#adobemax151

P2P on the Flash Platform with RTMFP

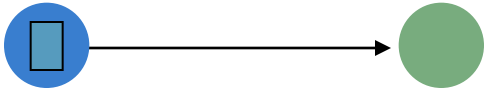
Matthew Kaufman

Sr. Computer Scientist, Project Lead

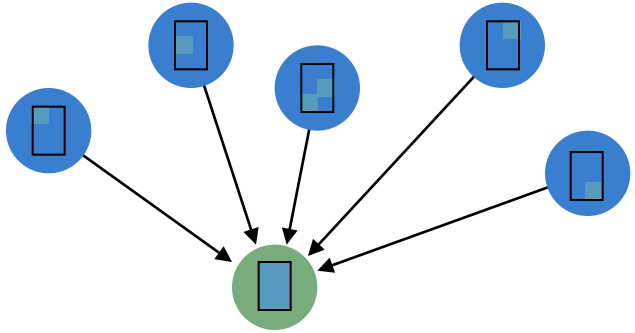
Adobe

What is “Peer-to-Peer”?

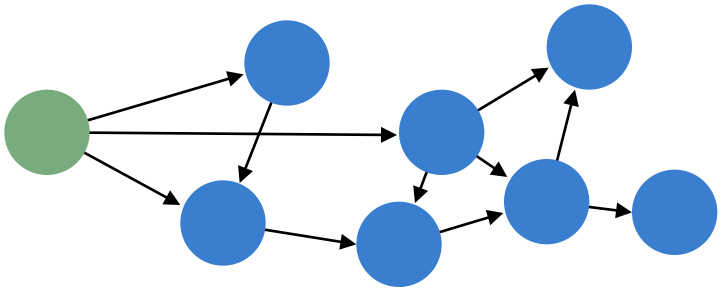
- Point-to-point
  - Live streaming
  - Document delivery



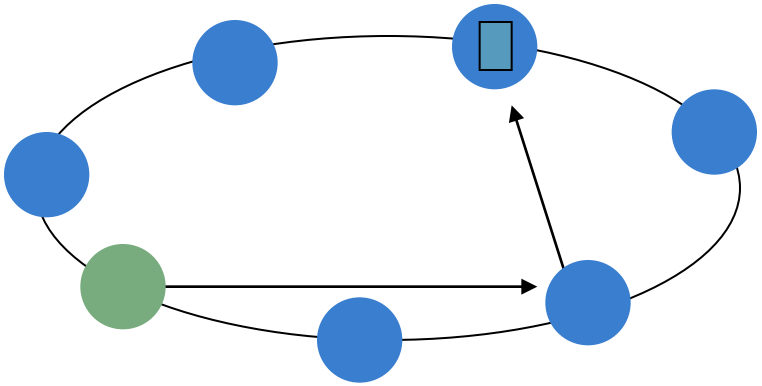
- “Swarming”
  - Large-file download (possibly progressive)



- Live Application-Level Multicast
  - Broadcast (1 to many, some latency tolerable)
  - Interactive (many to many, or 1 to many with feedback, low latency required)



- Distributed Data Storage
  - DHT-like structures to form distributed database



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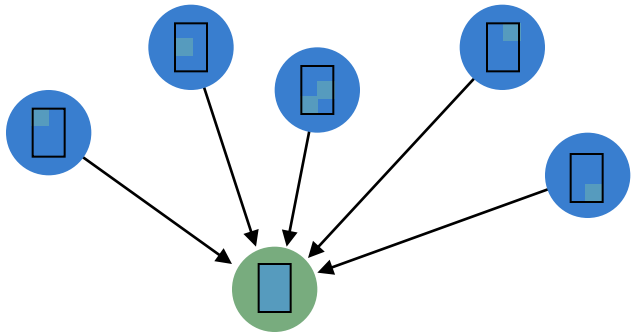
Peer-to-Peer Capabilities in Flash Player 10.0

- Point-to-point
  - Live streaming
  - Document delivery

- "Swarming"
  - Large-file download (possibly progressive)



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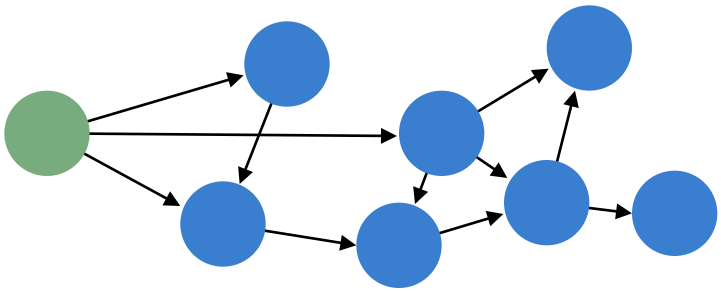

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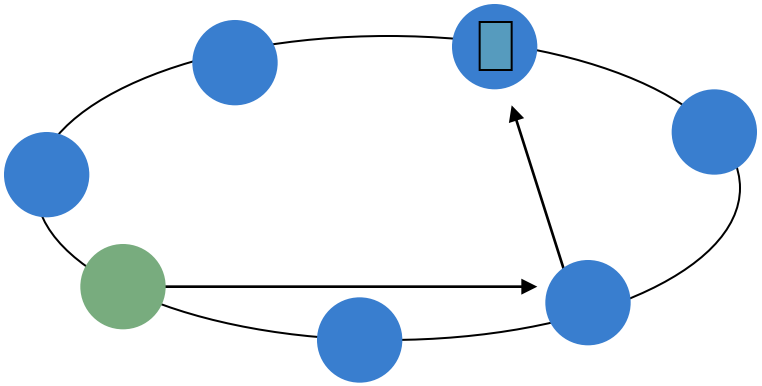

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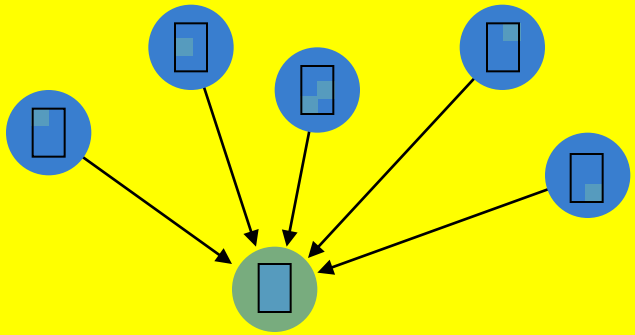
New Peer-to-Peer Capabilities in Flash Player

- Point-to-point
  - Live streaming
  - Document delivery

- “Swarming”
  - Large-file download (possibly progressive)



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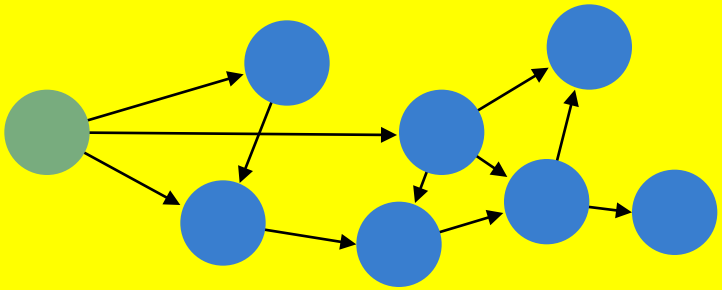

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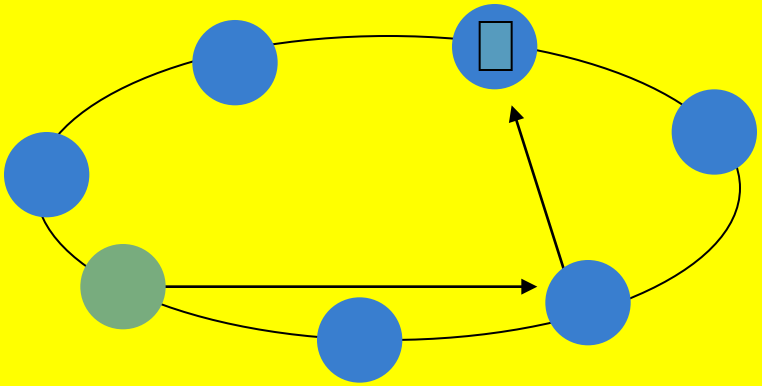

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Overview of New Peer-to-Peer Capabilities

- Join and participate in a self-organizing peer-to-peer overlay network
- Use that network for:
  - Directed Routing
  - Object Replication
  - Posting
  - Application-Level Multicast
- Use Native IP Multicast together with Application-Level Multicast
  - “Fusion”

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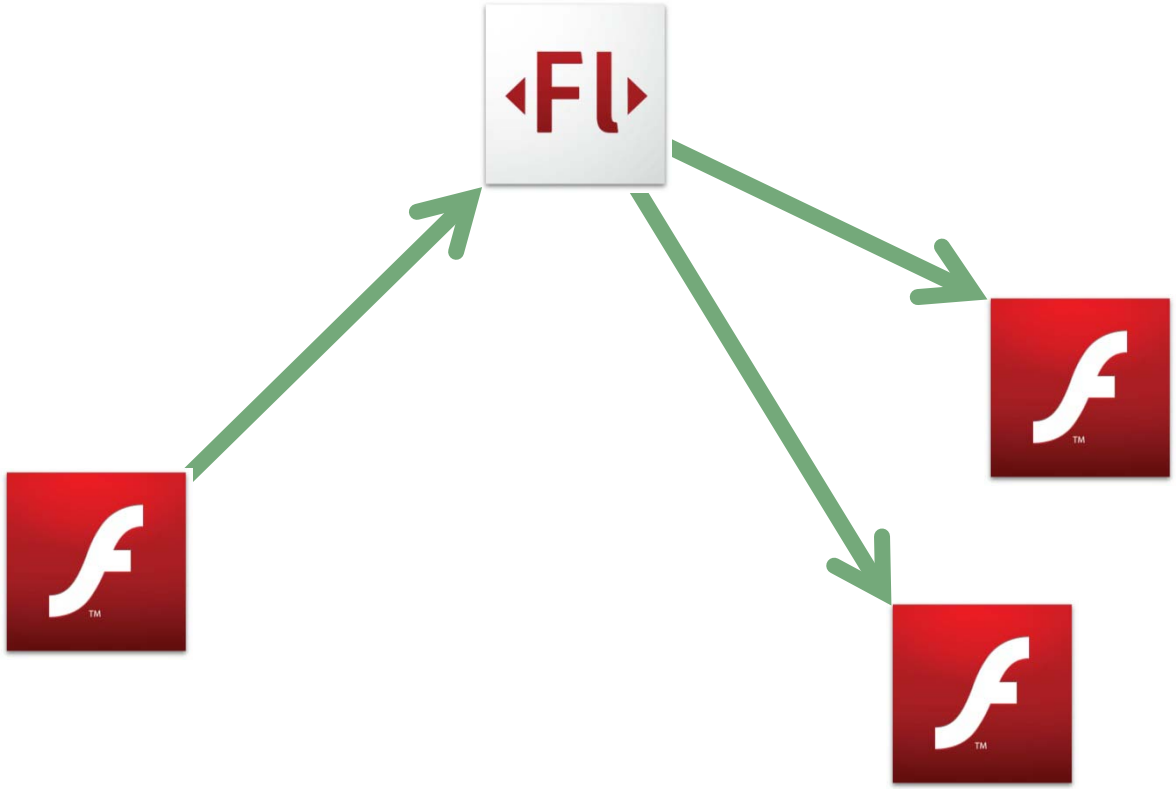
Publishing to (a few) Subscribers through FMS



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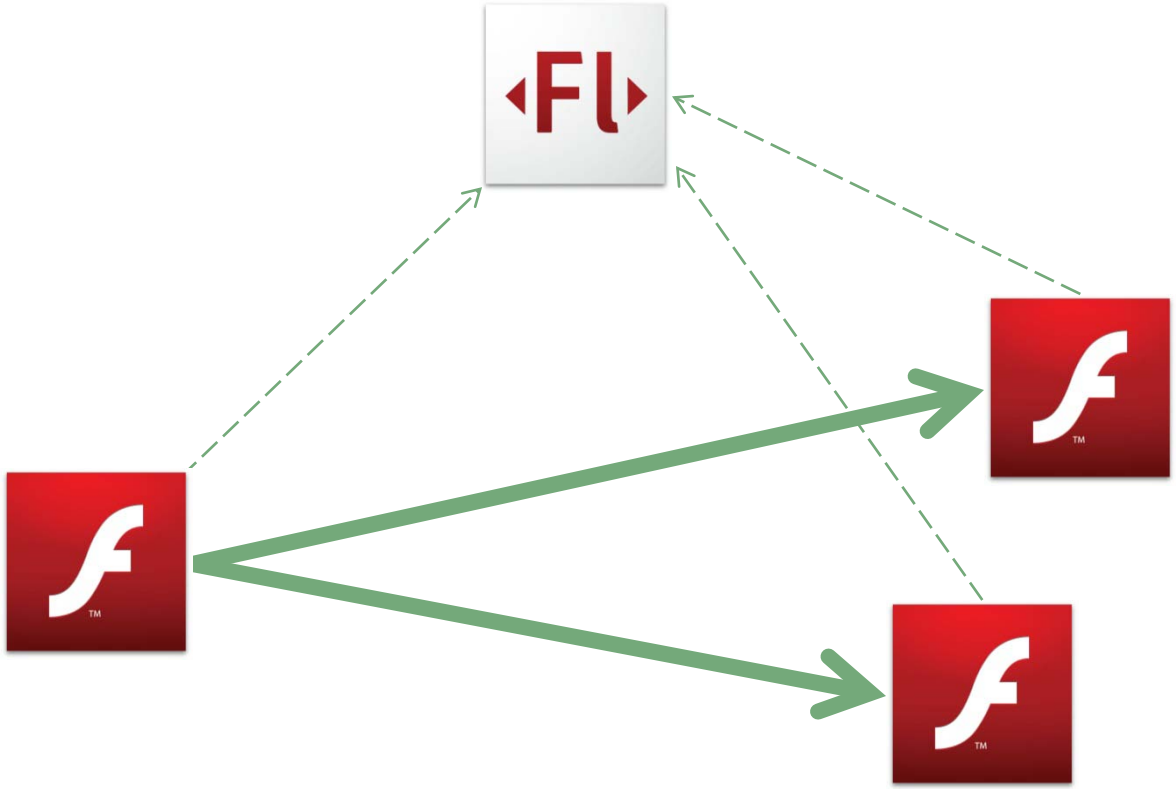
Publishing to (a few) Subscribers Peer-to-Peer



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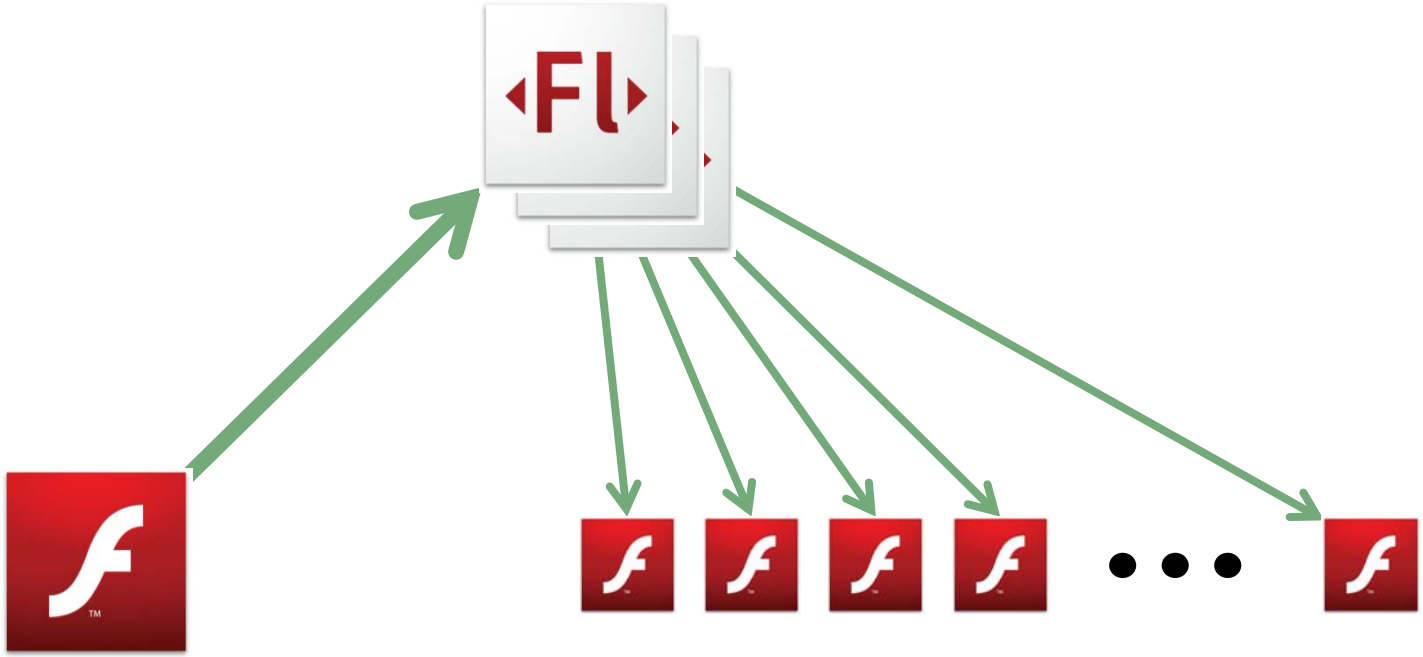
Publishing to (many) Subscribers through FMS



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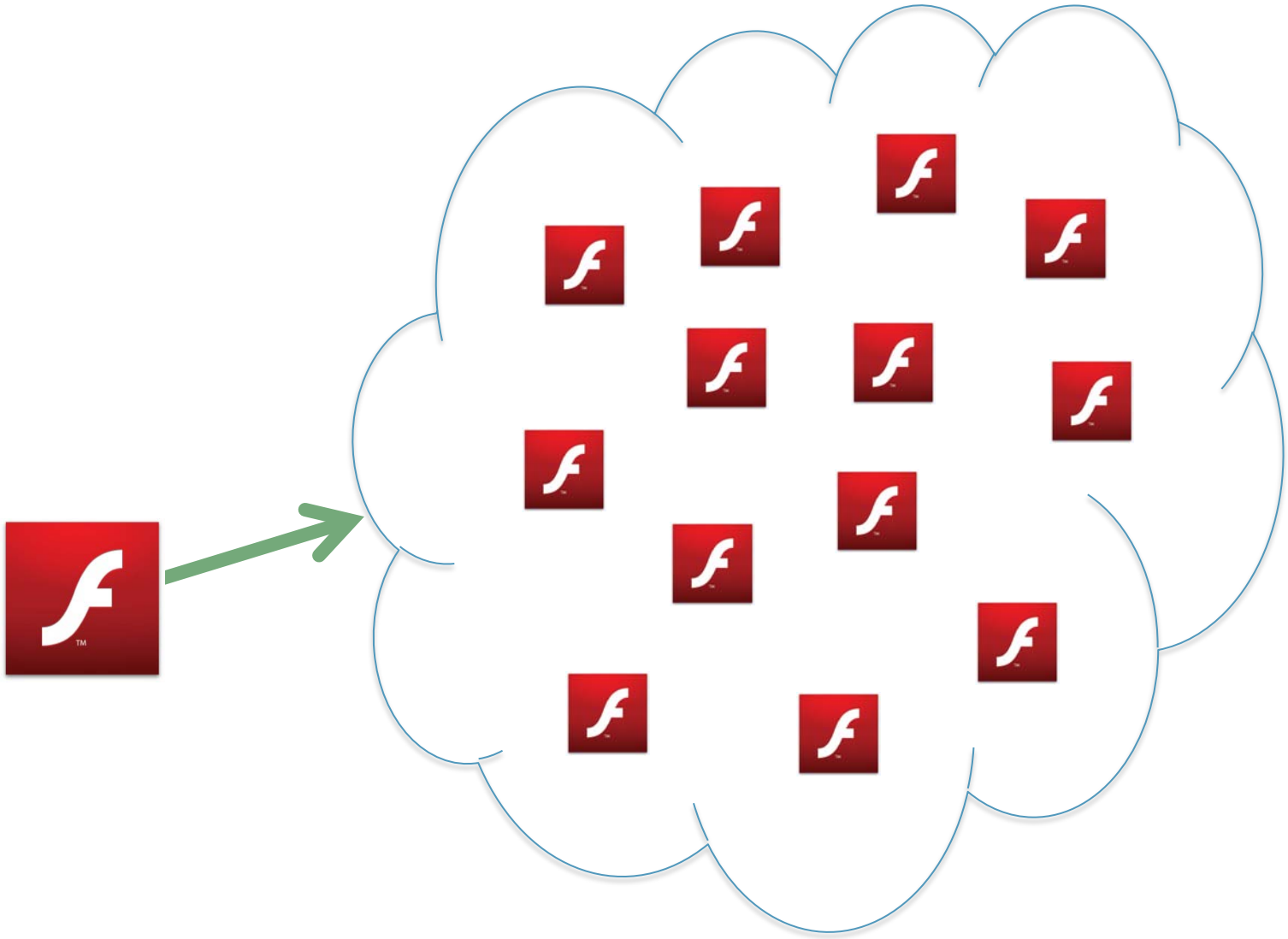
Publishing to (many) Subscribers using RTMFP Groups



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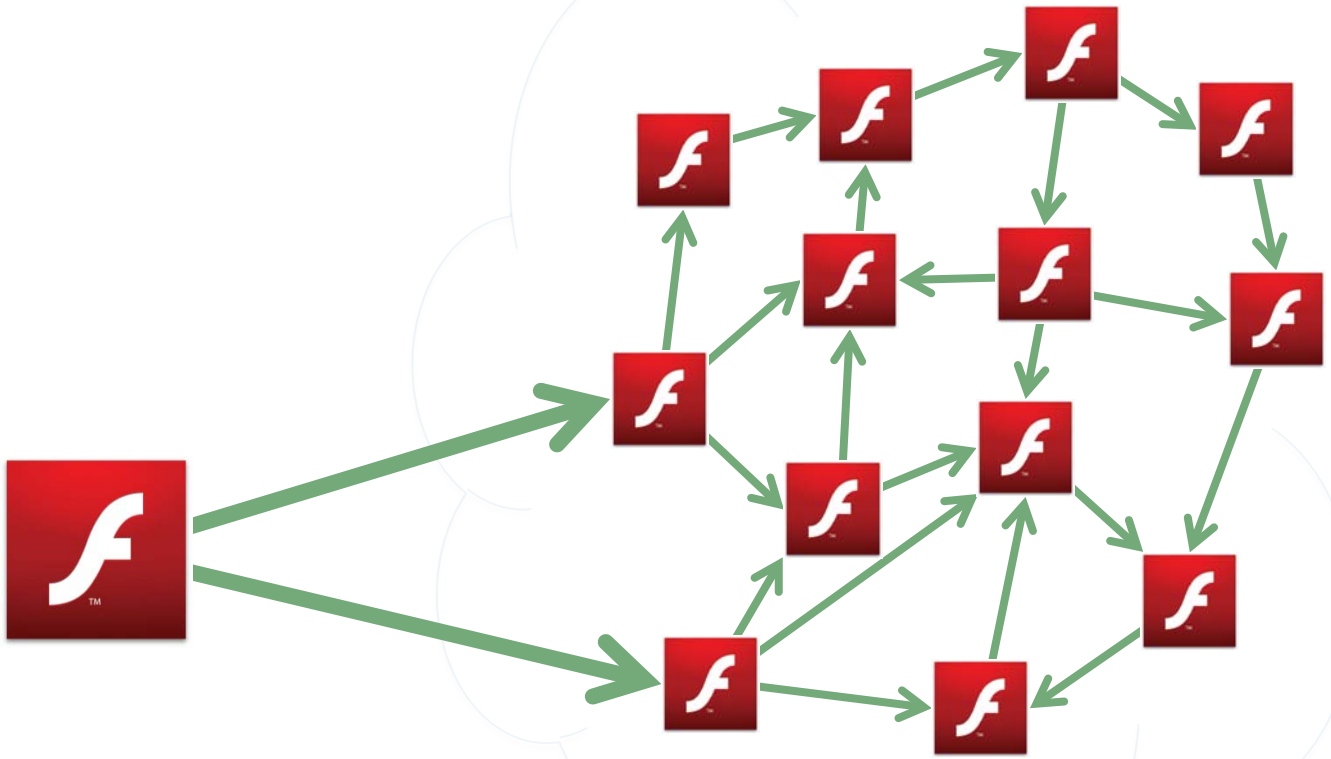
Publishing to (many) Subscribers using RTMFP Groups



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Flash Player Communication

- 1 to 1 (1 to few)
  - Communicate via Server
    - RTMP (RTMPT, RTMPS)
    - RTMFP
  - Communicate Directly
    - RTMFP
- 1 to Many, Many to Many
  - Communicate via Server
  - Communicate using RTMFP Groups

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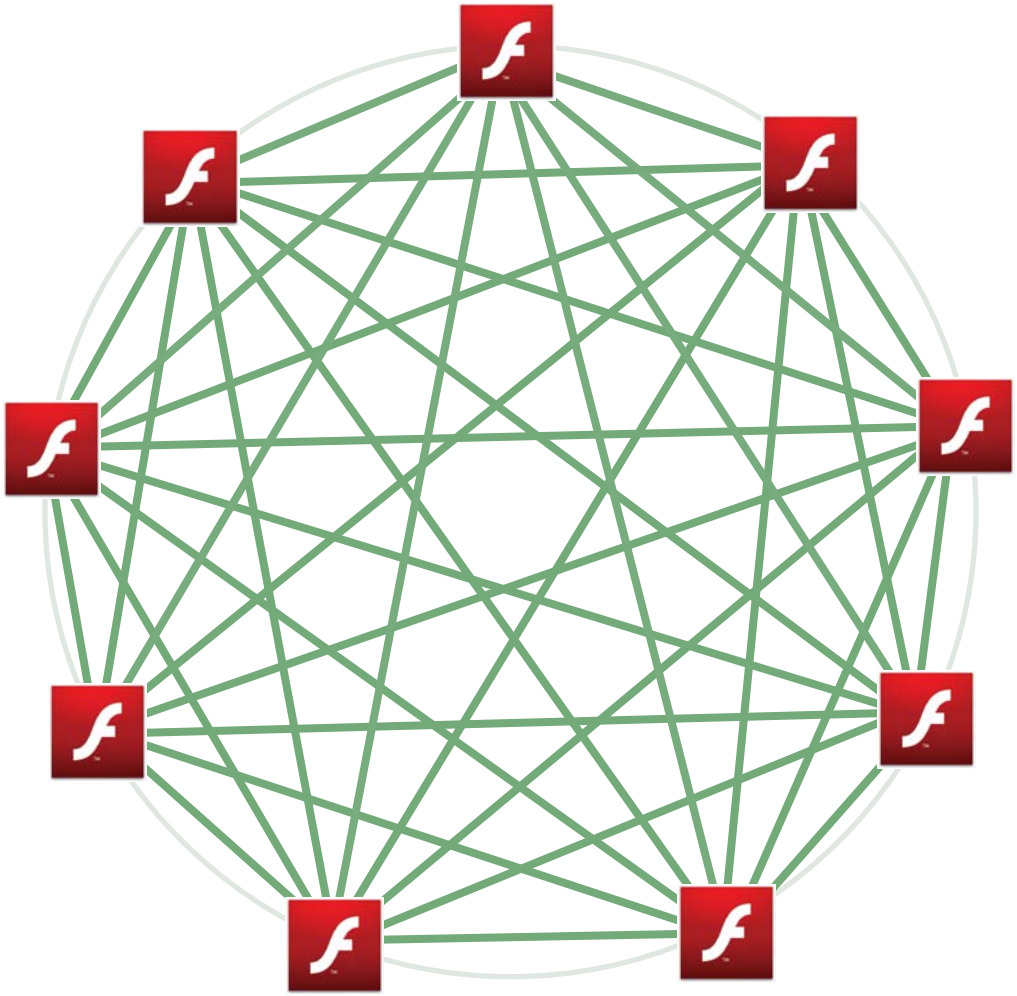
Full Mesh of Peers



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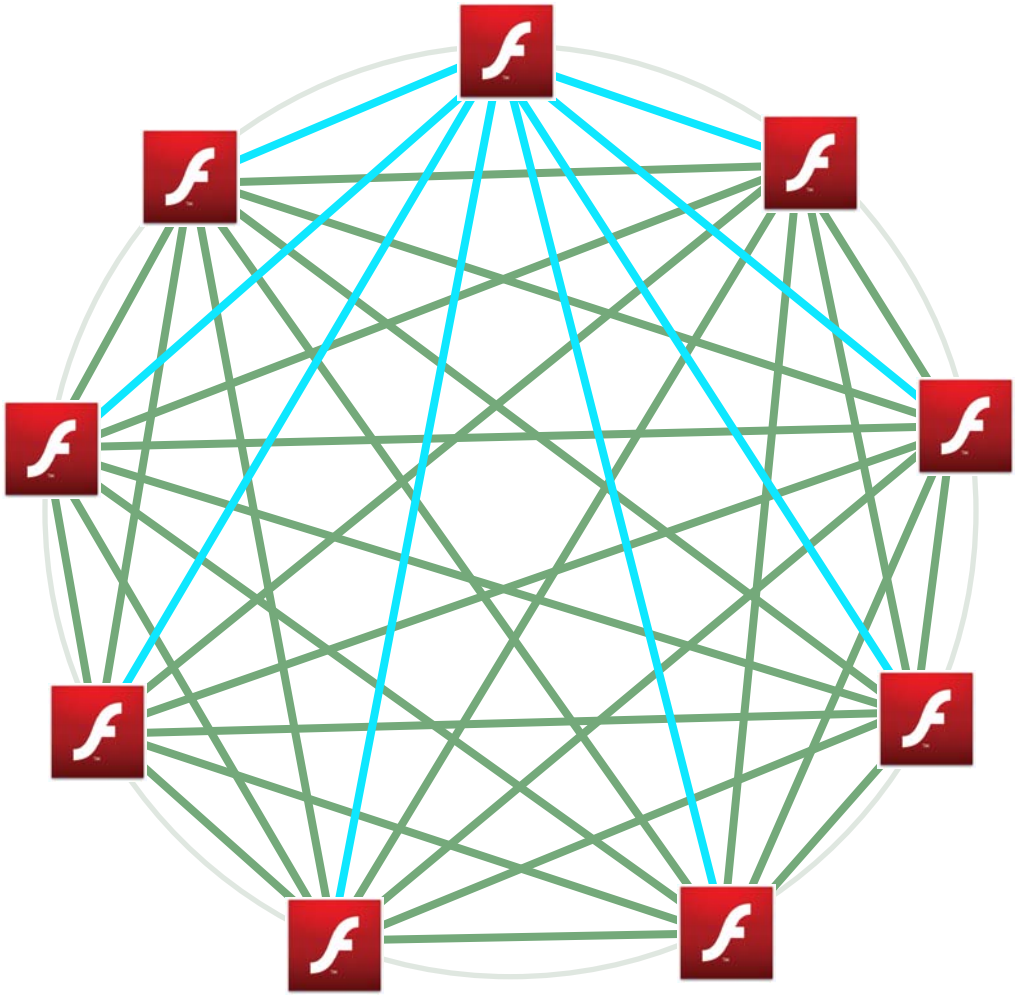

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RTMFP Groups

- Player needs to communicate with *n* peers efficiently
  - *n* might be very large (millions)
  - O(*n*) at each peer (O(n^2) overall) doesn't scale
- Solution: Overlay network
  - Topology optimized for multiple uses

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RTMFP Group Topology

- RTMFP is used as transport
  - NAT/Firewall traversal, Encryption, IP Address Mobility, Congestion Control, Partial Reliability, etc.
- Each peer has O(log *n*) connections
  - Typical: $2 \log_2 n + 13$
- Epidemic theory answers probability of connectedness
  - For $\log_2 n + c$ connections, probability is $e^{-e^{-c}}$
    - So c should be at least 10
- Topology management
  - decoupled from data transport
  - distributed to peers
- Controlled access
  - Ensures joiners have secret (the Groupspec) without exposing secret

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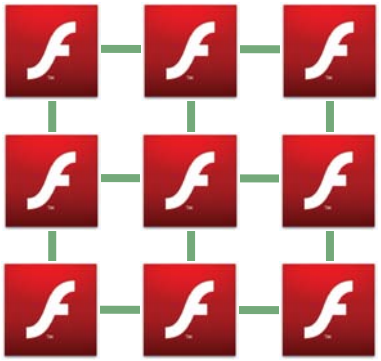
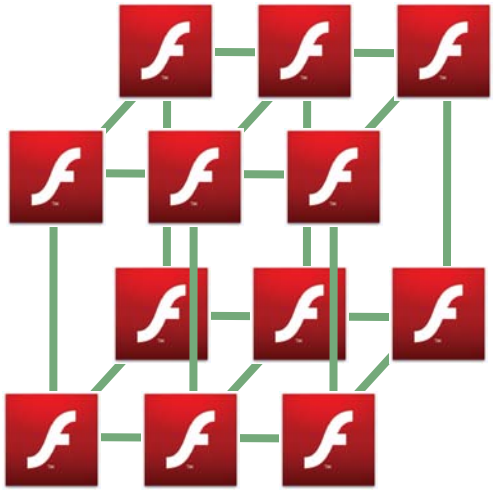
Group Topology





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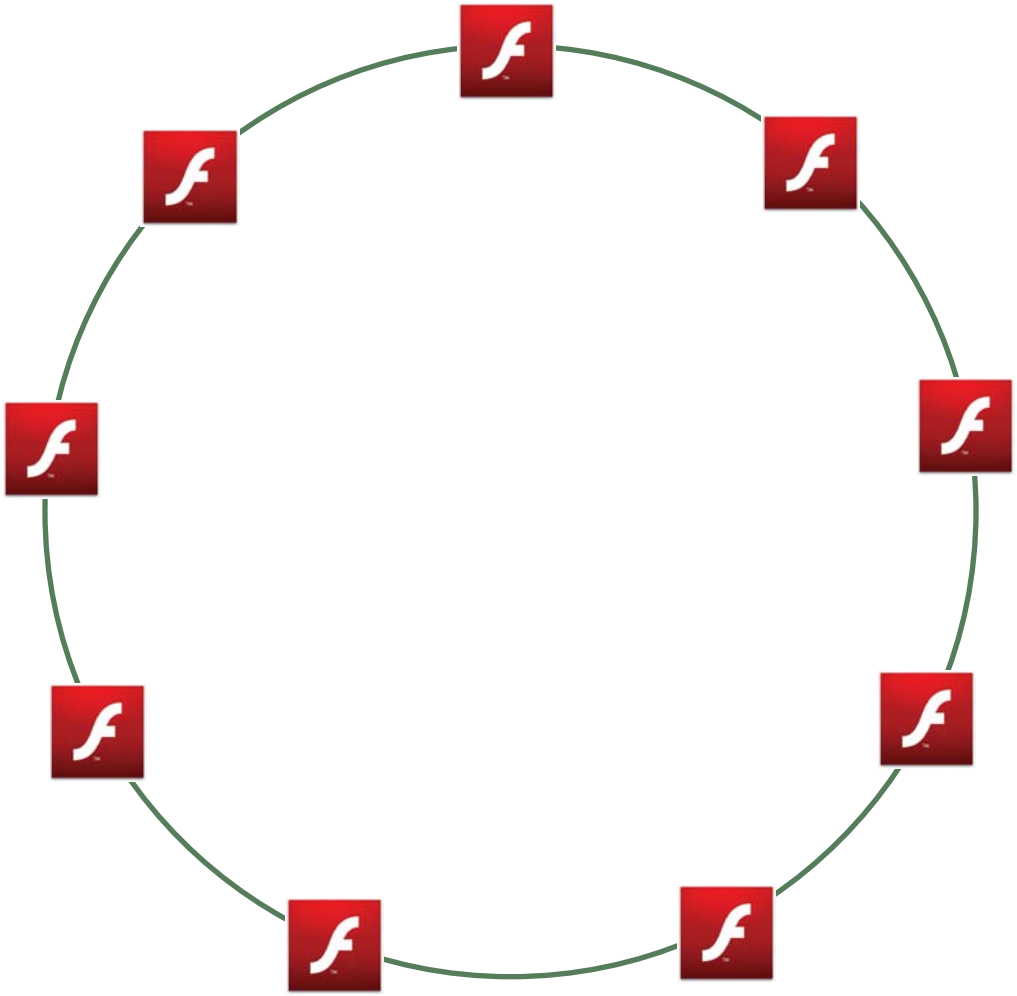

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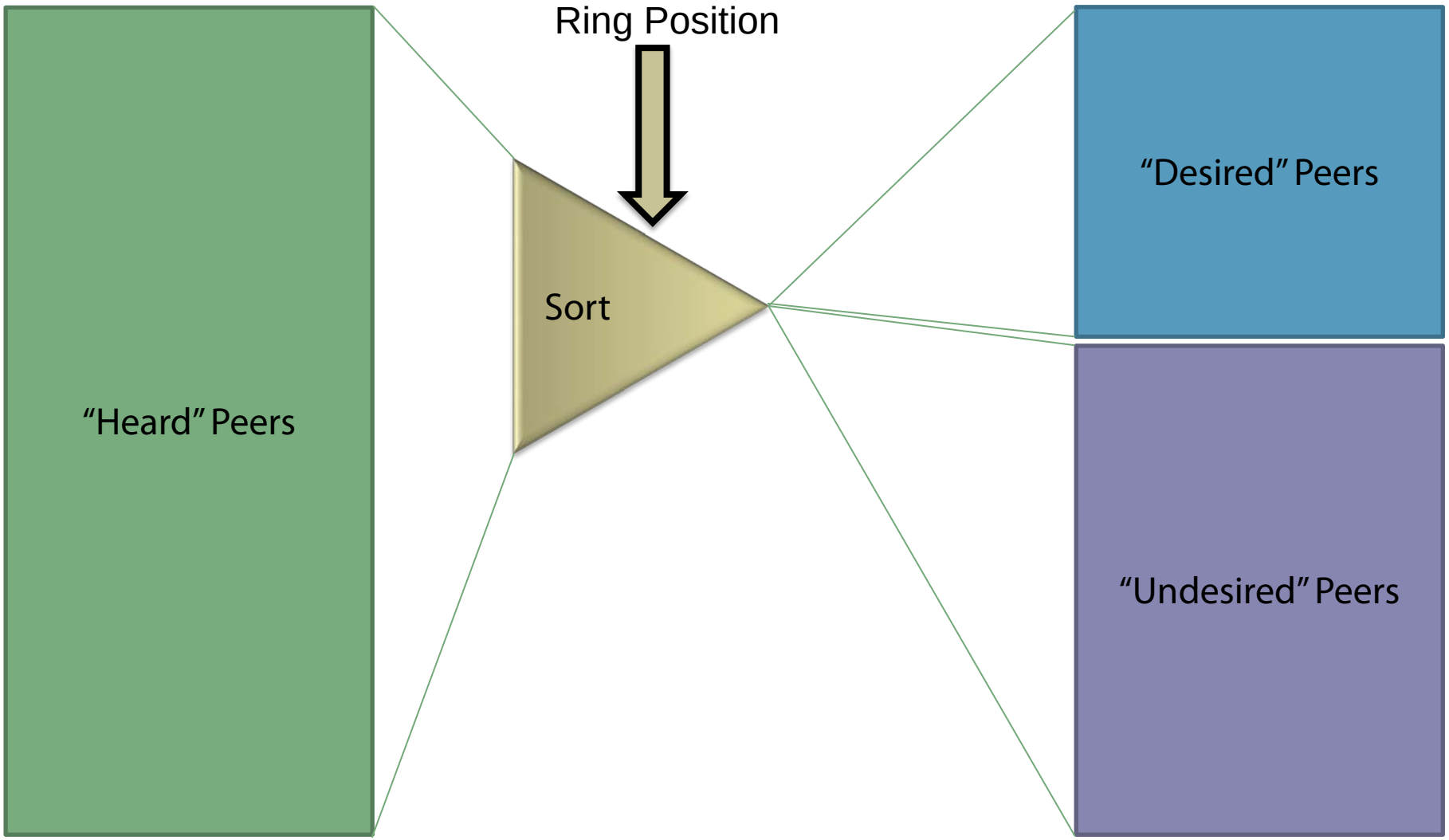
Group Topology Management



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Topology Management Algorithm

- Initialize the “heard list” from one or more bootstrap nodes
- Repeat forever:
  - Sort the “heard list” to find what is best for self making a “best” list
  - Connect (or stay connected) to the nodes on the “best” list
  - Ask connected nodes that are no longer on the “best” list to disconnect
  - If a node asks you to disconnect, do so only if not in your “best” list
  - Every interval, pick one node at random that you are talking to
    - Sort the “heard list” to find what is best for them
    - Send them the result of that sort and ask them to do the same in return (“push-pull”)
  - Every time you hear about new nodes, merge them into the “heard list”
  - Delete nodes from “heard list” if their age limit is exceeded
- Resulting self-organizing topology depends entirely on sorting algorithm
- Continuous optimization through gossip, rate is higher than natural churn

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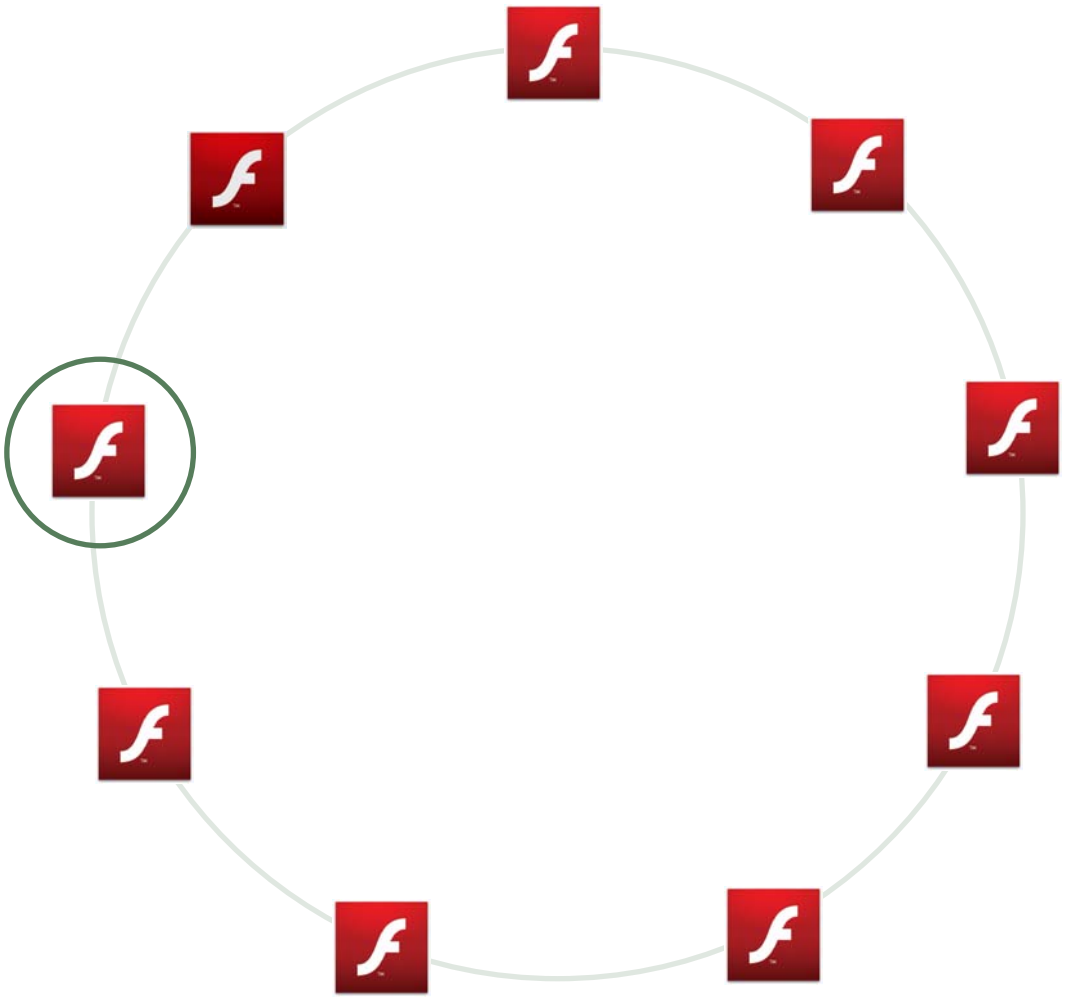
Group Topology Details



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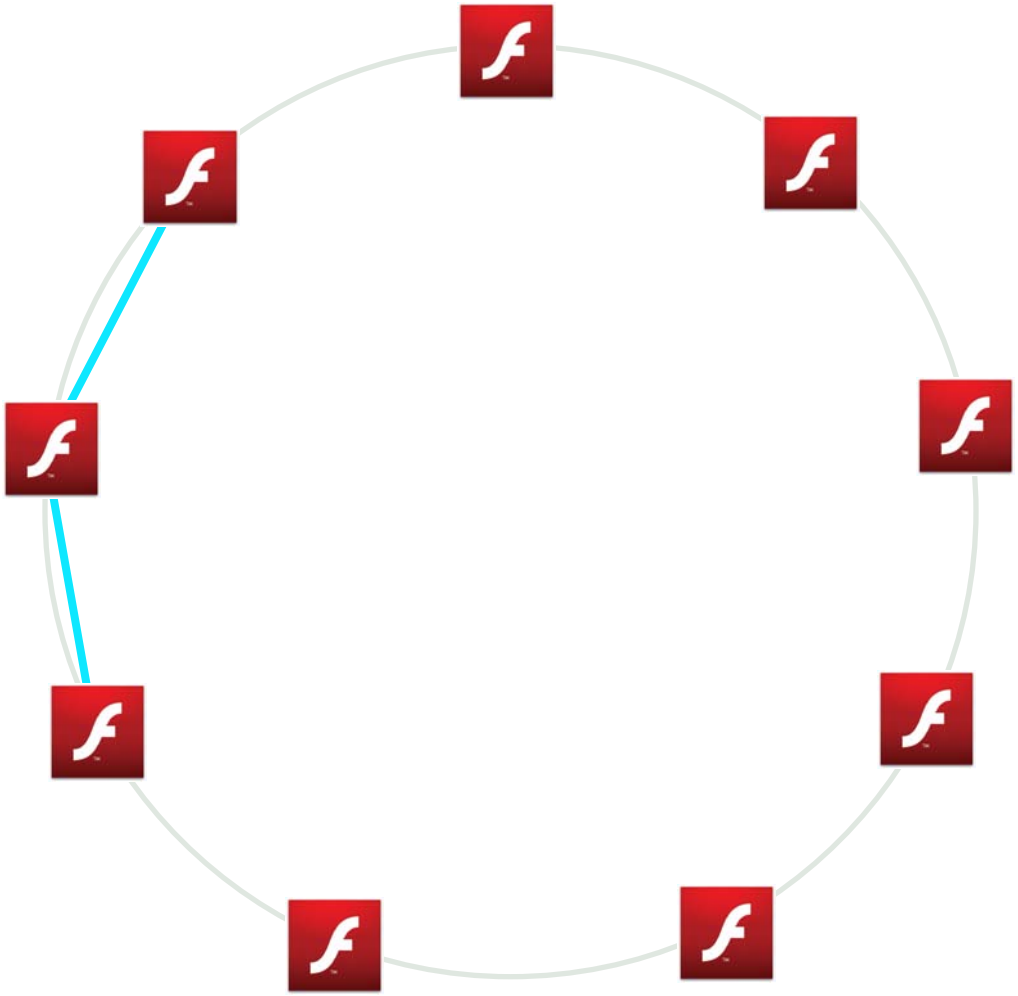

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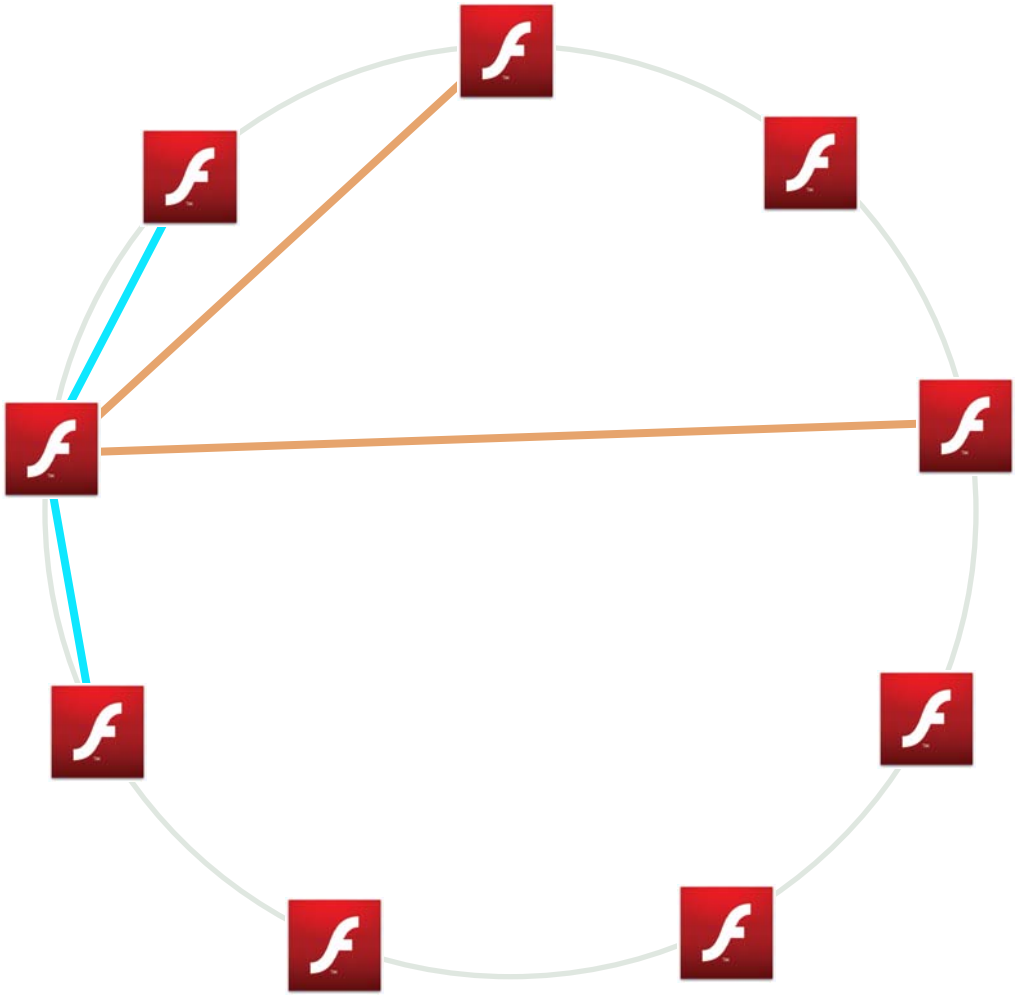

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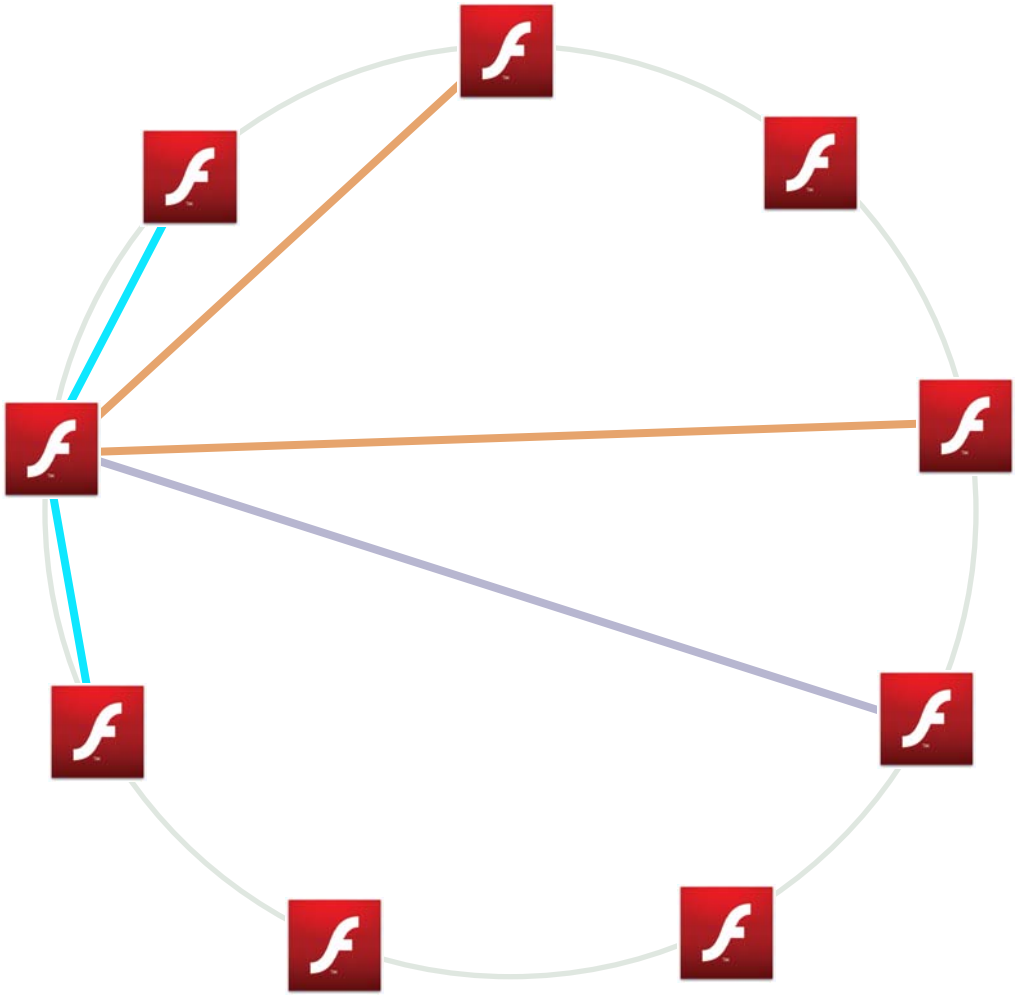

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Topology Management Details

- Nodes have a 256-bit numeric identifier ($0 \ldots 2^{256}-1$)
  - Number of dimensions = 1
- Sort chooses:
  - 6 closest (mod 2^{256}) in numeric space (3 closest on each side)
  - Numeric location + 1/2, 1/4, 1/8, 1/16, …
  - 6 nodes with lowest latency
  - 1 random node (per round)
- Results in a fully-connected ring, plus:
  - Redundant neighbor connections
  - Shortcuts across the ring to reduce average hop count to less than $\log_2 n$
  - Additional nodes that are nearby (based on measured latency)
  - Random nodes sufficient to continue optimizing

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Describing Groups in Flash Player

- Groupspec
  - String starting with “G:” (e.g., “G:01010b…..”)
    - First part becomes the immutable “identity” of the Group
      - Certain options (permissions) must be in this part
      - If a peer tries to change, they are in a Group, but not this one
    - Note: Case-sensitive
- GroupSpecifier class makes them

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GroupSpecifier Class

- Properties
  - `routingEnabled`
  - `multicastEnabled`
  - `objectReplicationEnabled`
  - `postingEnabled`
  - `peerToPeerDisabled`
  - `ipMulticastMemberUpdatesEnabled`
  - `serverChannelEnabled`
- Methods
  - `GroupSpecifier(name:String)`
  - `makeUnique()`
  - `setPublishPassword()`
  - `setPostingPassword()`
  - `addBootstrapPeer()`
  - `addIPMulticastAddress()`
- Getting the Groupspec
  - `groupspecWithAuthorizations()`
  - `groupspecWithoutAuthoriziations()`

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Describing Self within Group

- Ring Position
  - 256-bit numeric identifier
  - Formed from PeerID

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Accessing Groups from ActionScript

- NetGroup
  - Management and statistics
  - All Group functionality except Multicast
- NetStream
  - Multicast
- More than one object can refer to the same Group
  - As long as in same NetConnection, overhead is shared

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NetGroup Functionality

- Properties
  - `estimatedMemberCount`
  - `neighborCount`
  - `info`
    - `NetGroupInfo` properties
- Methods
  - `addNeighbor`
  - `addMemberHint`
  - `close`
- NetStatusEvents
  - `NetGroup.Neighbor.Connect`
  - `NetGroup.Neighbor.Disconnect`

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Using Groups

- Connect
  - Peer-Assisted Networking dialog will be displayed
    - When NetStream or NetGroup is constructed
    - Unless user remembers “allow” for your domain,
    - or `peerToPeerDisabled` is set in GroupSpecifier
- Use
  - Directed Routing
  - Object Replication
  - Posting
  - Multicast
    - Fusion

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Directed Routing

- Requires stable and correct topology to work well
- Works with ring positions
- API
  - `receiveMode`
    - `NetGroupReceiveMode.EXACT` (Initialized in this mode)
    - `NetGroupReceiveMode.NEAREST`
  - `sendToNearest`
  - `sendToNeighbor`
    - `NetGroupSendMode.NEXT_INCREASING, NetGroupSendMode.NEXT_DECREASING`
  - `sendToAllNeighbors`
- At each hop, arrives in ActionScript as event
  - `NetGroup.SendTo.Notify`

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Directed Routing

- Each hop can
  - Forward, Modify, Reply, or Discard
- Use cases:
  - Replying to specific node
  - Distributed Hash Table database
  - Research projects

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Object Replication

- Objects are addressed by numeric Index
- ActionScript provides backing store
  - Easier to use files from AIR
- API
  - `addHaveObjects / removeHaveObjects`
  - `addWantObjects / removeWantObjects`
  - `writeRequestedObject / denyRequestedObject`
  - `NetGroup.Replication.Fetch.Result`
  - `NetGroup.Replication.Request`
- Use cases:
  - Workspace replication
  - Whiteboard
  - File transfer
  - …

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Object Replication

- One Object ID space per group
- Fully reliable delivery
  - All other RTMFP Groups data transports are best-effort
- Hints for moving around large amounts of data:
  - Break up into reasonable-sized objects (64k)
  - Consider using block 0 as descriptive object block
  - Consider making Group “name” be related to hash of descriptive object block

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Posting

- Per-sender state (efficiency) tradeoff
  - Multicast is for a small # of senders @ high data rates
  - Posting is for a large # of senders @ low data rates
- API
  - `post()`
  - `NetGroup.Posting.Notify`
- Hints:
  - Messages must be unique to be considered new
    - Add a serial number
  - Keep messages small and relatively infrequent per sender
- Works without ActionScript involvement (unlike previous two modes)
- Use cases:
  - Text chat, sensor reporting, opinion polls

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Multicast

- Uses NetStream API
  - Construct with Groupspec instead of PeerID
- Designed for low latency
- Again, works without ActionScript involvement

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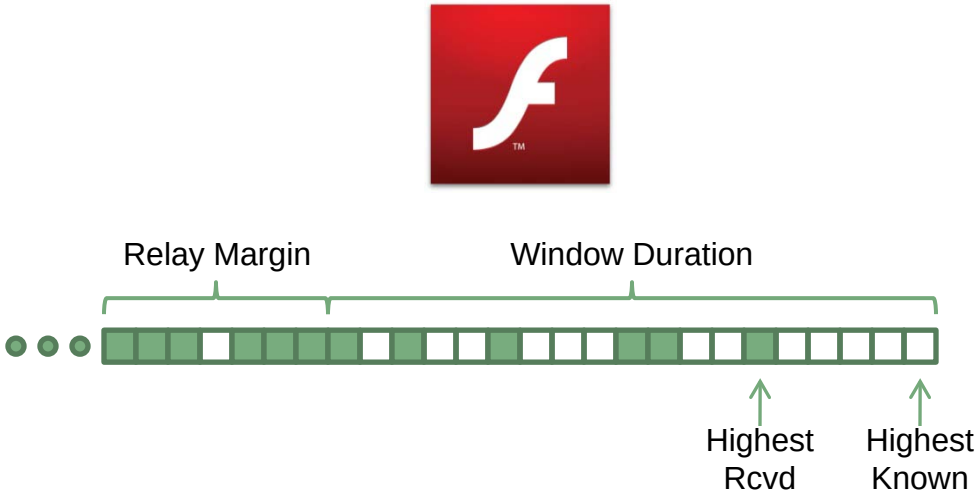
Multicast



- Multicast system attempts to get every block in the Window Duration
  - Once all blocks arrive for a message, message is processed
  - If any block of a message falls outside the Window, system no longer attempts to get any other block of that message
- Relay Margin provides extra time for in-flight requests to be fulfilled
- Both are in terms of time

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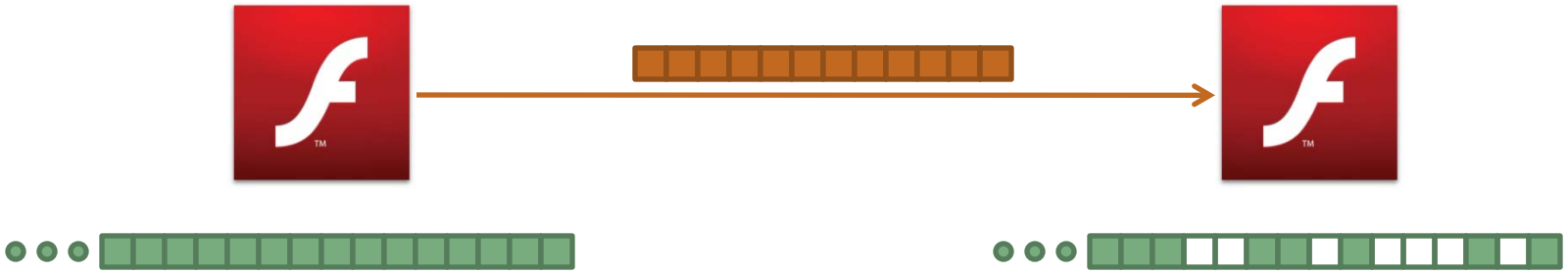
Multicast – Pull



- Send map of what blocks you have to one (or all) neighbor(s)
  - Neighbor waits a short time to see who can source each block

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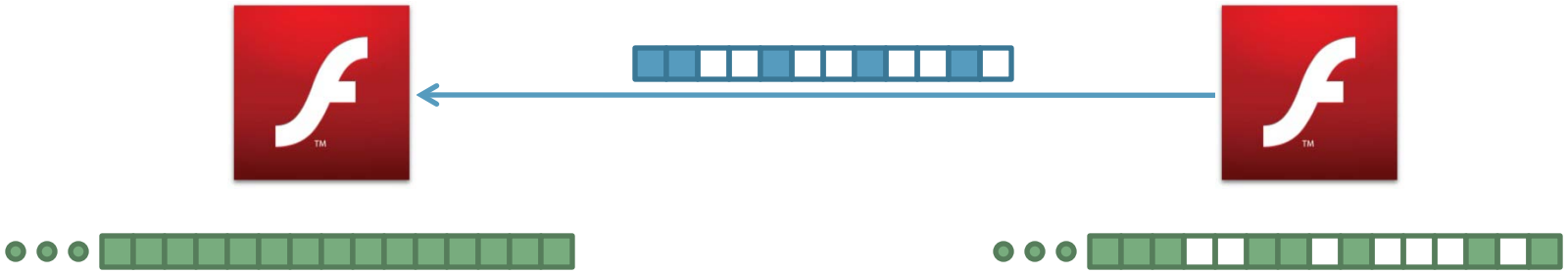
Multicast – Pull



- Send map of what blocks you have to one (or all) neighbor(s)
  - Neighbor waits a short time to see who can source each block
- Neighbor picks you to send some of the blocks and sends request

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Multicast – Pull

- Send map of what blocks you have to one (or all) neighbor(s)
  - Neighbor waits a short time to see who can source each block
- Neighbor picks you to send some of the blocks and sends request
- Send requested blocks to neighbor
  - All transmissions are partially-reliable
  - Neighbor will ask someone else if request goes unfulfilled

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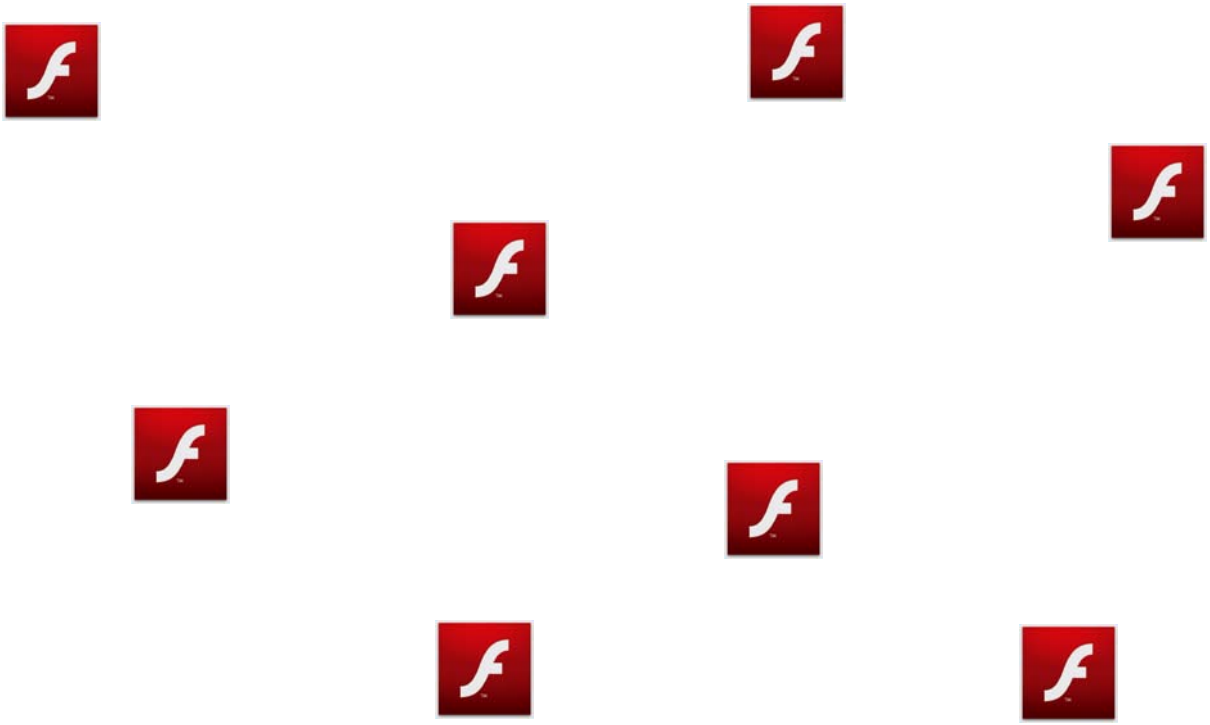
Multicast – Pull



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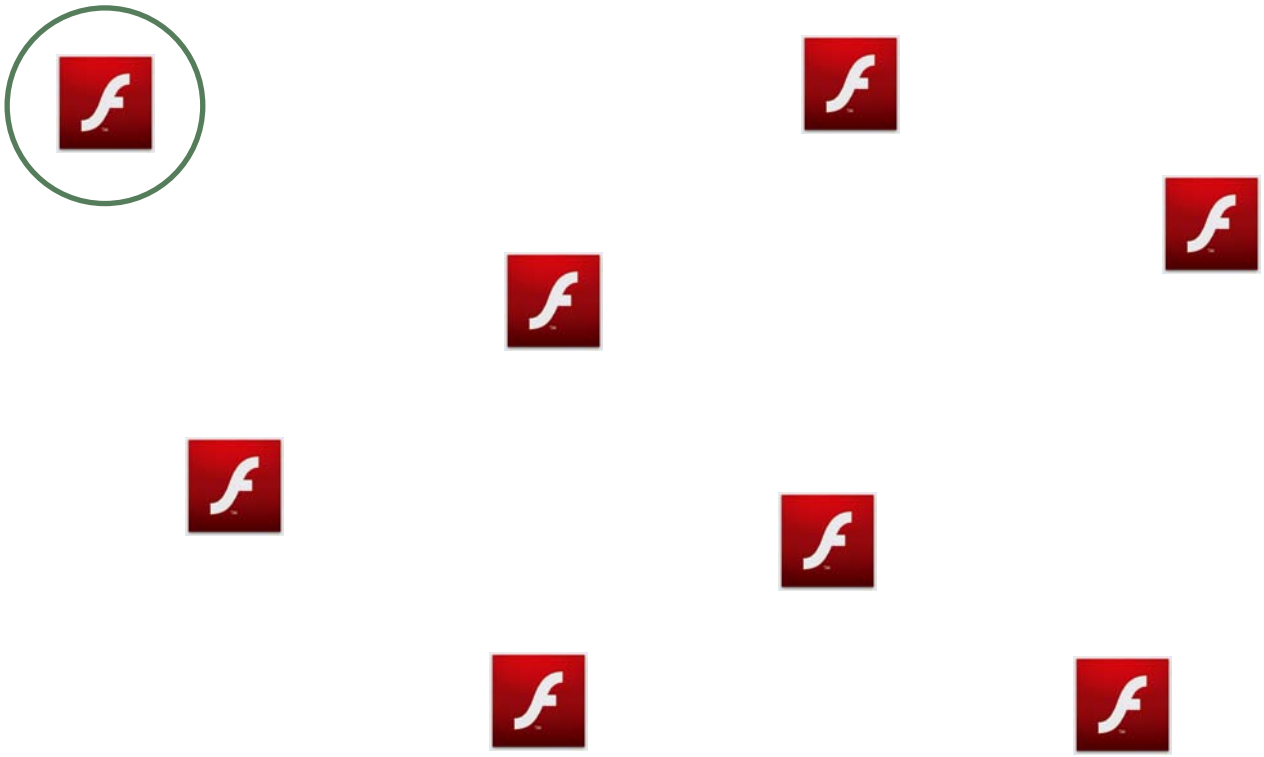
Multicast – Pull



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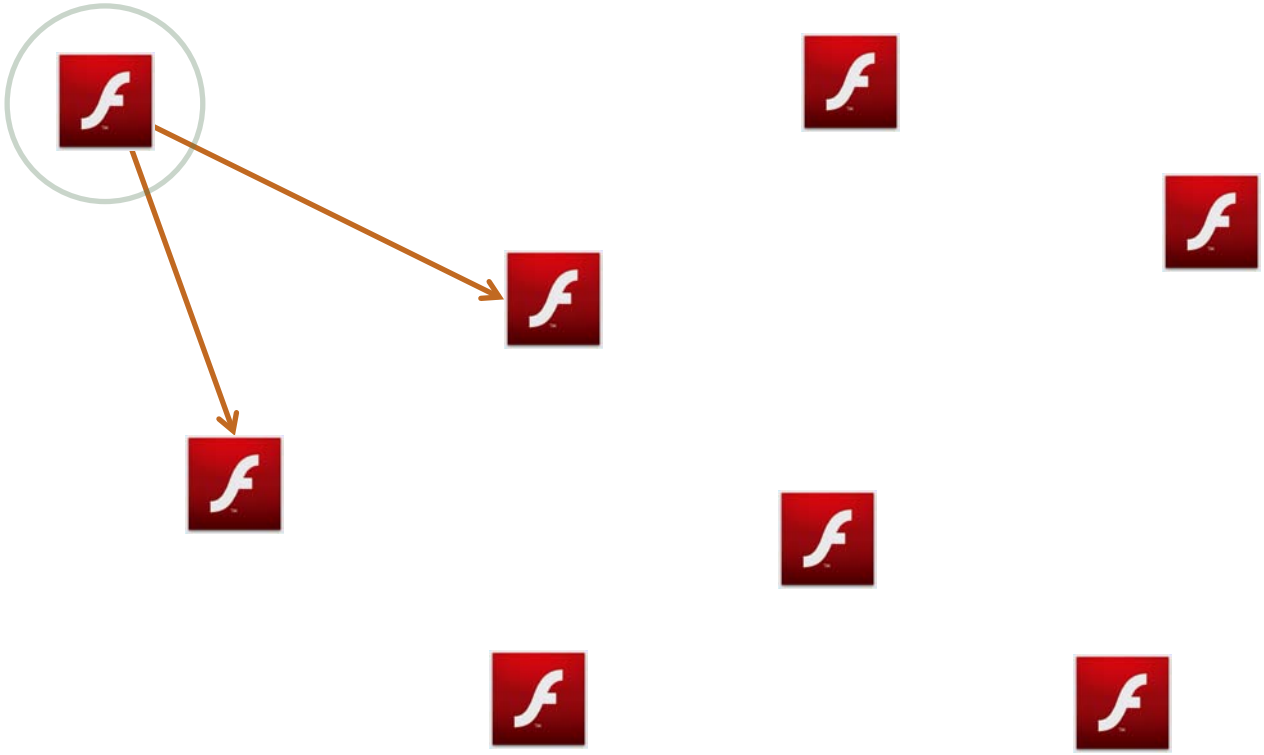

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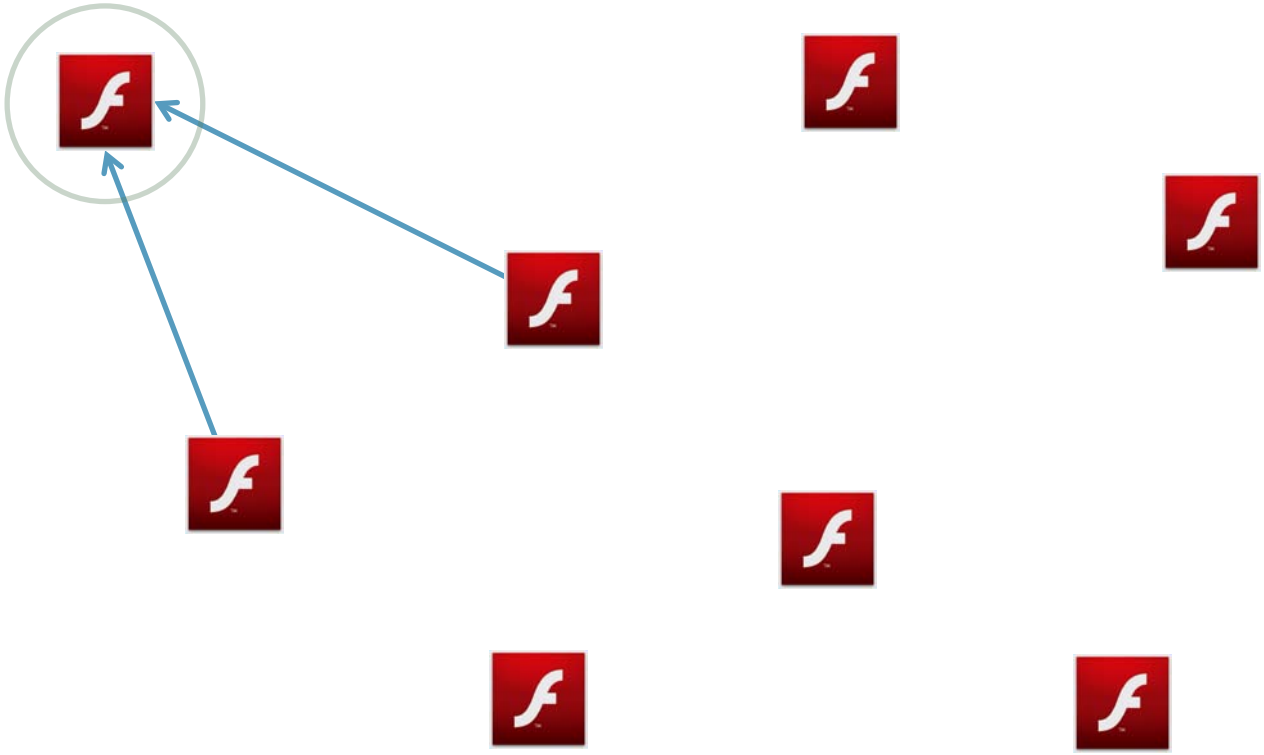

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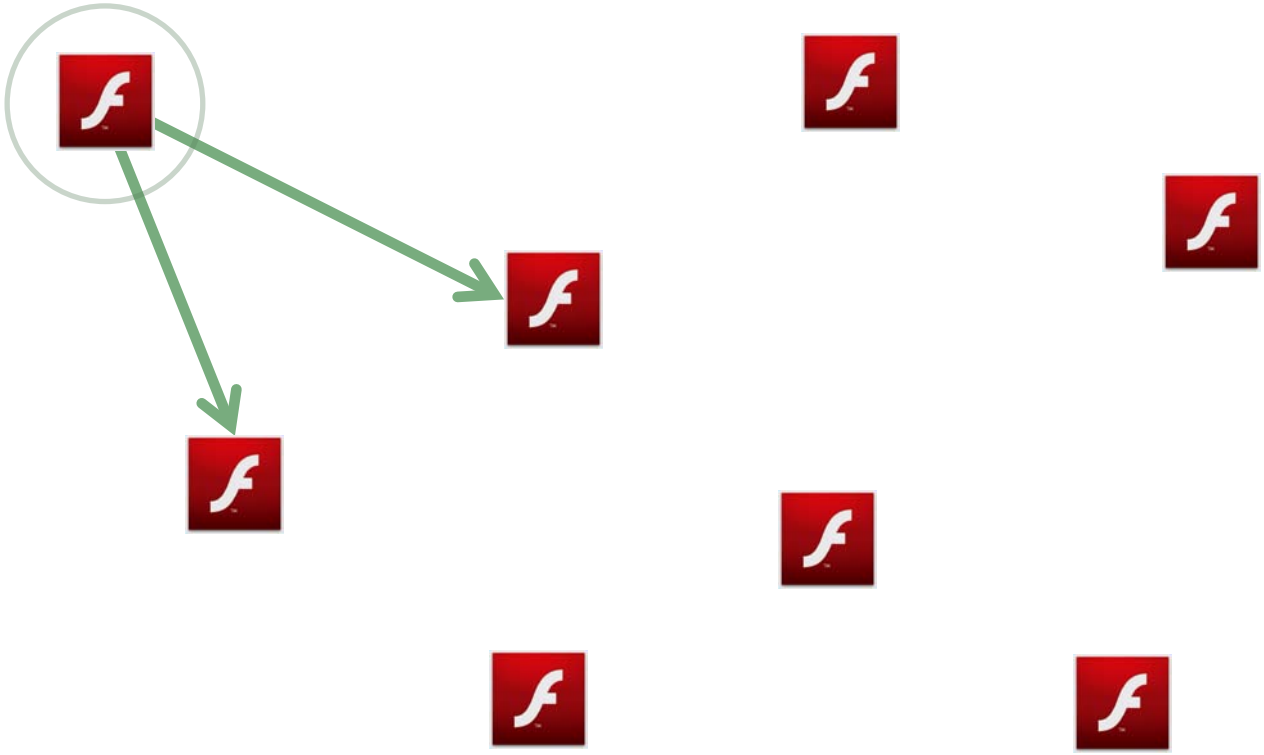

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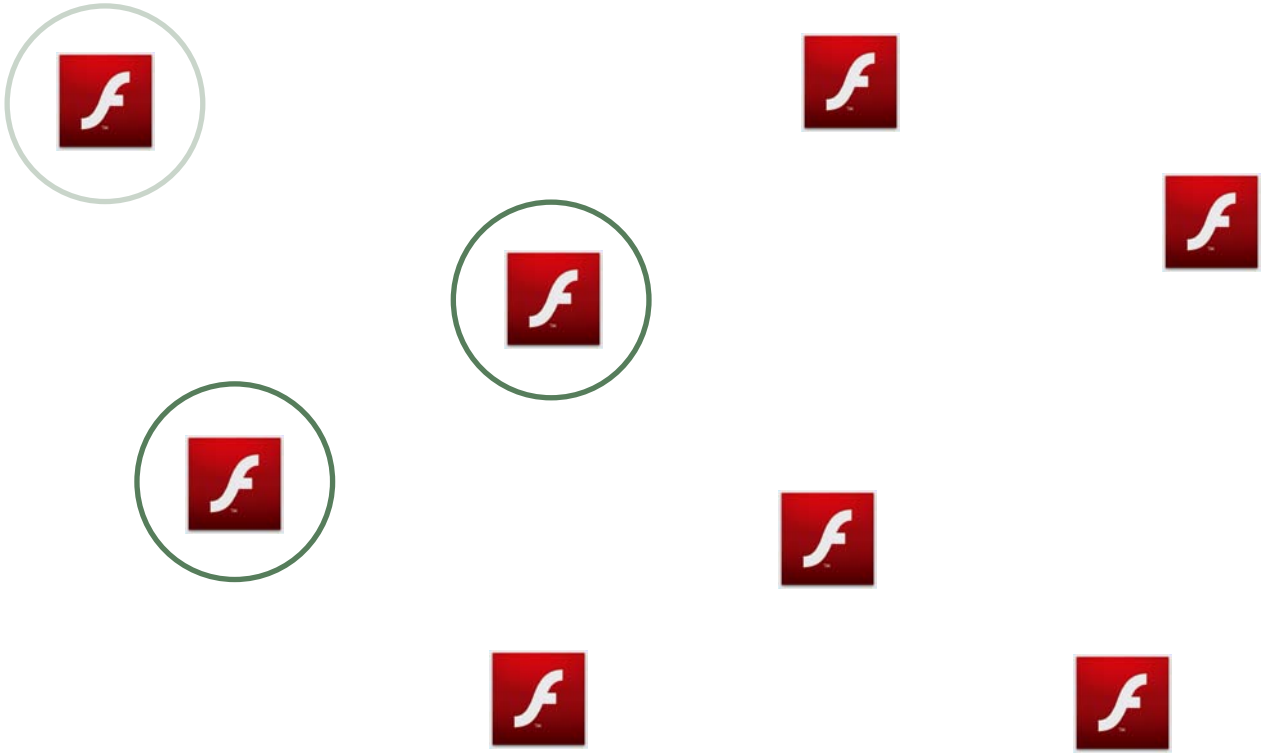

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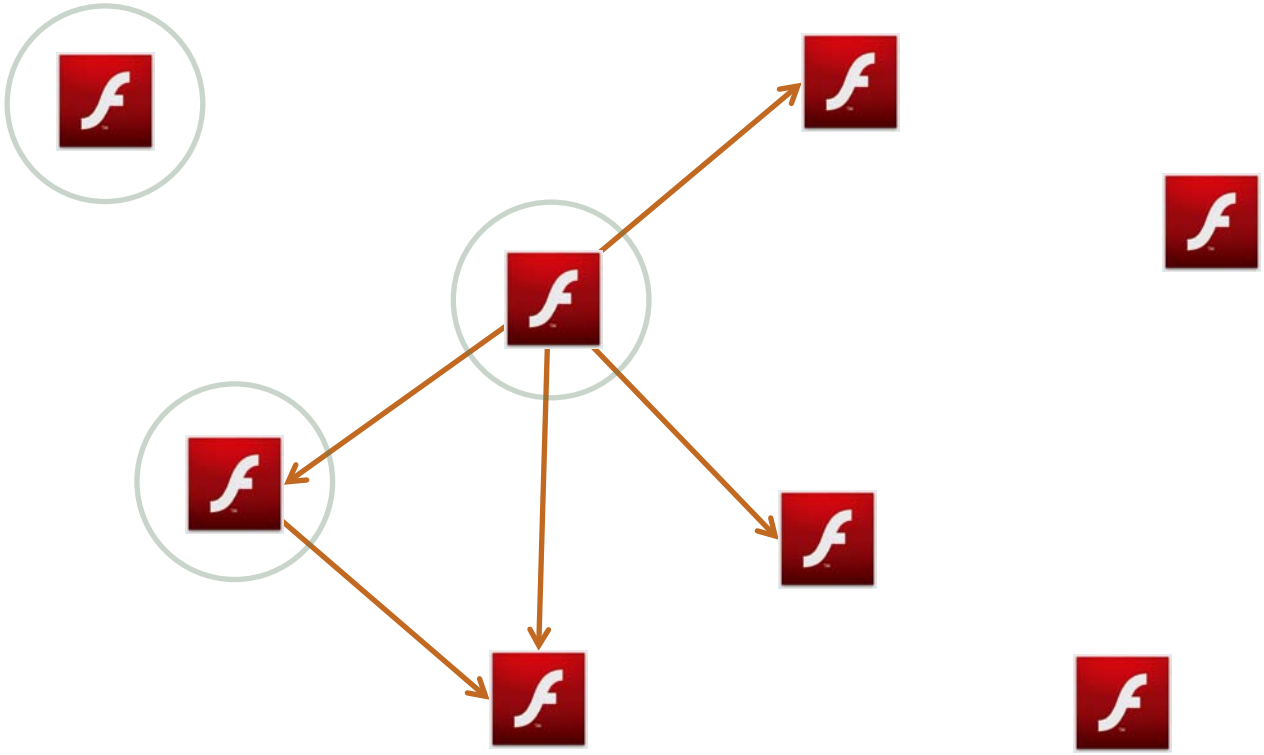

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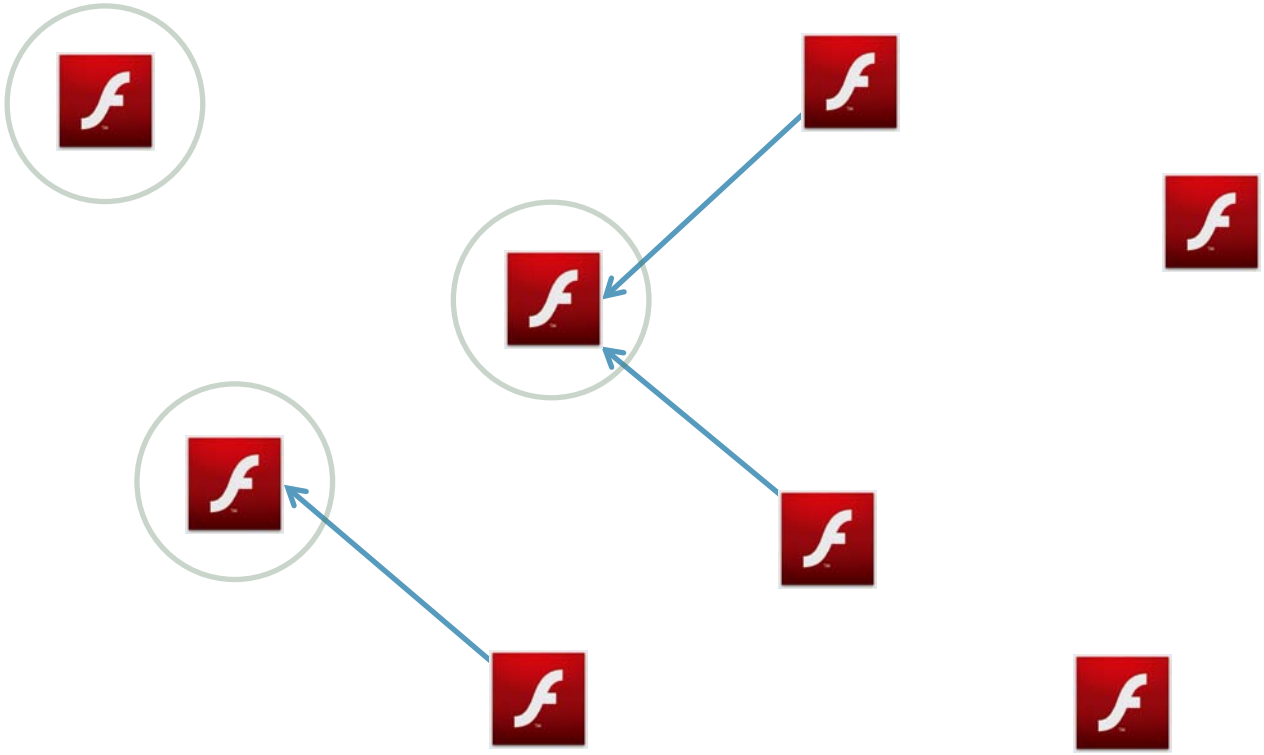

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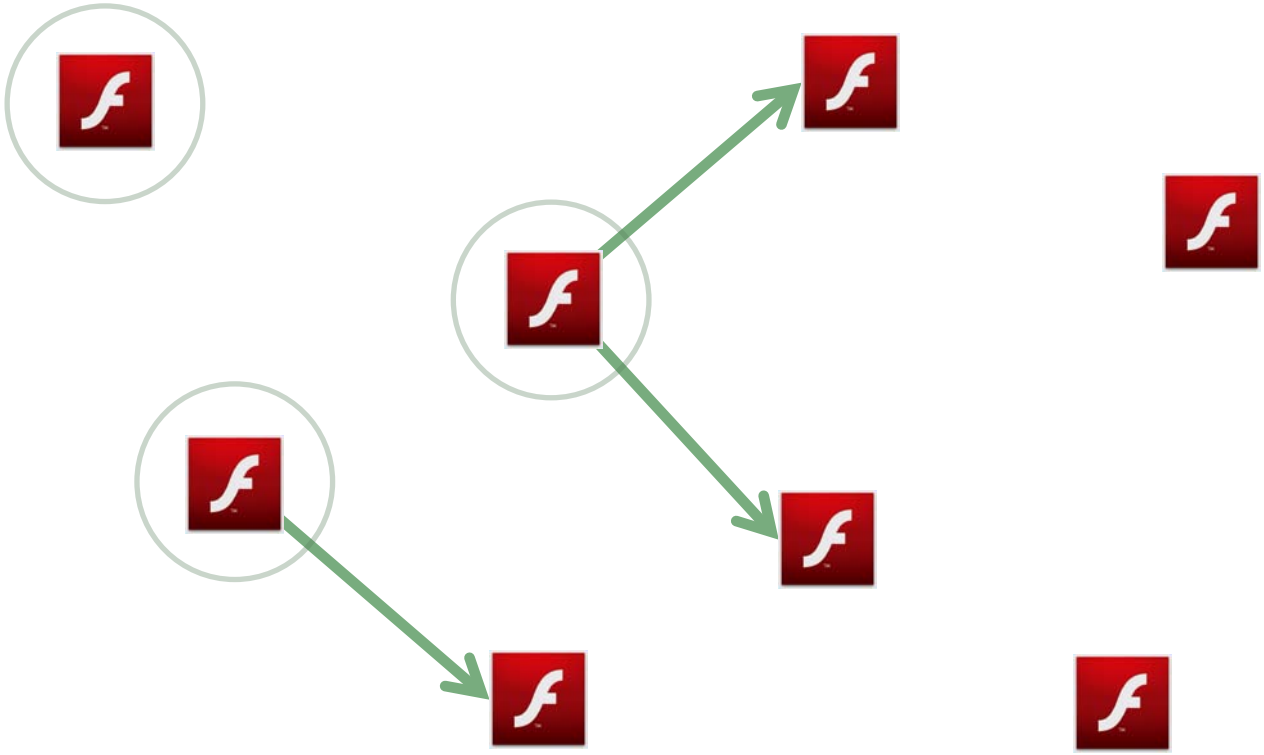

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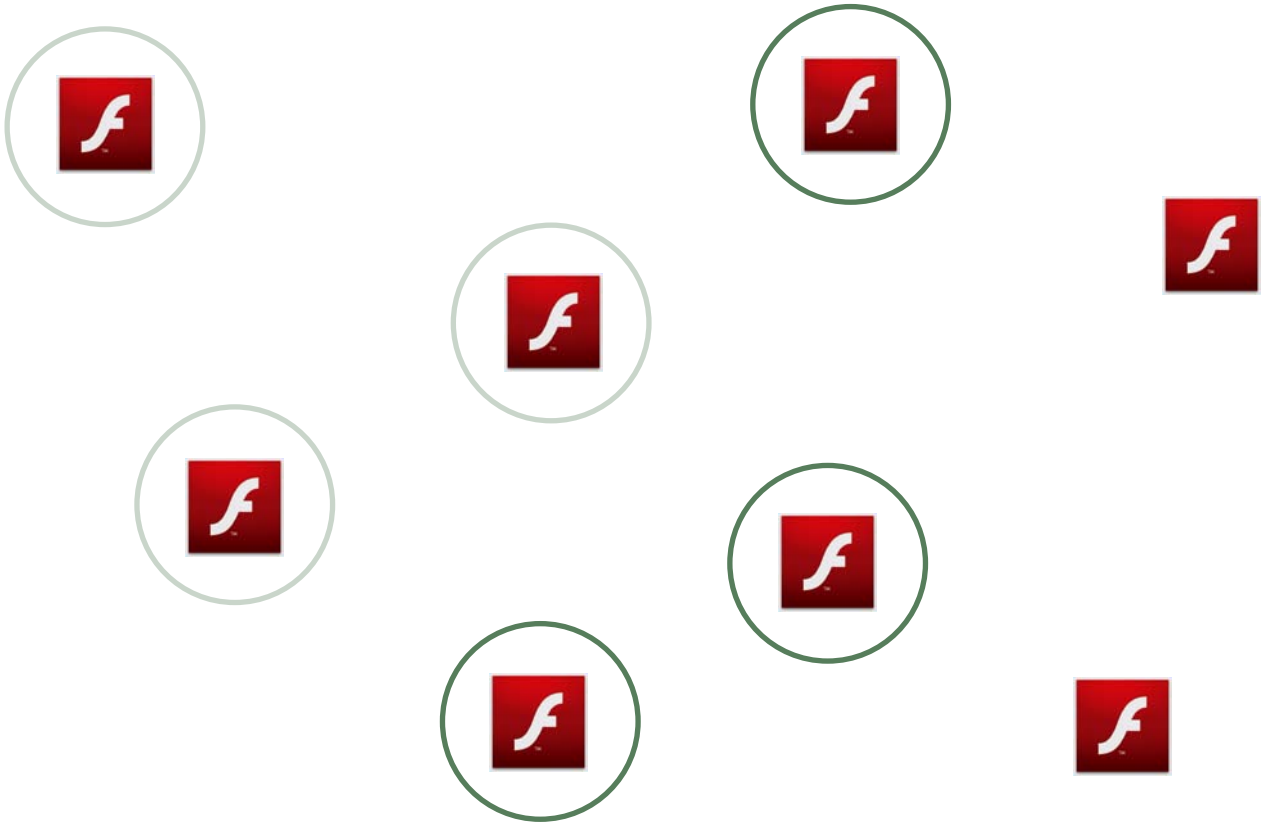

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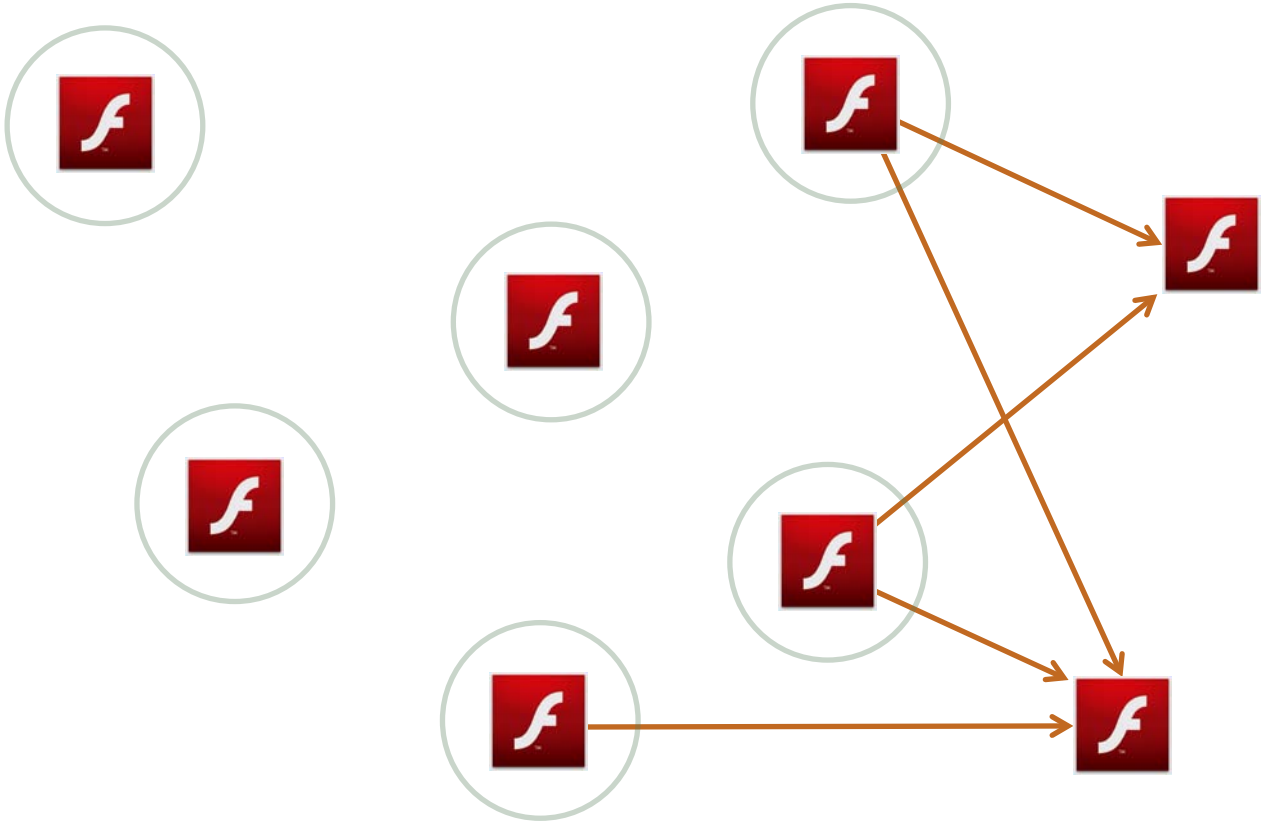

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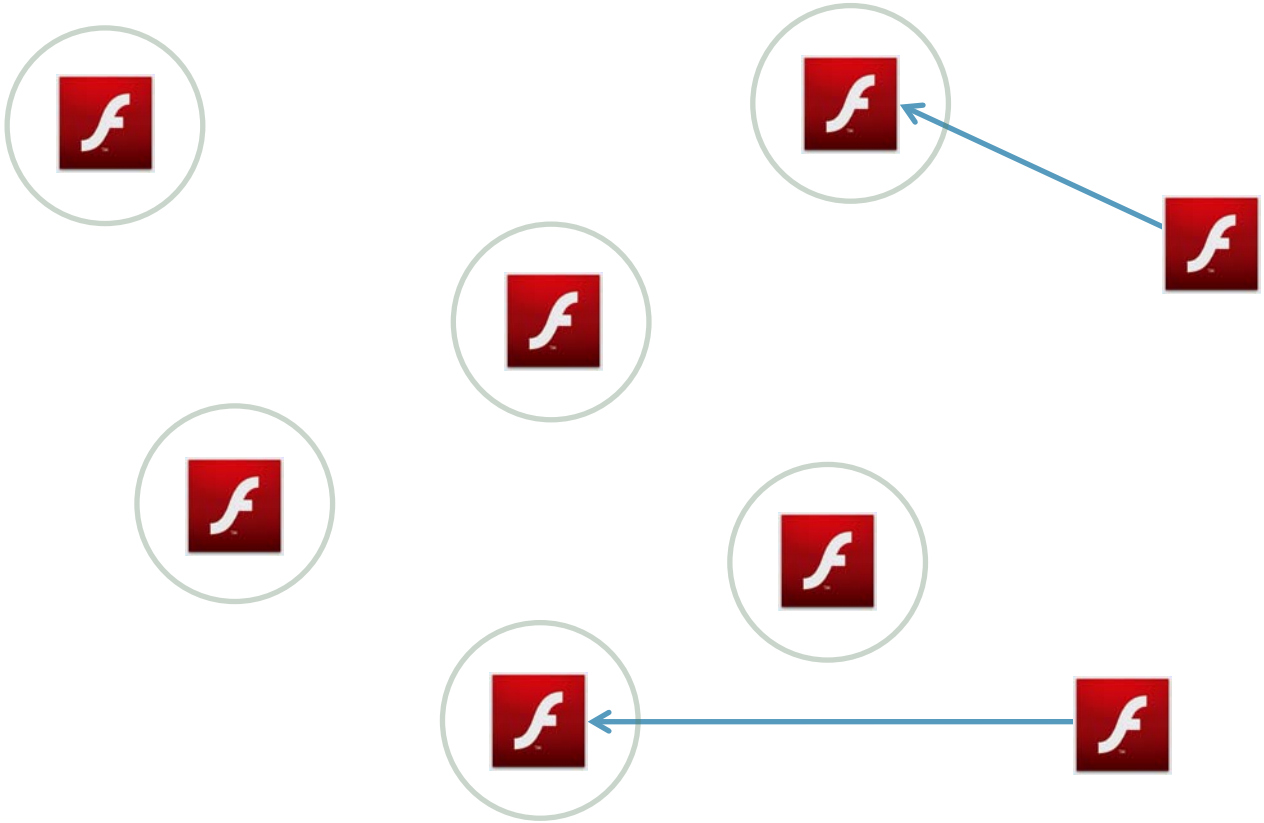

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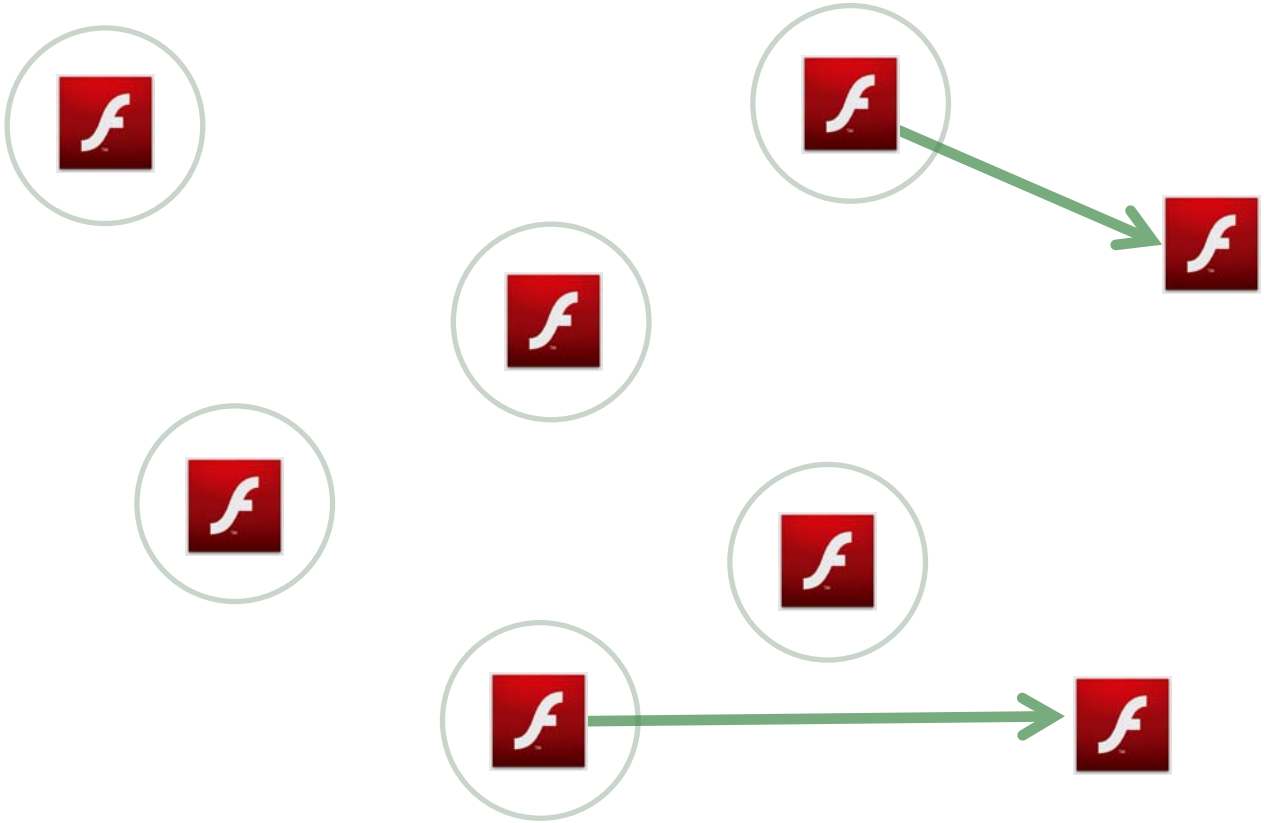

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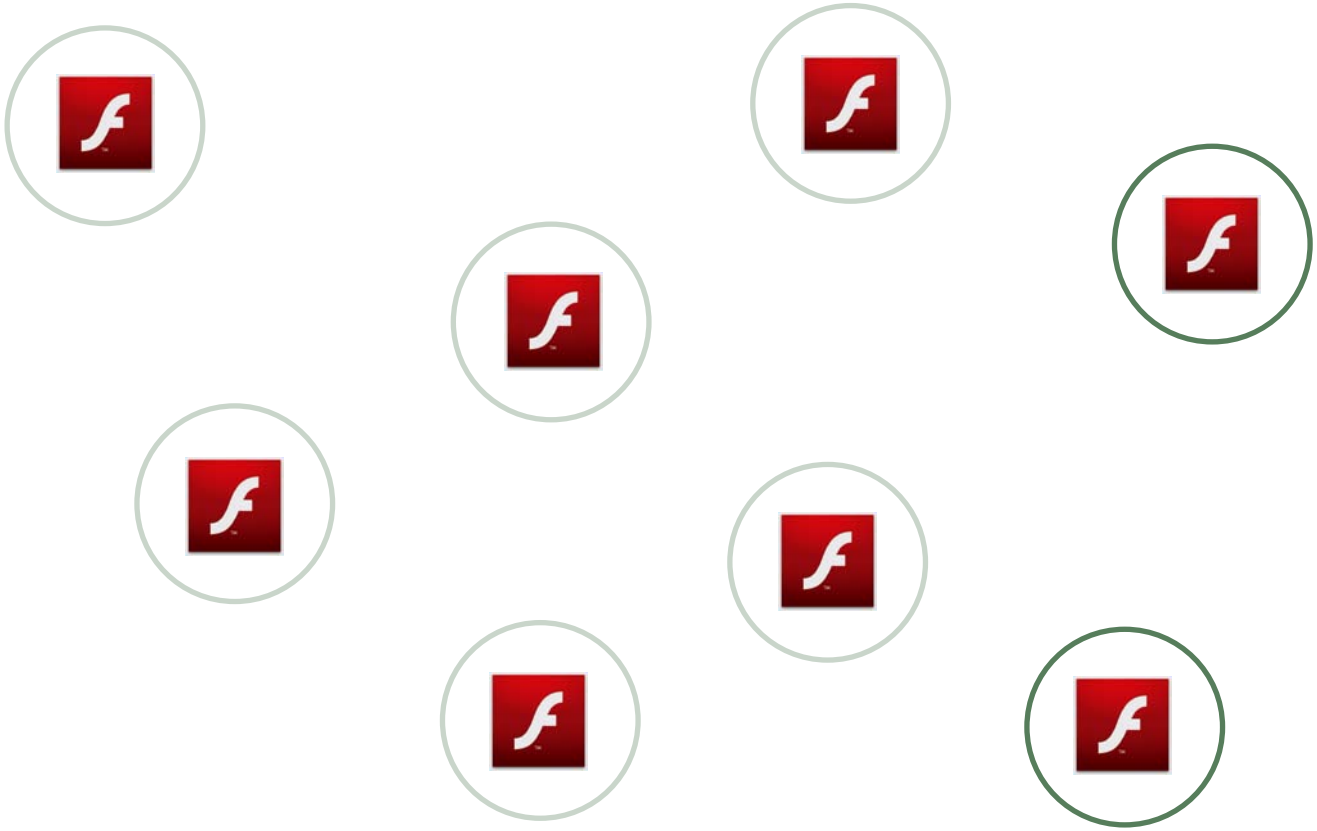

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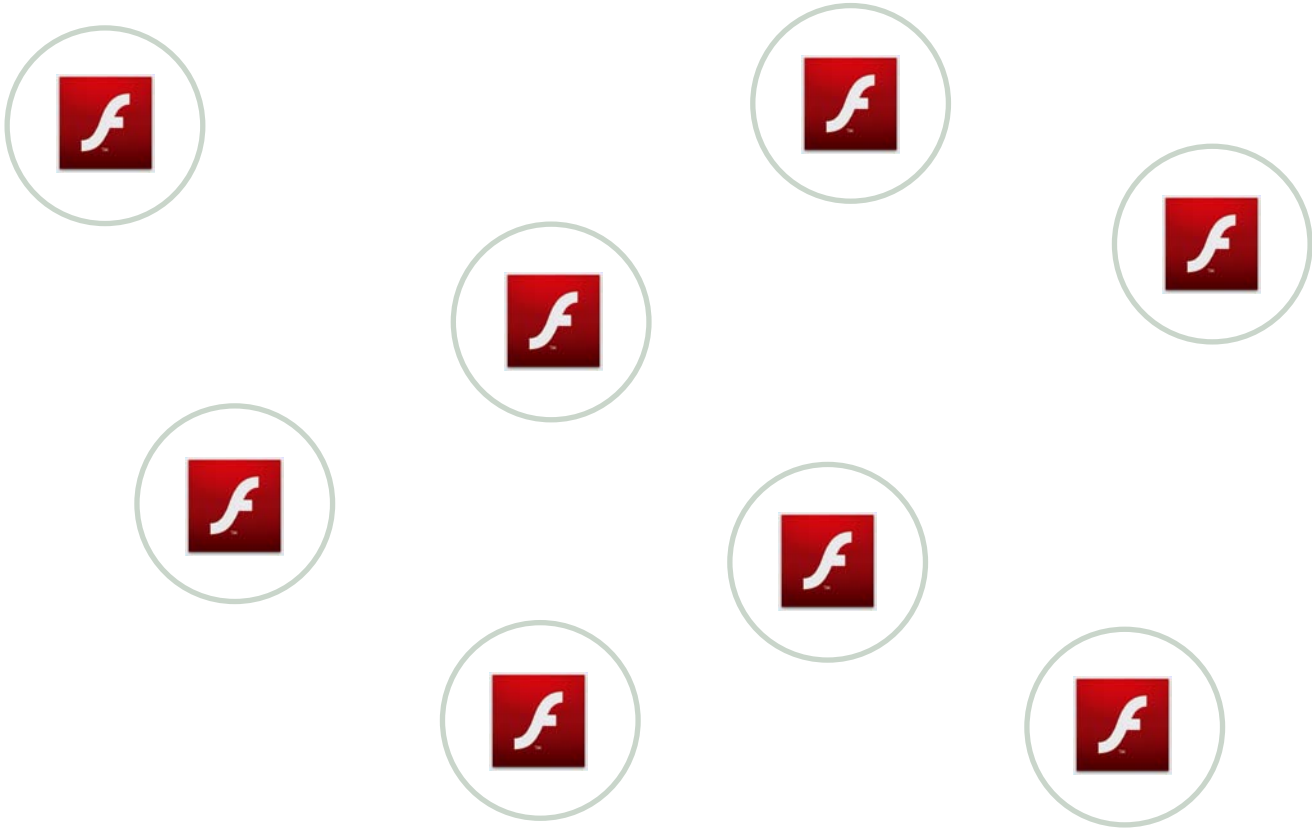

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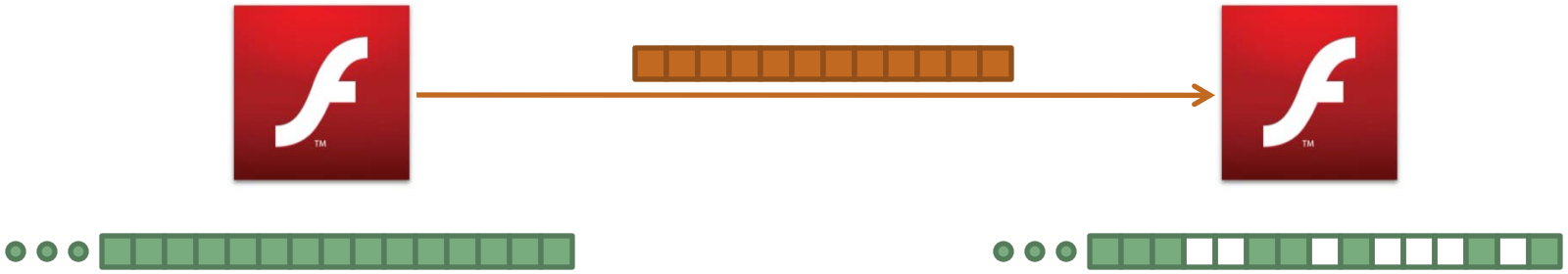
Multicast – Push



- Send map of what blocks you have to one (or all) neighbor(s)
  - Neighbor notices that data is flowing

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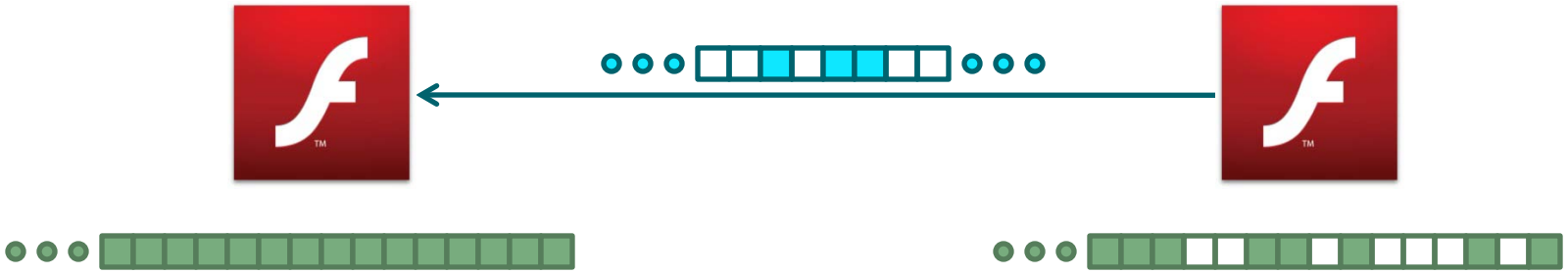
Multicast – Push



- Neighbor picks candidate sources for each sequence number slice
- Neighbor sends mask describing which sequence numbers to push
  - Modulo size of mask (in above example every 3rd, 5th, and 6th)
  - Periodically tests other neighbors to check for lower latency
  - For each sequence number slice, keeps just quickest source

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Multicast – Push

- Data is pushed immediately as it arrives for requested slices
- For each slice, there is a limit to the number of push clients served

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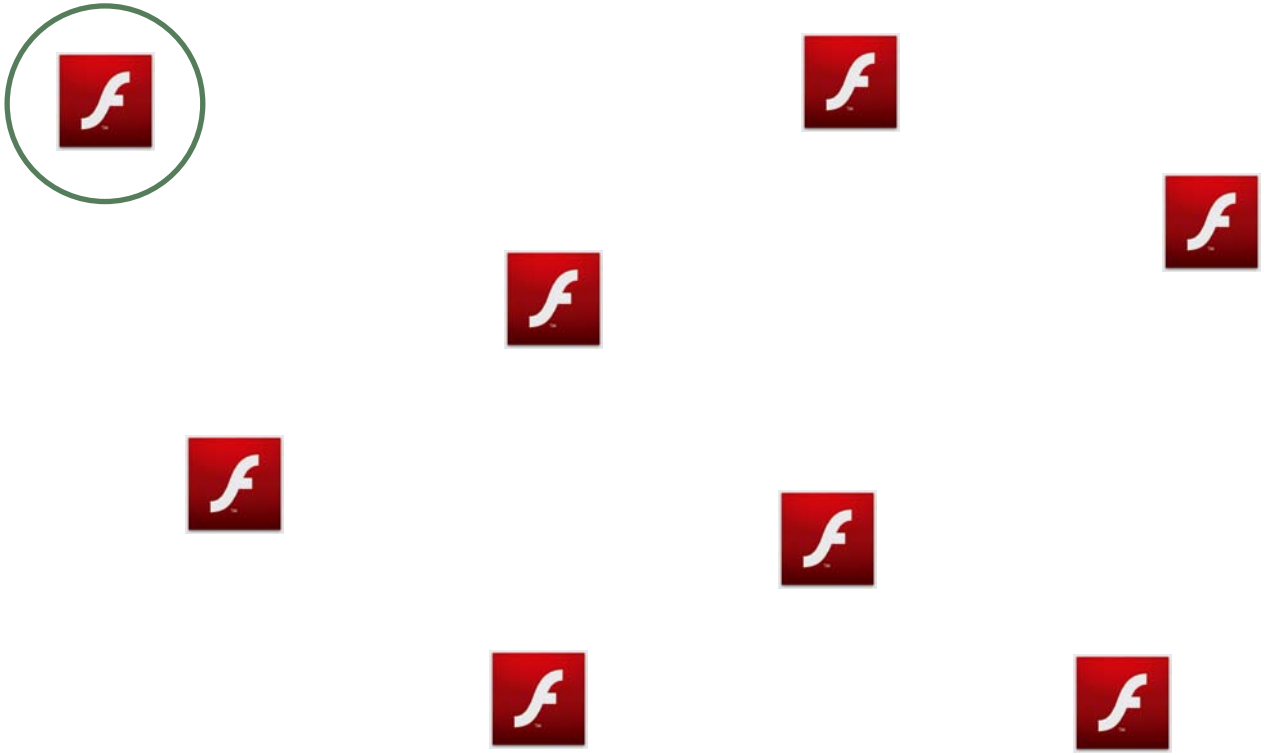
Multicast – Push



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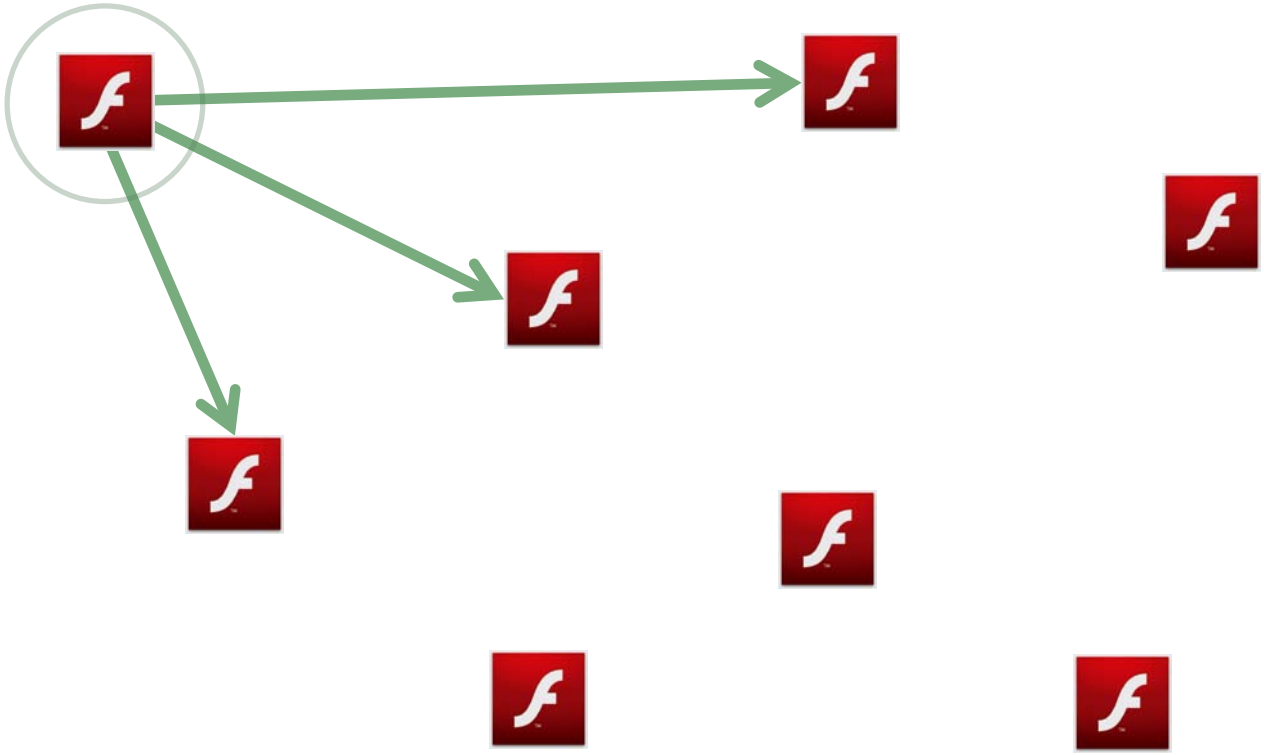
Multicast – Push



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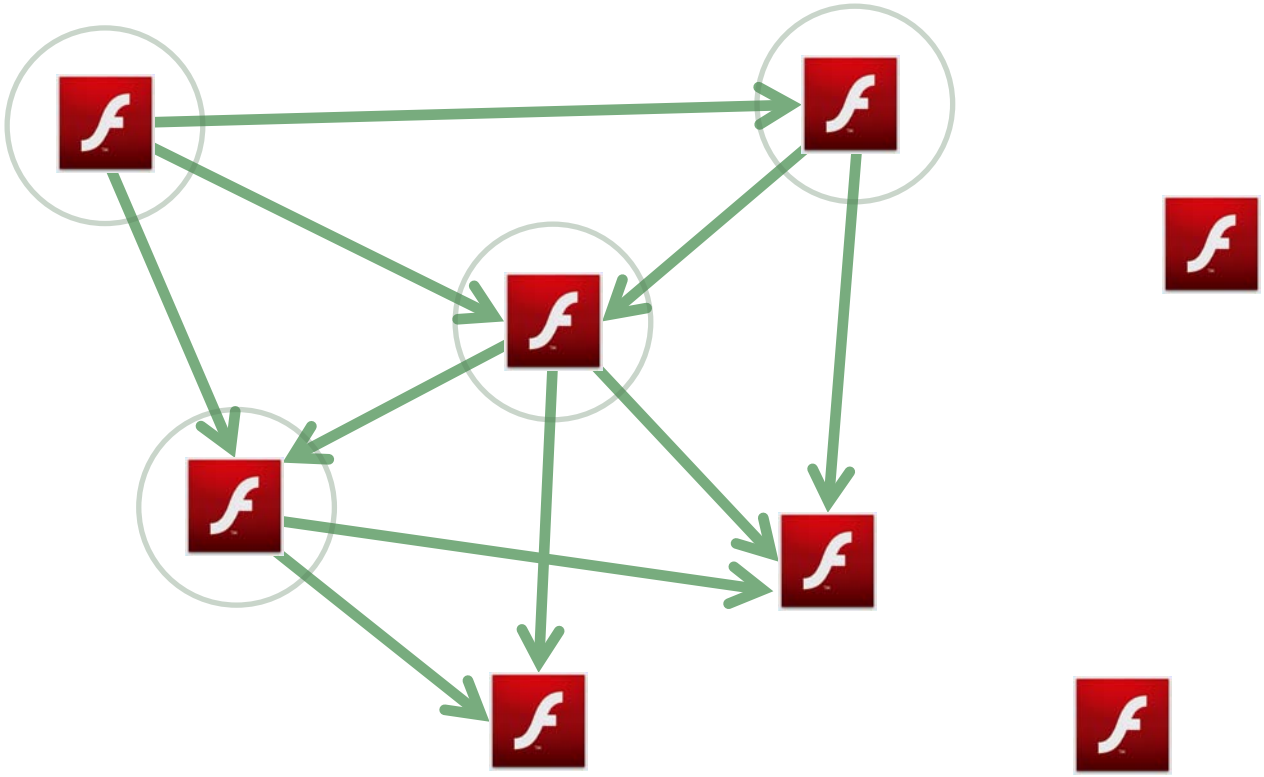

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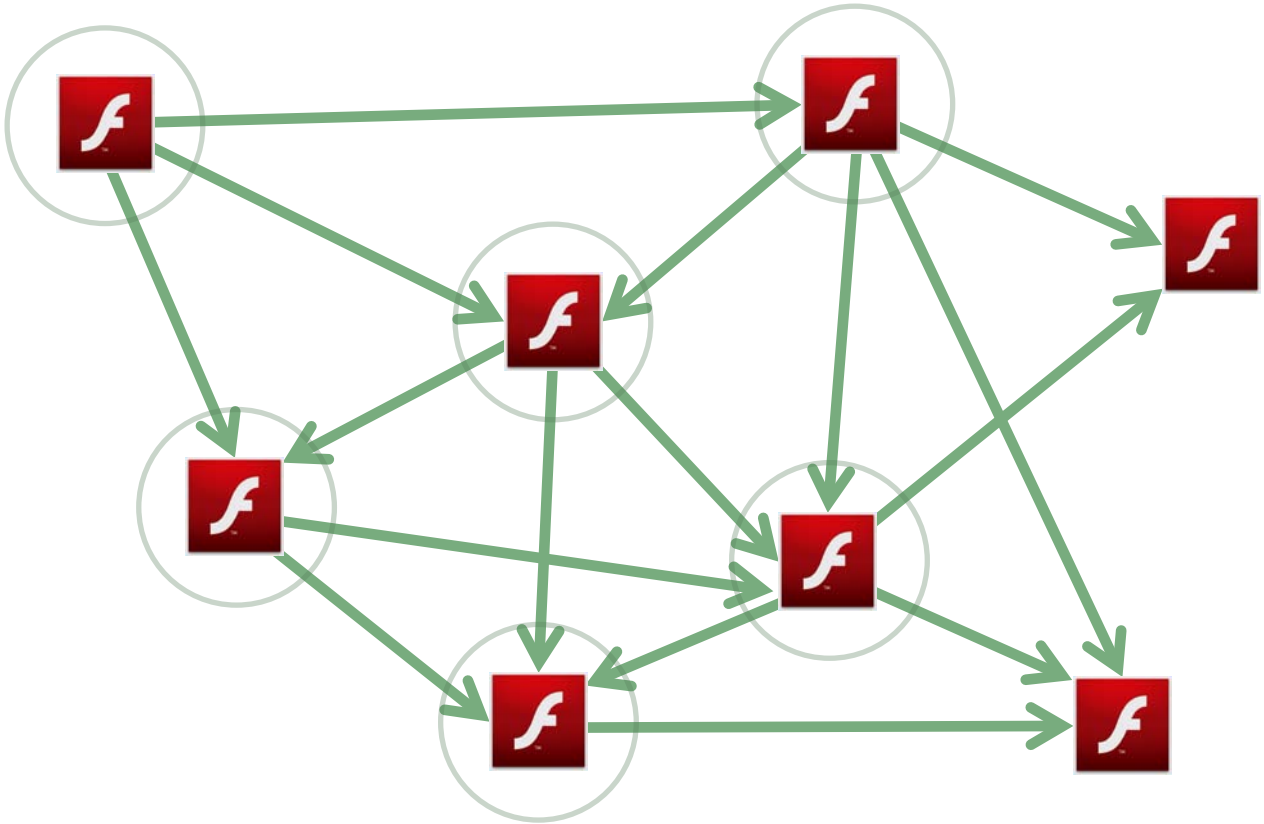

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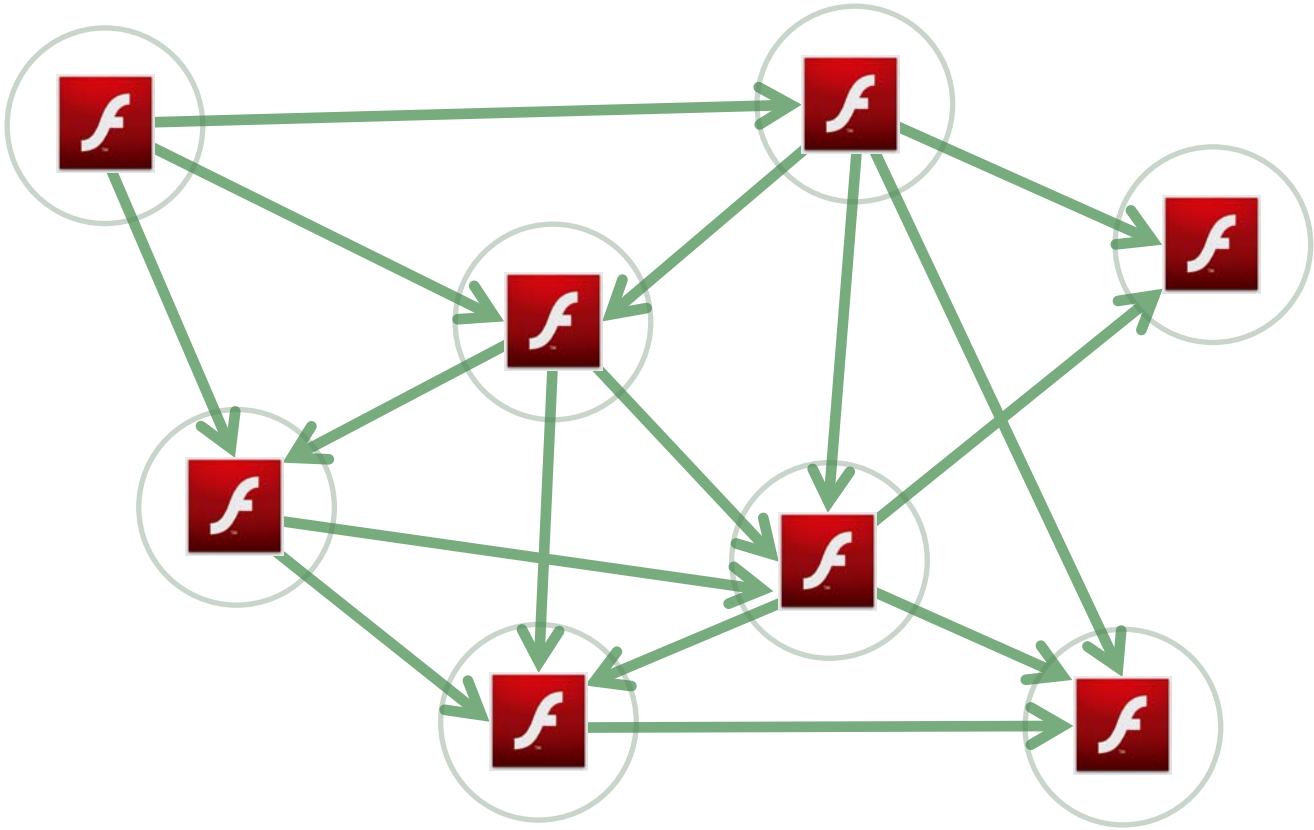

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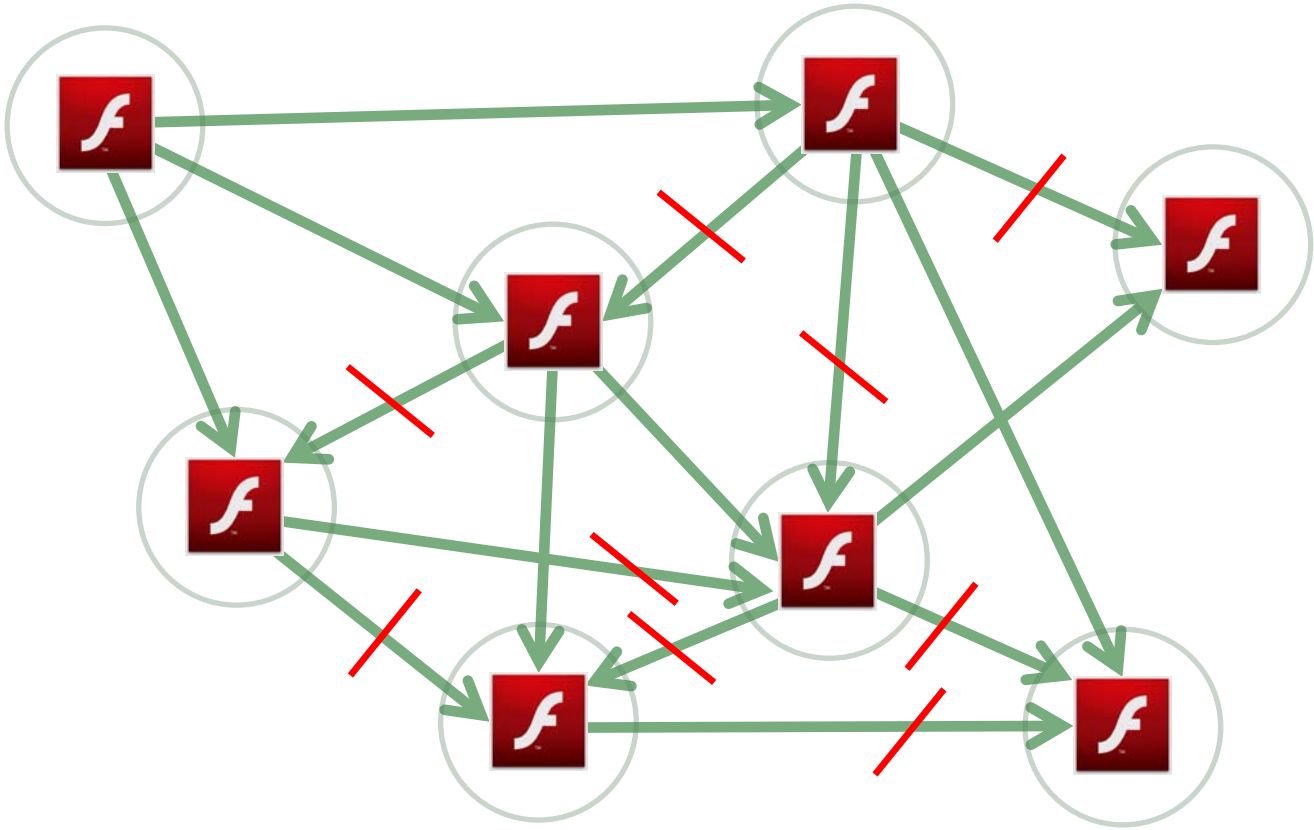

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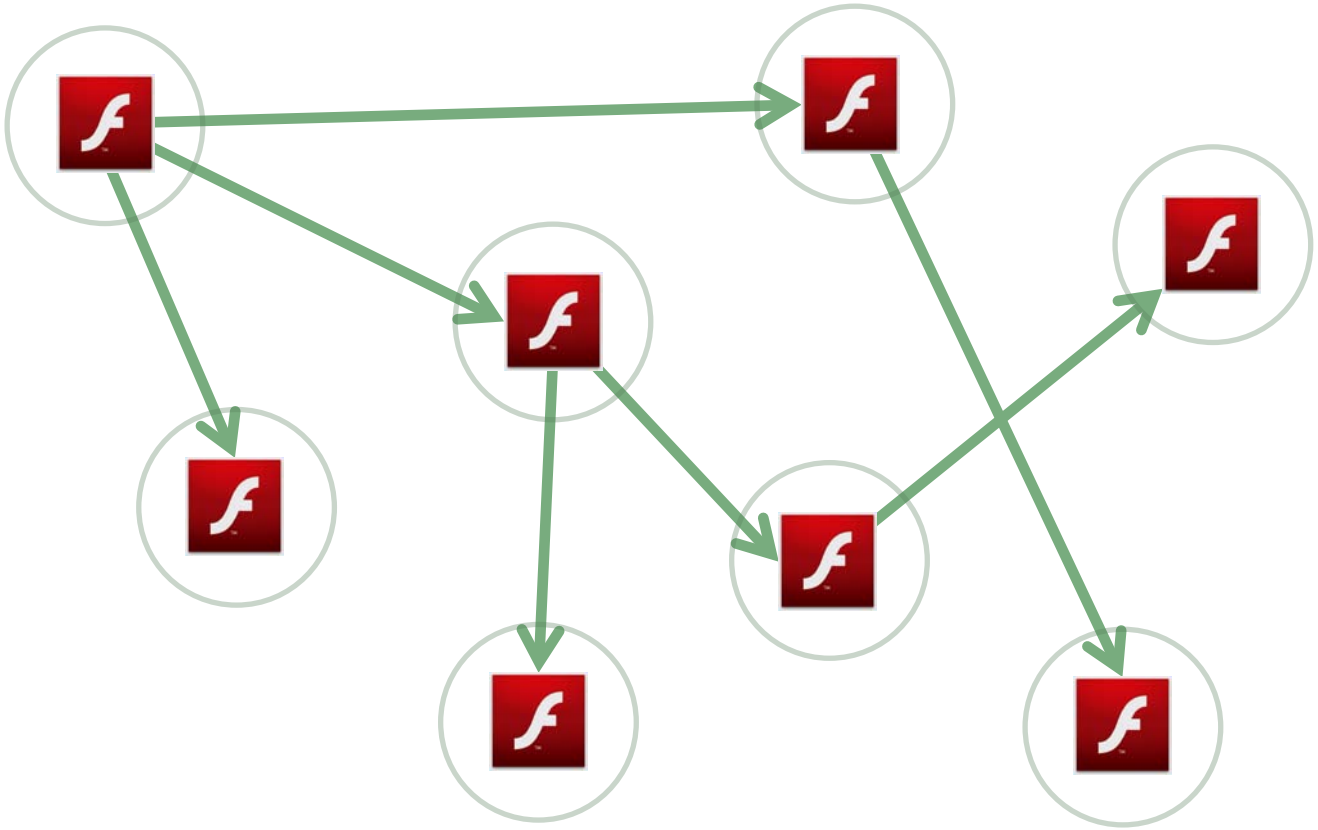
Multicast – Push



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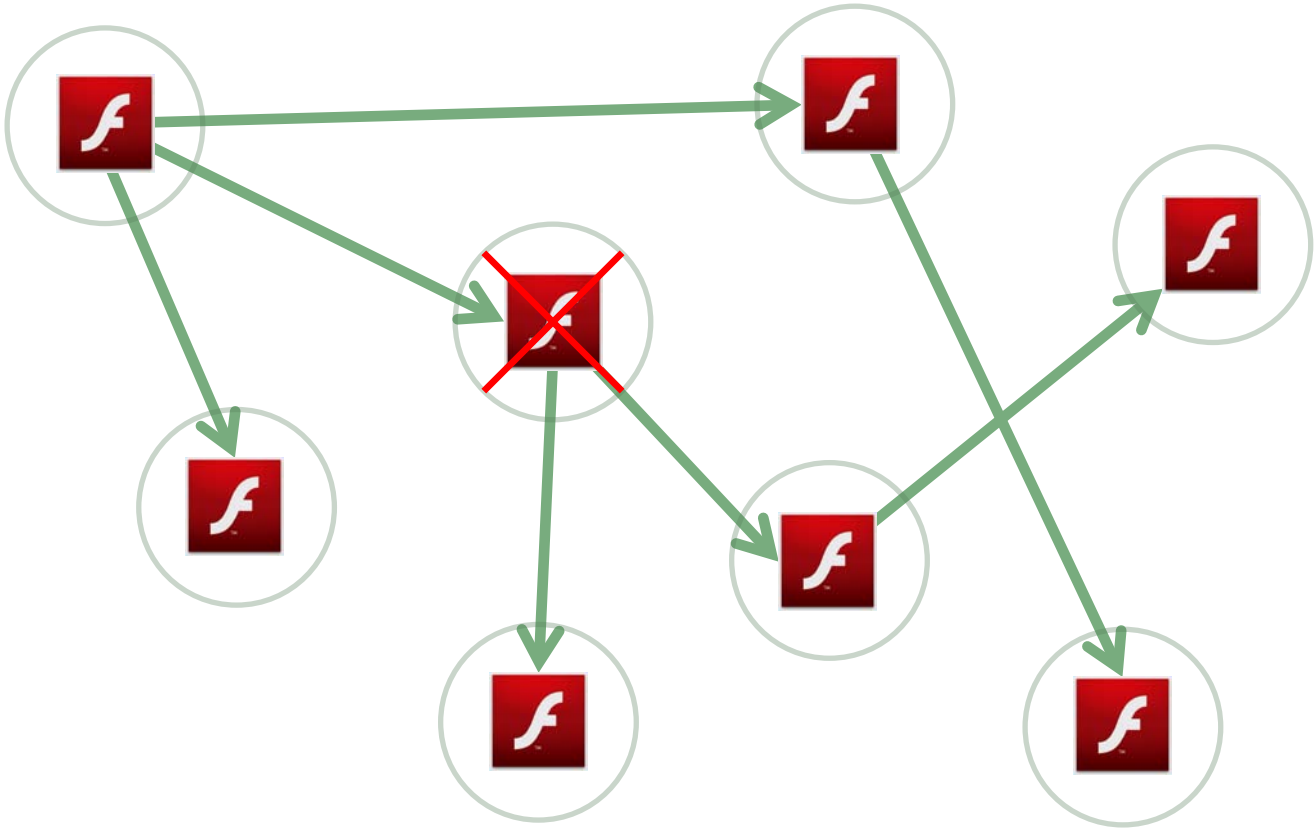
Multicast – Push-Pull



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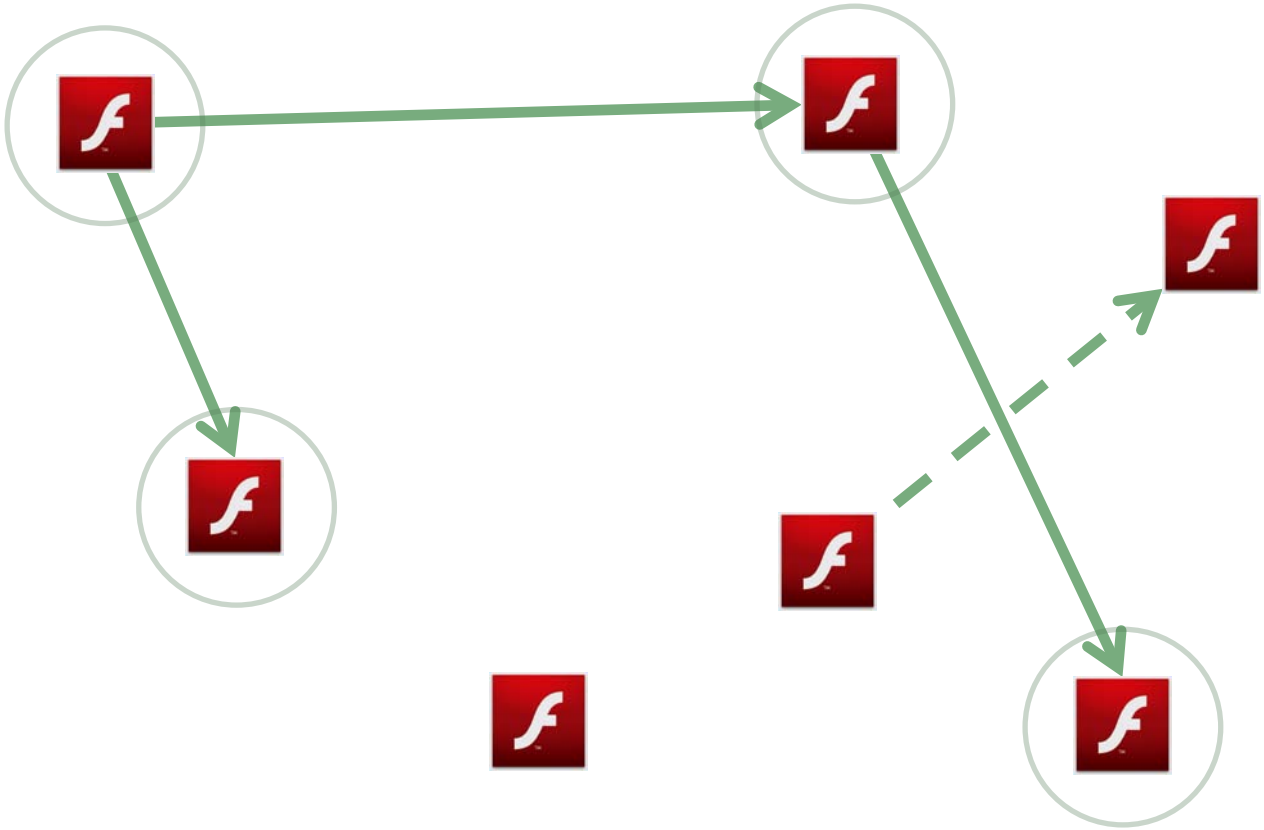
Multicast – Push-Pull



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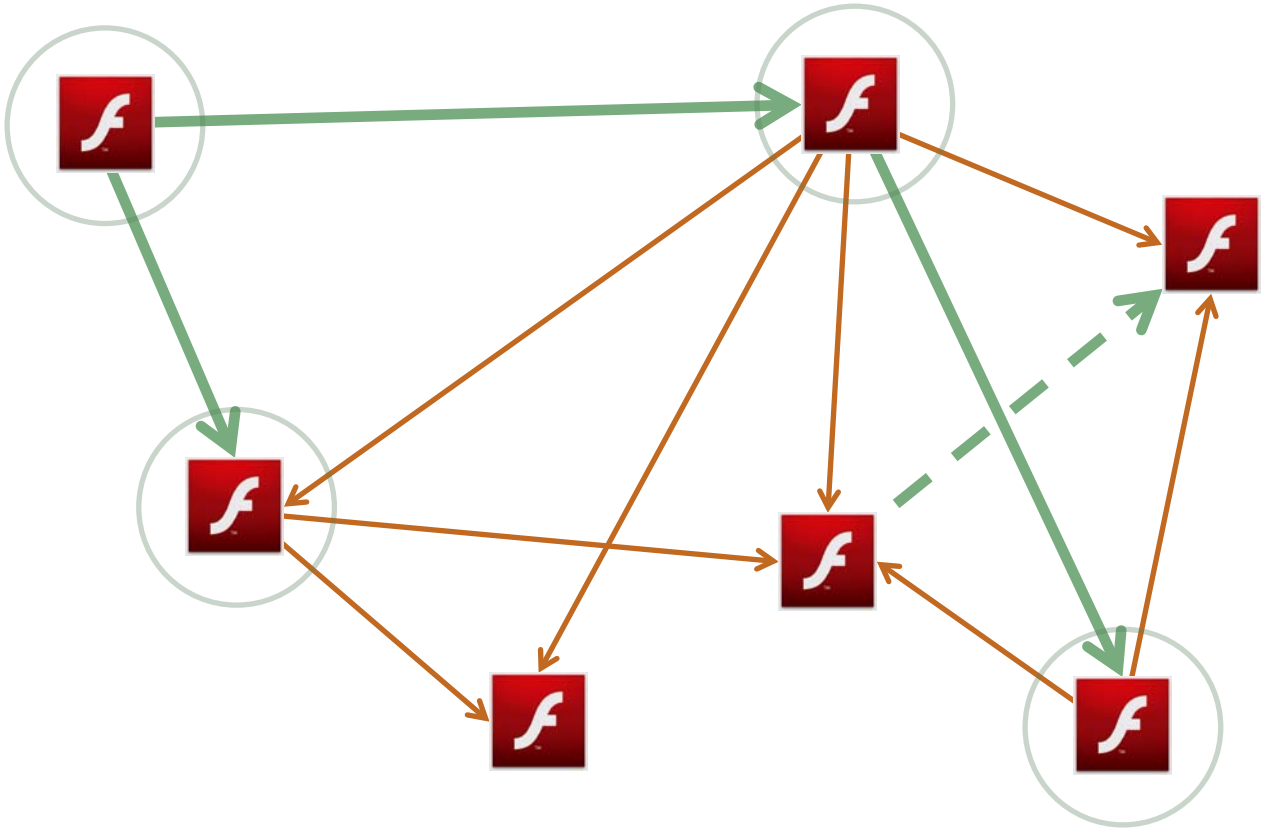
Multicast – Push-Pull



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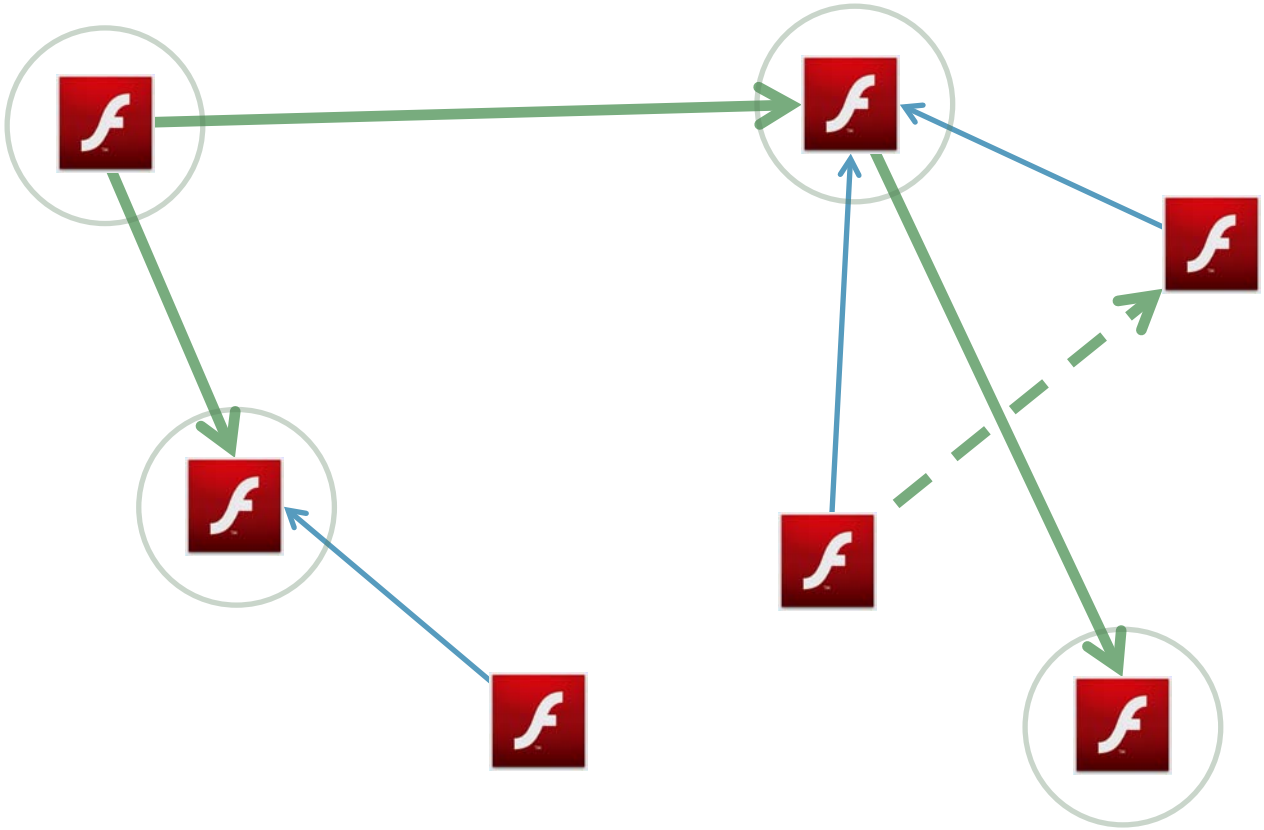
Multicast – Push-Pull



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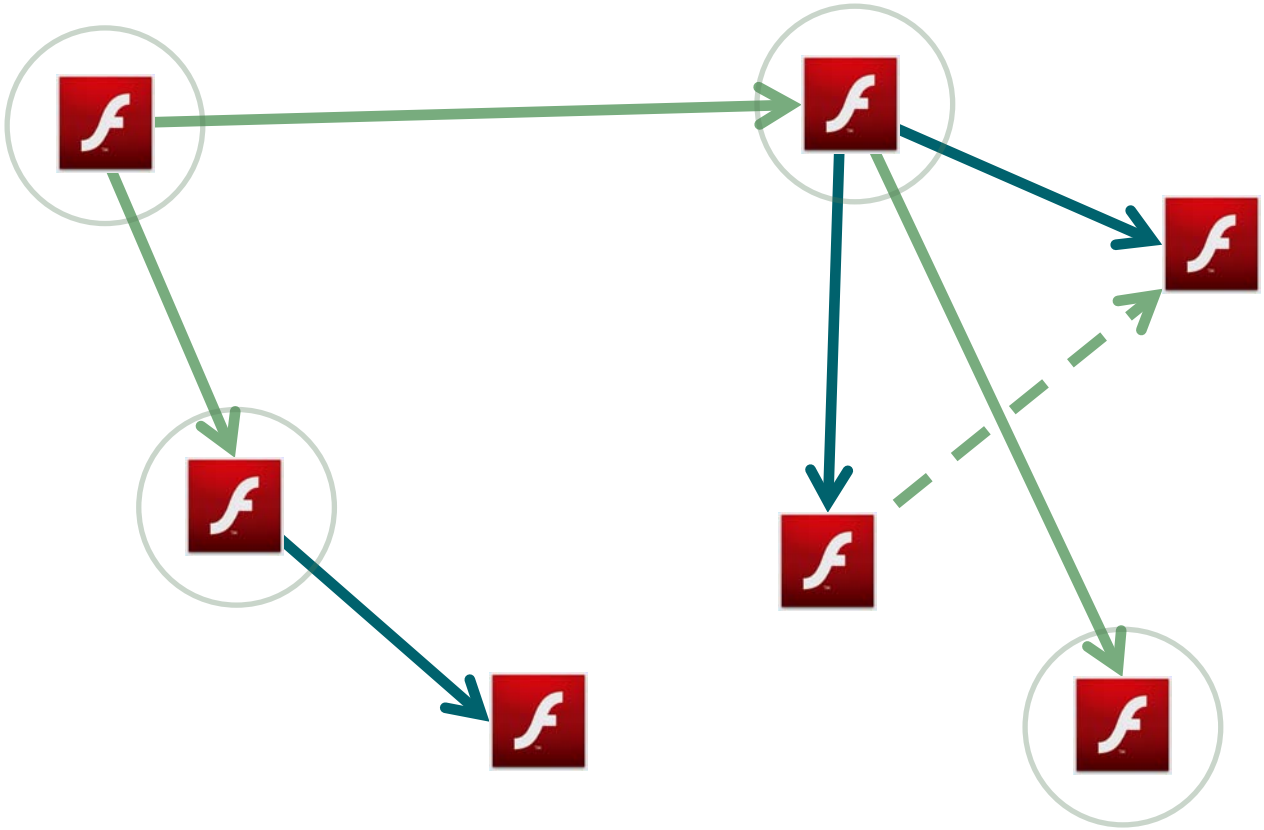
Multicast – Push-Pull



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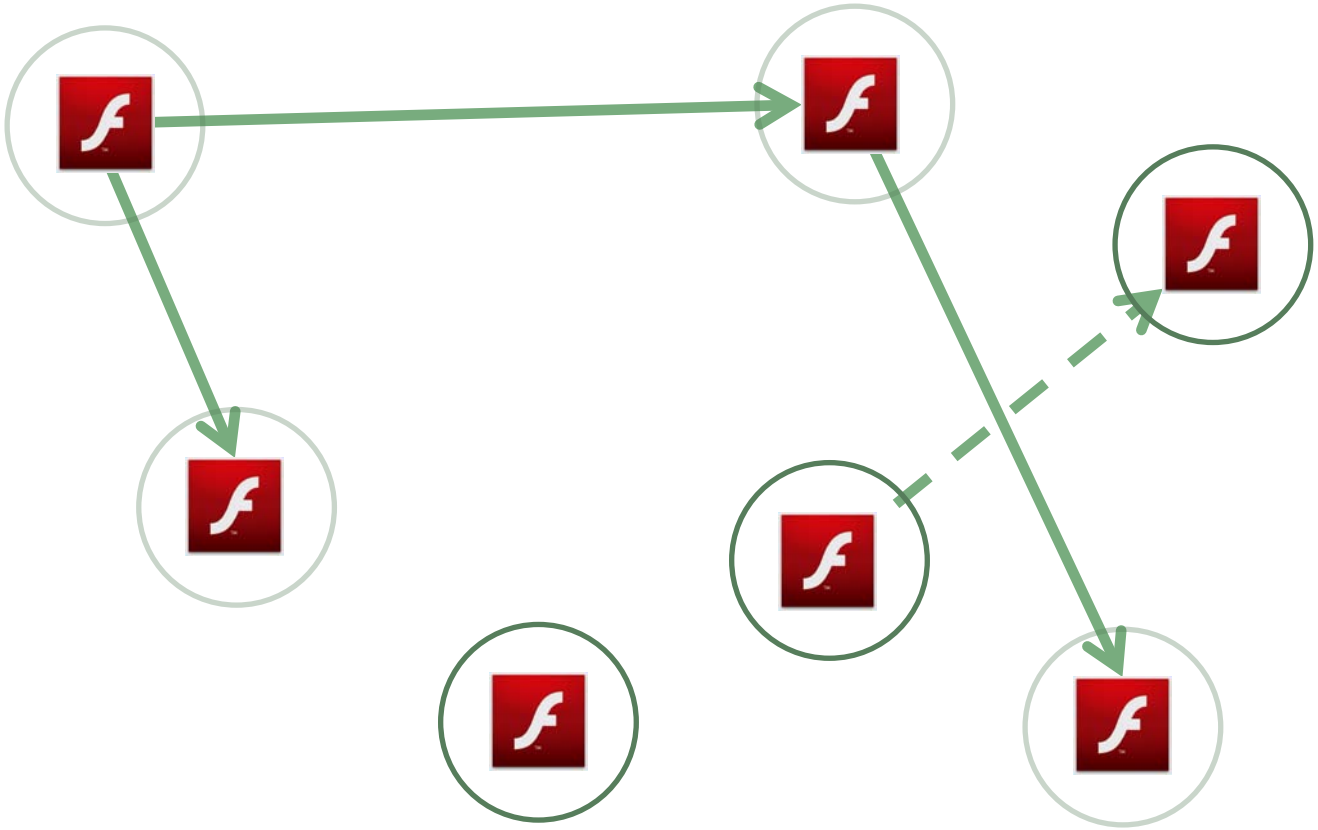
Multicast – Push-Pull



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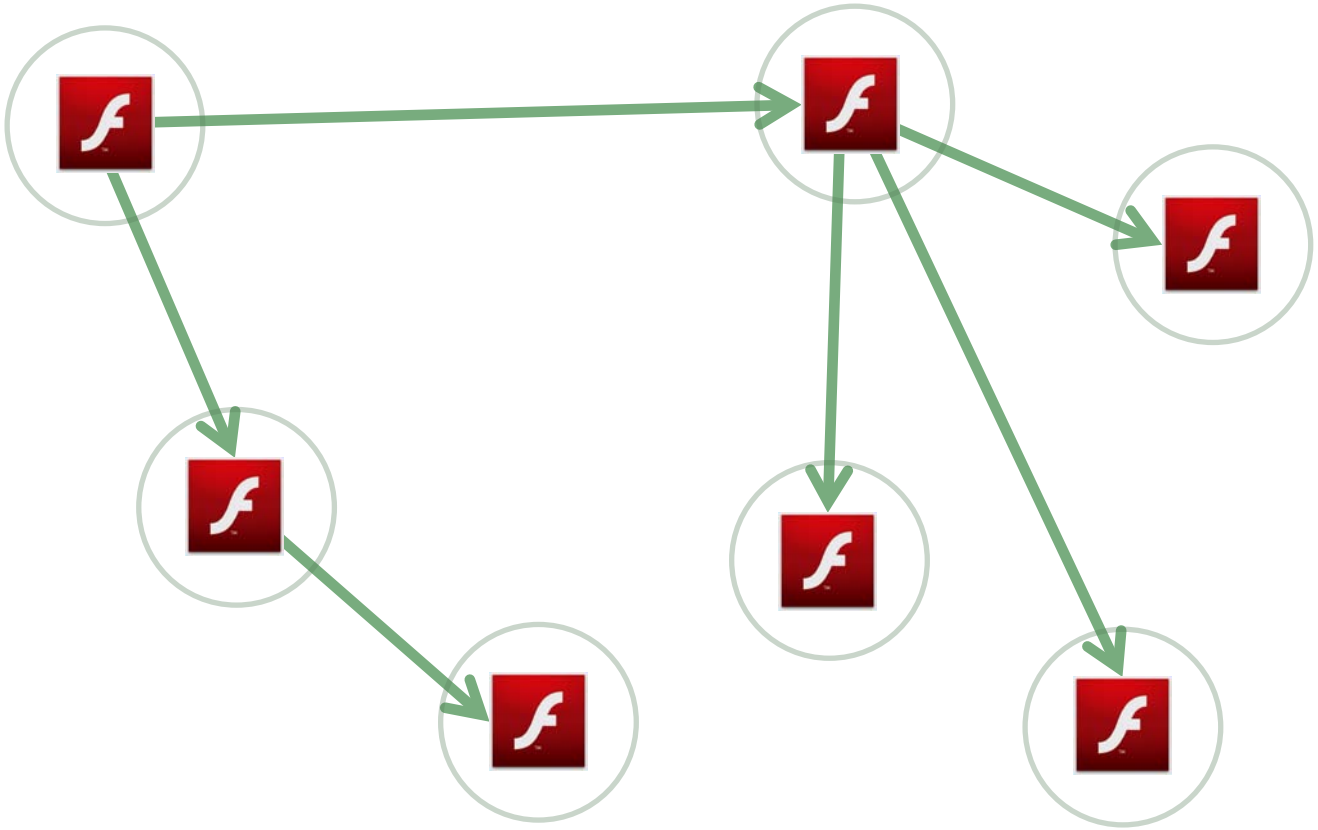
Multicast – Push-Pull



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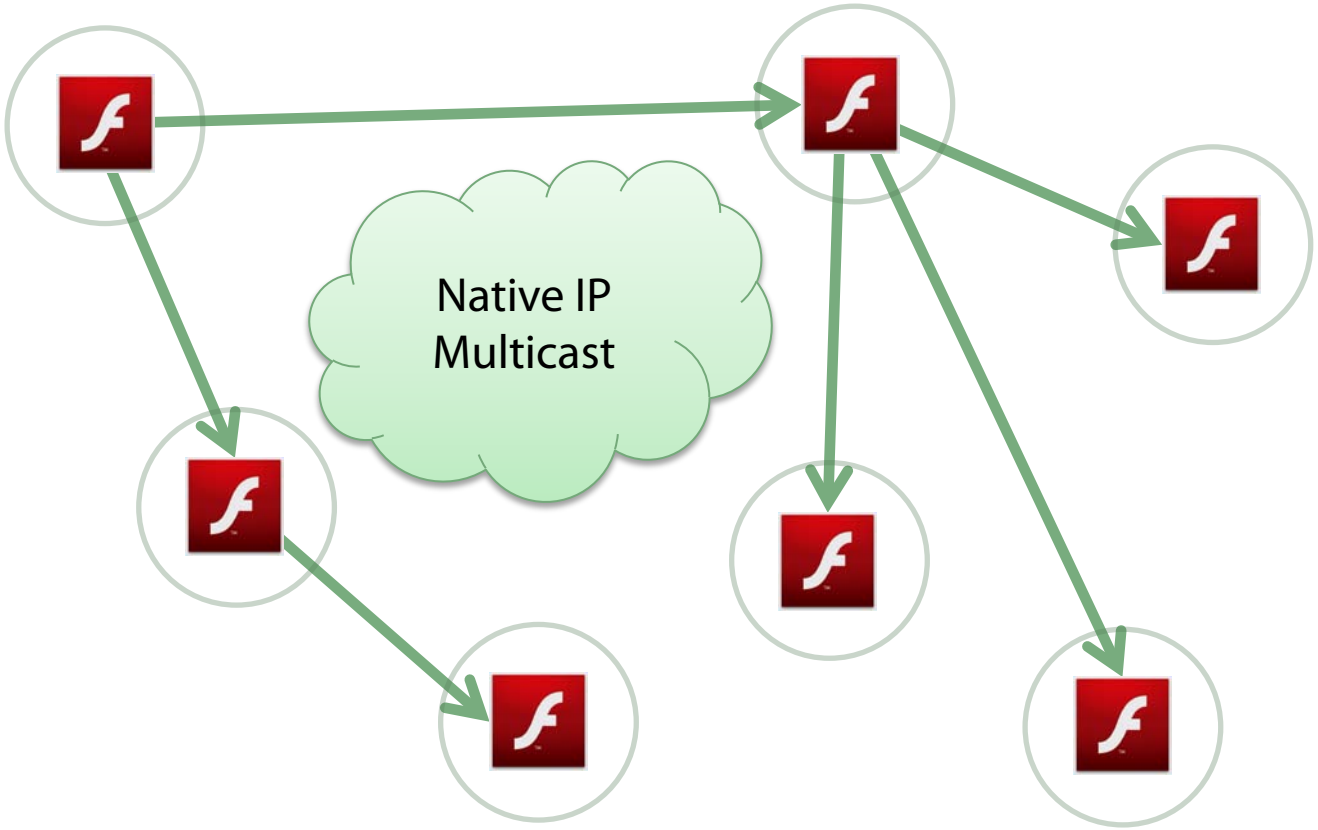
Multicast – Fusion



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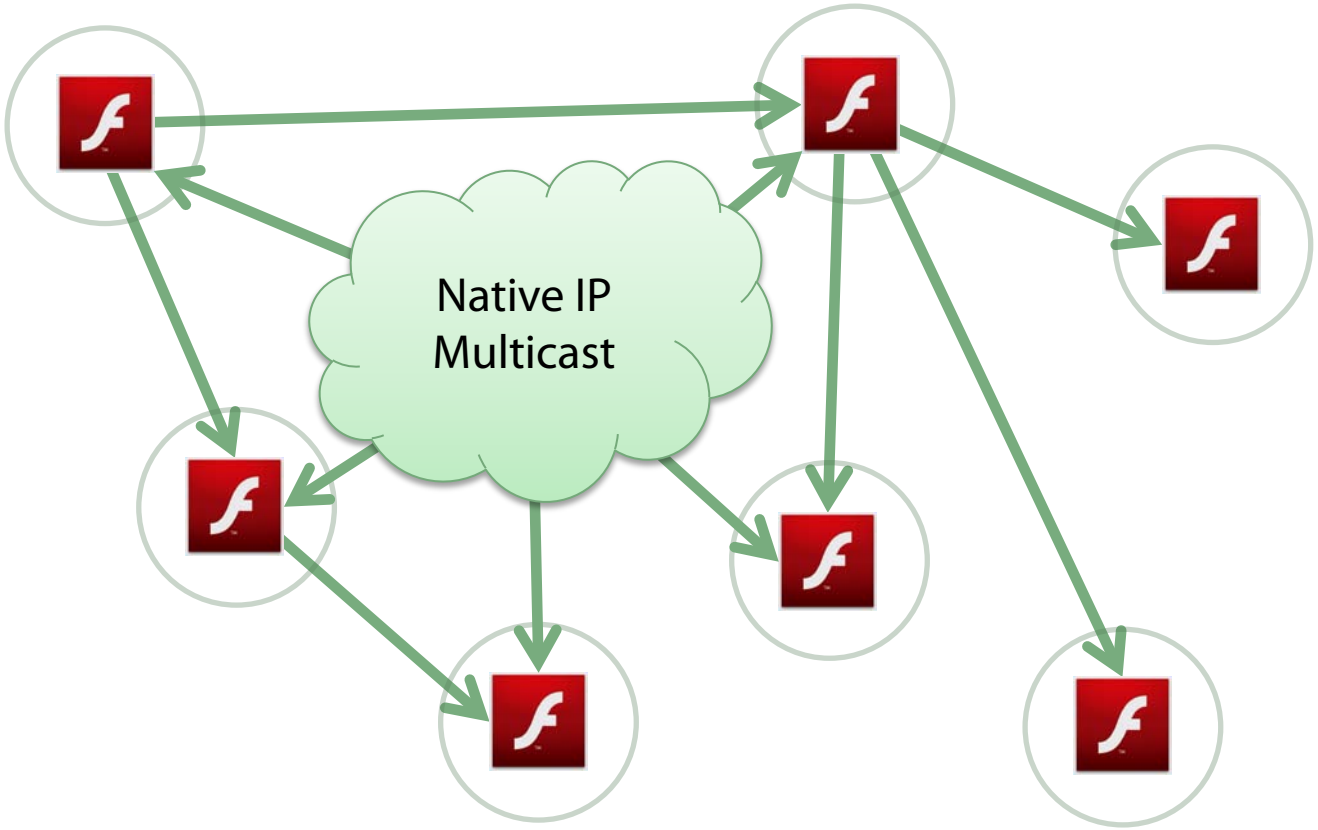
Multicast – Fusion



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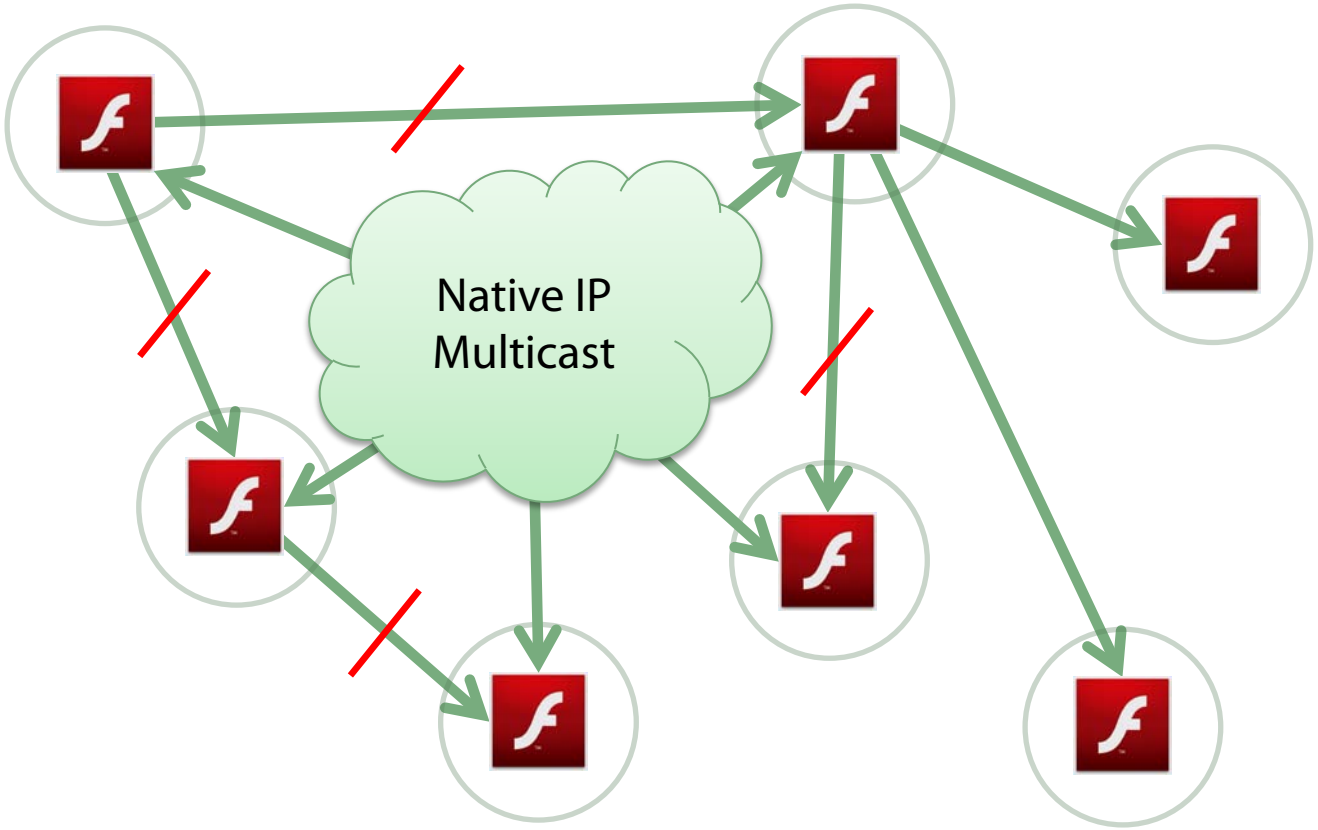

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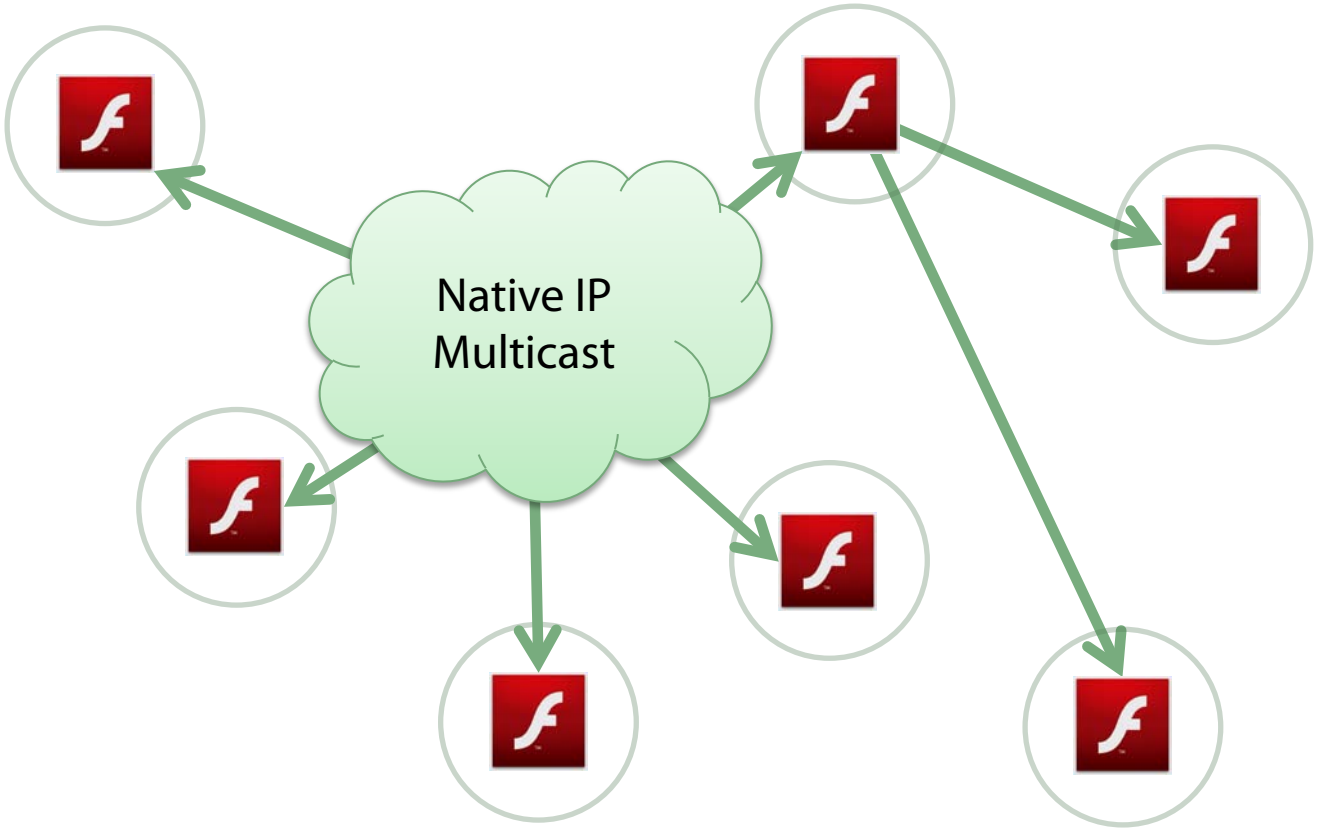

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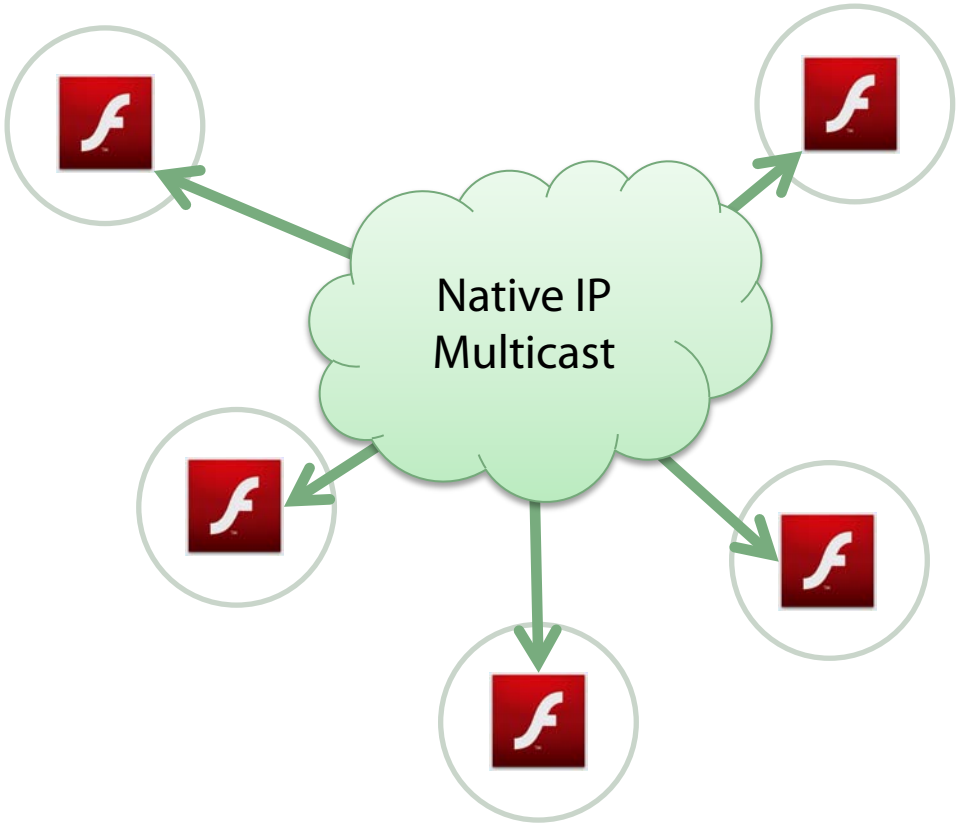
Multicast – IP-only



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Multicast

- Uses NetStream API
  - Construct with Groupspec instead of PeerID
- Low latency
  - Push/pull
    - Pull
      - Ensure nodes get the data
        - Initial source
        - Back-fill of loss (Fusion or Push)
        - Provides data when spanning tree temporarily wrong
    - Push
      - Reduce latency
        - Multiple spanning trees
- >1 Sender/group
- >1 Stream/sender (streams have names)

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Multicast API

- Properties
  - `multicastPushNeighborLimit`
  - `multicastWindowDuration`
  - `multicastRelayMarginDuration`
  - `multicastAvailabilityUpdatePeriod`
  - `multicastFetchPeriod`
  - `multicastAvailabilitySendToAll`
  - `multicastInfo`
- Events
  - `NetStream.MulticastStream.Reset`
  - `NetGroup.MulticastStream.PublishNotify`
  - `NetGroup.MulticastStream.UnpublishNotify`

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Multicast QOS

- sendDataBytesPerSecond
- sendControlBytesPerSecond
- receiveDataBytesPerSecond
- receiveControlBytesPerSecond
- bytesPushedToPeers
- fragmentsPushedToPeers
- bytesRequestedByPeers
- fragmentsRequestedByPeers
- bytesPushedFromPeers
- fragmentsPushedFromPeers
- bytesRequestedFromPeers
- fragmentsRequestedFromPeers
- sendControlBytesPerSecondToServer
- receiveDataBytesPerSecondFromServer
- bytesReceivedFromServer
- fragmentsReceivedFromServer
- receiveDataBytesPerSecondFromIPMulticast
- bytesReceivedFromIPMulticast
- fragmentsReceivedFromIPMulticast

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Native IP Multicast

- Provide Native IP Multicast address(es) in Groupspec
- LAN Discovery
  - Increase odds of finding nearby (low-latency) peers
  - Serverless ad-hoc RTMFP Group using new NetConnection.connect(“rtmfp:”);

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Multicast Fusion

- Fuse native IP multicast with peer-to-peer Multicast
  - Peers can use pull to fill in missing data
  - Peers with native IP can feed to peers without
- Single Groupspec (stream description) can be played in either environment
- Turn off peer-to-peer and use for Native IP-only
- (Future) FMS is publisher
  - Flash Player cannot **publish** Native IP Multicast
- Security of Native IP Multicast traffic (Fusion and LAN Discovery)
  - Protected (and separated from other traffic) with Groupspec-derived HMAC
  - Encrypted with Groupspec-derived AES key

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Server Control / Status Channel

- Enabled in Groupspec
  - `GroupSpecifier.serverChannelEnabled`
- Status monitoring
- Multicast
  - Server seed
  - Server fill-in
- Bootstrapping
  - Server can tell Flash Player about other peers to add
- New Stratus feature!
  - Group auto-bootstrapping

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Other New Things

- Partial Reliability Control at publishing peer
  - `NetStream.audioReliable`
  - `NetStream.videoReliable`
  - `NetStream.dataReliable`
- Peer-to-Peer Audio/Video Sample Access Control at publishing peer
  - `NetStream.audioSampleAccess`
  - `NetStream.videoSampleAccess`
- RTMFP NetConnection with no server
  - `NetConnection.connect("rtmfp:");`

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Q&A

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MAX
CONNECT. DISCOVER. INSPIRE.