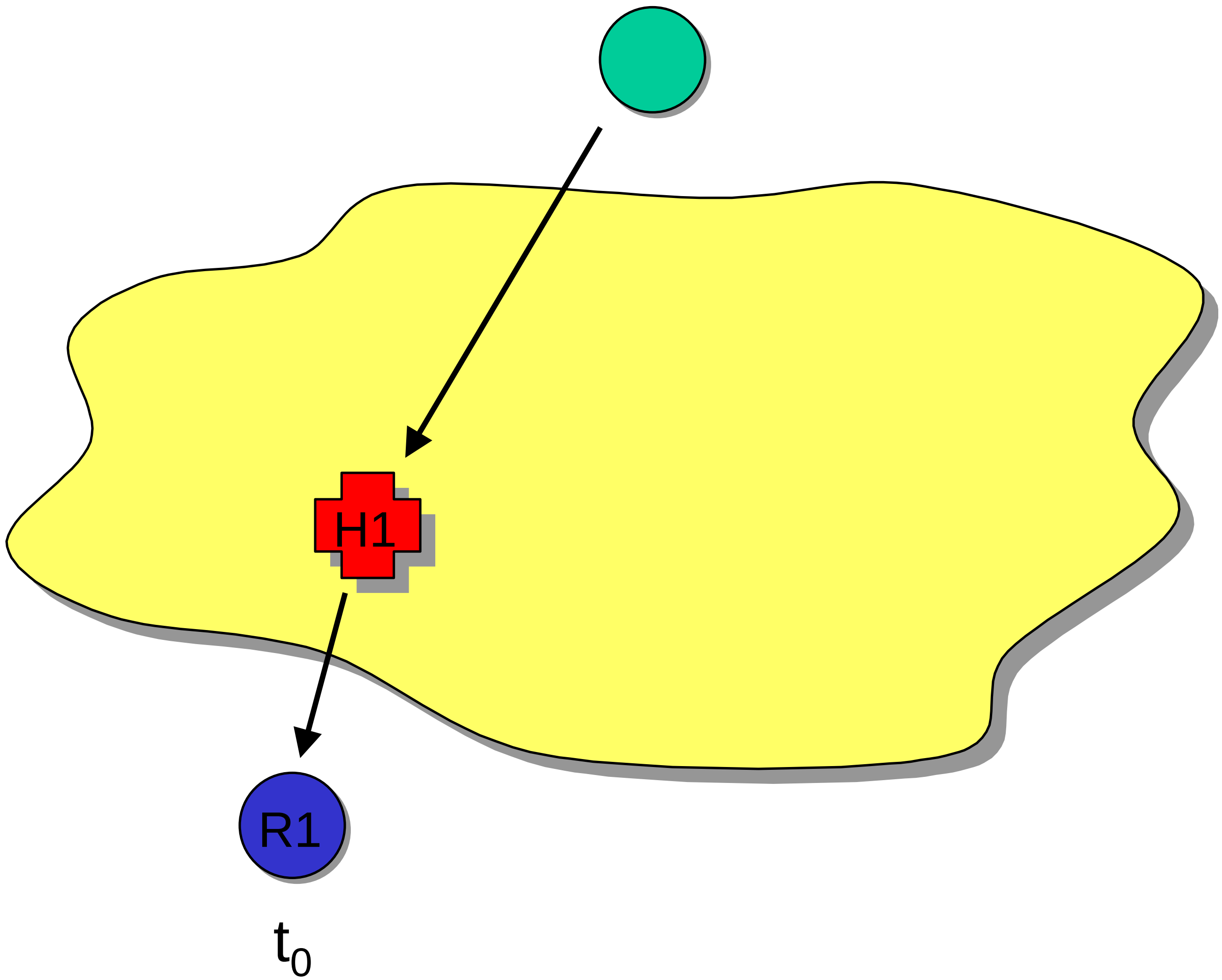


Helper Mesh Formation



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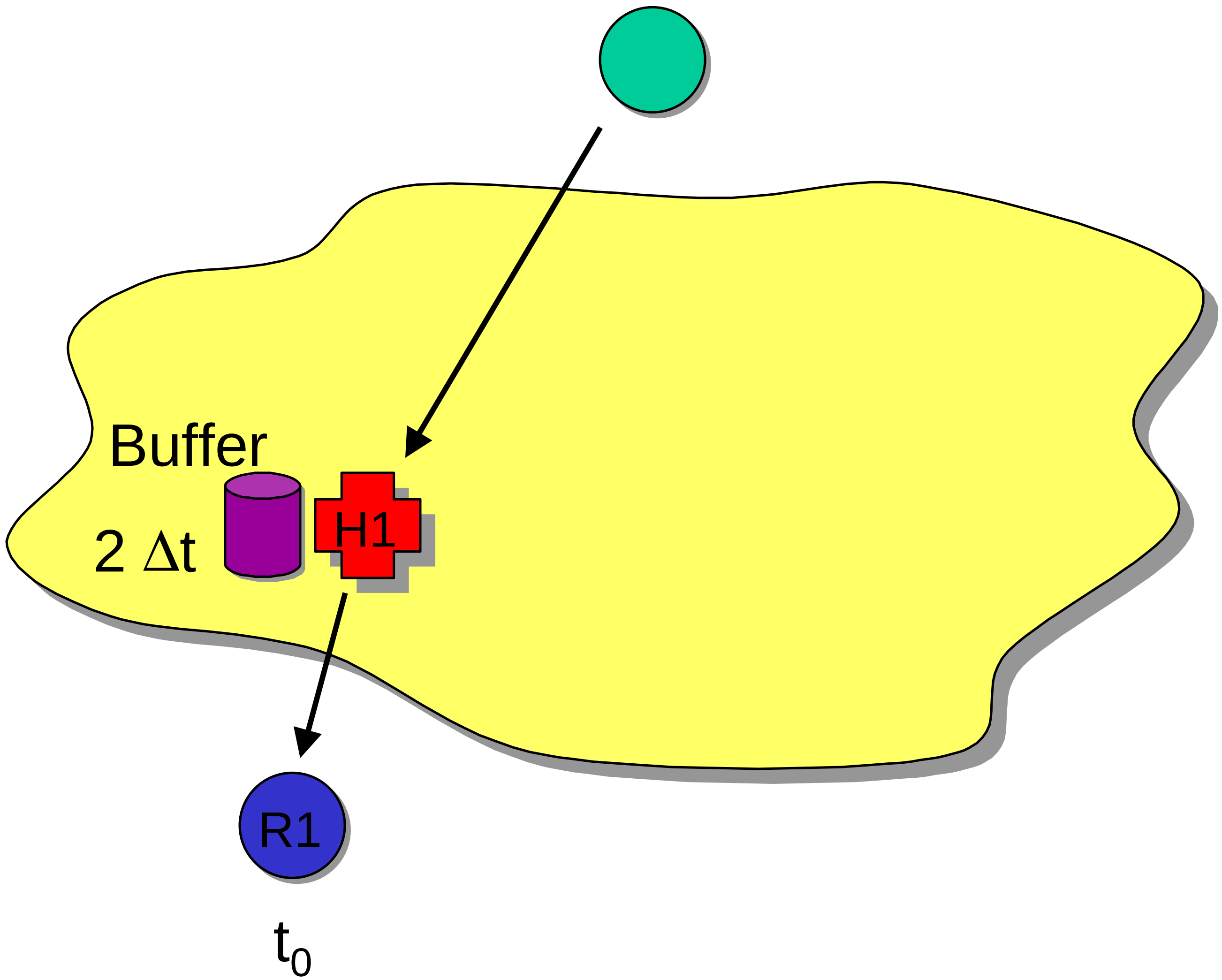

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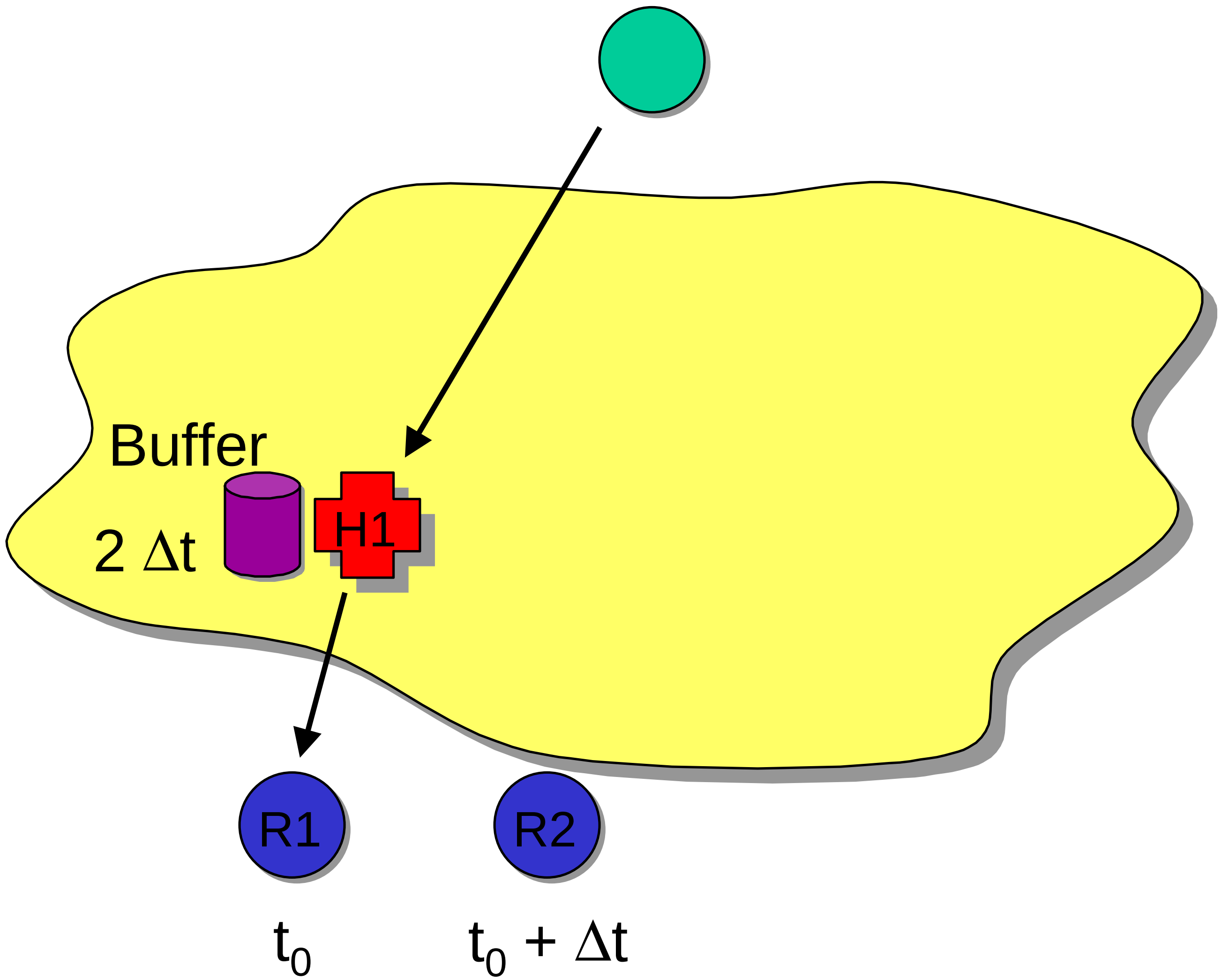

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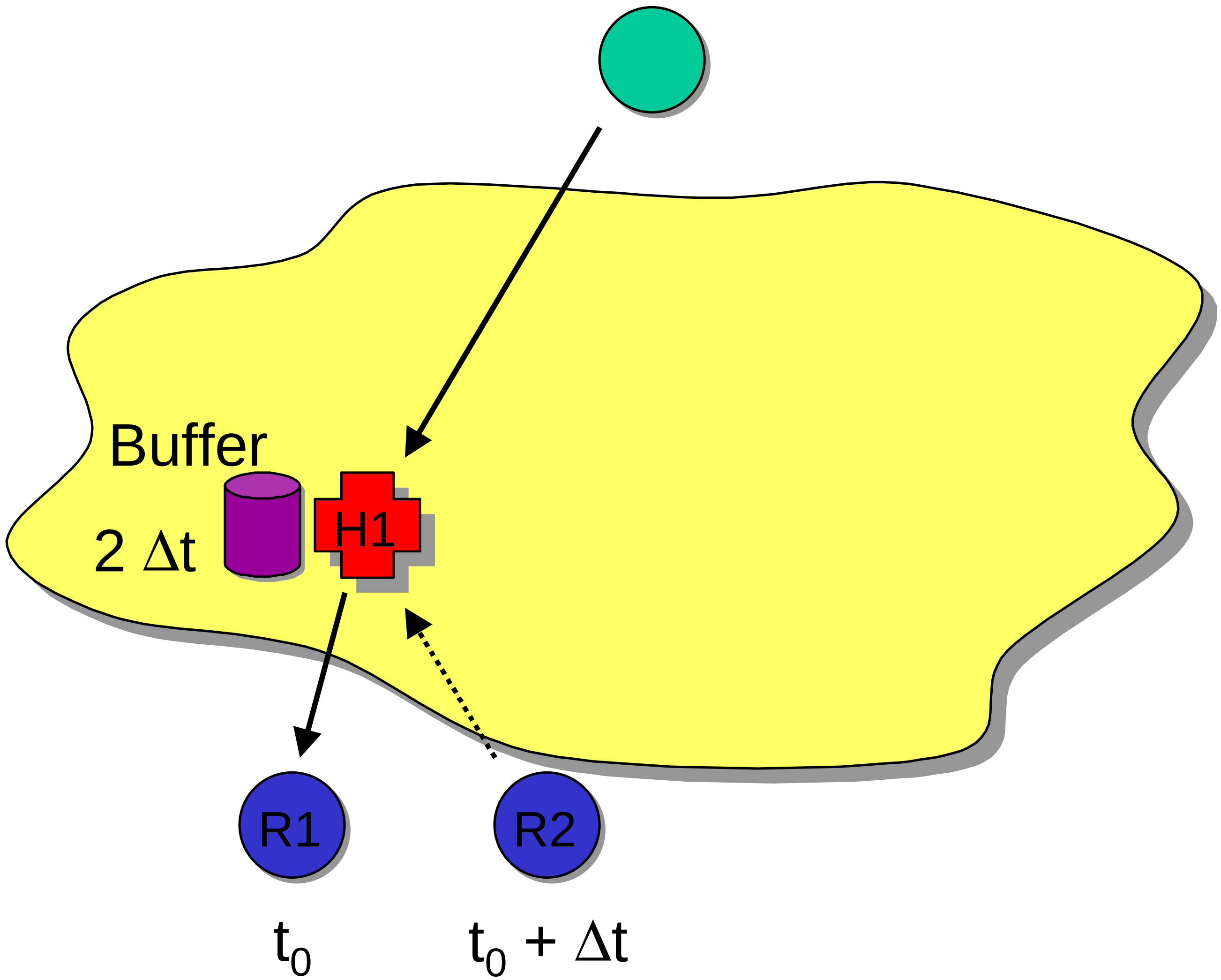

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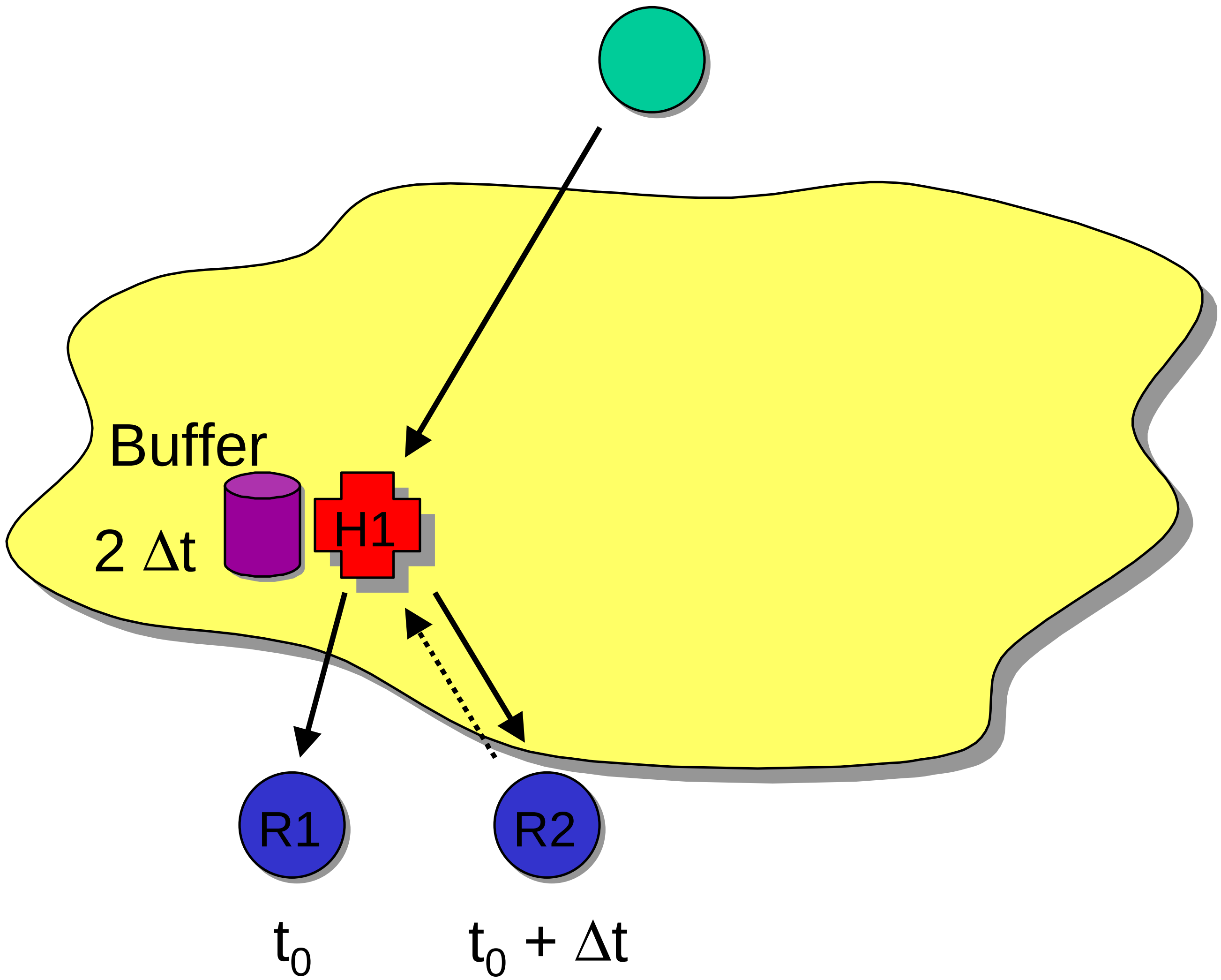

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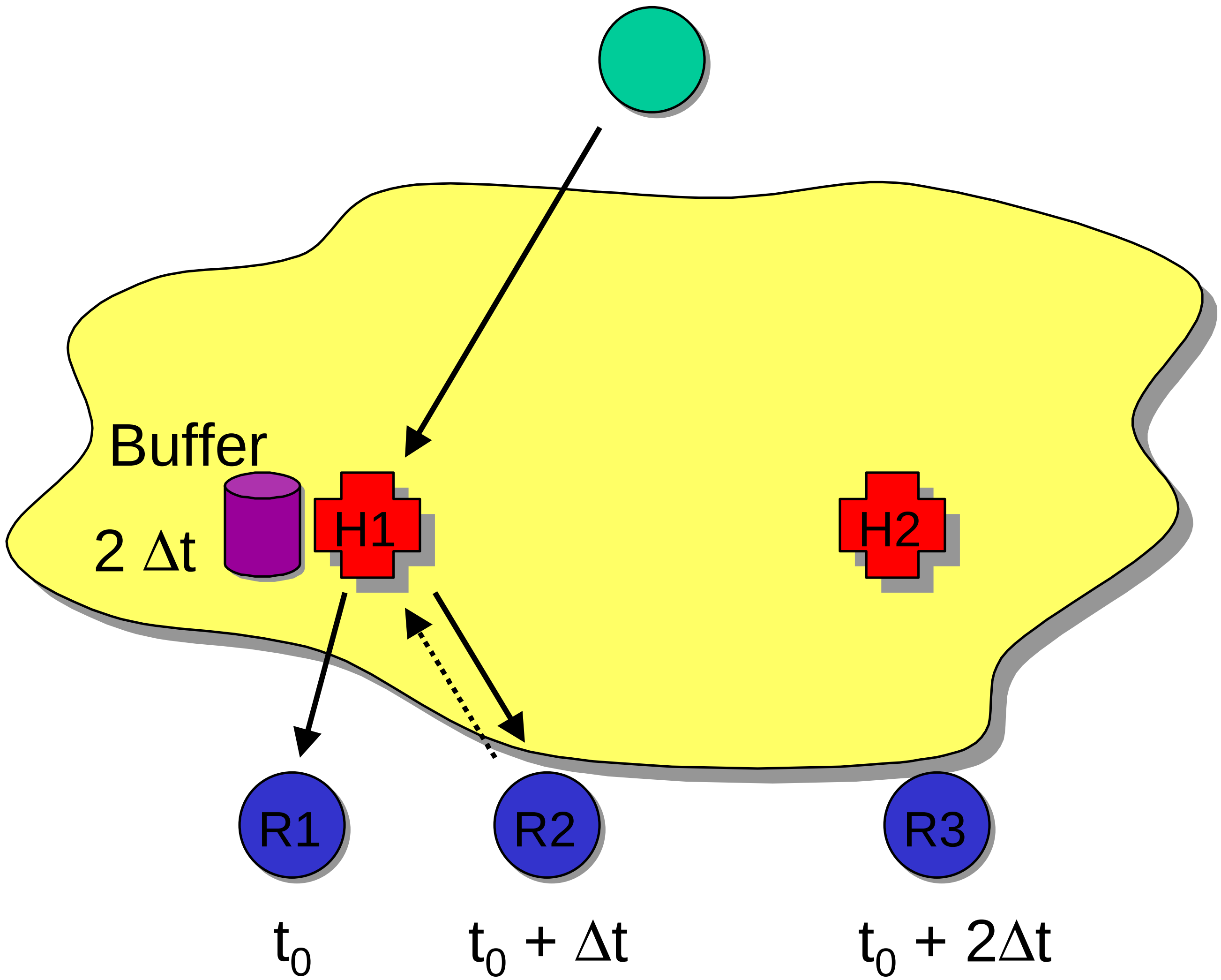

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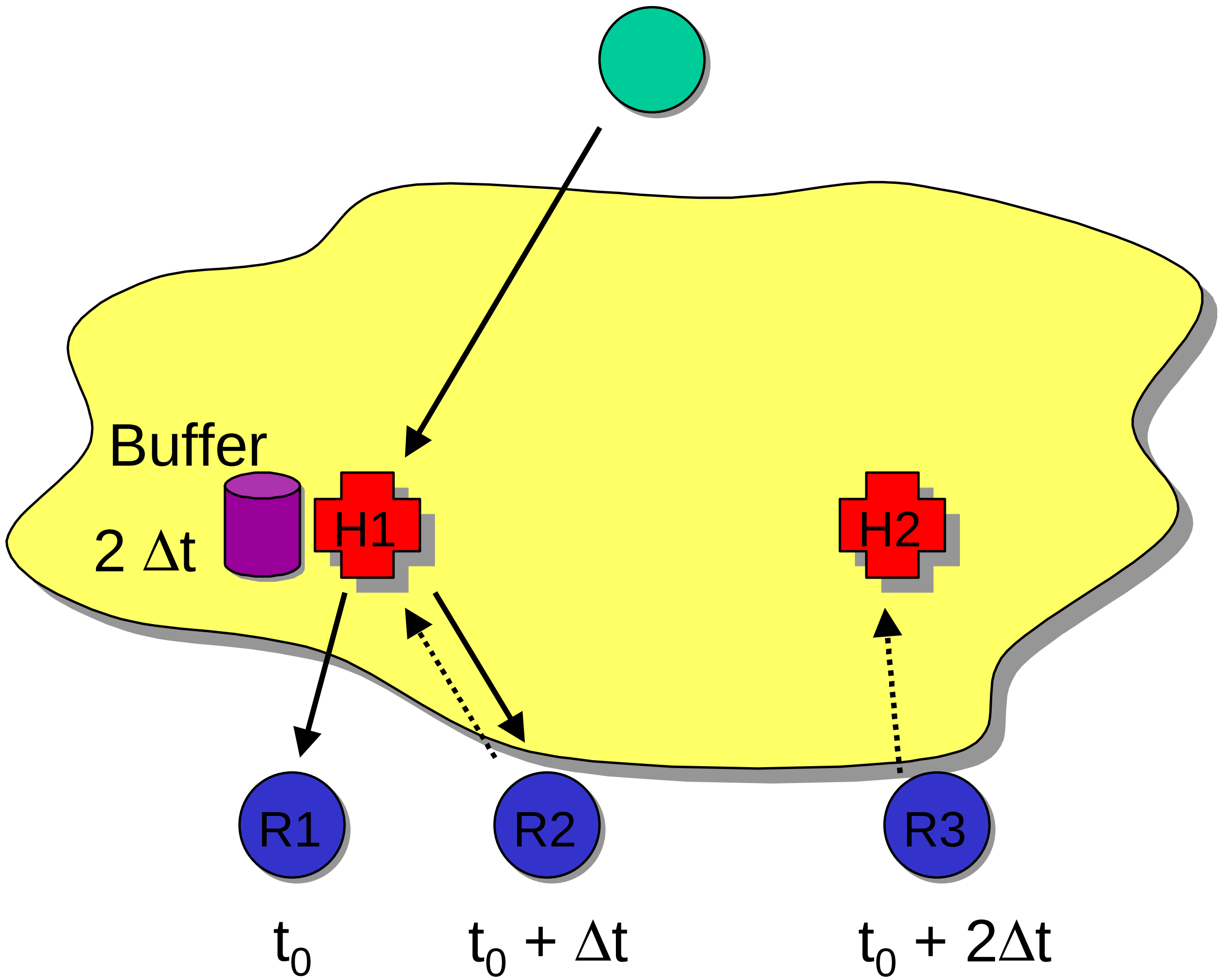

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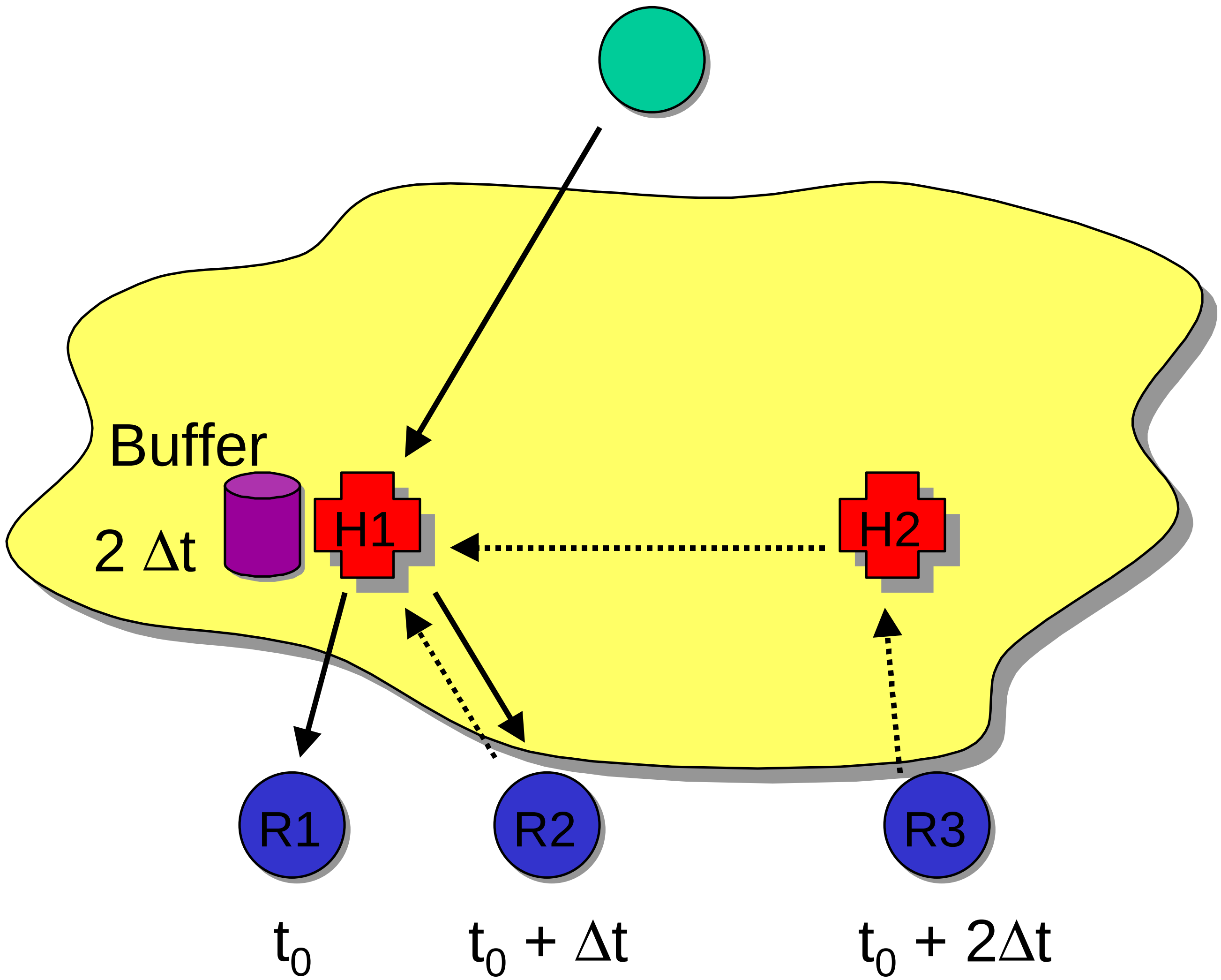

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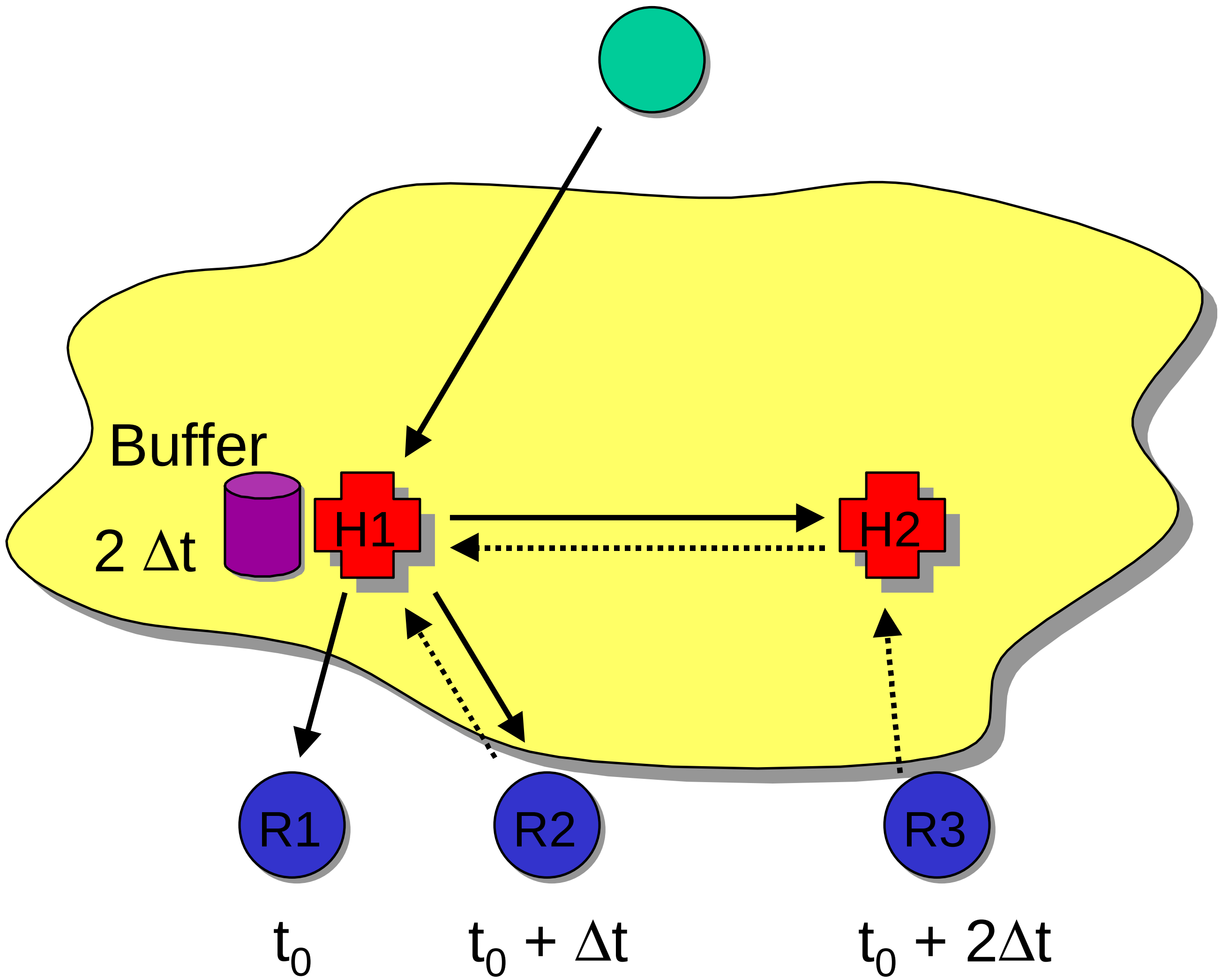

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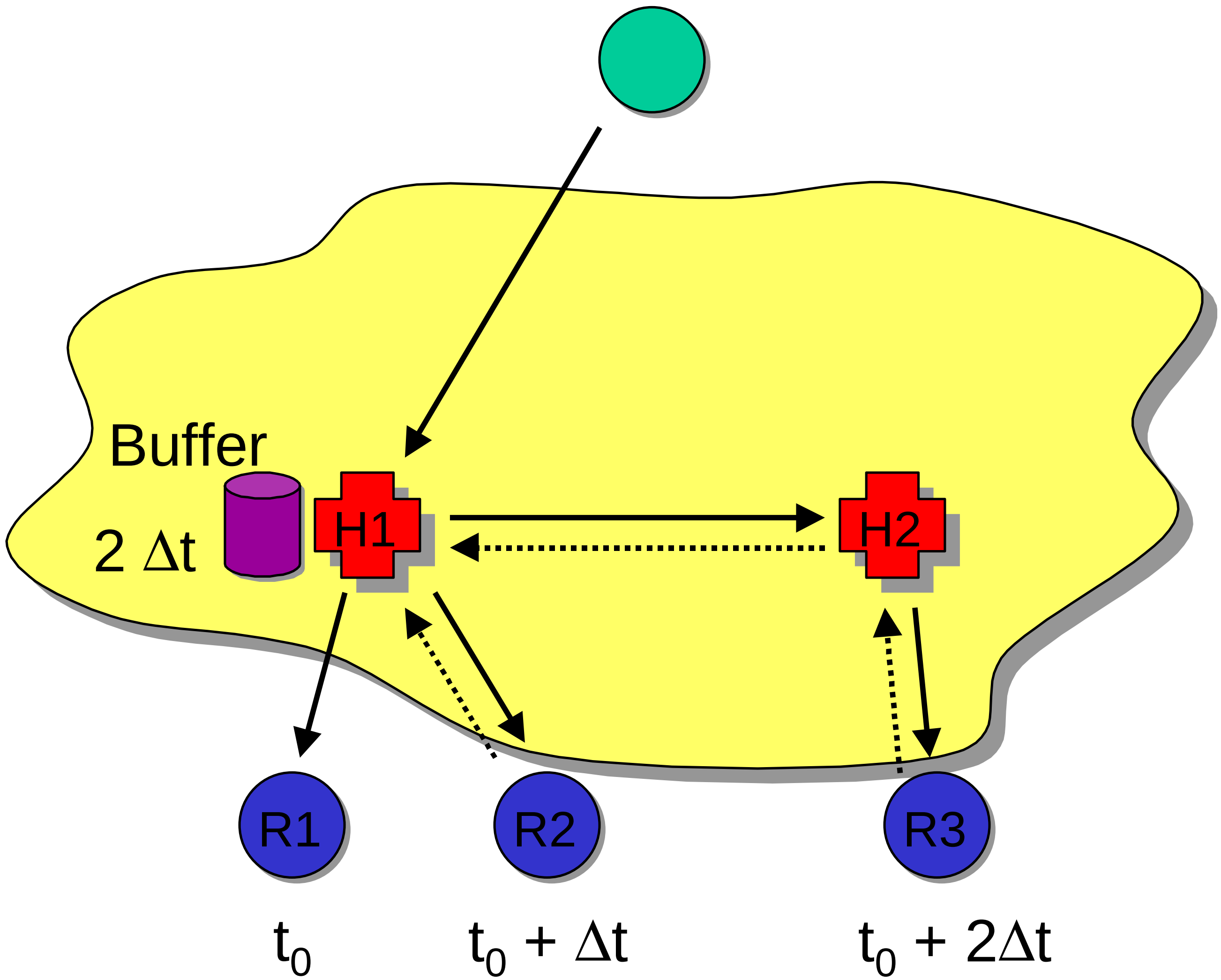
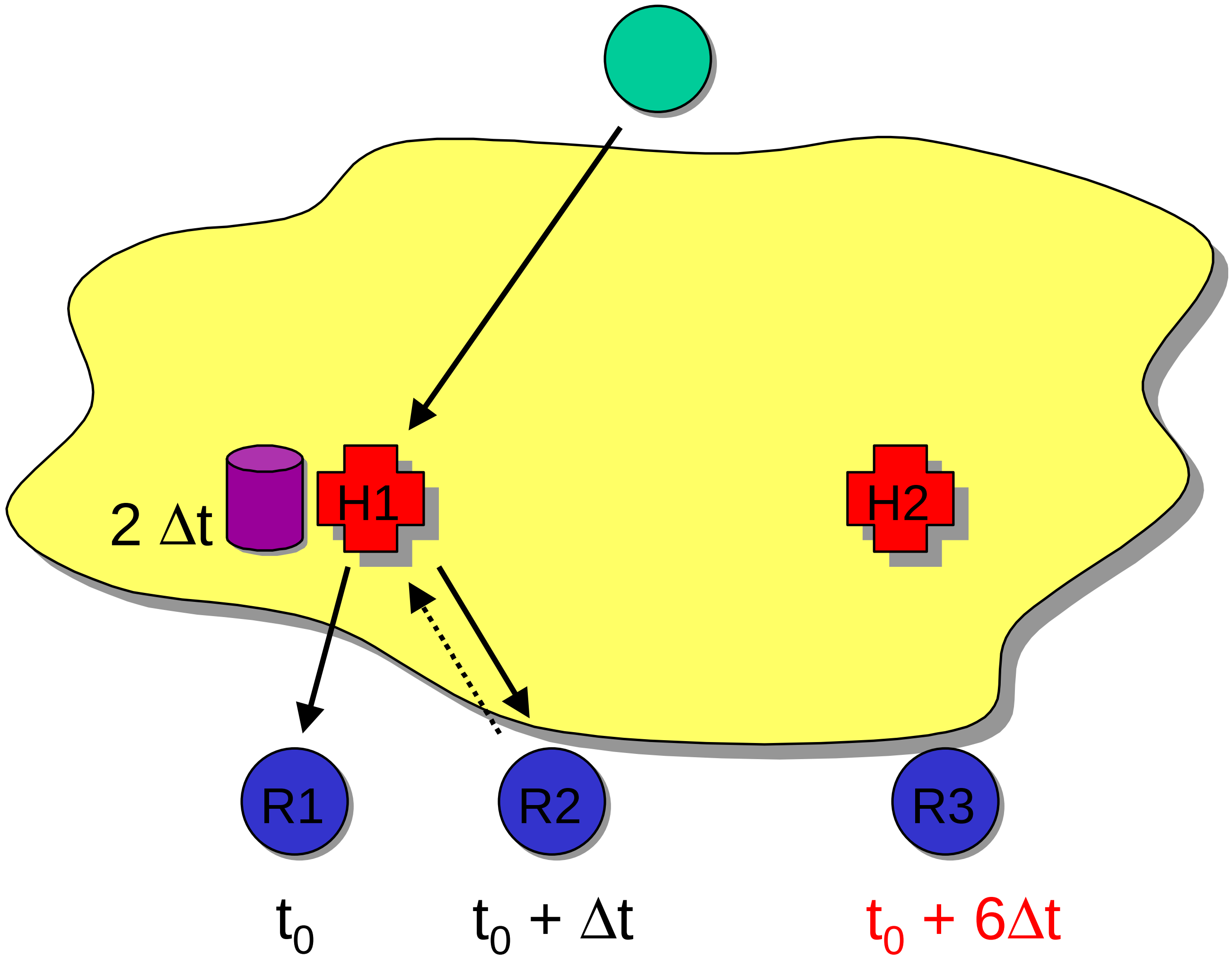


Using Buffer in the General Case



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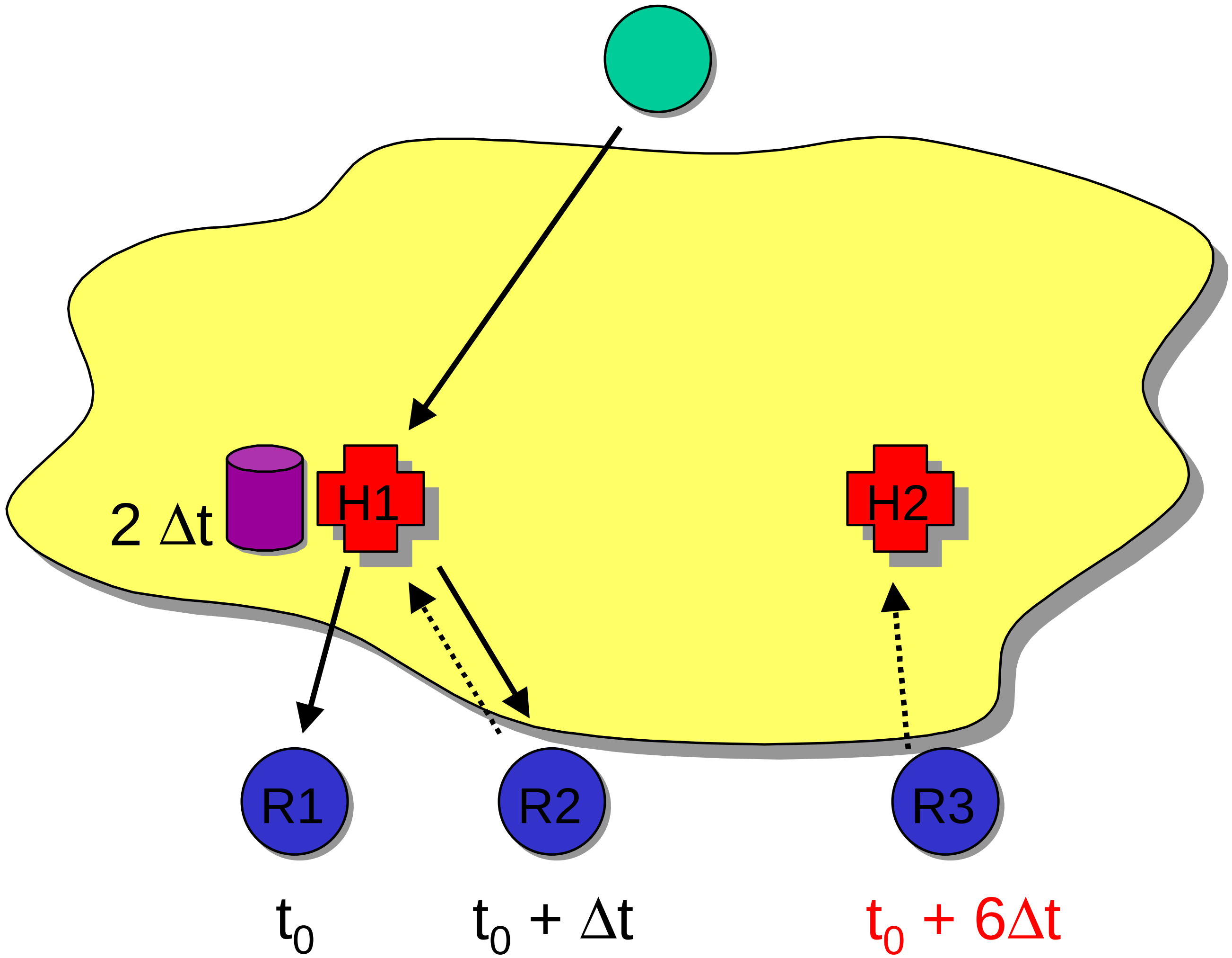

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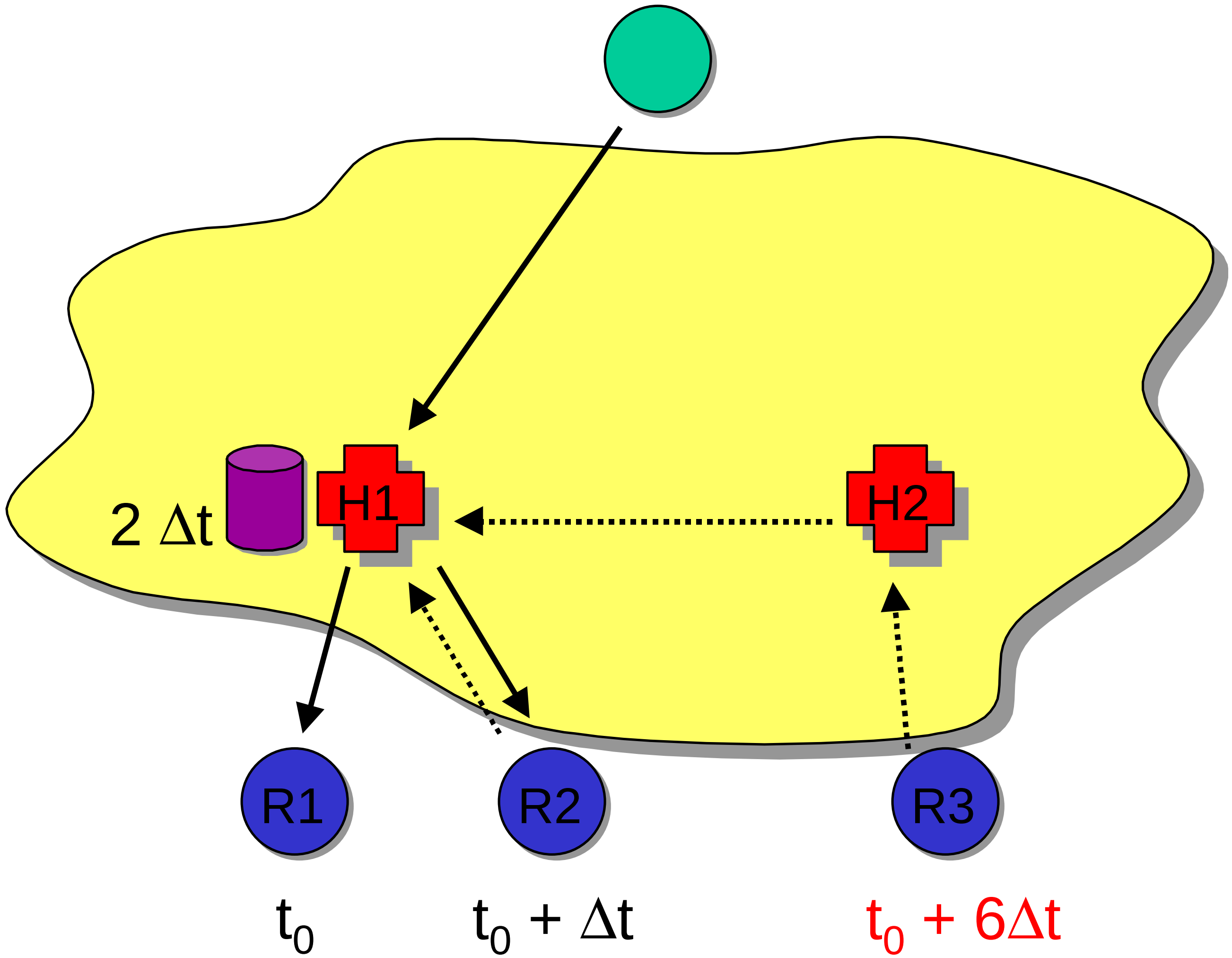

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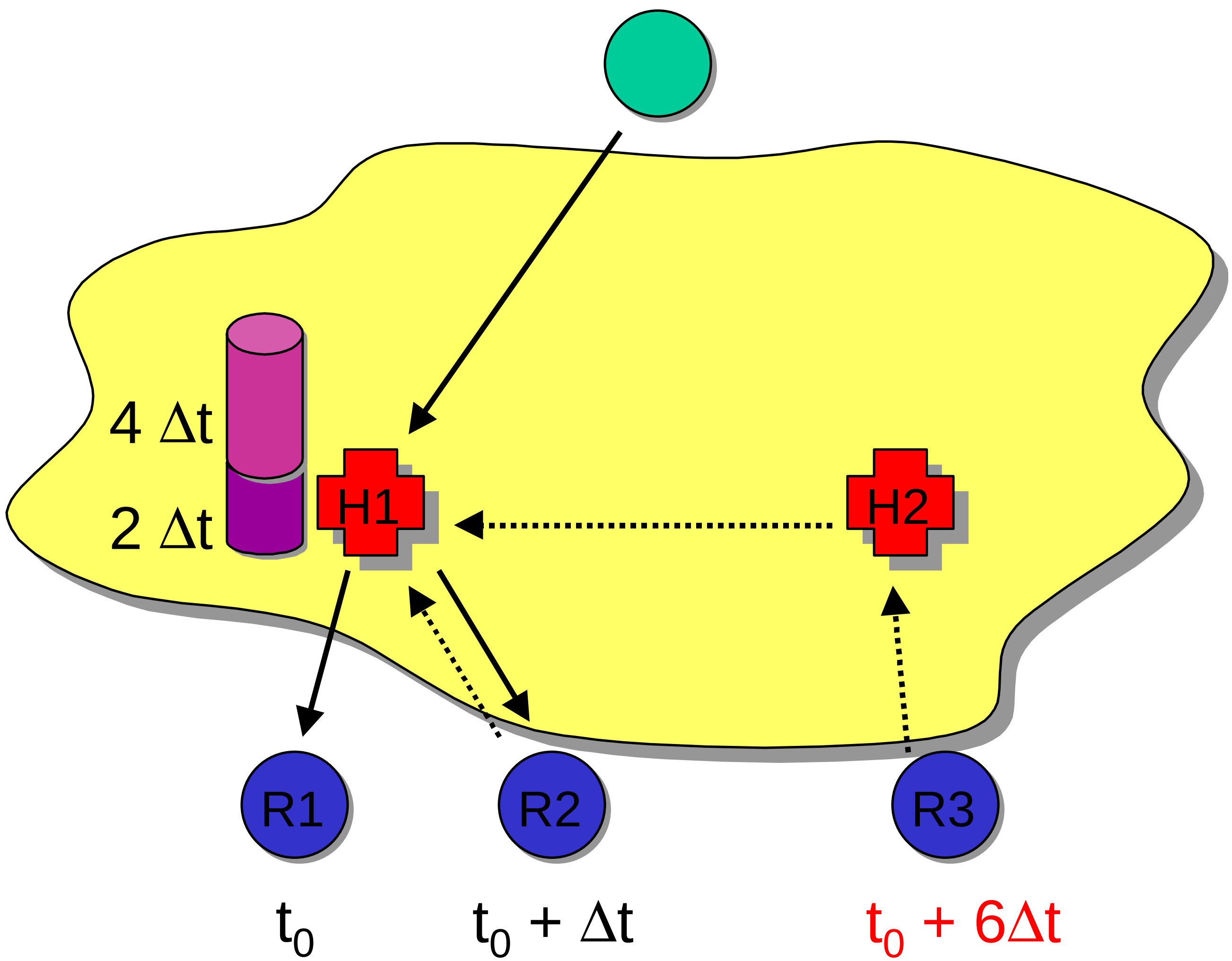

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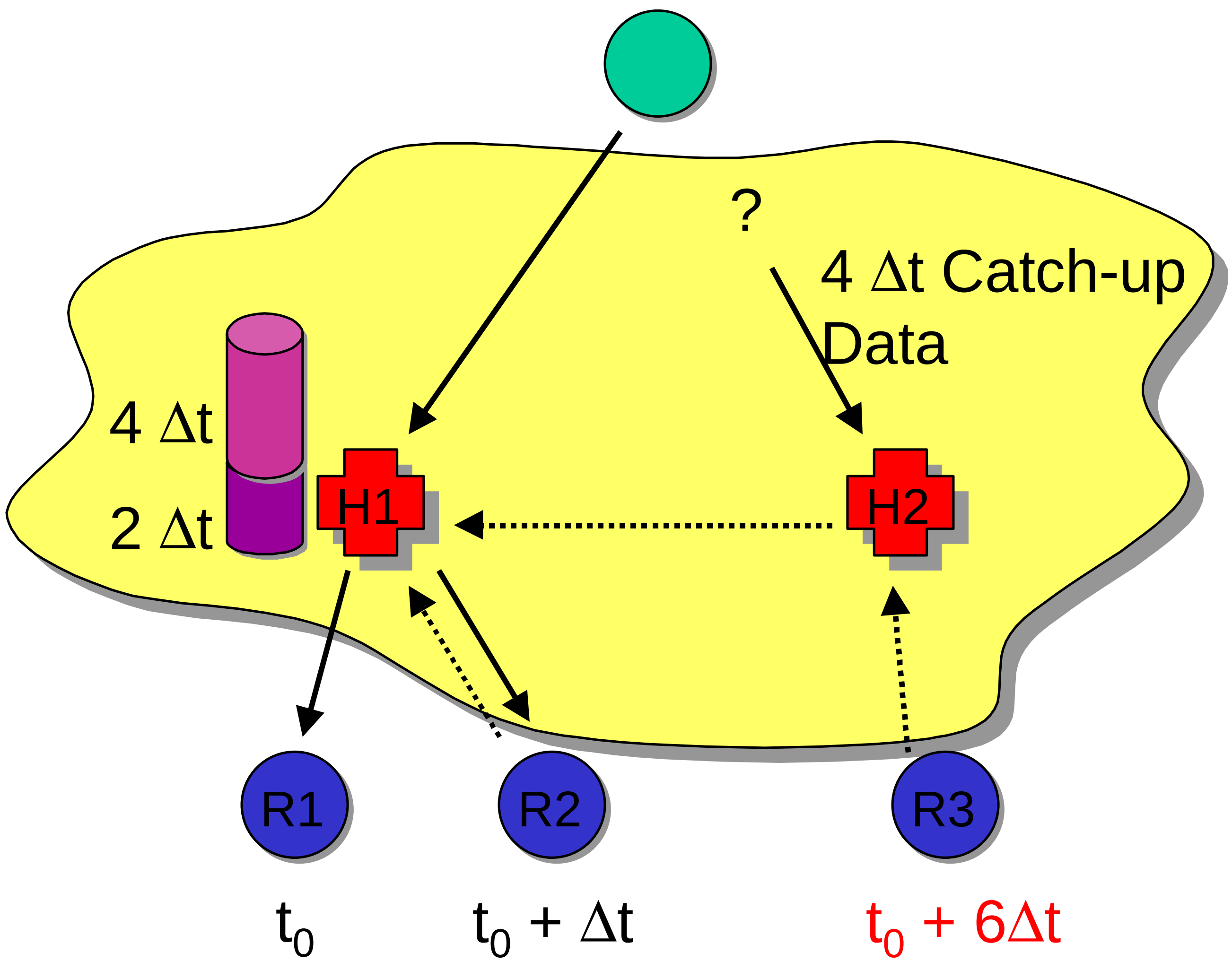

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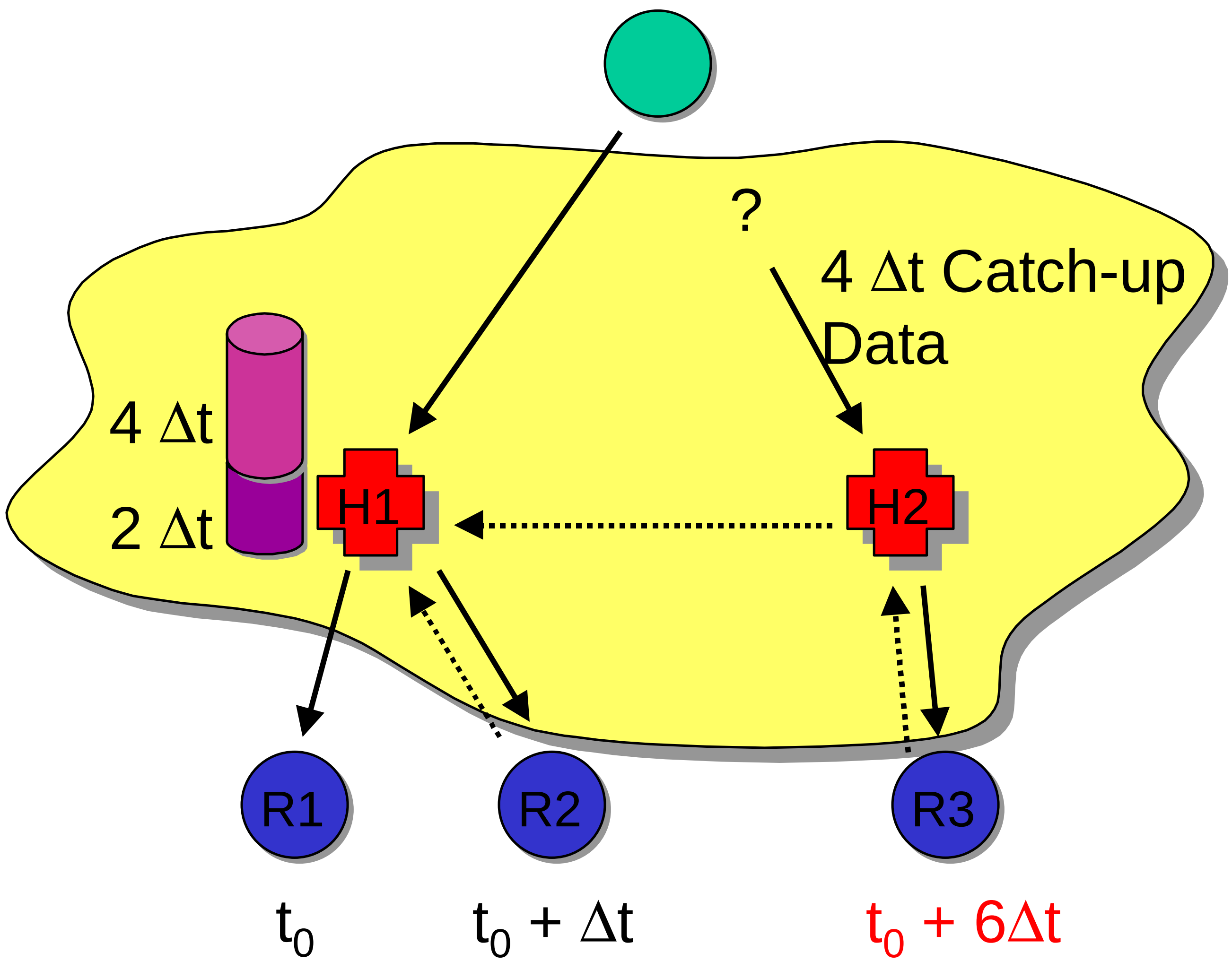

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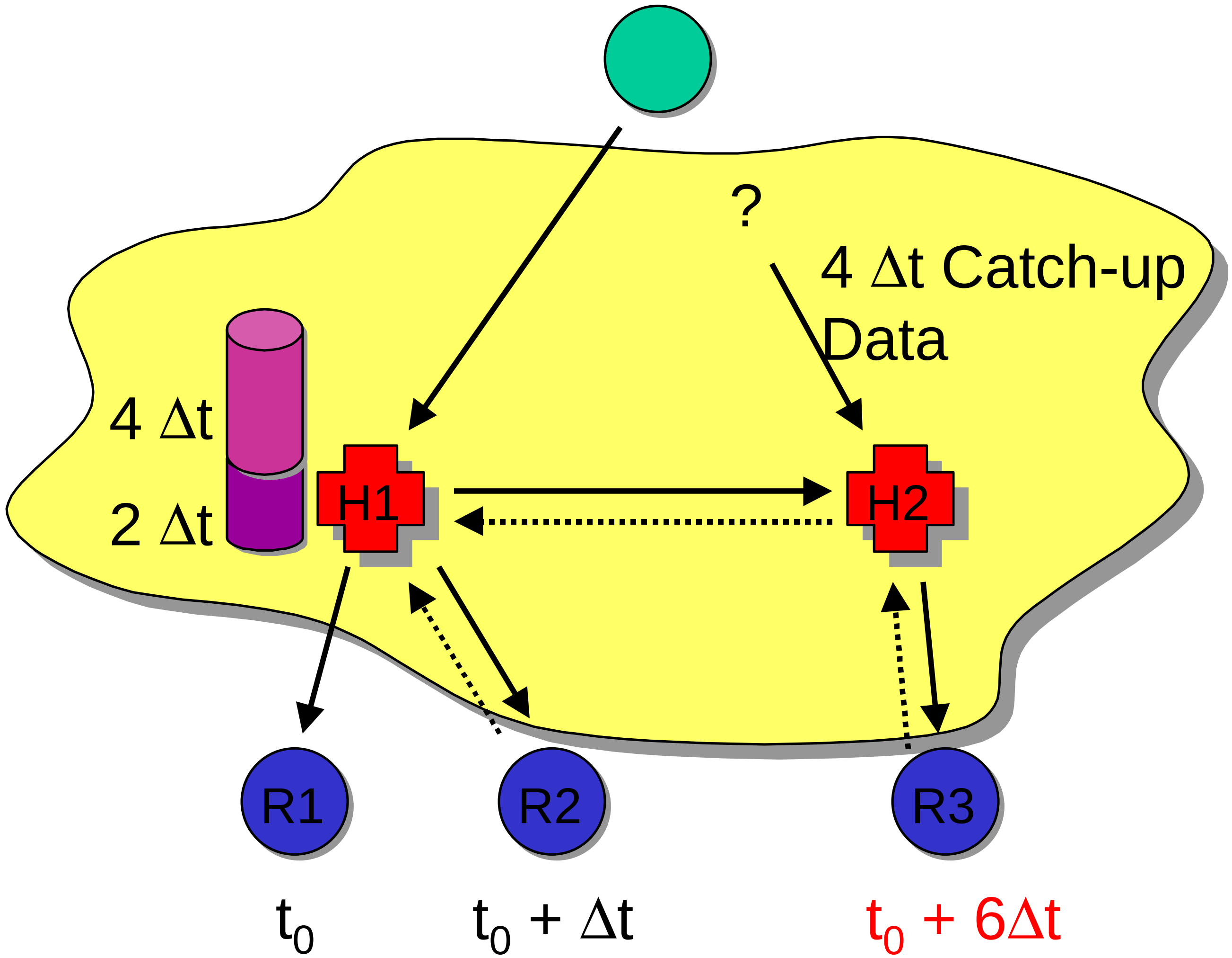
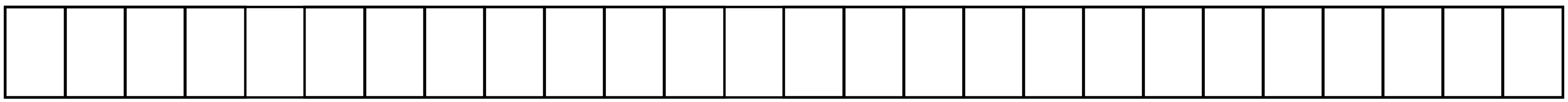
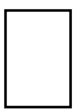


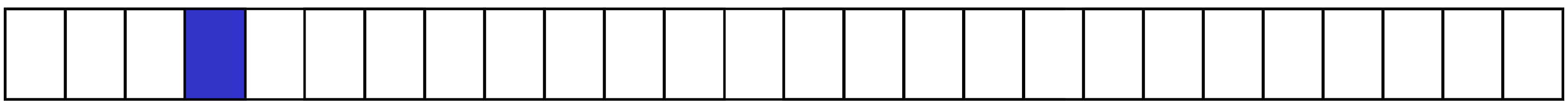
Defining Parameters Using Segments



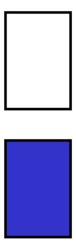


Segment

Defining Parameters Using Segments



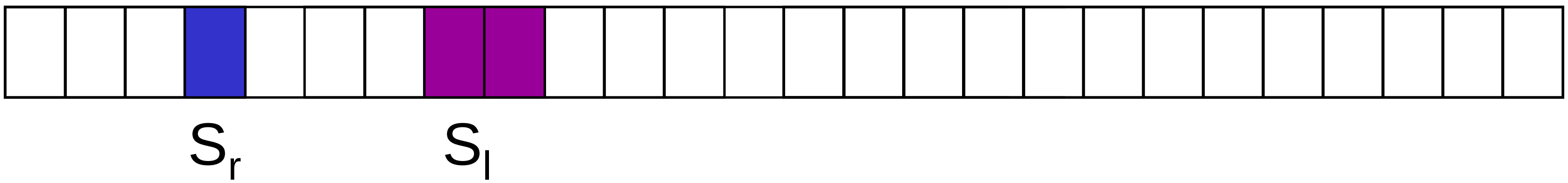
S_r

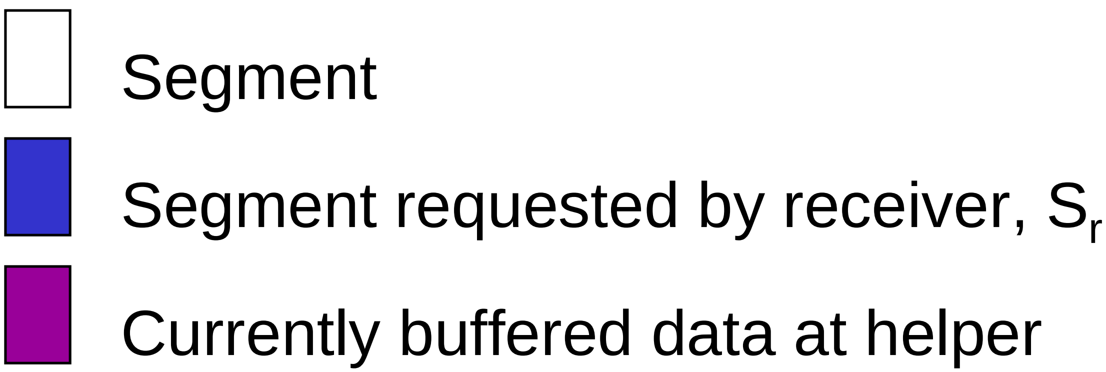


Segment

Segment requested by receiver, S_r

Defining Parameters Using Segments





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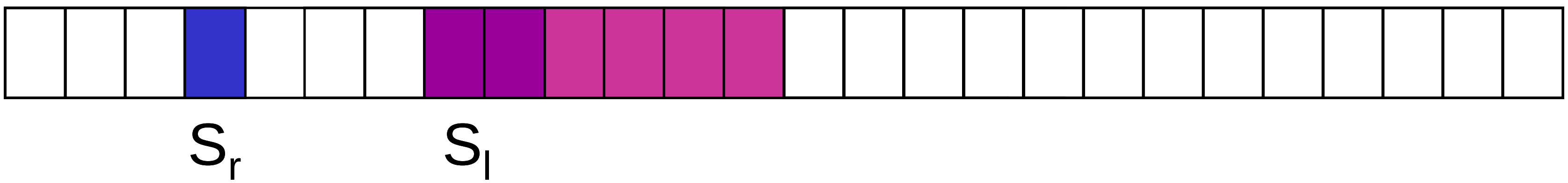
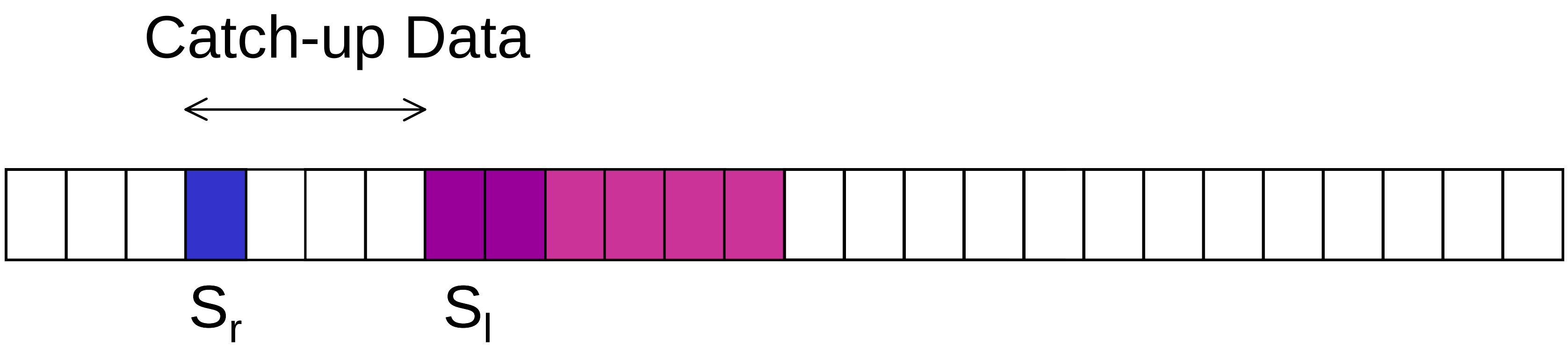


- Segment
- Segment requested by receiver, S_r
- Currently buffered data at helper
- Additional buffer required to bridge the gap, S_l - S_r

Defining Parameters Using Segments



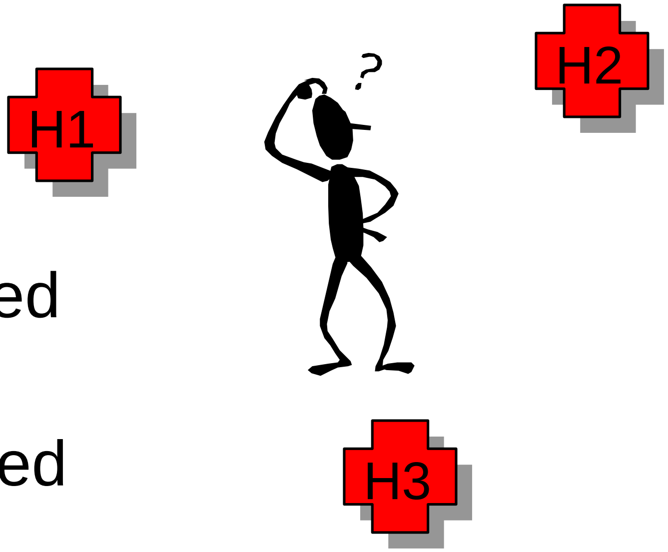
Segment

Segment requested by receiver, S_r

Currently buffered data at helper

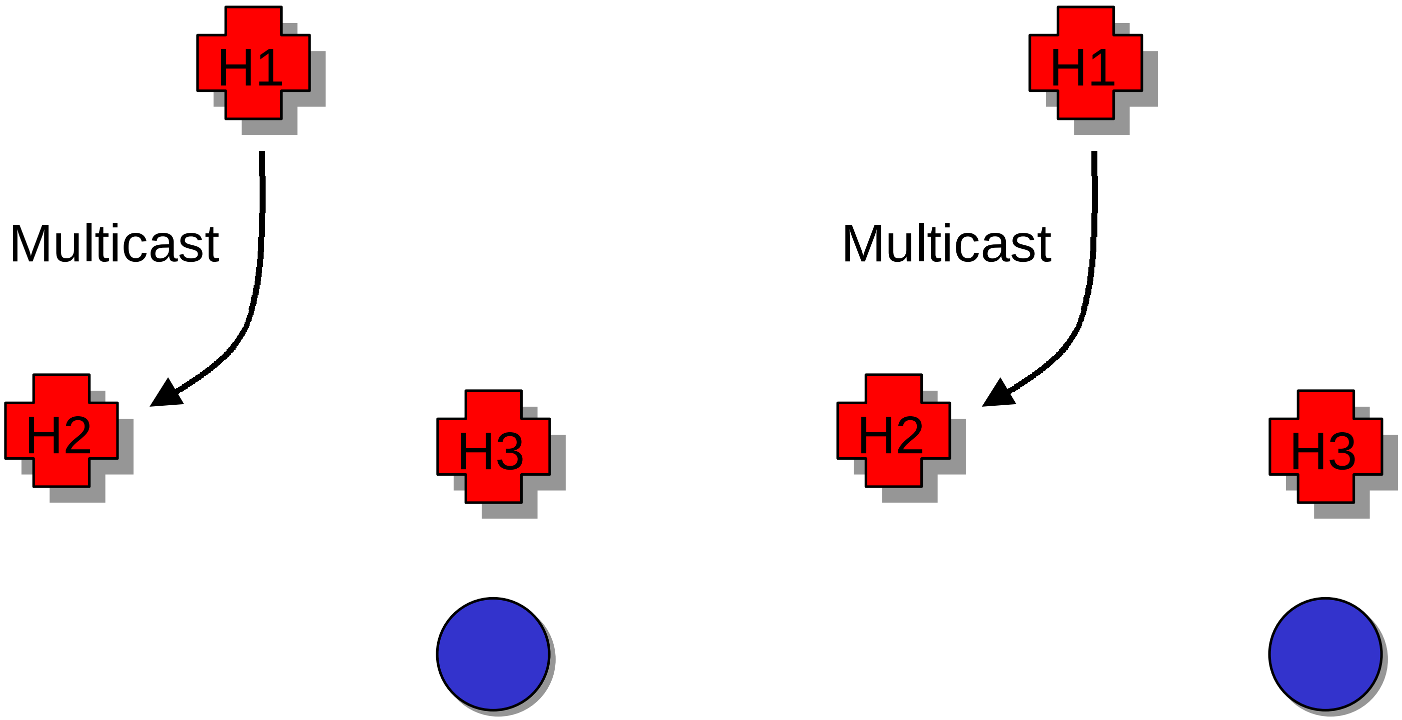
Additional buffer required to bridge the gap, S_l - S_r

Helper Selection Considerations



- Additional buffer space required
  - Knowledge of temporal distance
- Additional network load incurred
  - Knowledge of network distance
- Additional system load incurred
  - Bandwidth and buffer consumption
  - For load balancing
- Data stream sharing or not

Data Stream Sharing or Not



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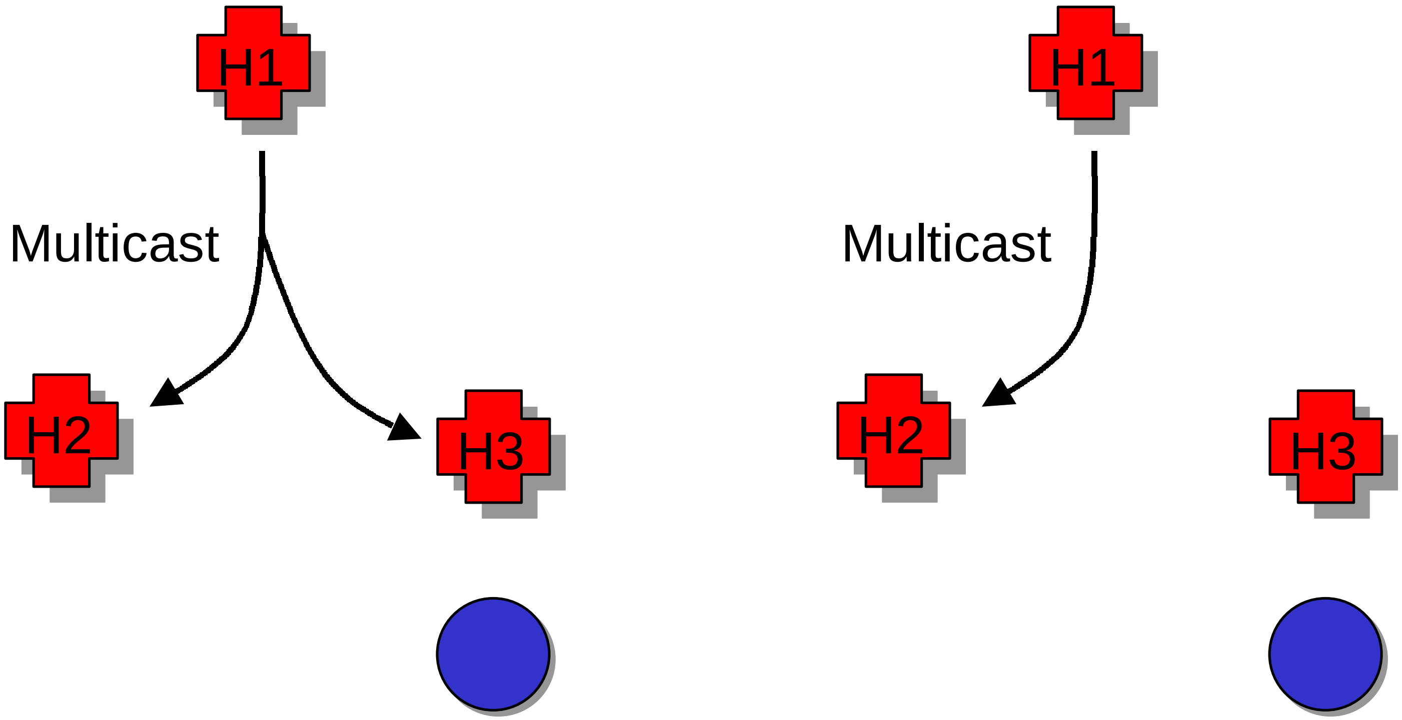

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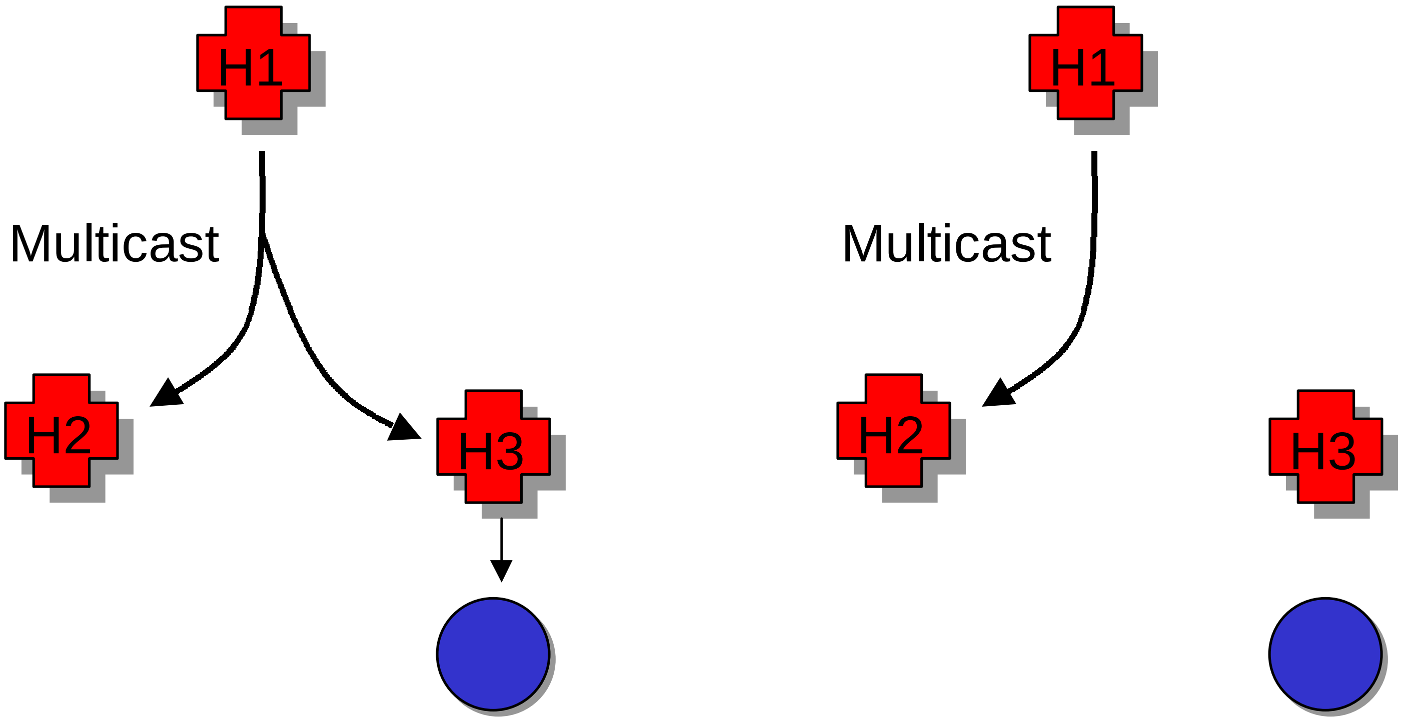

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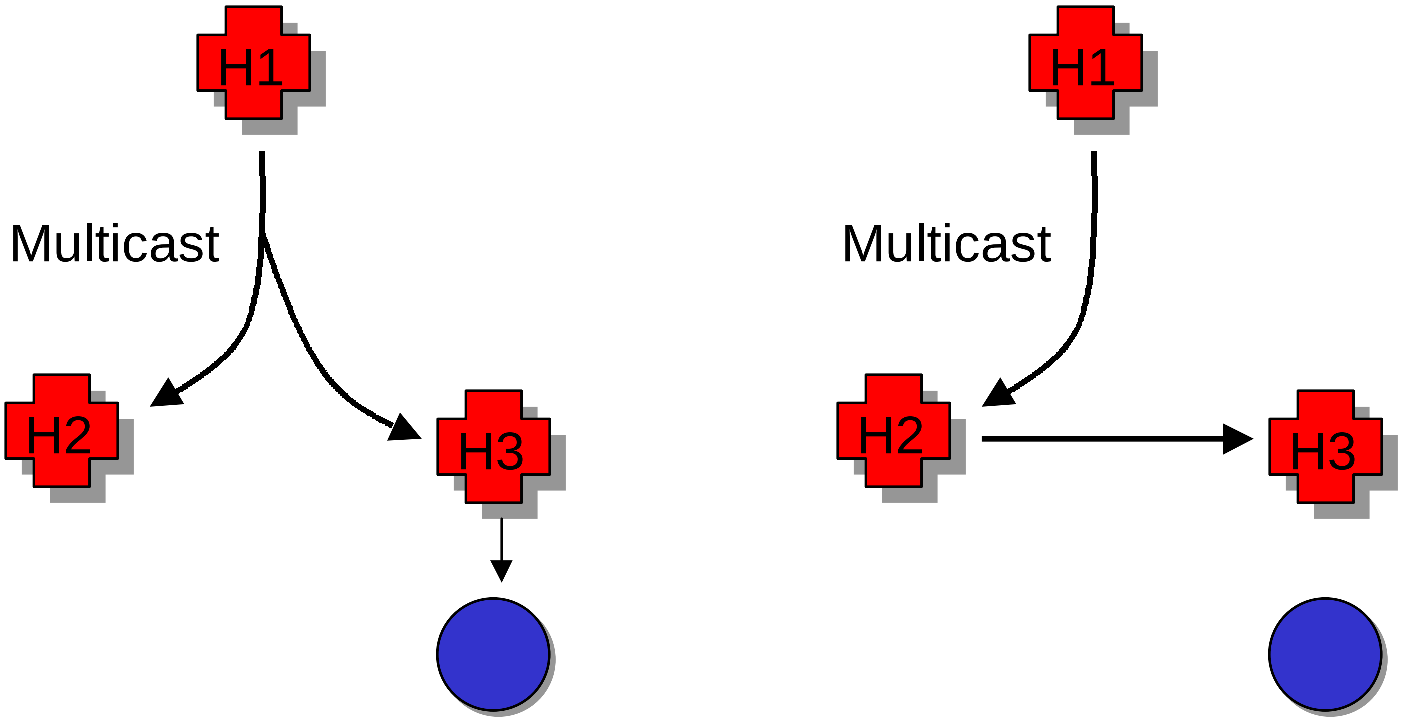

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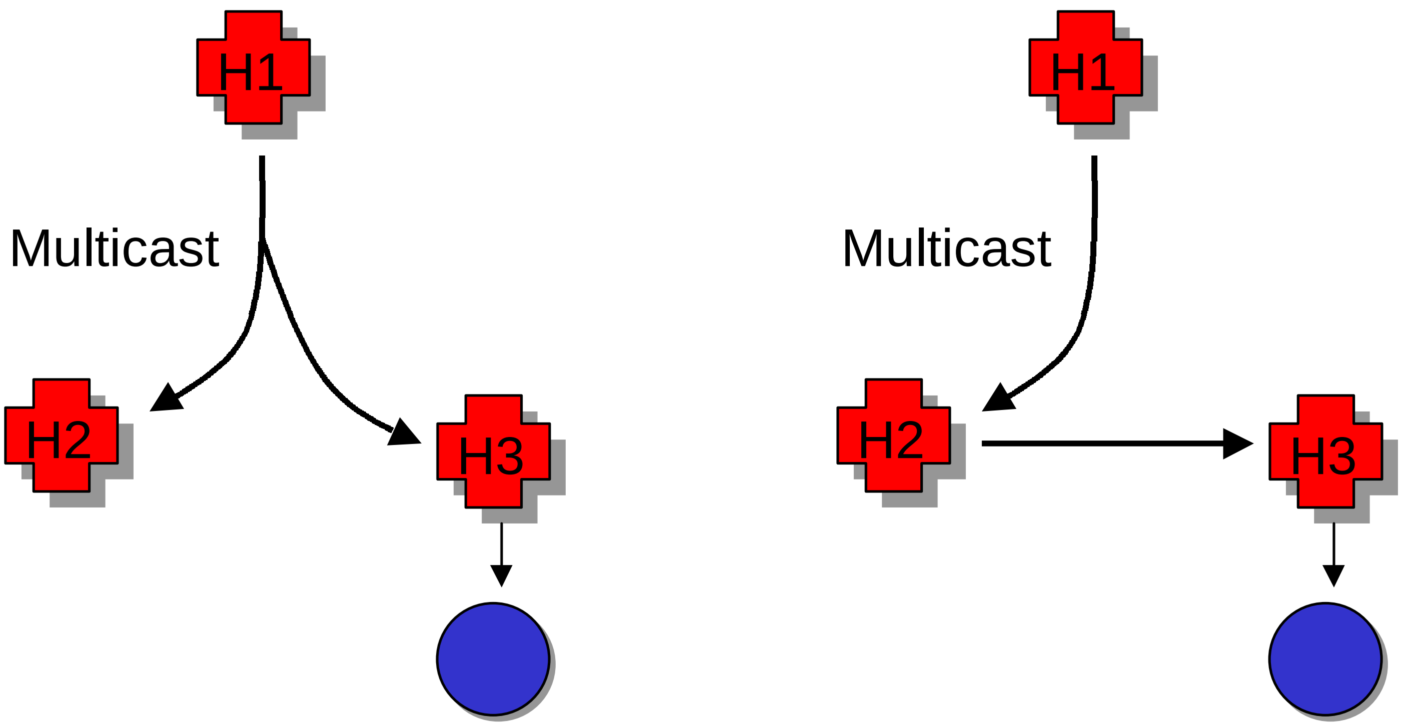

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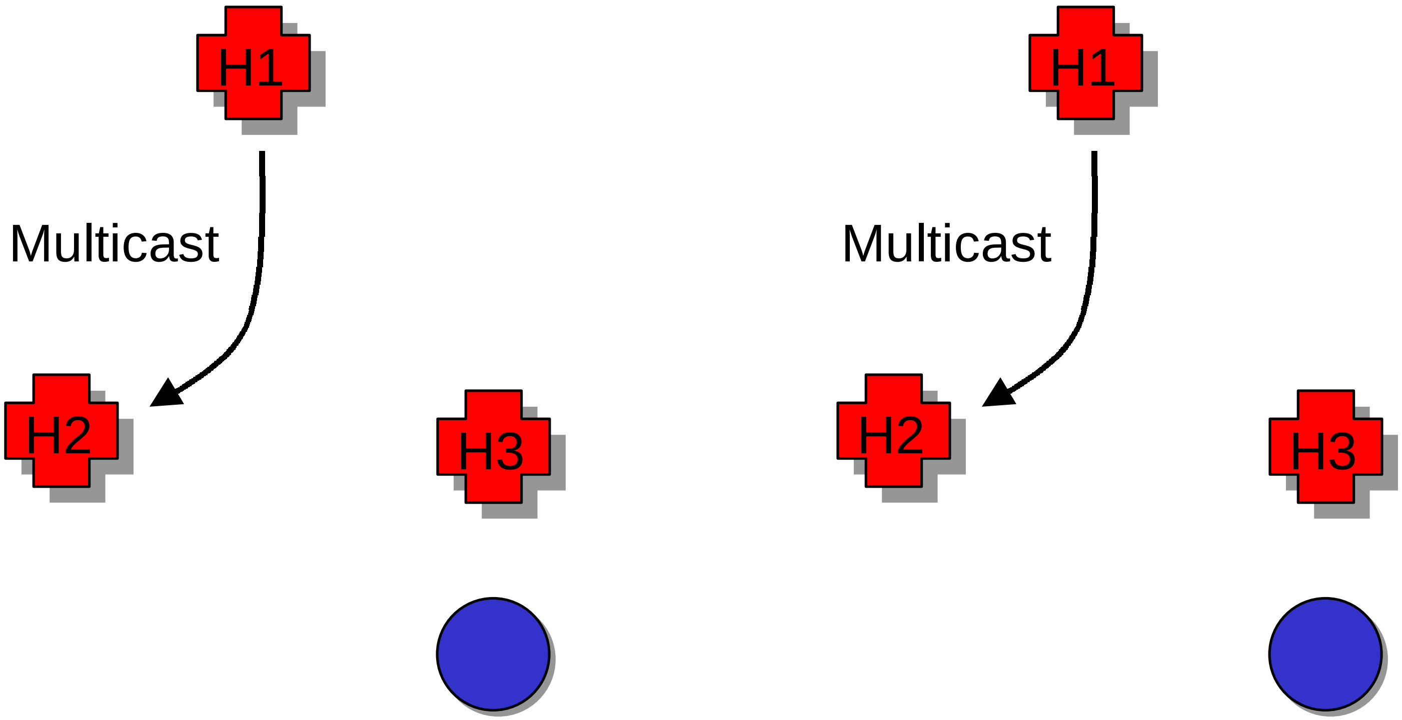

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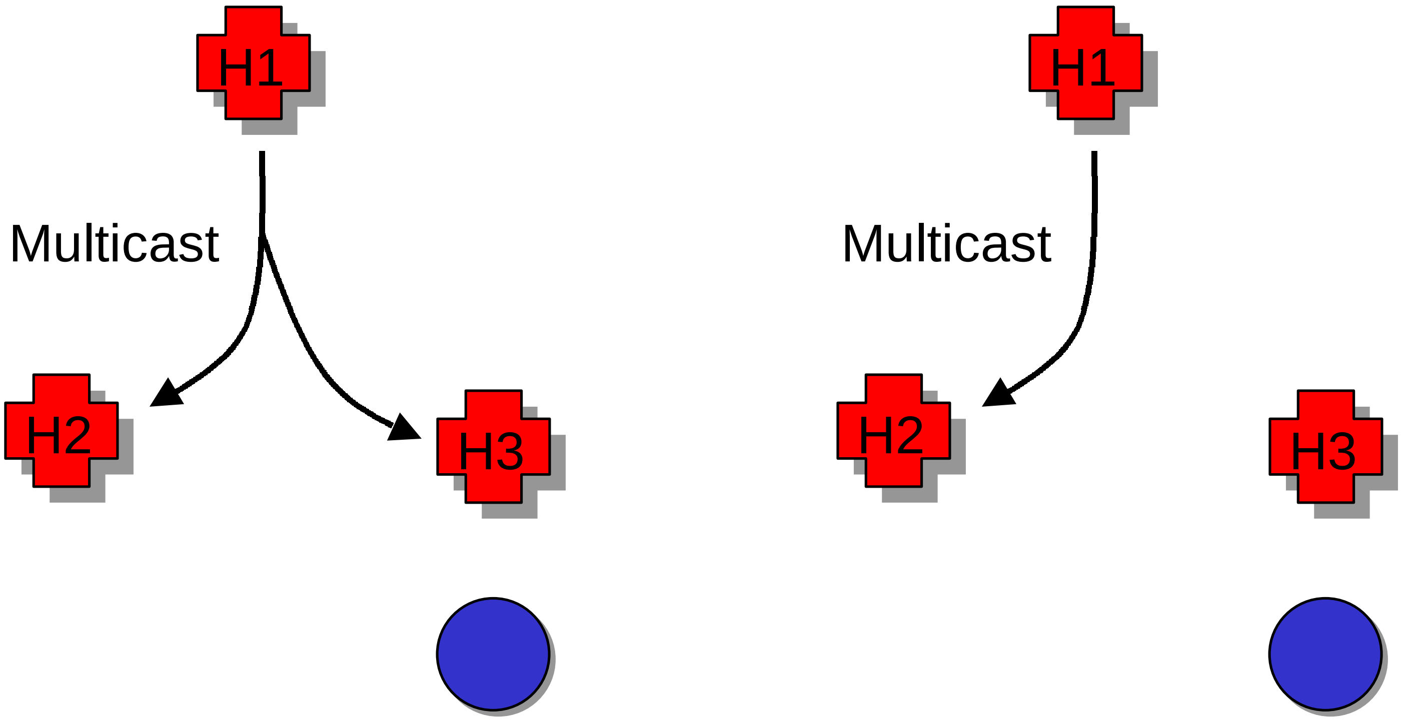

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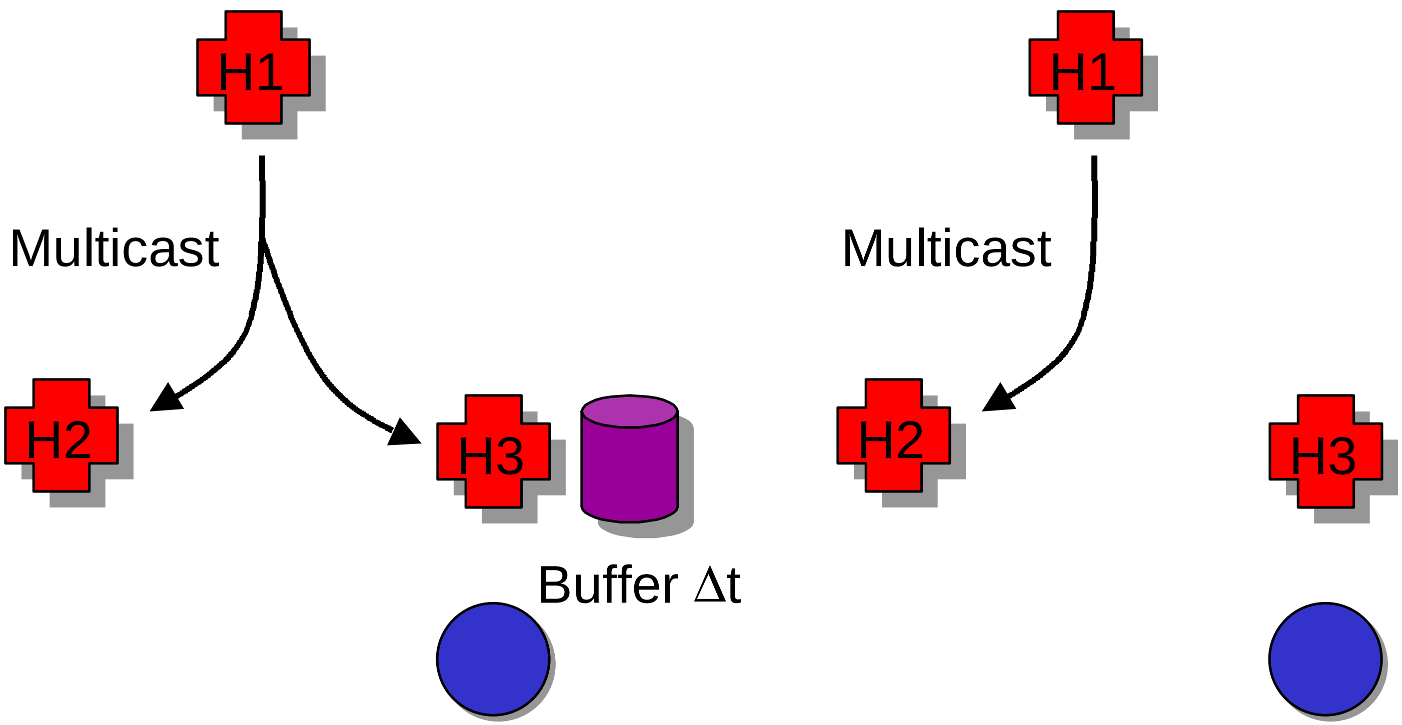

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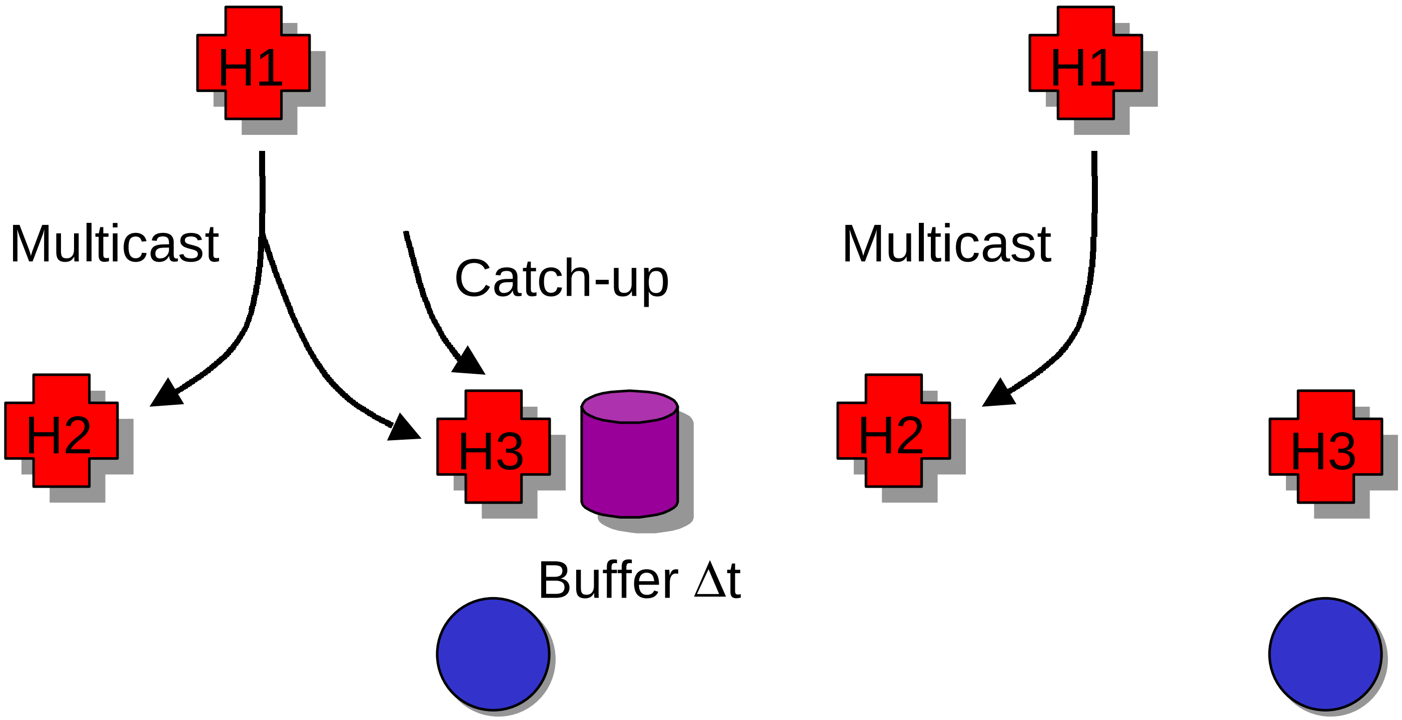

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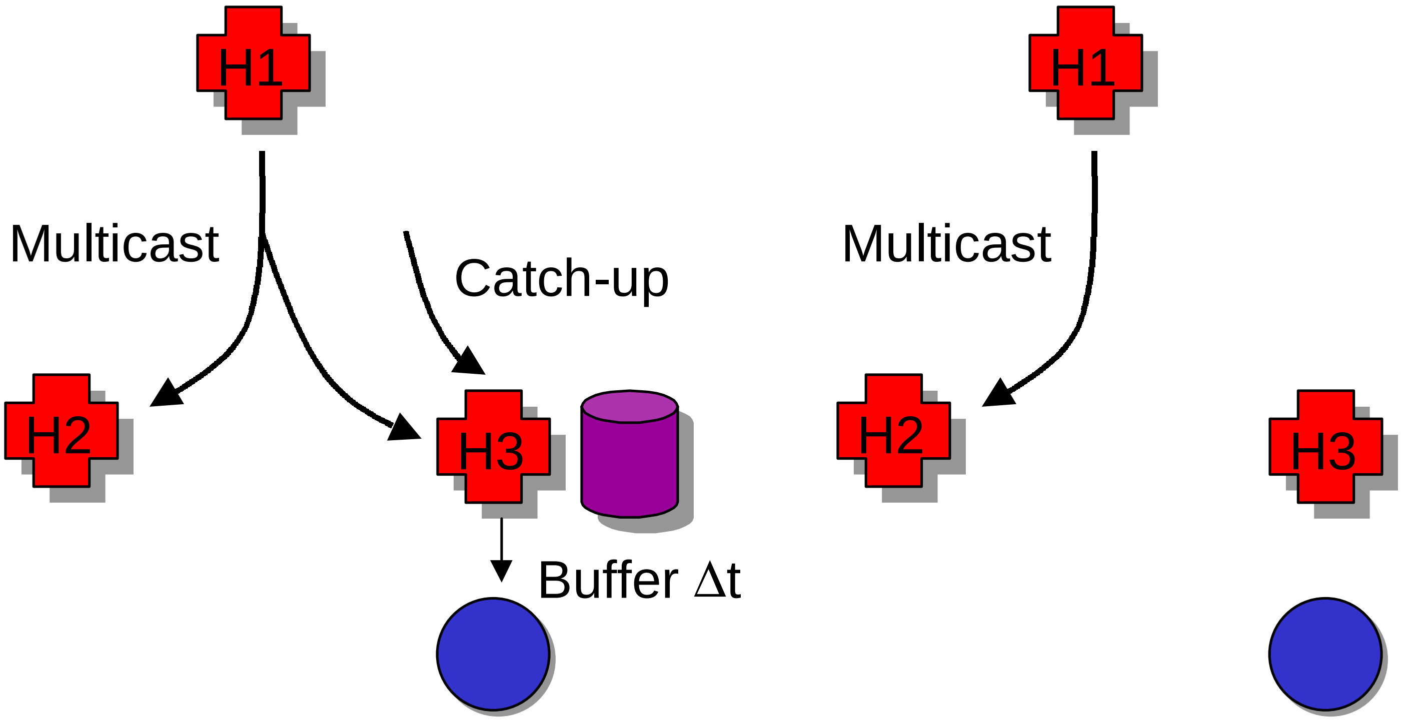

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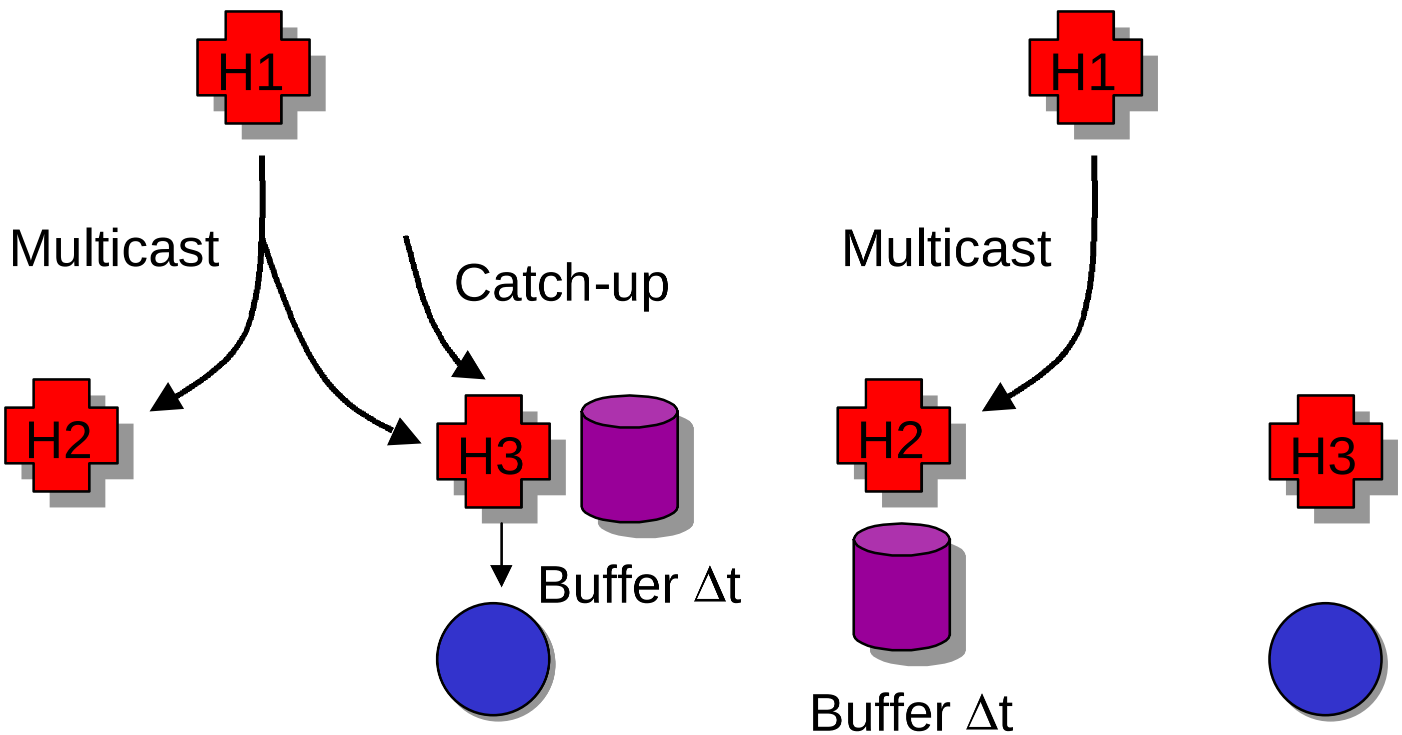

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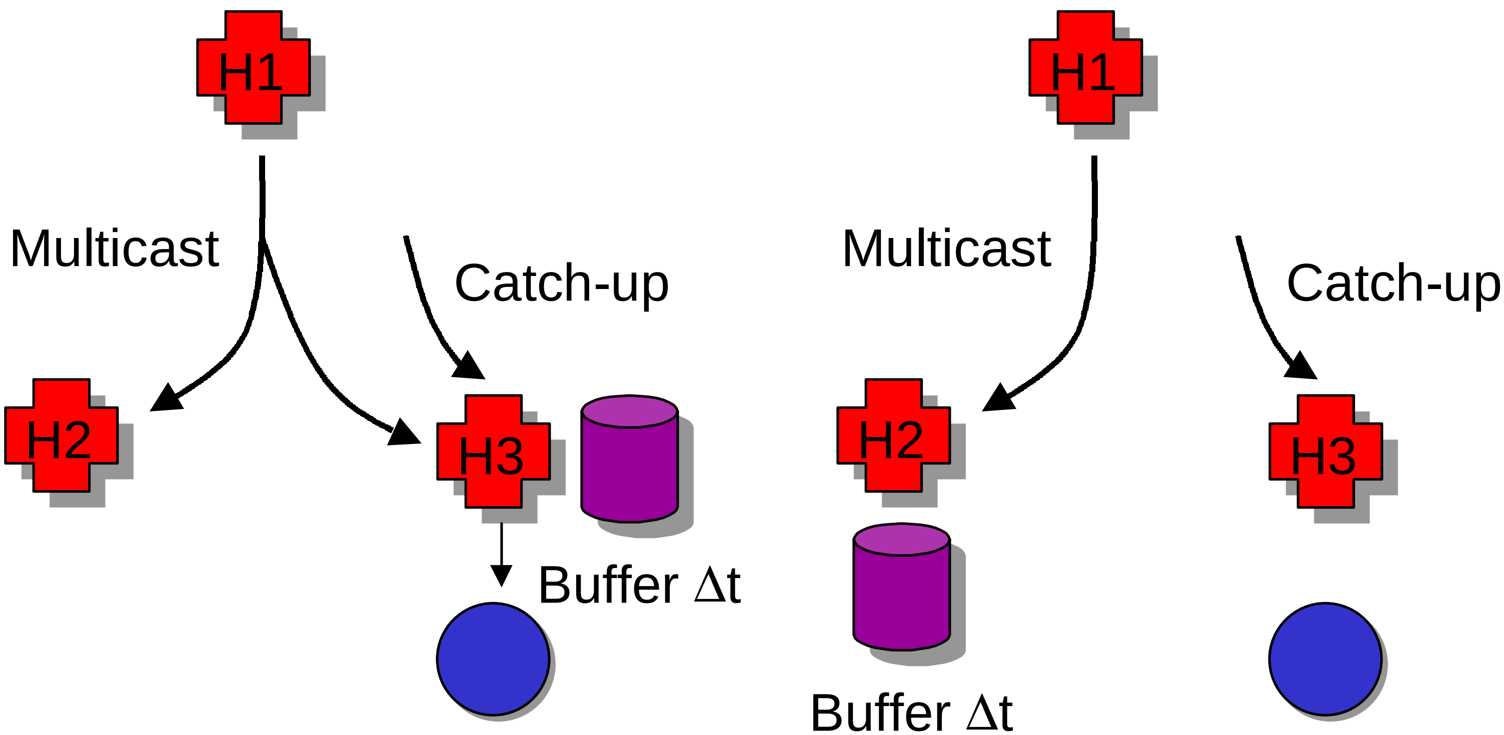

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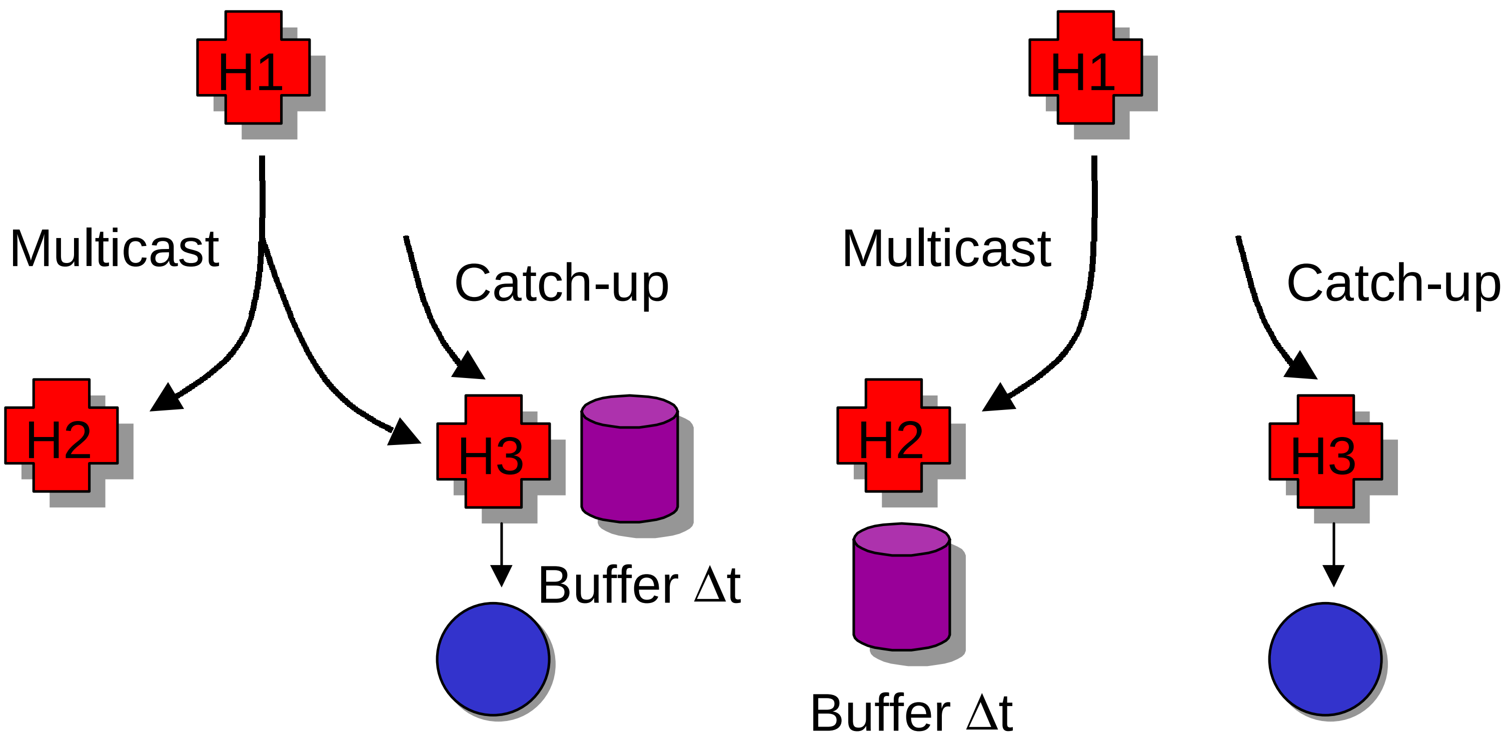

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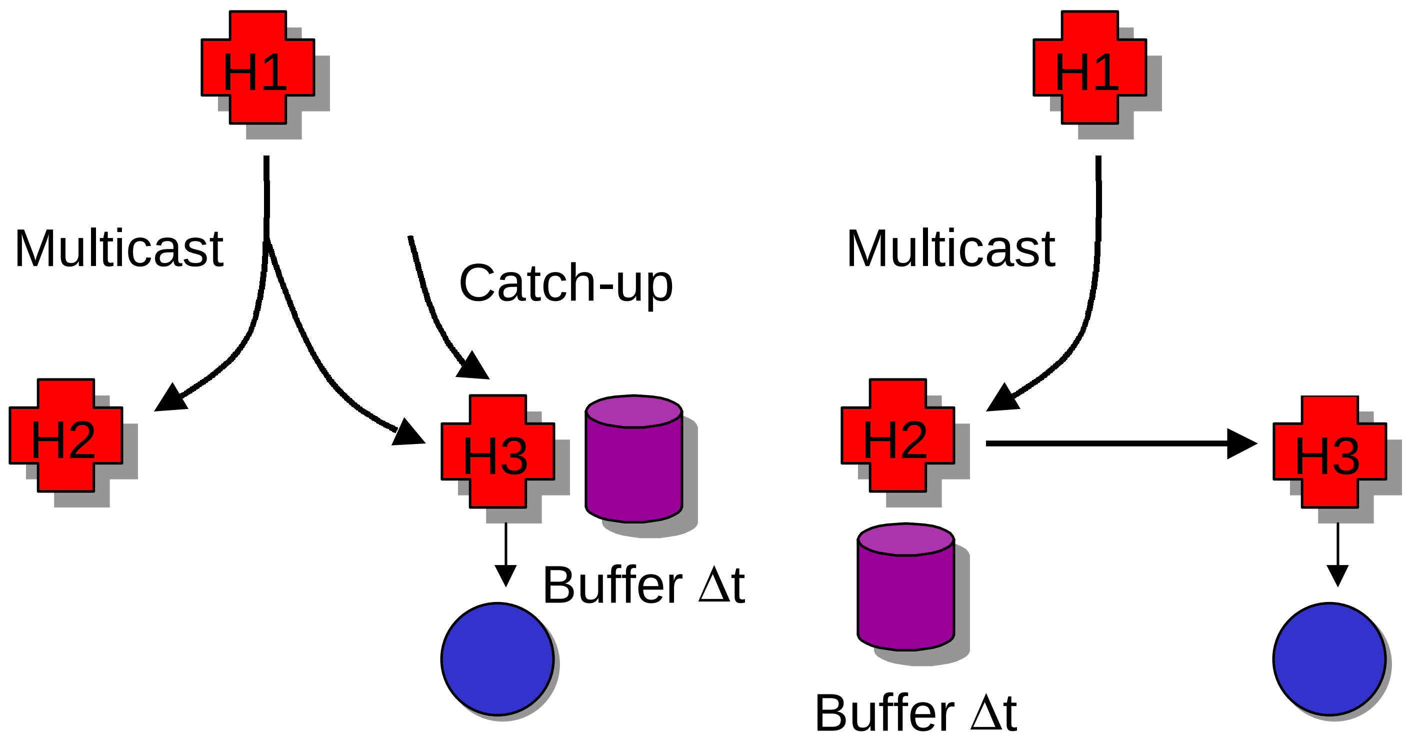
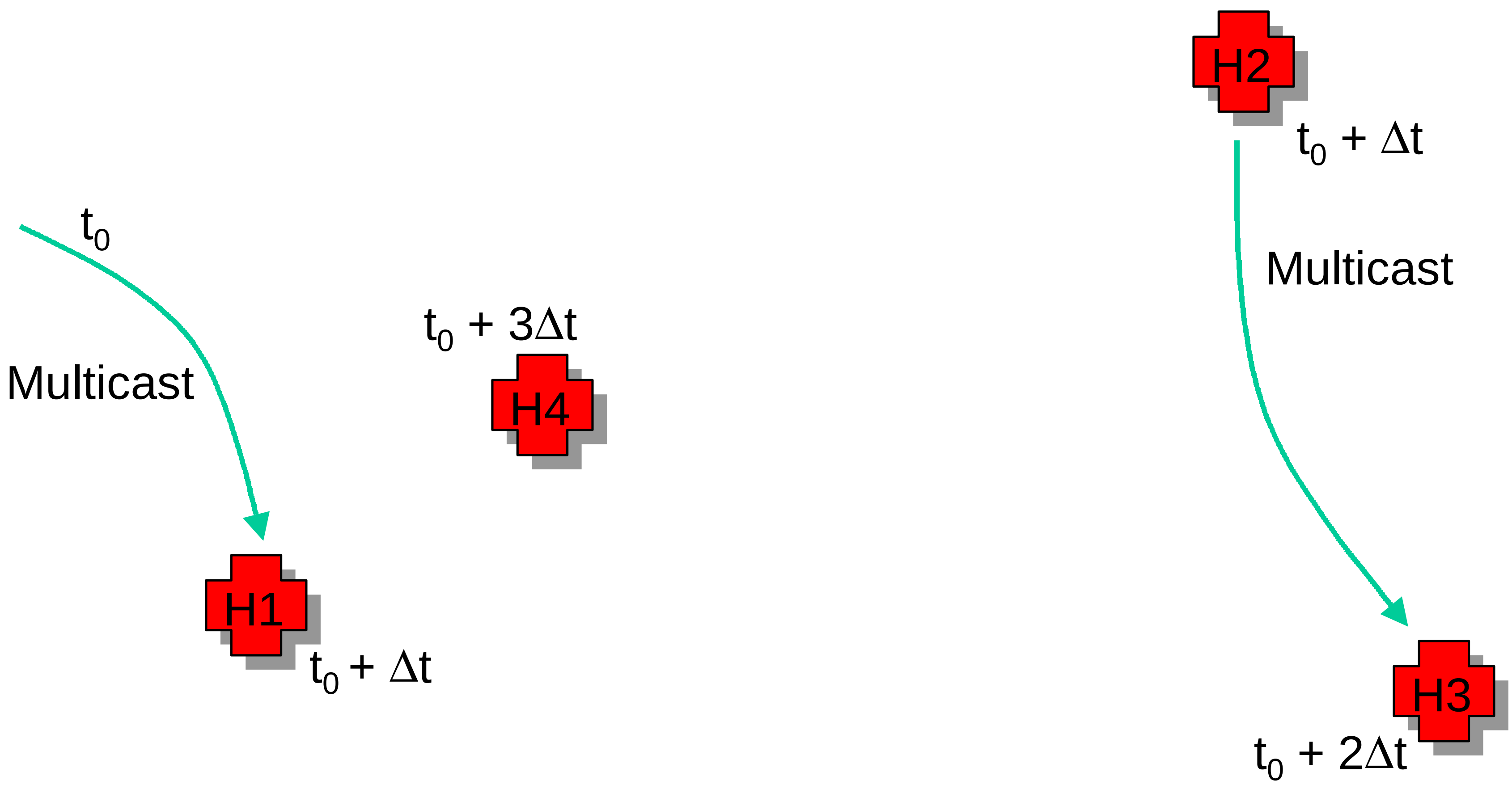


Example Helper Selection Algorithm

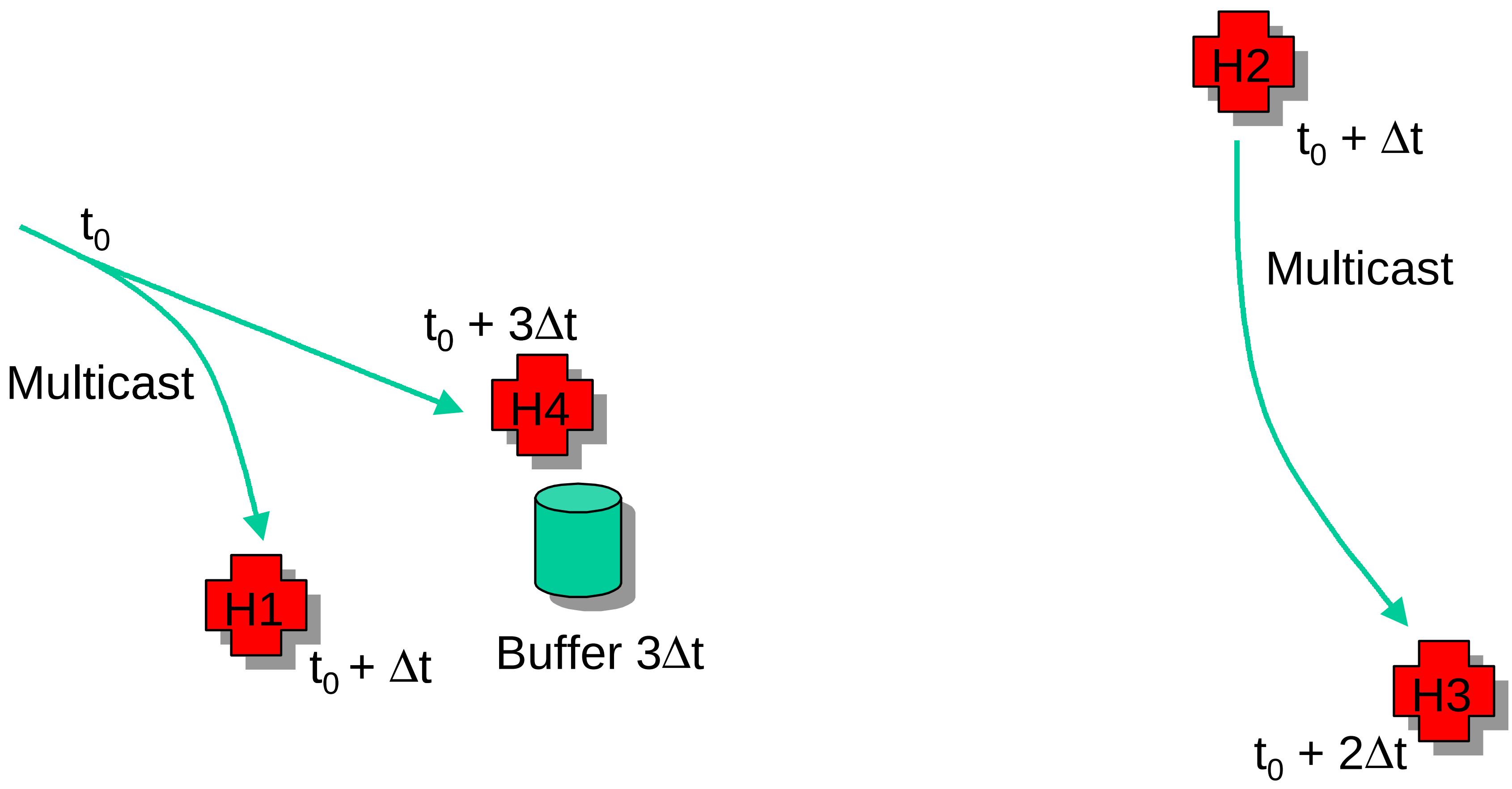
```
foreach region (local, regional, national, global) {
        if (! sHelper) {
                sHelper = findBestStreamSharingHelper(region);
        }
        if (! nHelper) {
                nHelper = findBestNewStreamHelper(region);
        }
        if (sHelper && nHelper) { break; }
}

if ( bufferReq(sHelper) * netDistance(sHelper)  <
   bufferReq(nHelper)  * netDistance(nHelper)) {
        return sHelper;
} else { return nHelper; }
```

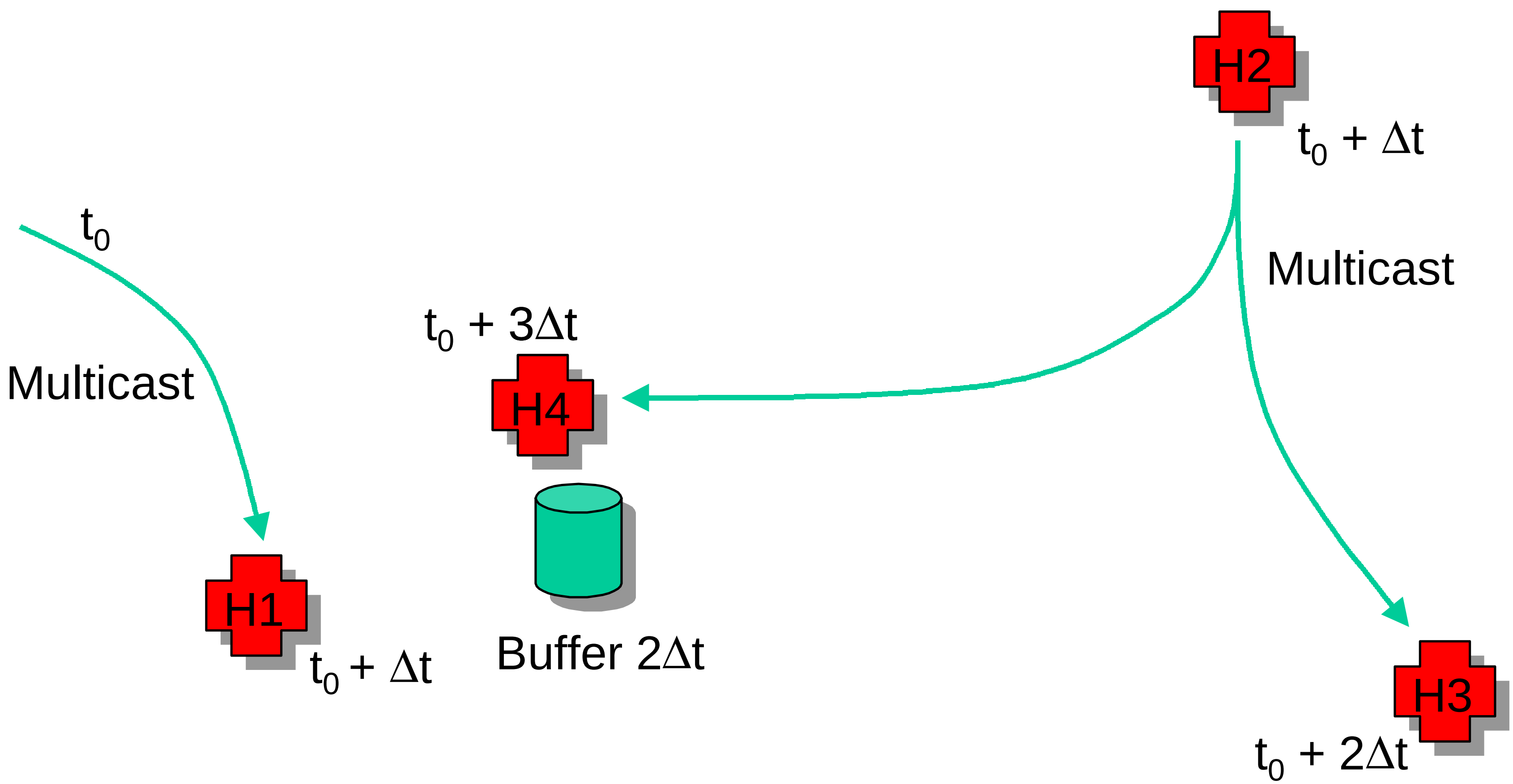
Algorithm in Action



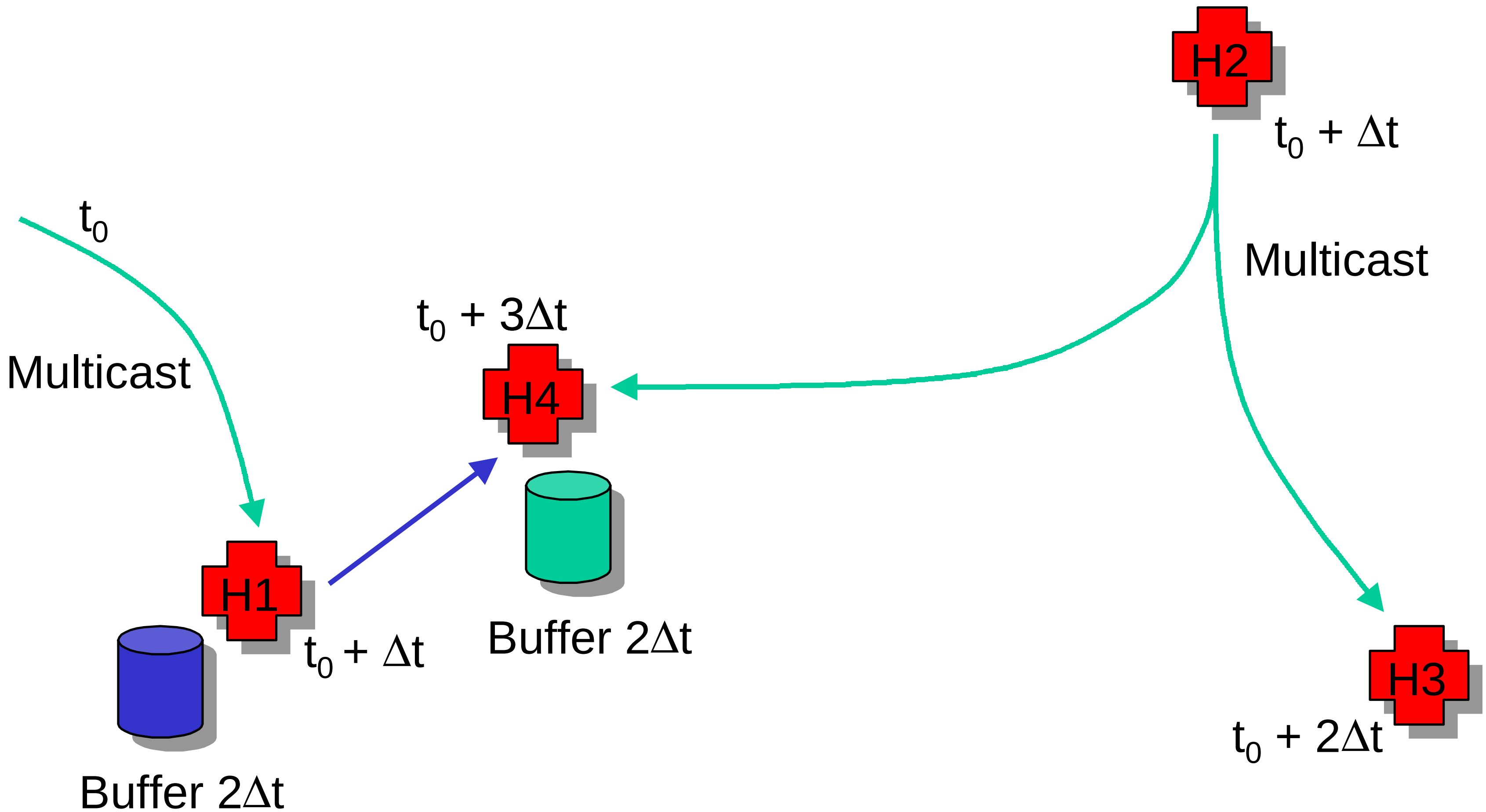
Algorithm in Action



Algorithm in Action



Algorithm in Action



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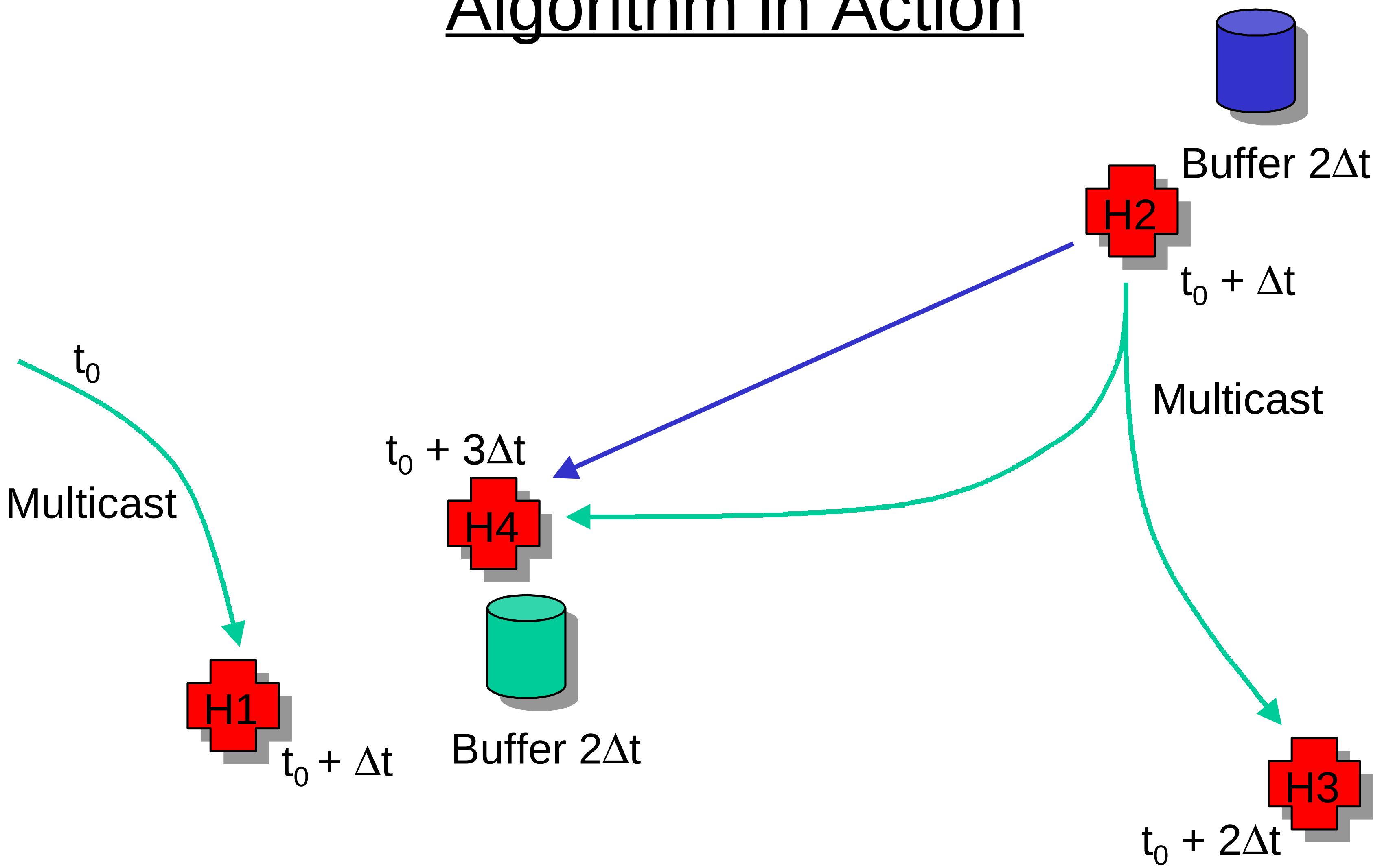

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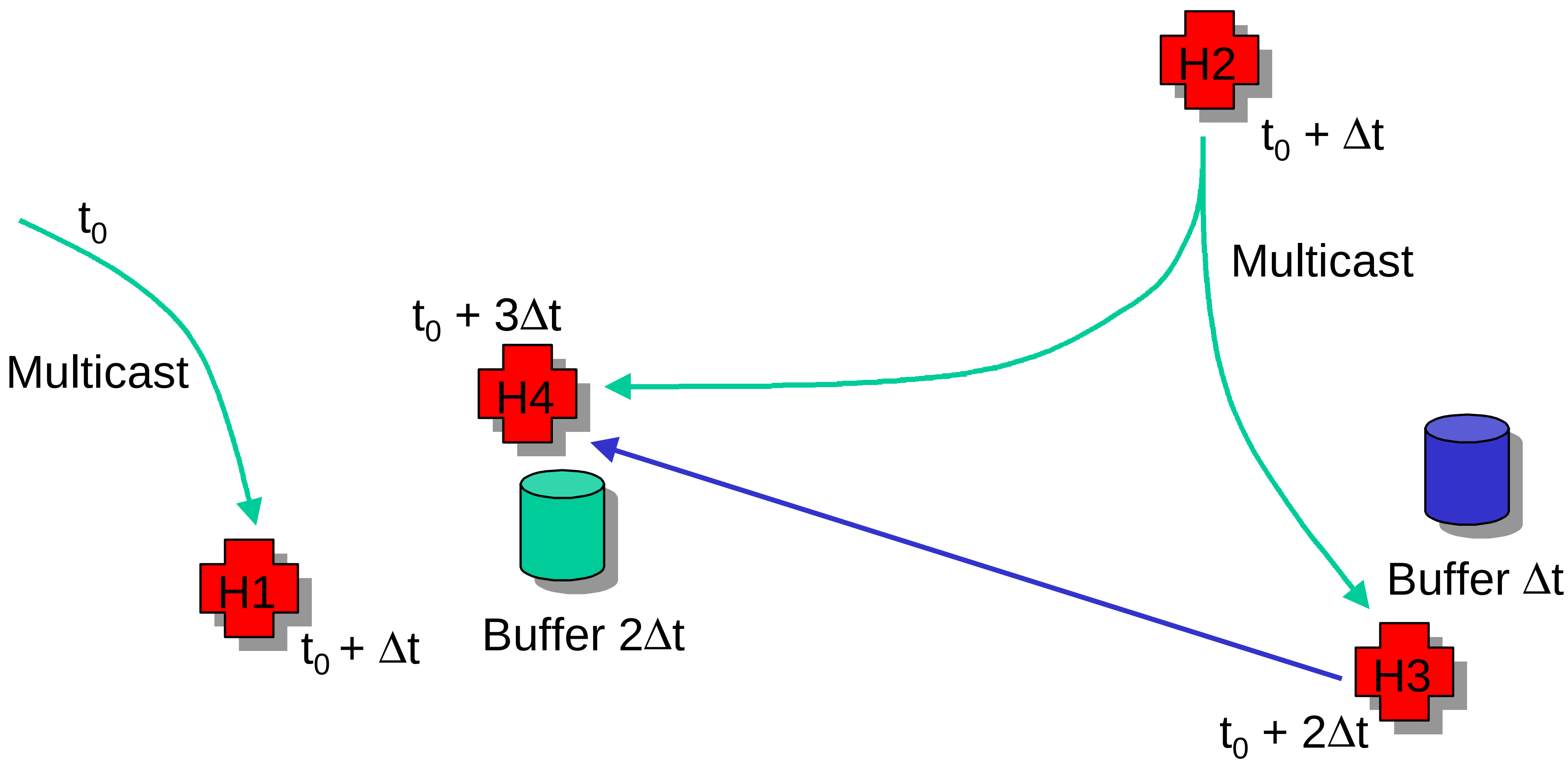
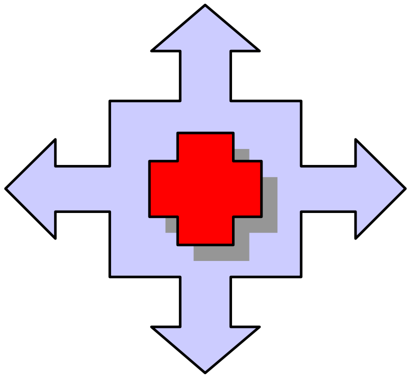
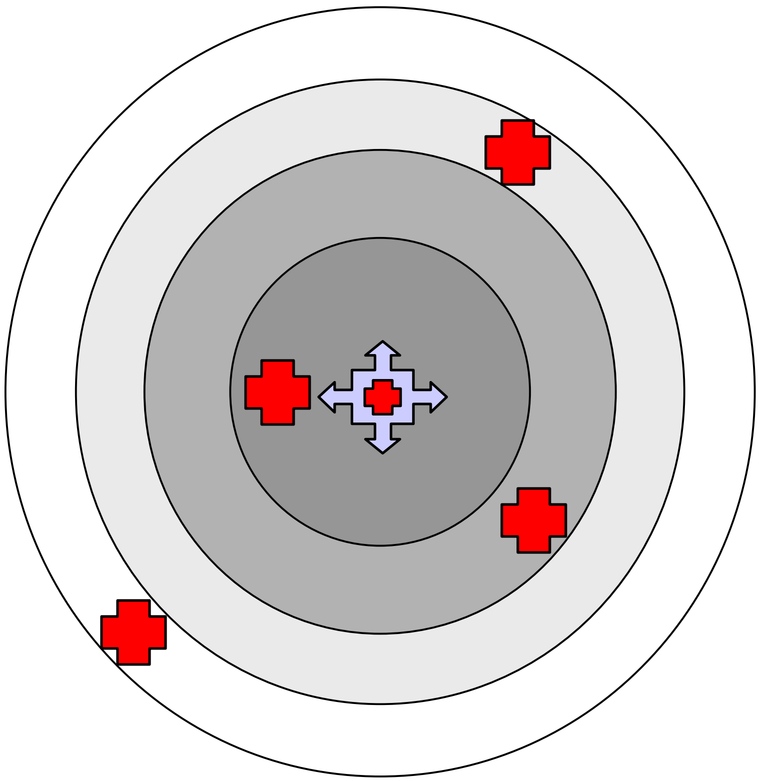


State Distribution: What?



- Streams currently buffered, for each stream:
  - Current lowest segment sequence number
  - Bandwidth of this stream
  - Source of this stream: Multicast vs Unicast
- Overall buffer used and free
- Overall bandwidth used and free

State Distribution: How?



TTL Scope	Frequency of Reception
15	Every Advertisement
31	Every 2nd Advertisement
63	Every 4th Advertisement
127	Every 8th Advertisement

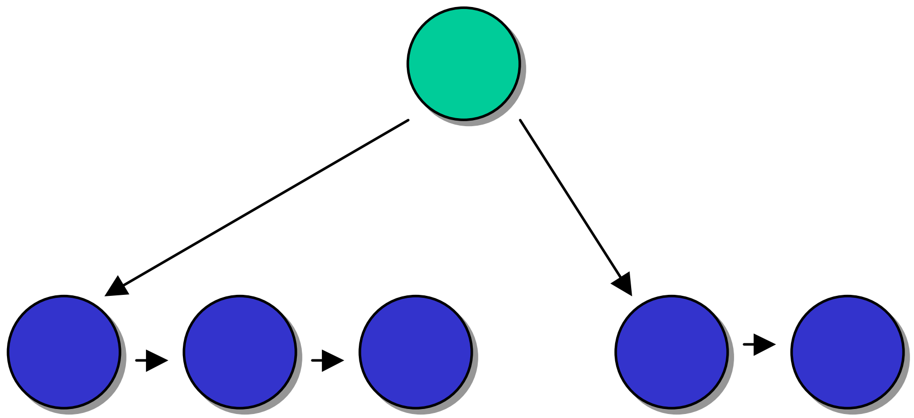
Listening Helper

Advertising Helper

Static Caching of Segments

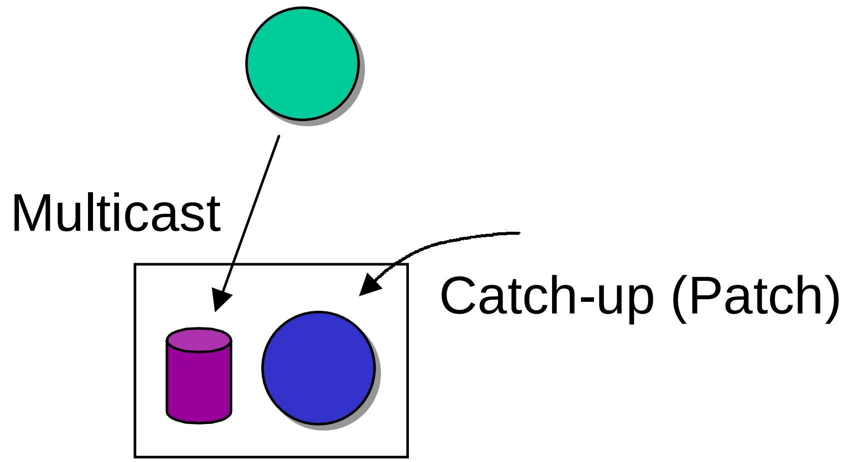
- Short clips
- Hot segments
  - e.g. A particular song in a concert
- Initial segments
  - If receivers tend to start listening from the beginning
  - Further reduce start-up latency
- Catch-up data
- Requires a measure of “hotness”

Related Work



- Chaining [Hua, Sheu and Tavanapong, ICMCS '97]
  - Every receiver buffers a fixed amount of data
  - Late comers can be served out of receiver buffers
  - Forms a chain of receivers
  - Focuses on reducing server load

Related Work



- Patching [Hua, Cai and Sheu, ACM Multimedia ‘98]
  - Each receiver allocates buffer to catch-up with an on-going multicast session originating from the server
  - Patching refers to the need for catch-up data from the server
  - No buffer sharing, data always originates from server

Conclusion

- By using Helpers as data forwarding, buffering, and caching agents, we believe
  - Streaming multimedia quality can be enhanced
  - Server load can be reduced
  - Network load can be reduced
  - It's a win, win, win
- Keys to success
  - Access pattern allows data sharing
  - Low mesh setup overhead, responsiveness is critical
  - Low state distribution overhead
- Huge design space remains to be explored
- System is currently being implemented in ns-2