Routing in NDN

Lan Wang (University of Memphis) & the NDN Team
FIA PI Meeting
11/14/2013

Roadmap

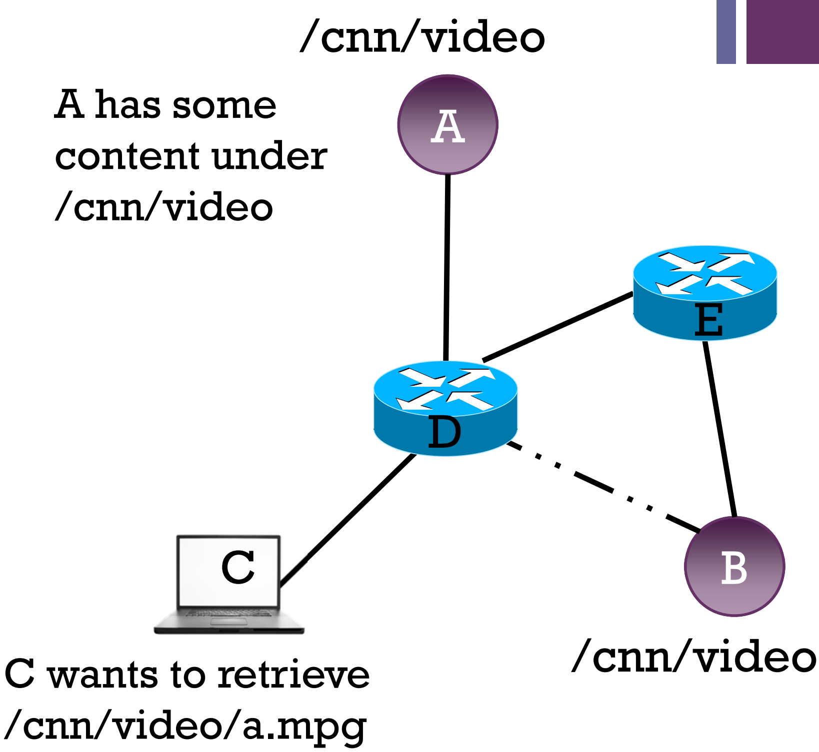
- What does NDN require from a routing protocol?
- How does NDN support in-network storage, anycast, and mobility?
- What does NDN provide as foundations for routing?
- Example: Named-data Link State Routing (NLSR)

NDN's Requirement on Routing

Requirement: routing to information

- guide each Interest packet to all potential providers (via all feasible paths)
- Some providers may not have all content in a name prefix.

Non-requirement: fast routing convergence: stateful forwarding plane can adapt to changes/failures quickly.



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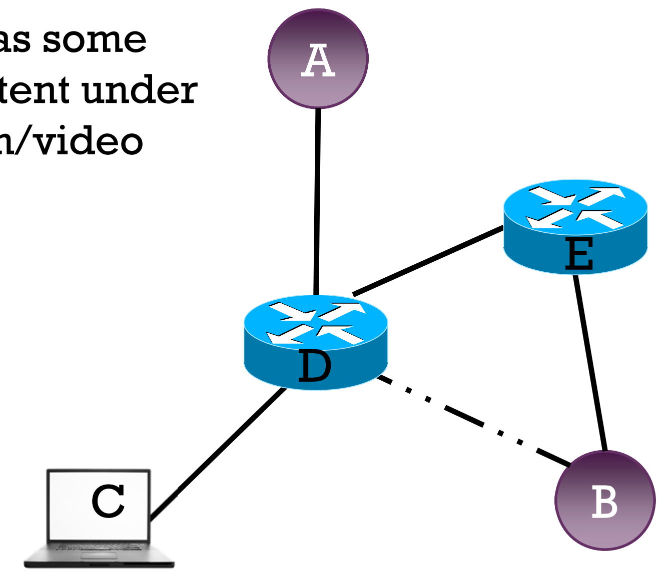

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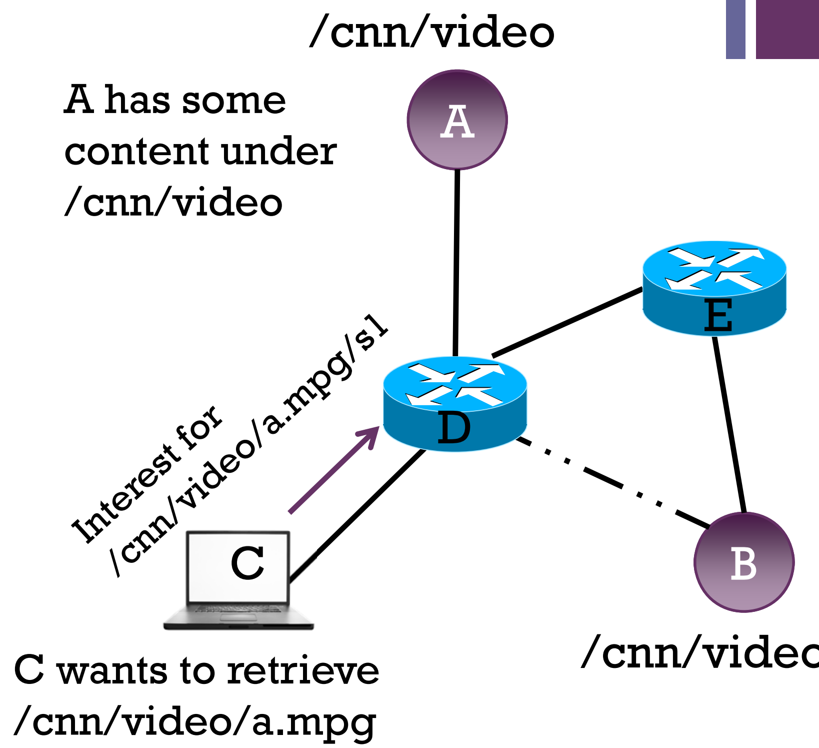

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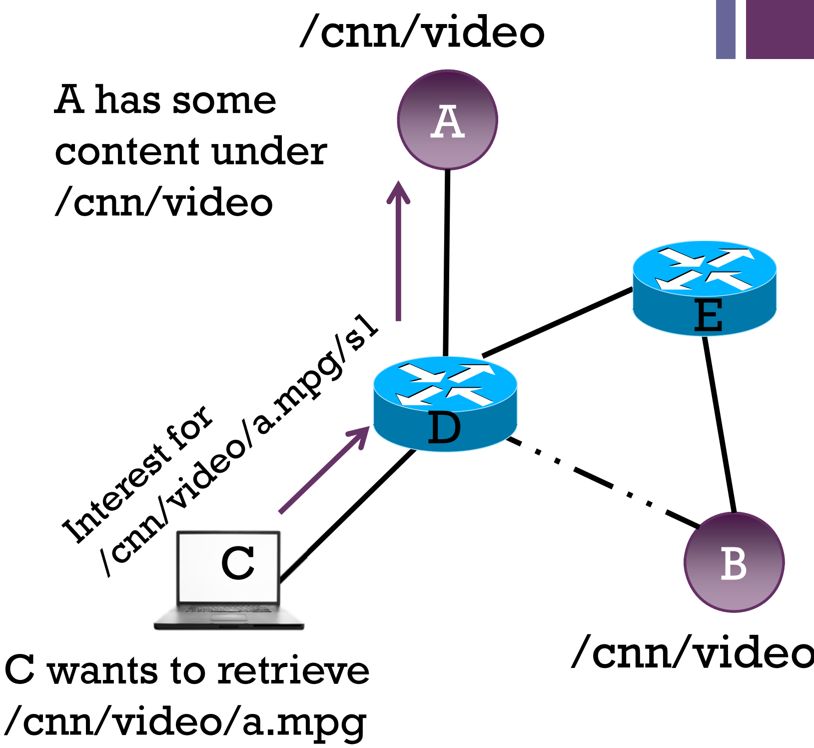

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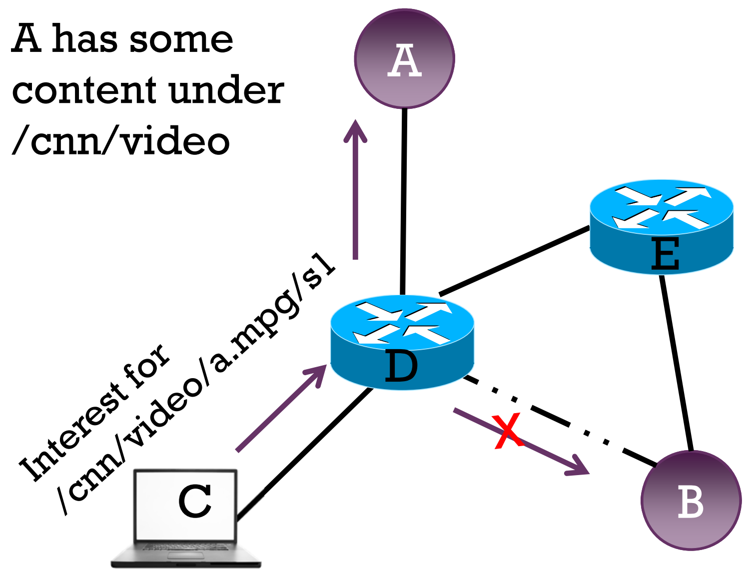

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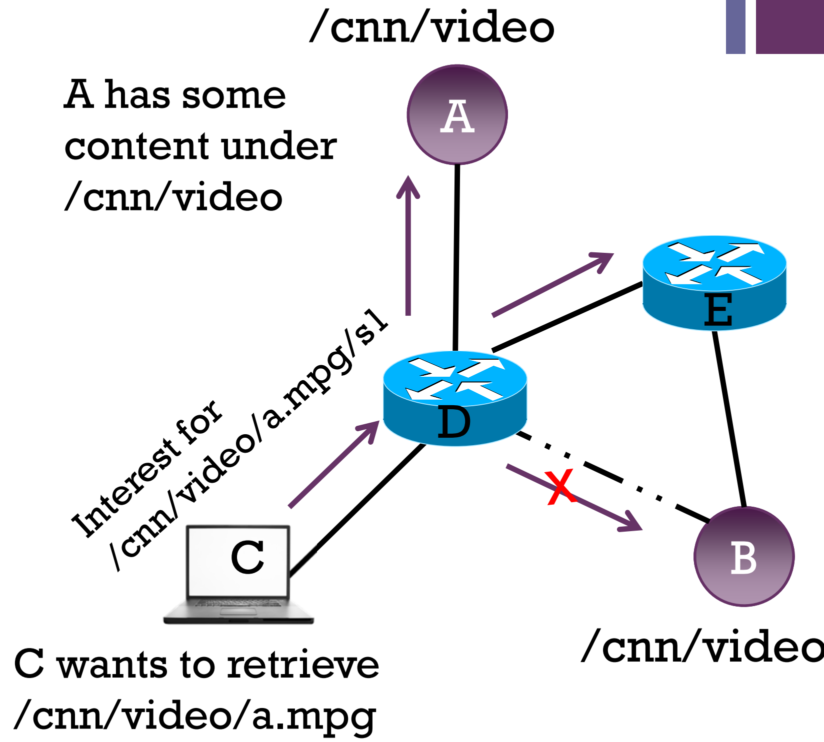

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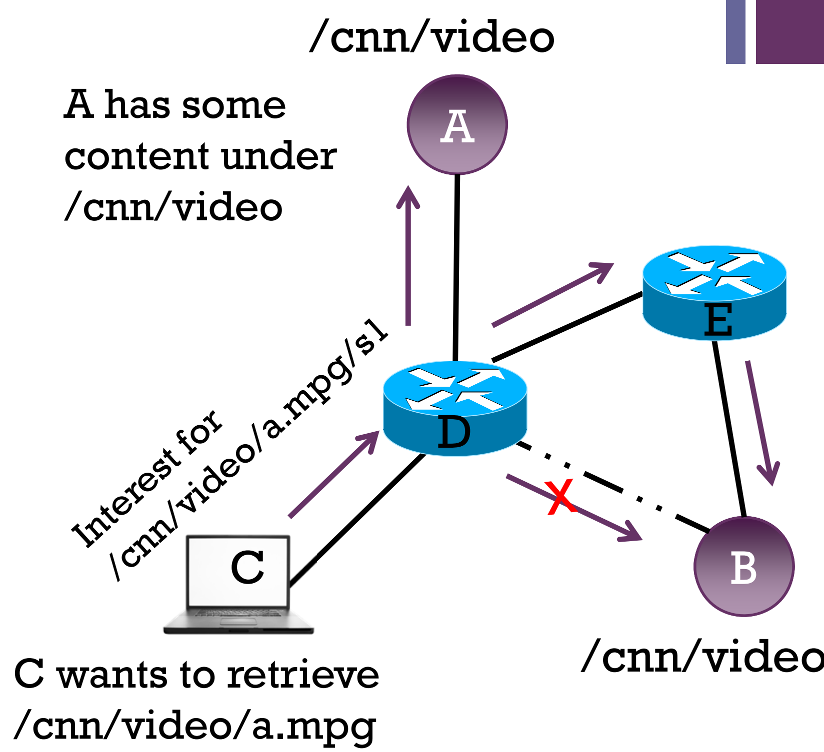

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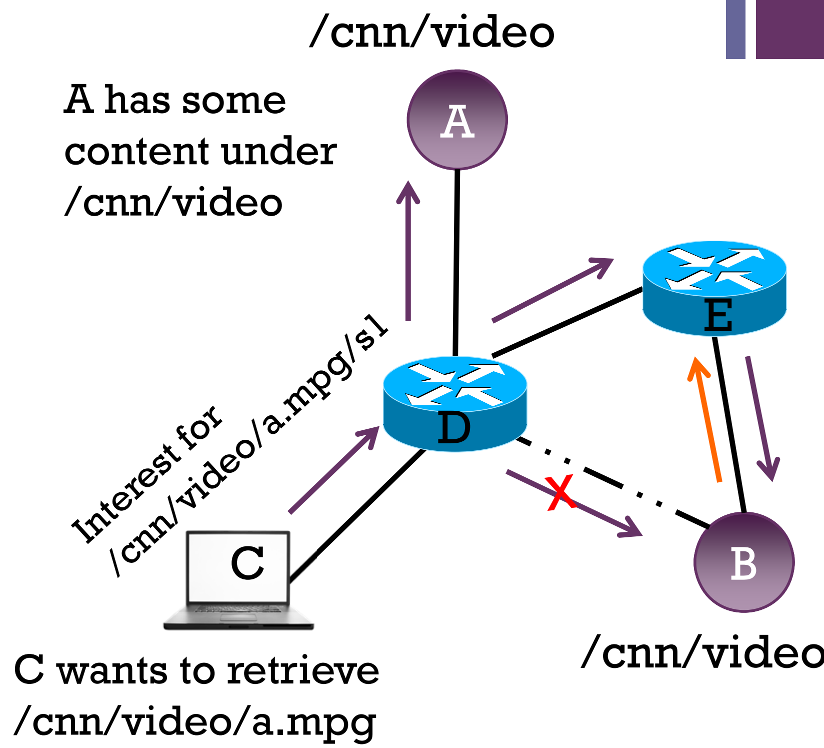

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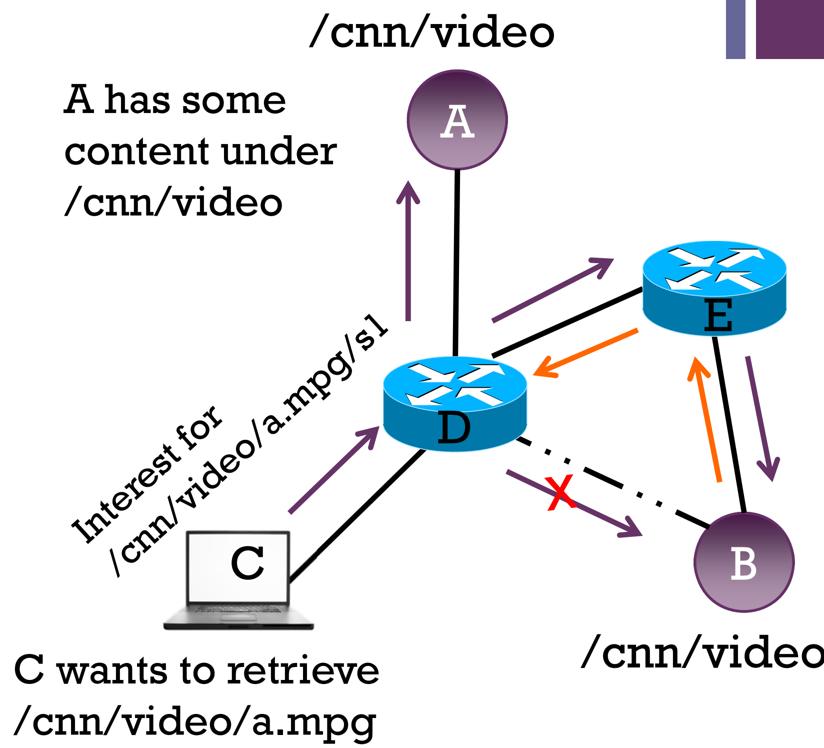

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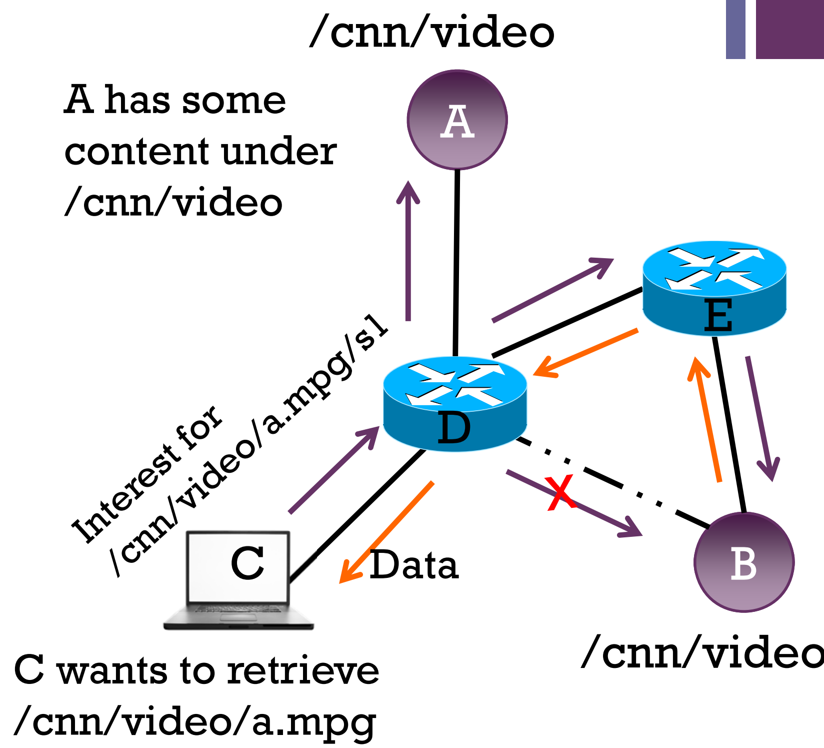

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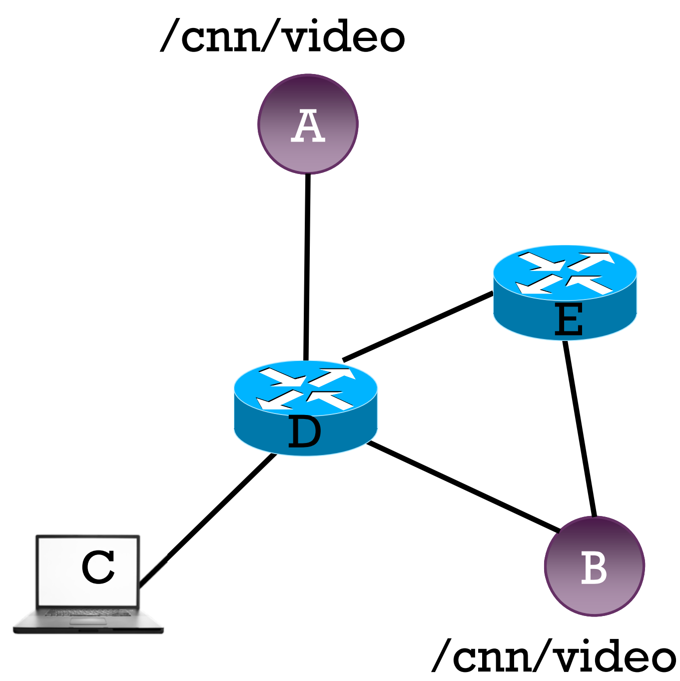
Routing Mechanism in NDN

Any routing algorithm that works for IP (e.g., link-state) can be used in NDN.

- NDN's forwarding semantics is a superset of the IP model.

Differences:

- replace IP prefixes with name prefixes
- calculate a list of next-hops for each name prefix
- use Interest/Data packets



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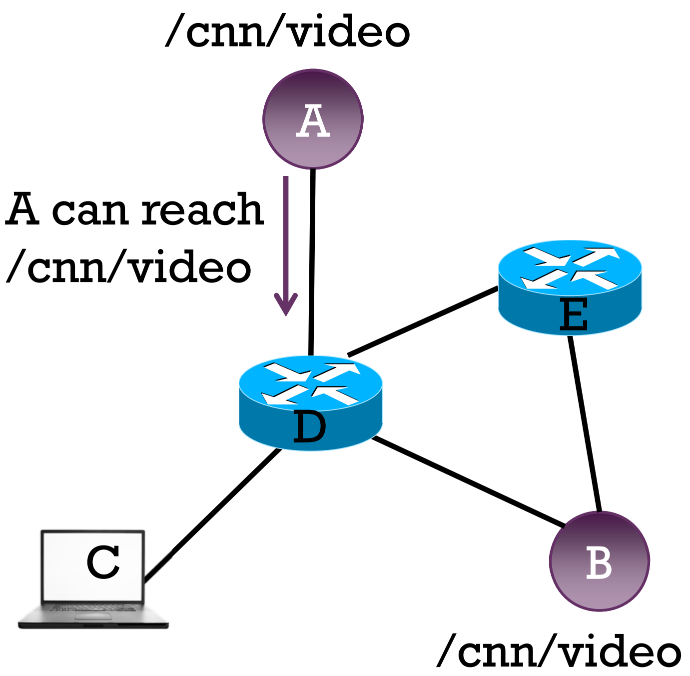

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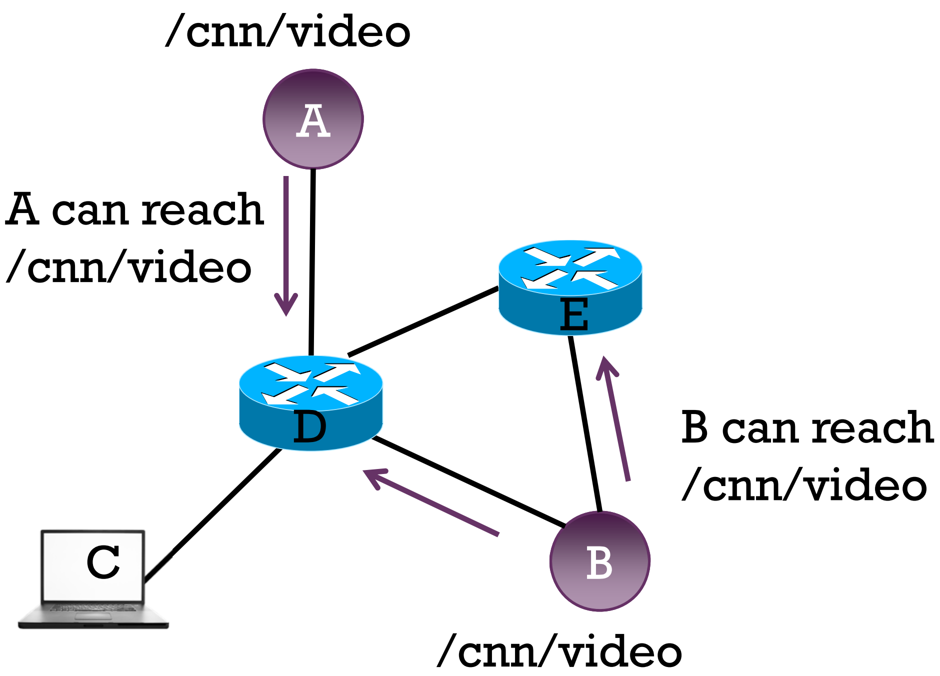

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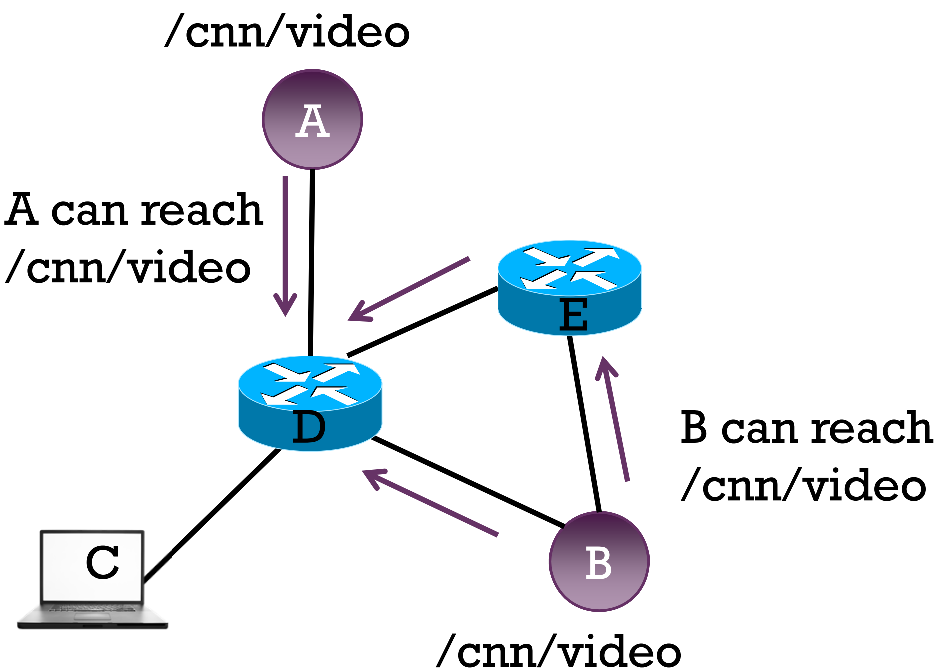

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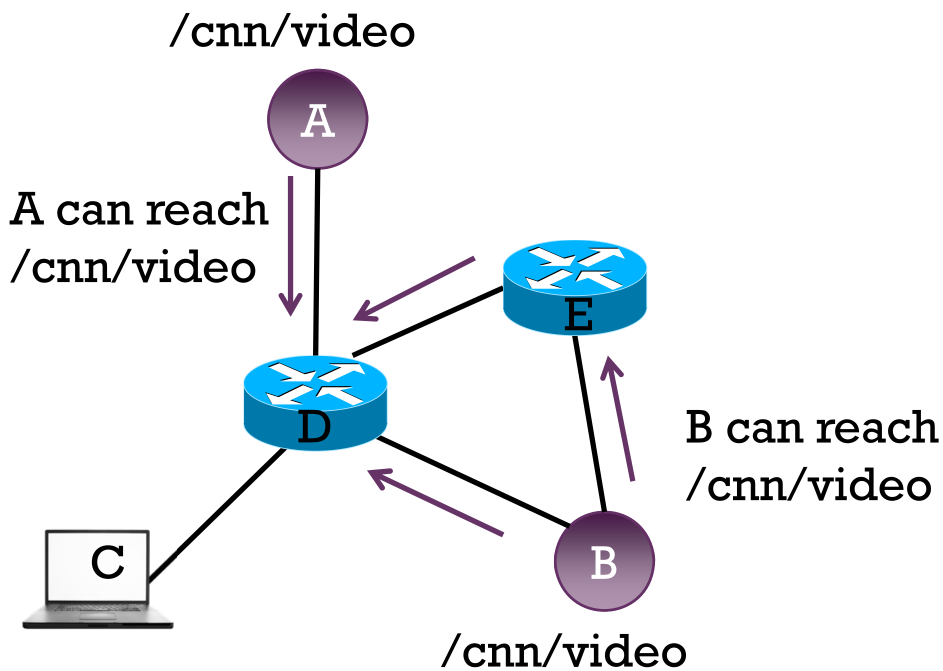

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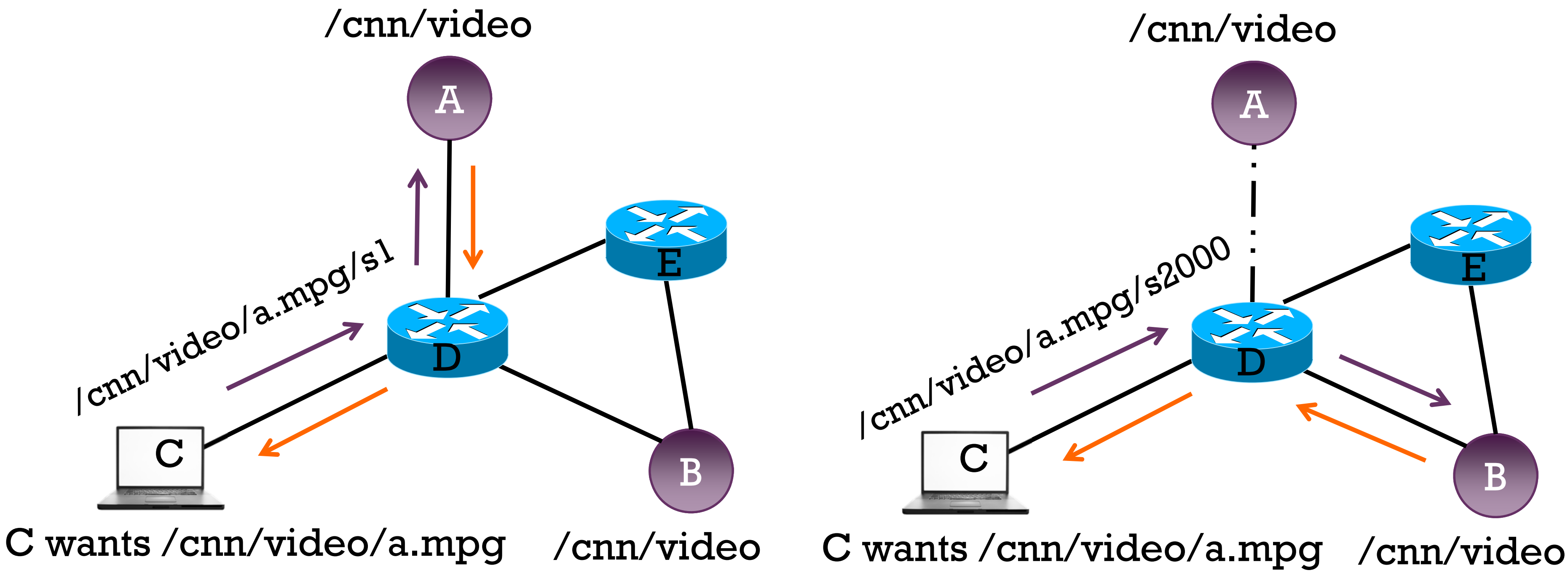
In-network Storage

- Routing to information unifies all types of storage.
  - data producer: stationary and mobile
  - in-network: persistent storage (e.g., repos) and transient storage (e.g., caches)

- In-network Storage
  - Routing support: advertise data's name prefix if data is expected to stay for a while.
  - Forwarding support: routers remember which faces data come from, so similar Interests will be forwarded to the storage.

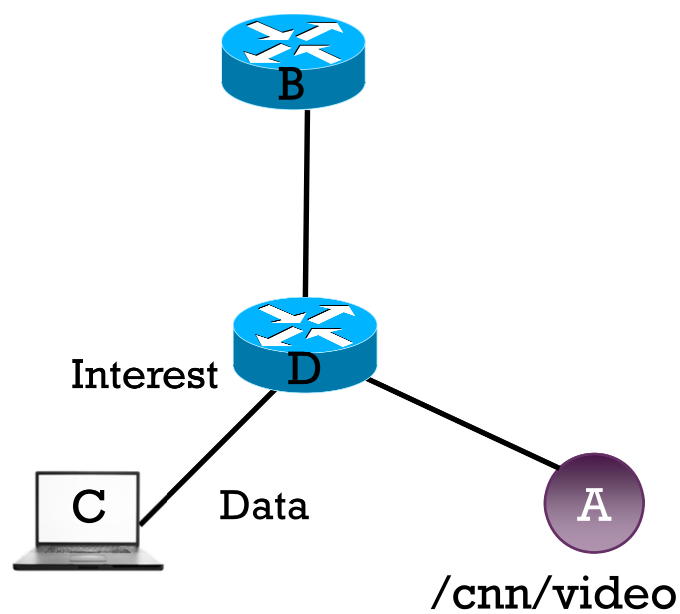
Anycast

- All data providers advertise the same prefix.
- Sessionless: a consumer is not bound to a particular anycast provider.



Mobility (1)

- NDN properties that facilitate mobility
  - Data names do not change with mobility.
  - granular data
  - sessionless
  - caching
- Consumer mobility
  - Data may go to the old location.
  - Consumer reissues Interest upon timeout.
  - Data may be returned by an intermediate cache.



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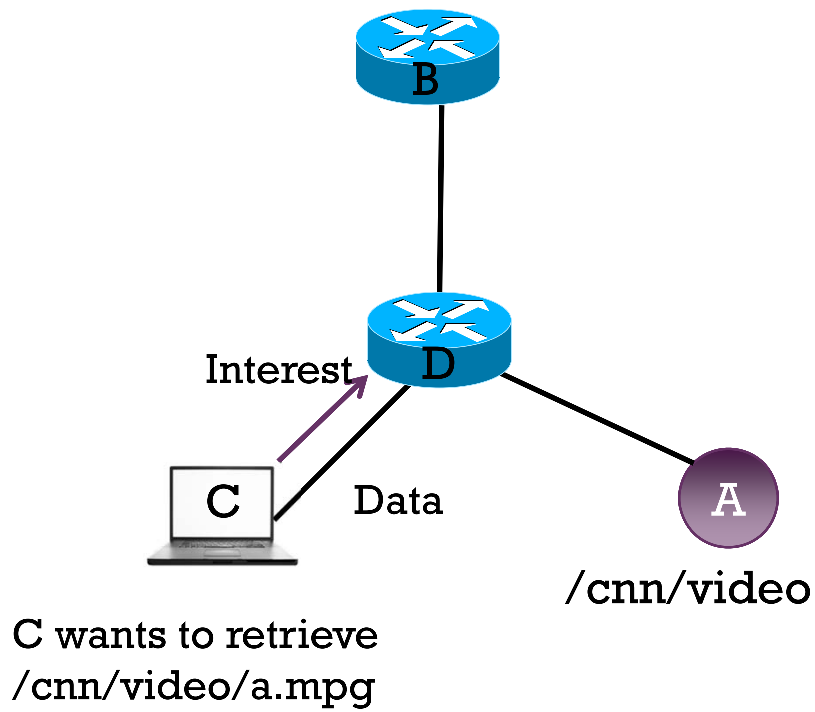

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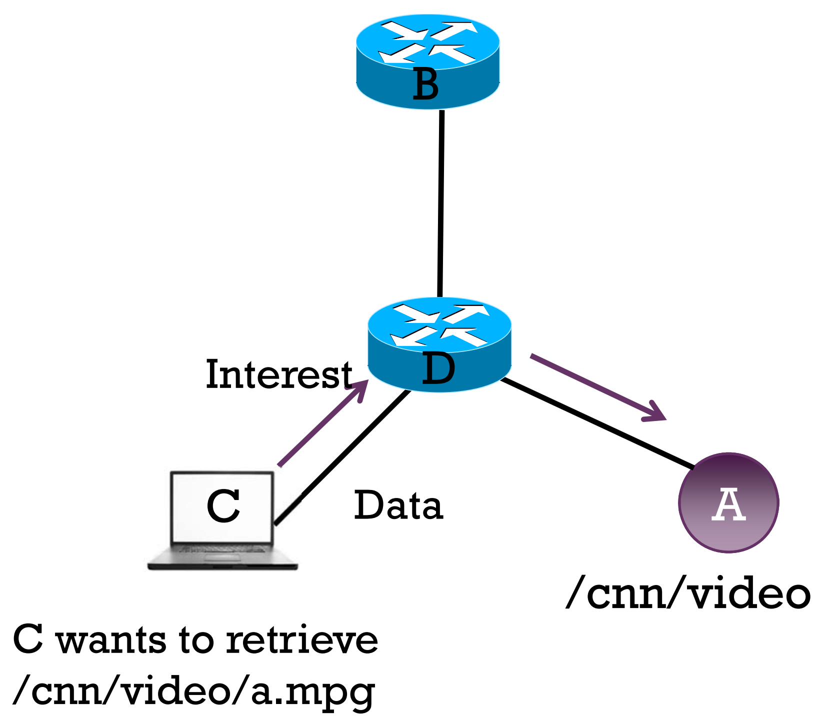

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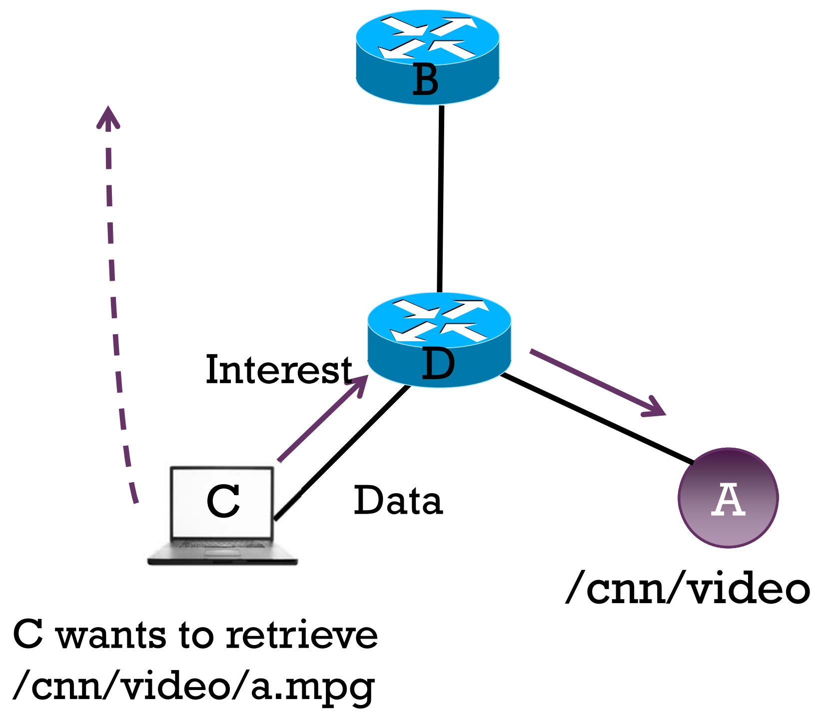

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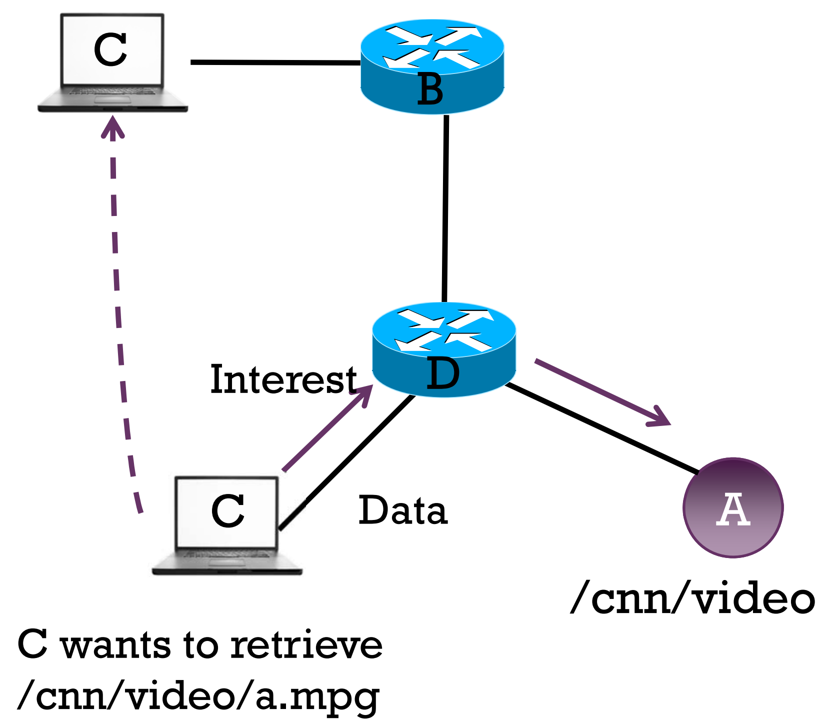

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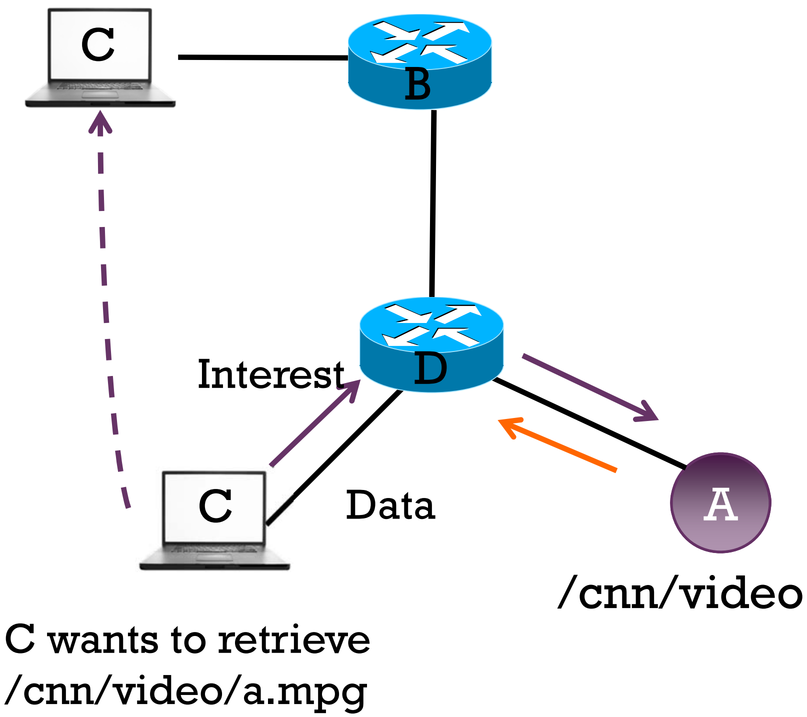

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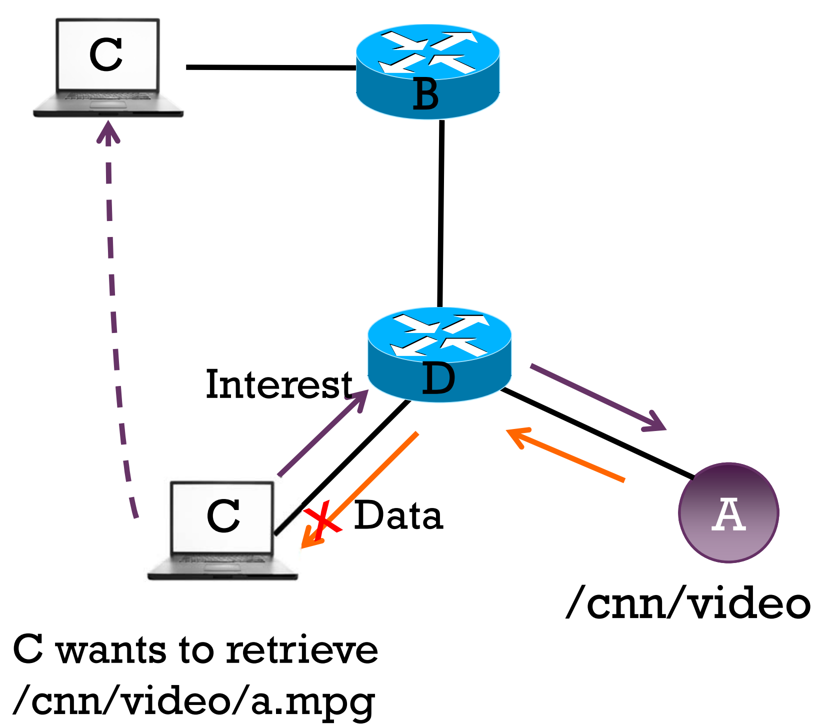

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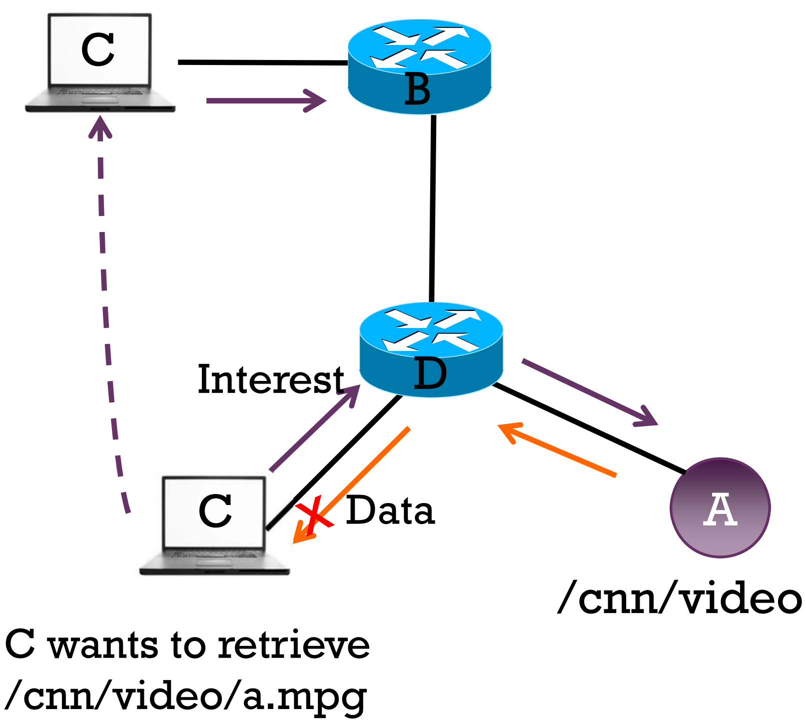

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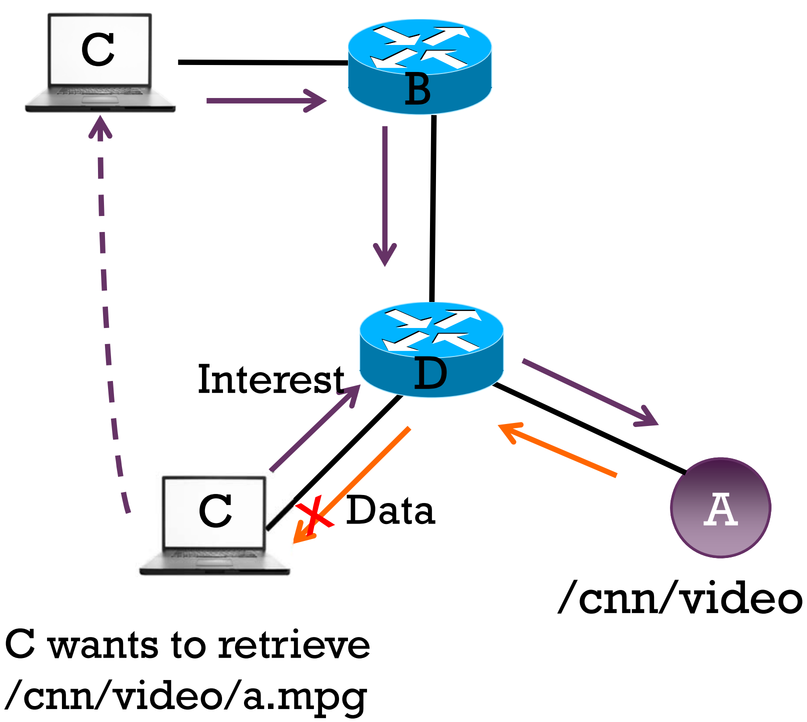

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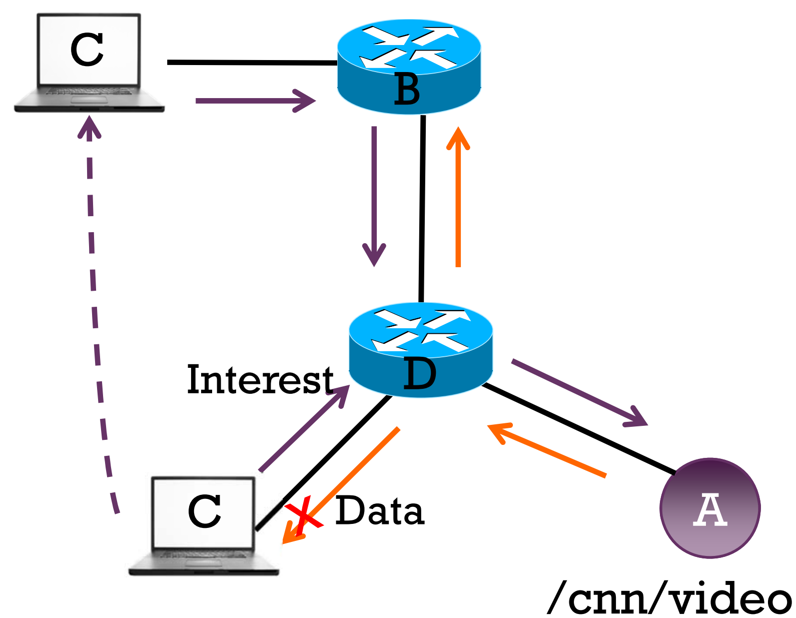

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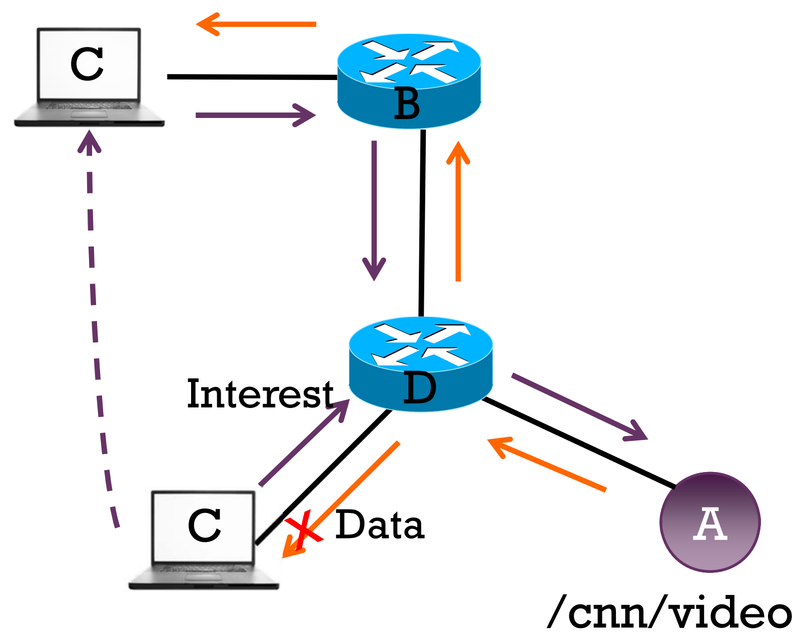

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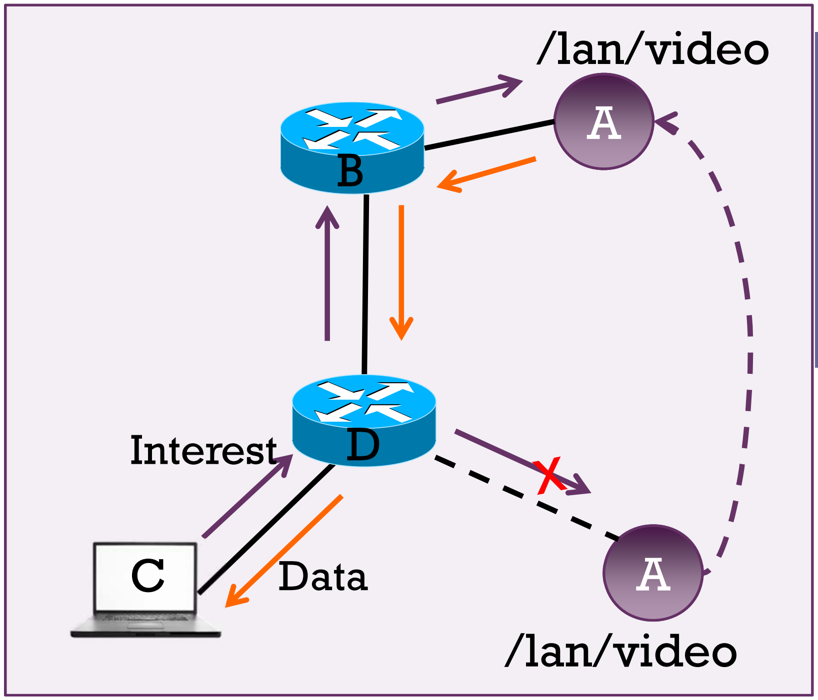
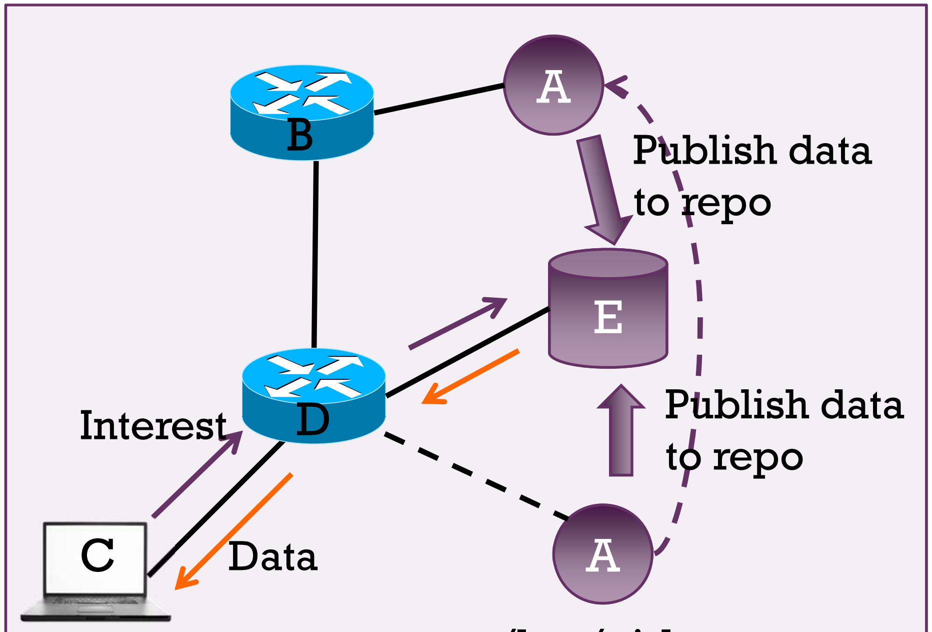
Mobility (2)

Producer mobility: multiple complimentary mechanisms

- ***Caching***: Interest for previously requested data may be satisfied by intermediate caches.
- ***Routing advertisements***: advertise same name prefix at new location → subsequent Interests will go to new location.
- ***Forwarding Hint***: use name of the new attachment point as a hint to guide forwarding
  - Name = /lan/video/a.mpg/s1
  - Hint = /att/atlanta/rtrB
- ***Rendezvous Points***: producer may publish data to the same repo regardless of location (or one of a set of sync'ed repos).





NDN's Support for Routing

- ***Built-in security***: routing data is signed by originator and can be verified by receivers.

- ***Naming***: names facilitate management and trust.
  - Names identify routing components and relationship.
    - /att/atlanta/rtr1 → rtr1 in Atlanta PoP of ATT
  - Naming of data and keys reflect trust relationship. → Given a piece of data, you can derive the name of the signing key based on the trust model.

- ***Sync mechanism***: a new notion of transport to ensure multiple parties have the same information.
  - efficient way of set reconciliation
  - Routing protocol uses Sync to distribute routing information.

Named-data Link State Routing (NLSR)*

- Reuse a mature routing algorithm: link state
- NDN native
  - Names, not addresses (networks, routers, processes, data, keys)
  - Interest/Data are used to distribute routing info.
- Multipath support: modified Dijkstra's algorithm to produce a ranked list of next-hops for each name prefix.
- Security
  - a trust model for intra-domain routing
  - Routing data is signed by originating router and verified by receivers based on trust model.

* AKM M. Hoque, S. O. Amin, A. Alyyan, B. Zhang, L. Zhang, and L. Wang. *NLSR: Named-data link state routing protocol*. In ACM SIGCOMM ICN Workshop, 2013.

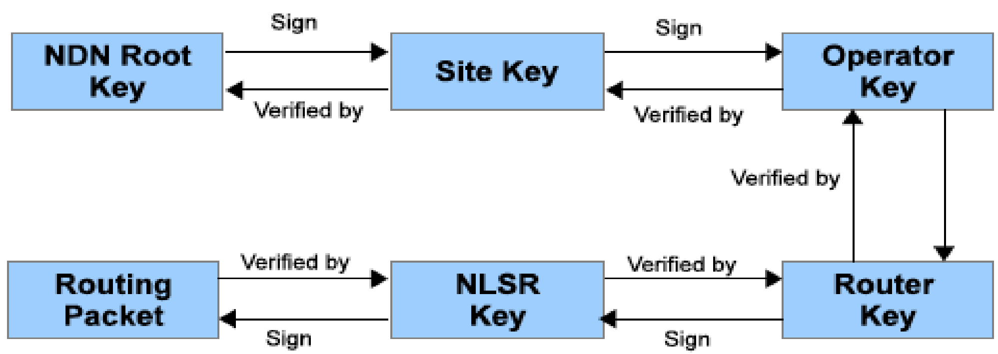
Naming in NLSR

- Follow the hierarchy within a network
  - Easy to identify the relationship among entities
  - Easy to associate keys with key owners
- Topology
  - /<network/<site>/<router>
    - E.g., /ndn/memphis/rtr1
- Updates
  - /<network>/NLSR/LSA/<site>/<router>/<type>/<version>
- Keys
  - NLSR key: /<network>/keys/<site>/<router>/NLSR
  - Router key, operator key, …

Message Authenticity and Integrity

- Every NLSR Data packet is signed.
- "key locator" includes information about the key.
- Receiver retrieves the key and verifies the signature.

Signing and verification in NLSR

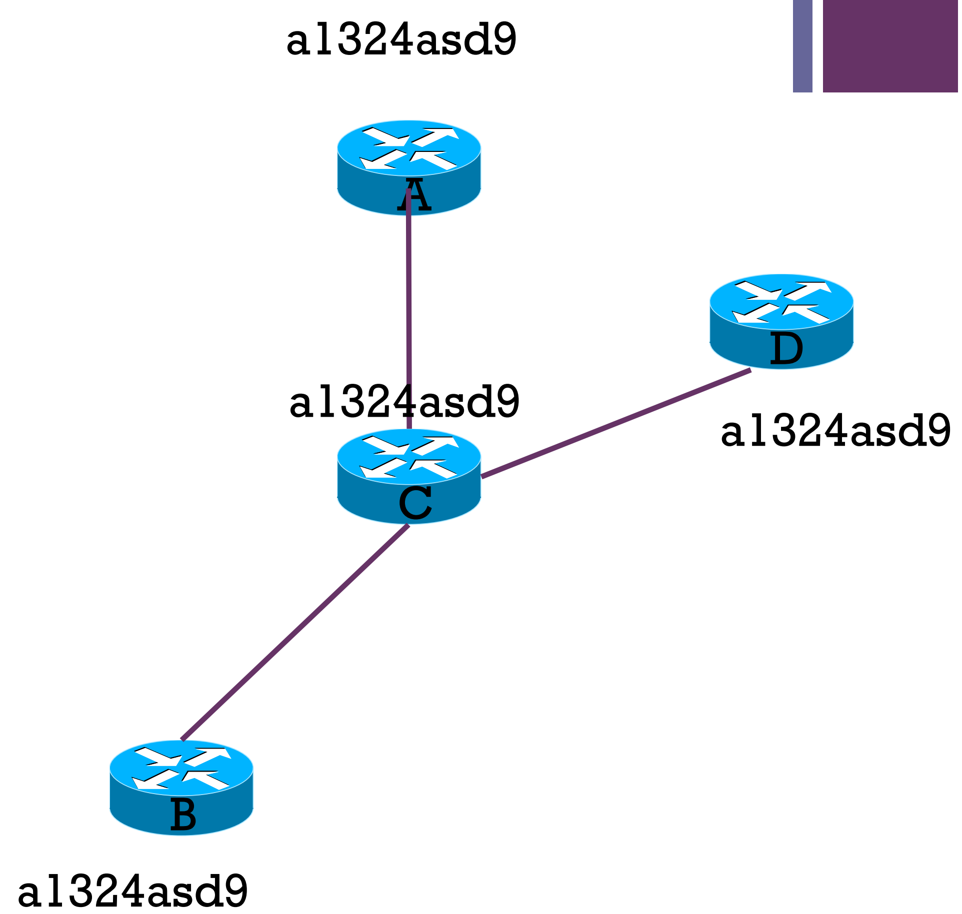


Key Owner	Key Name
Root	/<network>/keys
Site	/<network>/keys/<site>
Operator	/<network>/keys/<site>/<operator>
Router	/<network>/keys/<site>/<router>
NLSR	/<network>/keys/<site>/<router>/NLSR

From Flooding to Synchronization

NLSR synchronizes LSDB among routers.

- Every node periodically sends a digest of LSDB to others in Interest packets.
- When a node has a new LSA, its digest changes and it will reply to others' Interests with name of new LSA.
- Other nodes fetch new LSAs.
- More resilient/scalable, fits NDN model.



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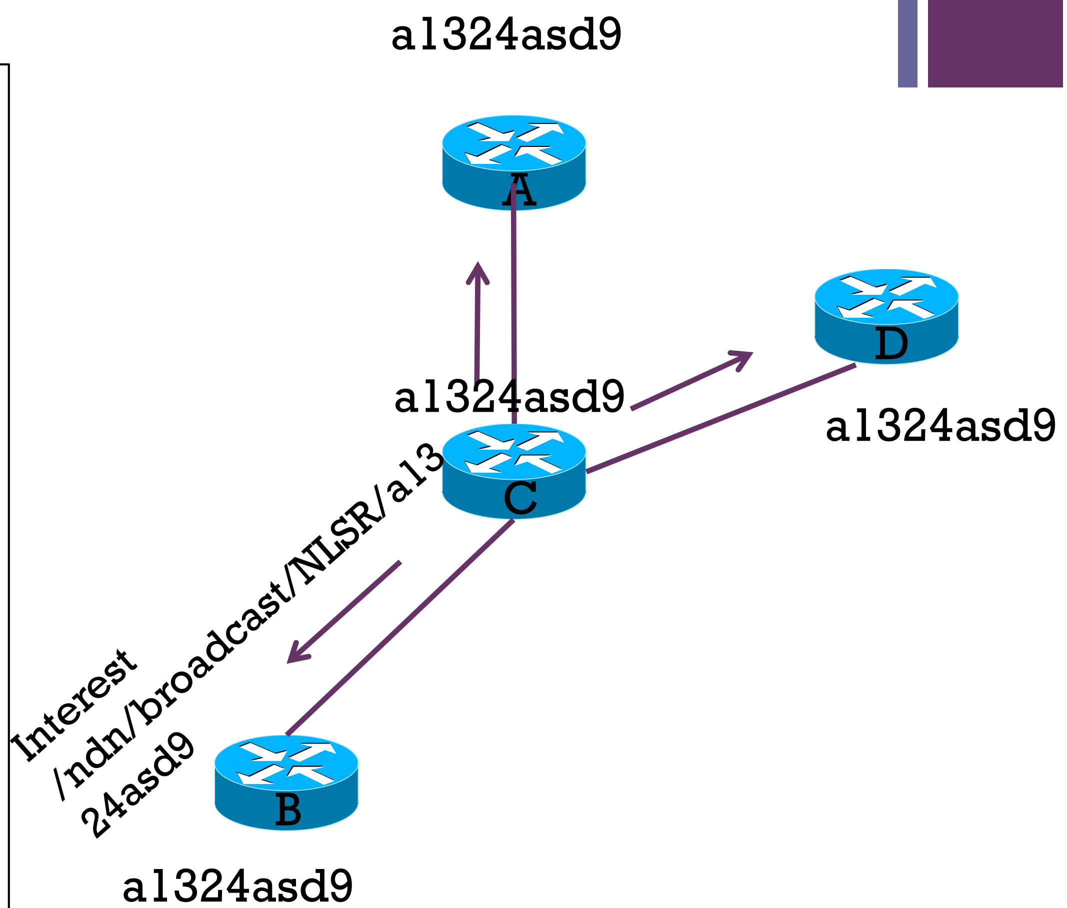

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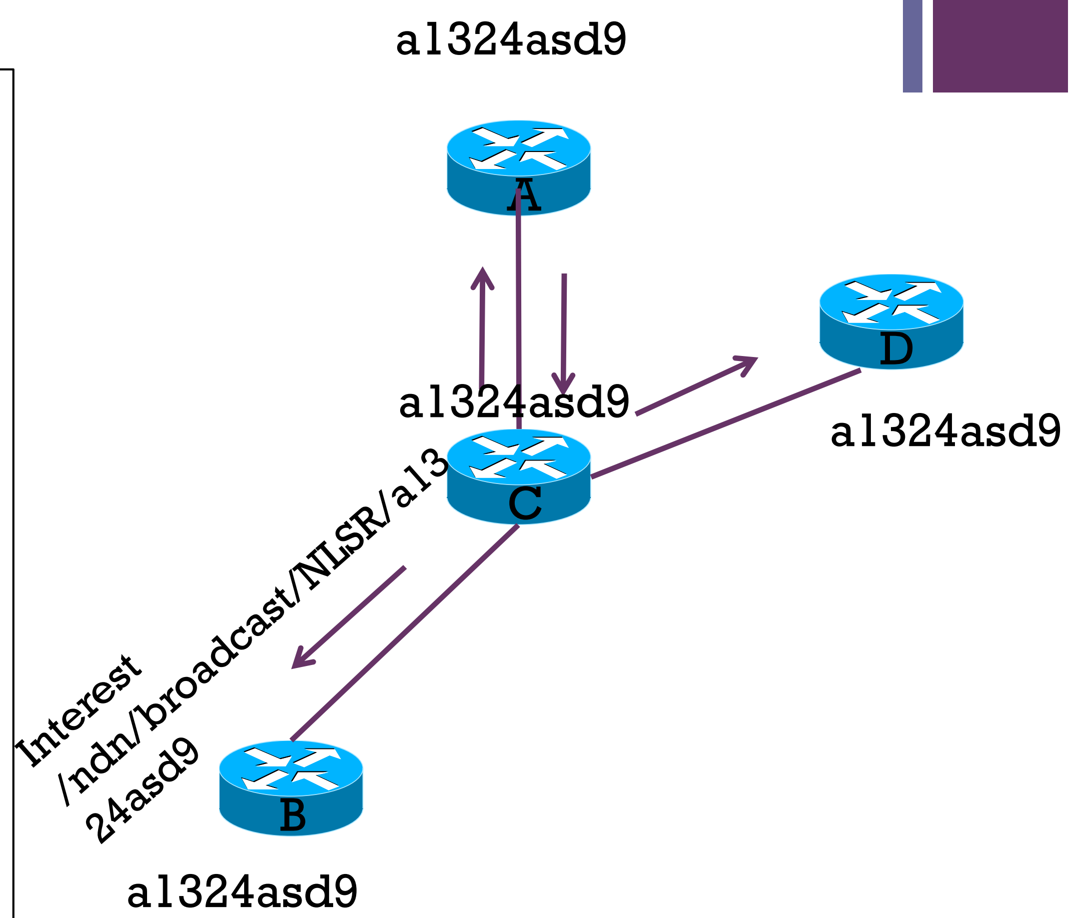

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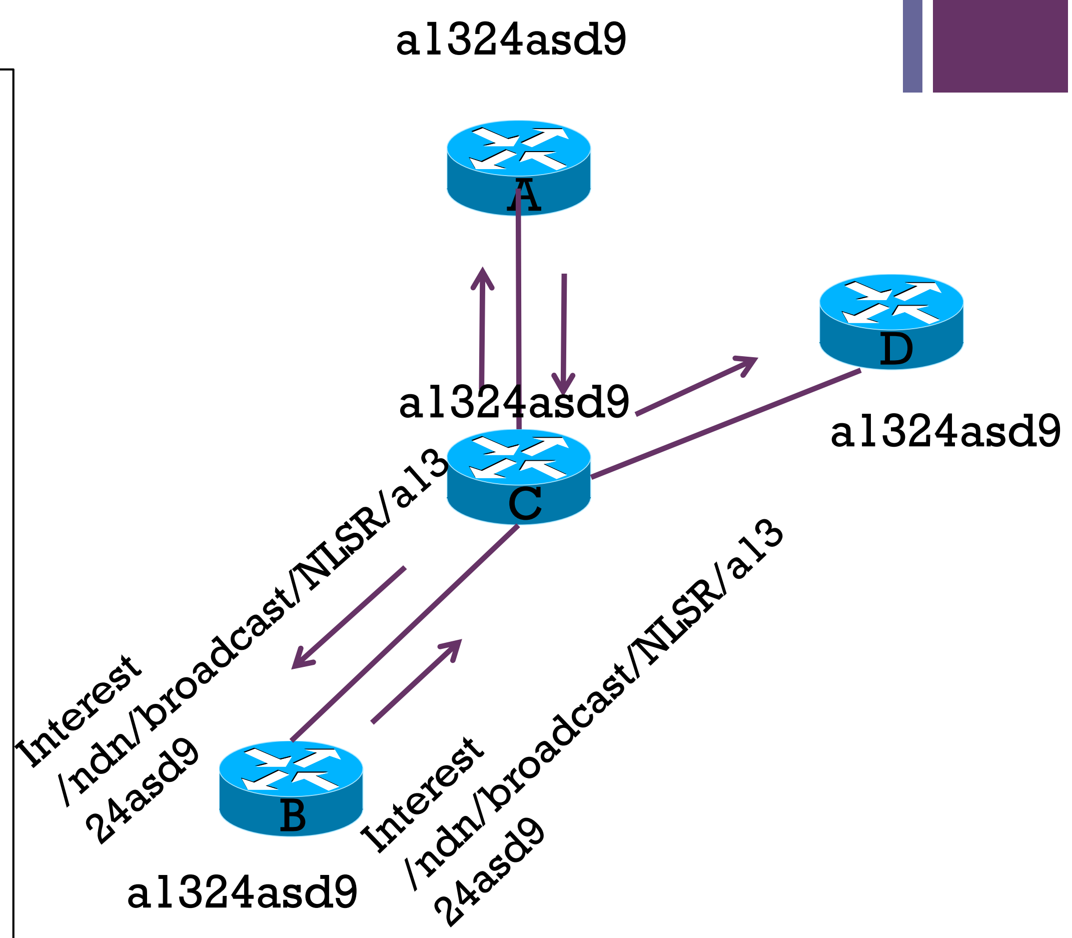

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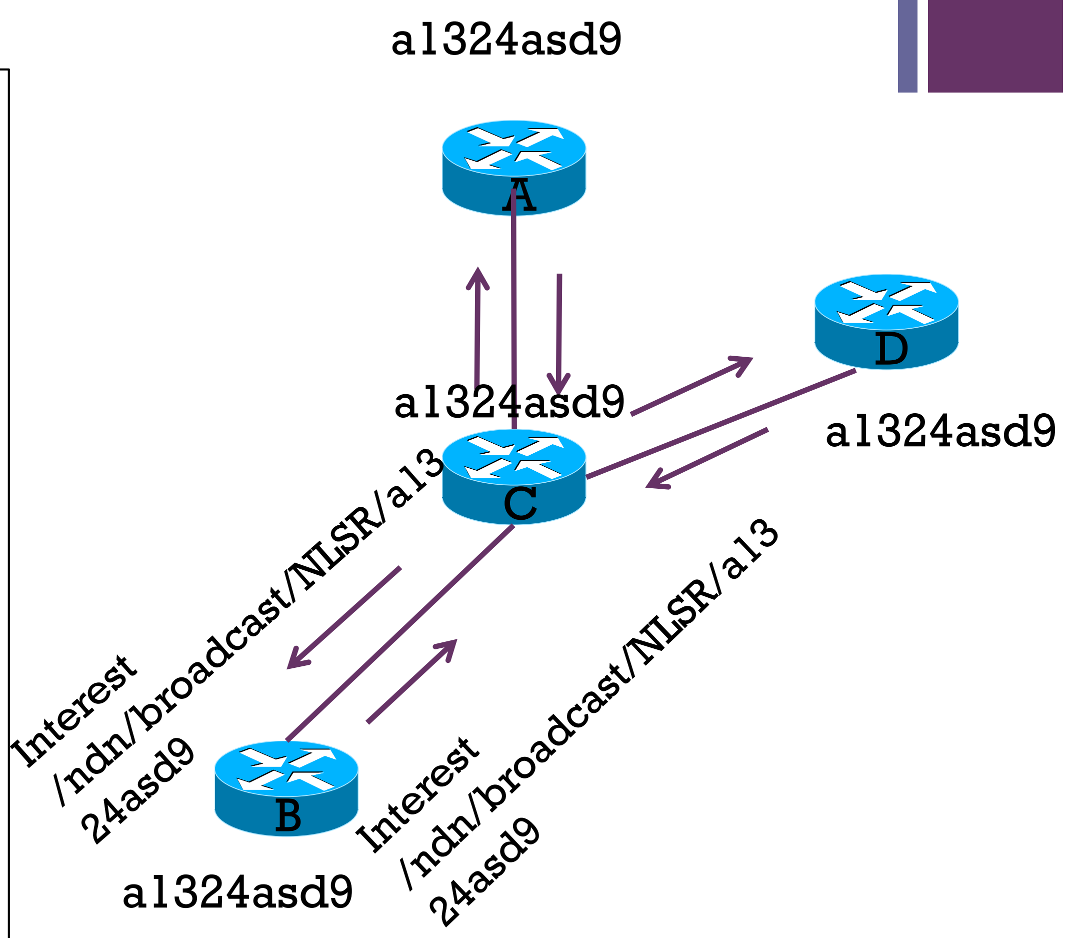

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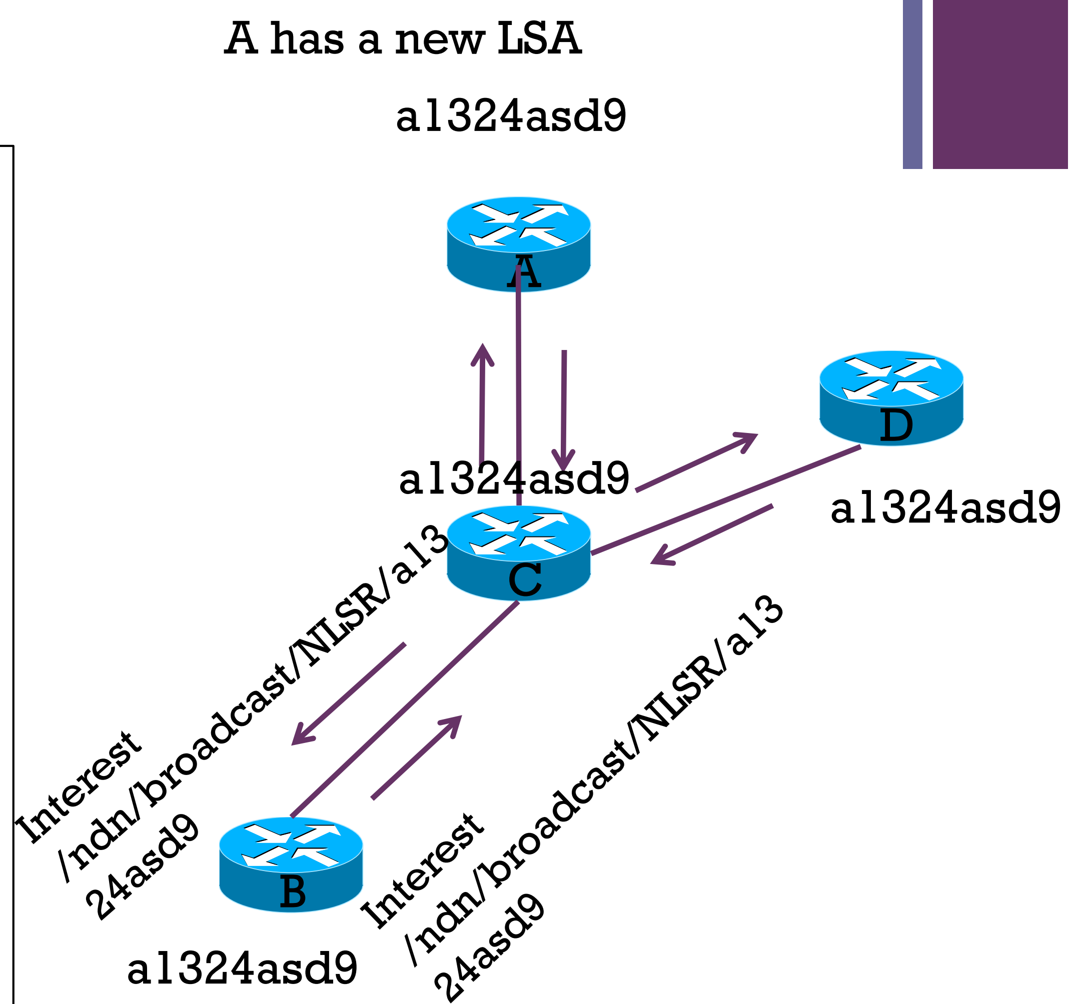

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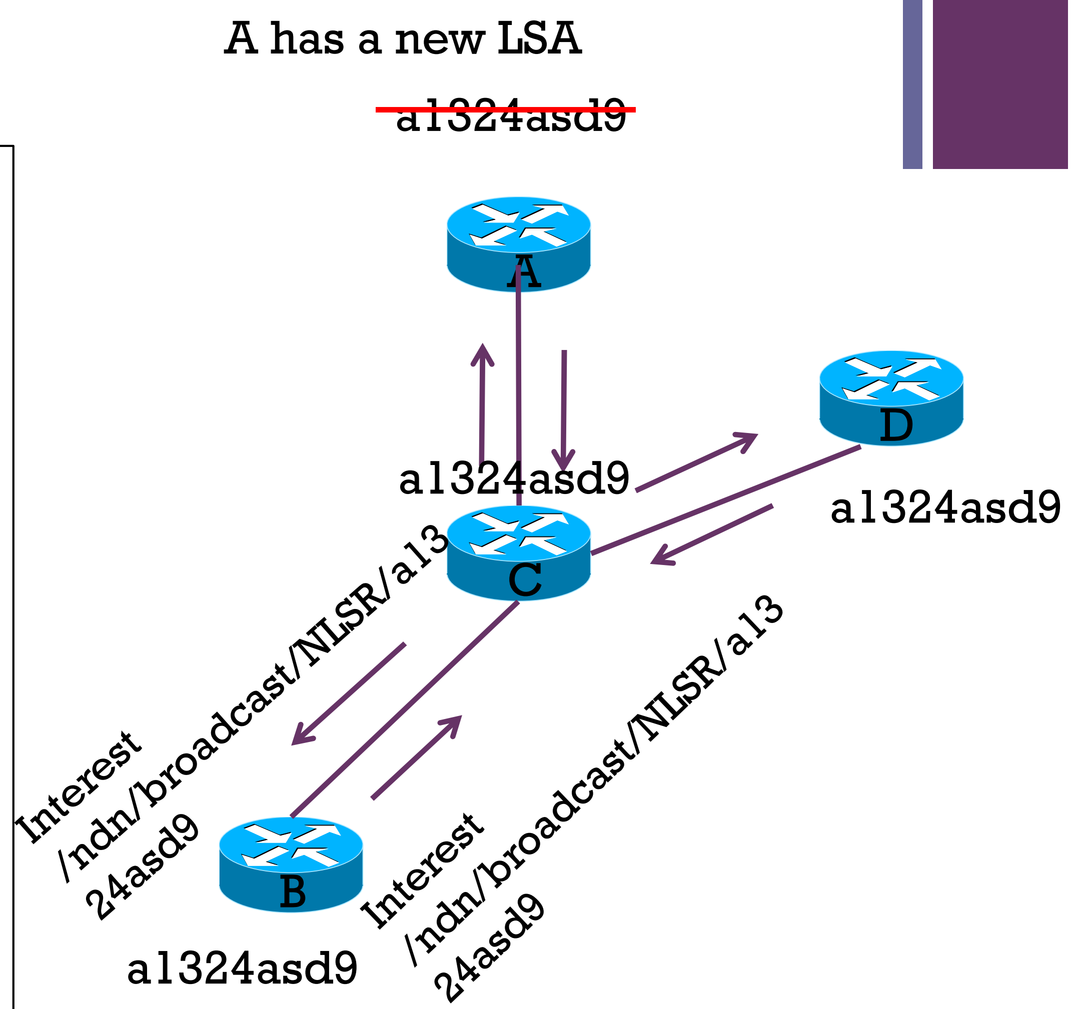

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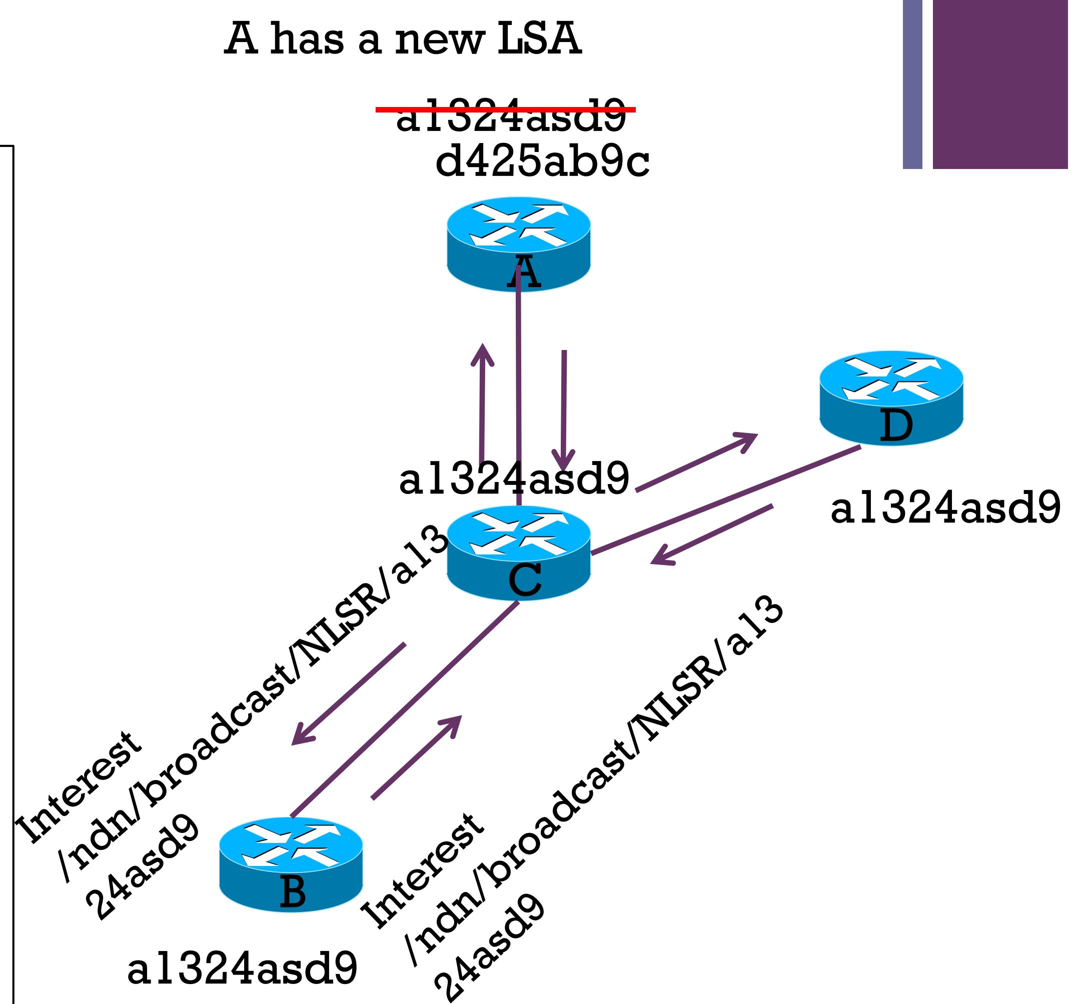

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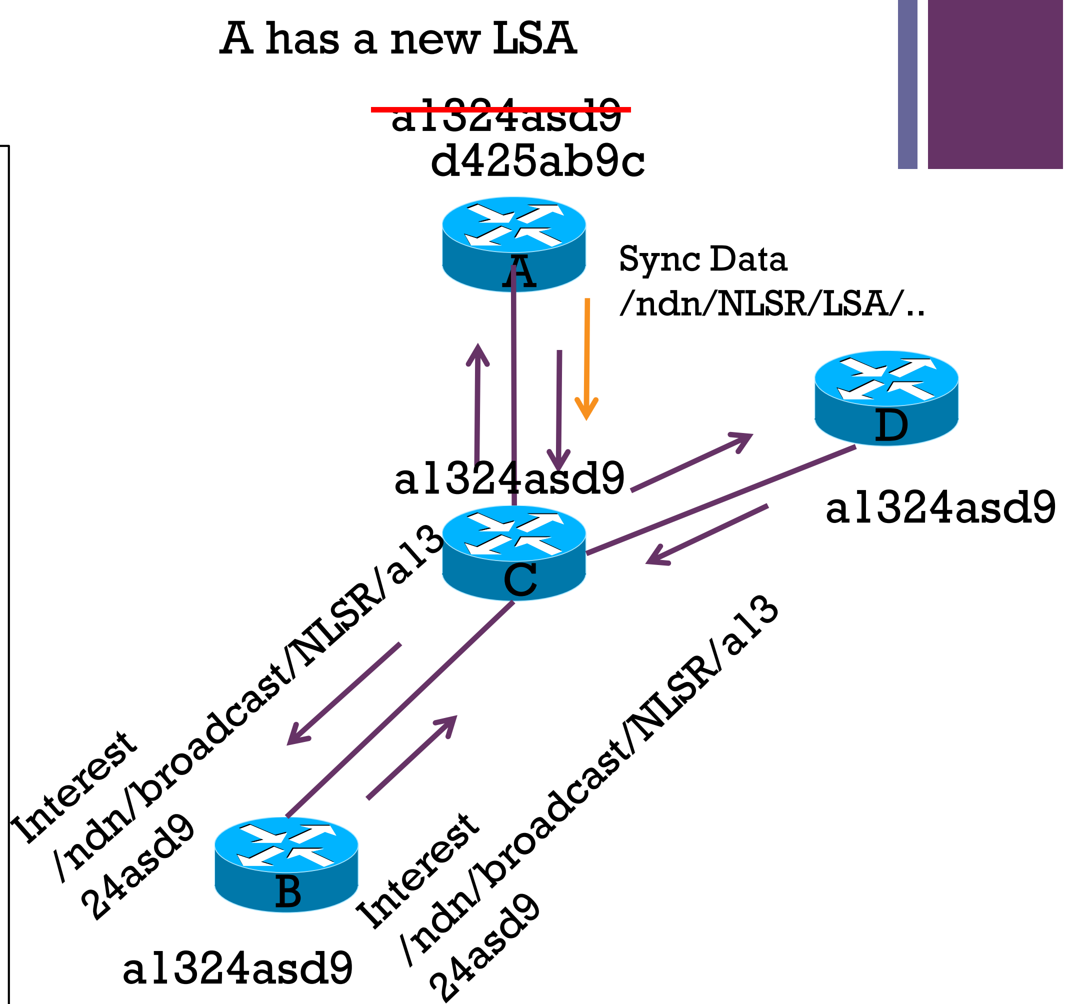
- When a node has a new LSA, its digest changes and it will reply to others' Interests with name of new LSA.
- Other nodes fetch new LSAs.
- More resilient/scalable, fits NDN model.



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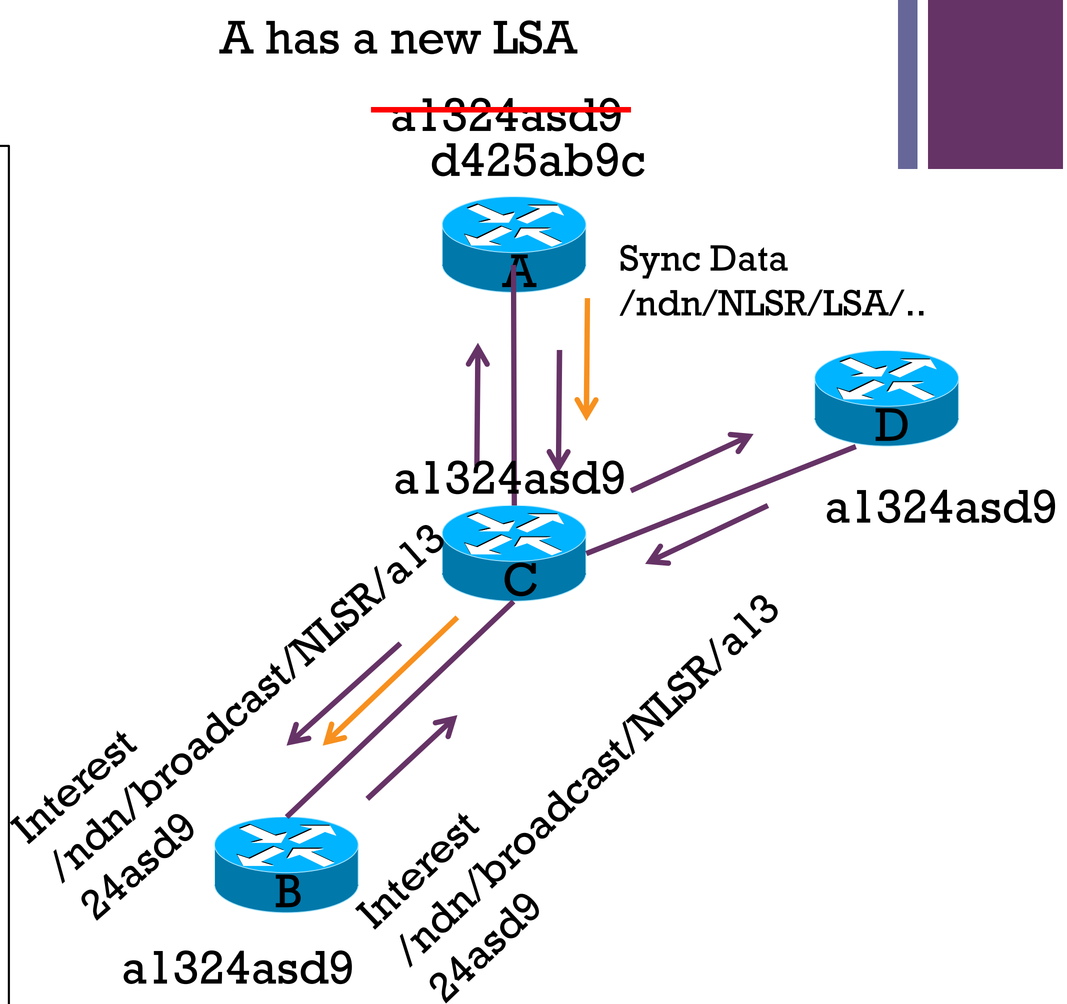

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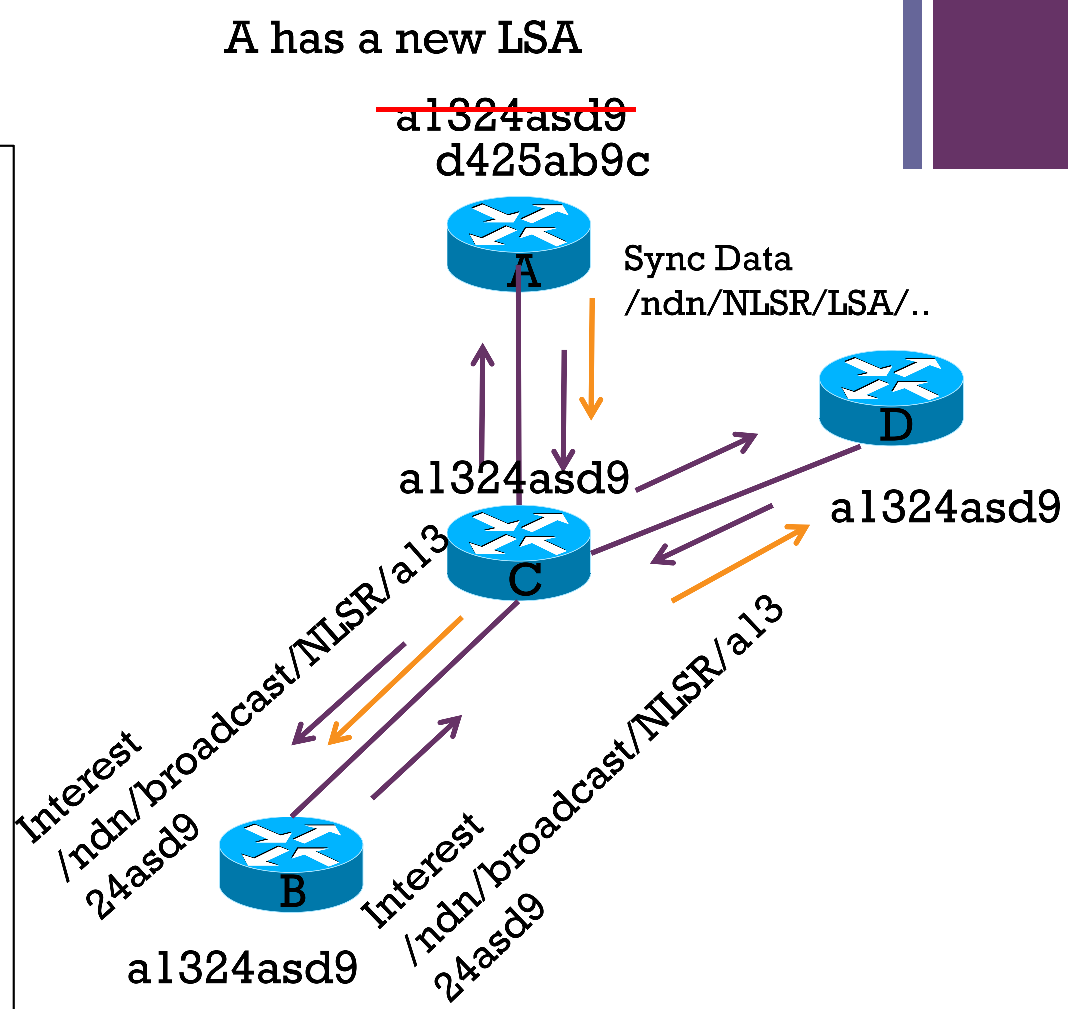

Status

- AKM M. Hoque, S. O. Amin, A. Alyyan, B. Zhang, L. Zhang, and L. Wang. *NLSR: Named-data link state routing protocol*. In ACM SIGCOMM ICN Workshop, 2013.
- Code available on github
  - https://github.com/NDN-Routing/NLSR0.0/tree/nlsr-sync
- Plan to deploy on NDN testbed soon.

Scaling

- Next step: Inter-domain routing
  - routing policy and trust model
- Hyperbolic routing
  - Each node has a set of hyperbolic coordinates.
  - Each name prefix has a set of hyperbolic coordinates.
  - Calculate next-hops based on each neighbor's distance to the name prefix
  - No need to distribute topological information.
- Map-and-Encap
  - Map application name prefixes to routable name prefixes (typically ISP name prefixes)
  - Orders of magnitude fewer routable name prefixes than application name prefixes
  - How to do mapping? ongoing research, e.g., DNS-like system

OSPF vs. NLSR

- Both are link-state intra-domain routing protocols.

	OSPF	NLSR
Naming	addresses	hierarchical names
Updates	network flooding	neighbor syncing
Next-hop	single	multiple
Security	password	public keys and trust model