Supporting Mobility in Named Data Networking

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3rd Workshop on Name-Oriented Mobility: Architecture, Algorithms and Applications (NOM'2016)

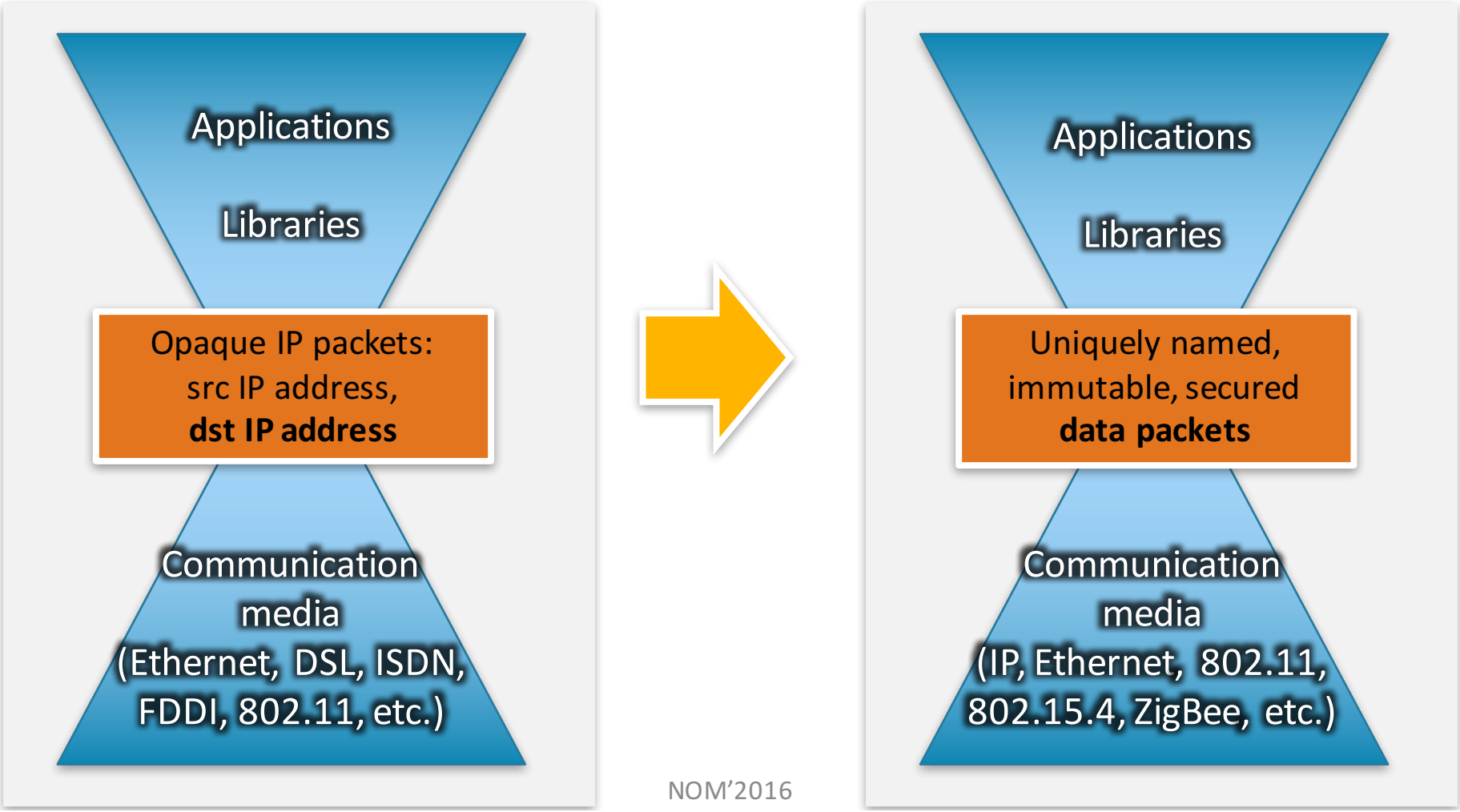
San Francisco, April, 2016

IP Mobility: Range of the Solutions

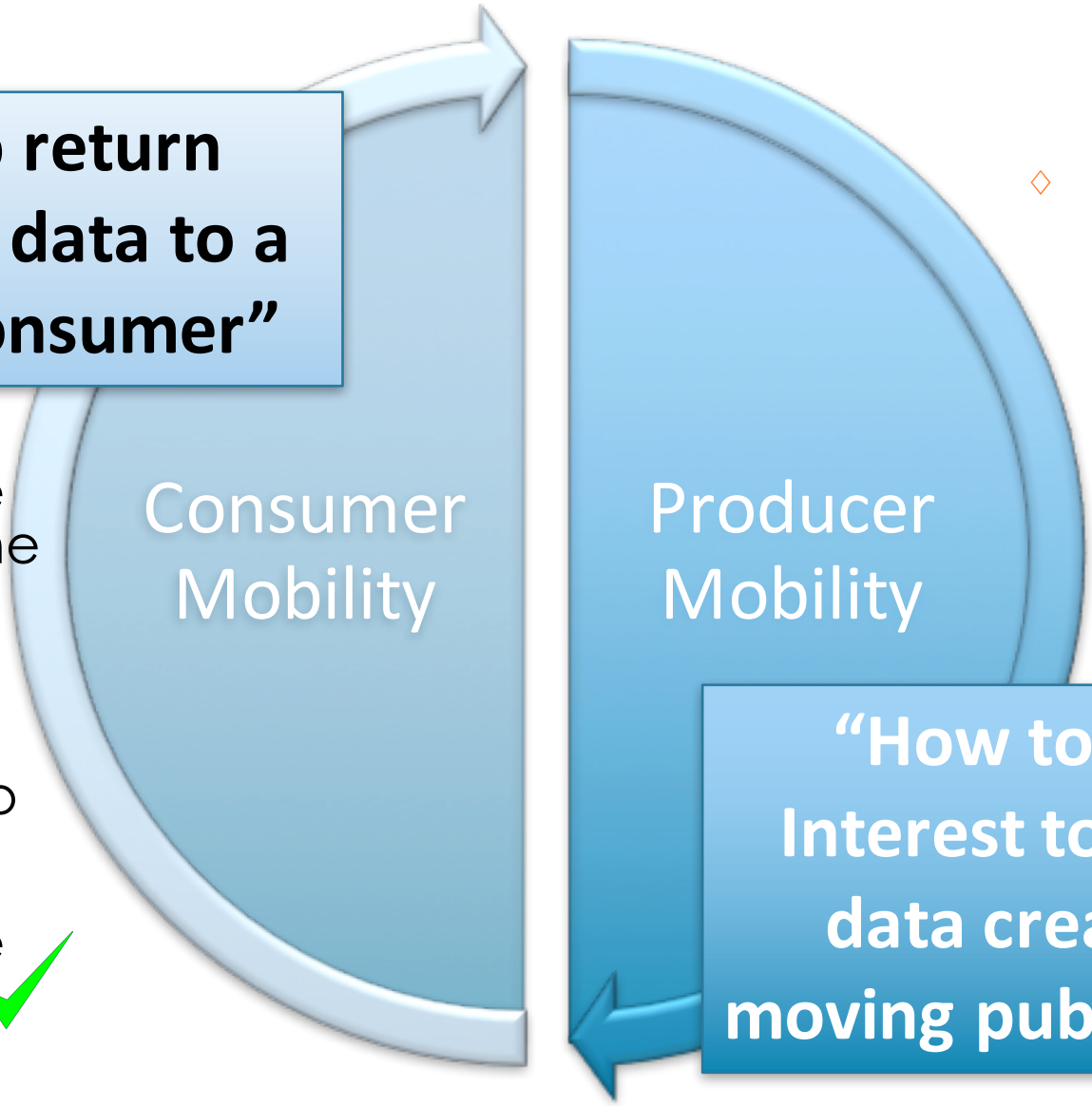
- Goal: **delivering packets to a mobile node**
- Core: reaching a moving destination through a rendezvous mechanism
- *Dynamic Routing*
  - Connexion
- *Mapping*
  - Mobile IP
  - BackToMyMack
  - ILNP
- *Tracing*
  - Cellular IP
  - MSM-IP (sparse mode)
- *Geo-routing*
  - Special case apps
  - Landmark routing

NDN Mobility Problem

- Goal: **Retrieve data while either/both consumer and producer may be moving**



NDN Mobility Problem Components



"How to return requested data to a moving consumer"

- Network knows where to forward the interest
- Stateful interest forwarding to return data ✓
- Refresh state after move (re-express interests) ✓

- Rendezvous mechanisms for interests to meet data
  - Chase MP
  - Rendezvous with data

"How to forward Interest towards the data created by a moving publisher (MP)"

Identified Producer Mobility Approaches

Mobile Producer (MP) Chasing	
Mapping	The MP reports to the rendezvous (RV) routable name(s) through which its data can be retrieved
Tracing	The MP creates a "breadcrumb trail" from the RV back to itself, that Interests can follow
Rendezvous Data	
Data depot	The MP moves its data to a known stationary depot
Data spot*	Data is produced in a stationary region by any MP in that region

*Special case apps

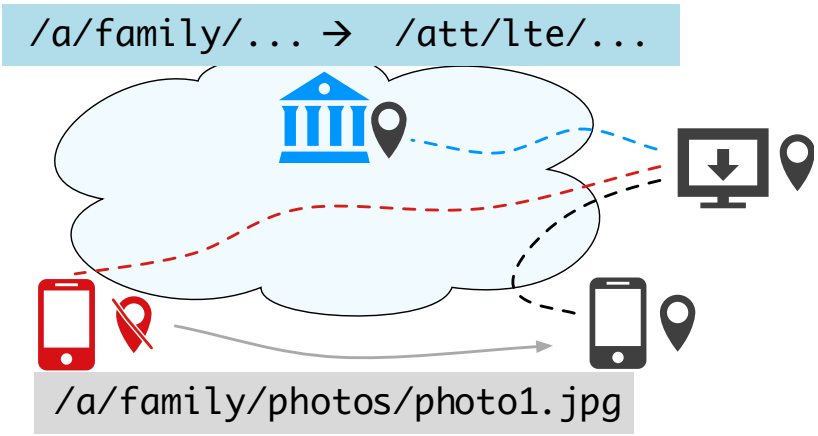
MP Chasing: Mapping

- MP report its current "reachable prefix" to the rendezvous

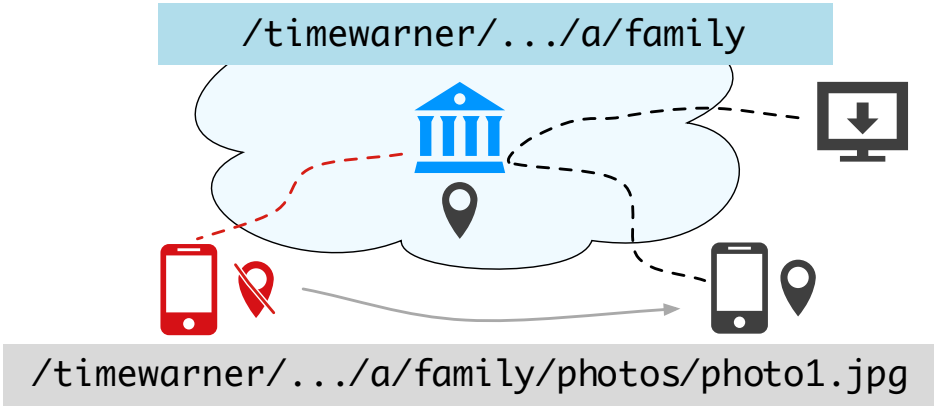
- What is the specific function of the rendezvous?
- How the reachable prefix is carried in an interest packet?

Function of the Rendezvous

- Mapping service[1,2,3]
  - MP publishes under its own namespace
  - Consumers lookup "reachable" prefix for MP's data*



- Home agent (HA)[4,5,6]
  - MP publishes under HA's prefix
  - Consumer interests reach HA, HA forwards towards MP*

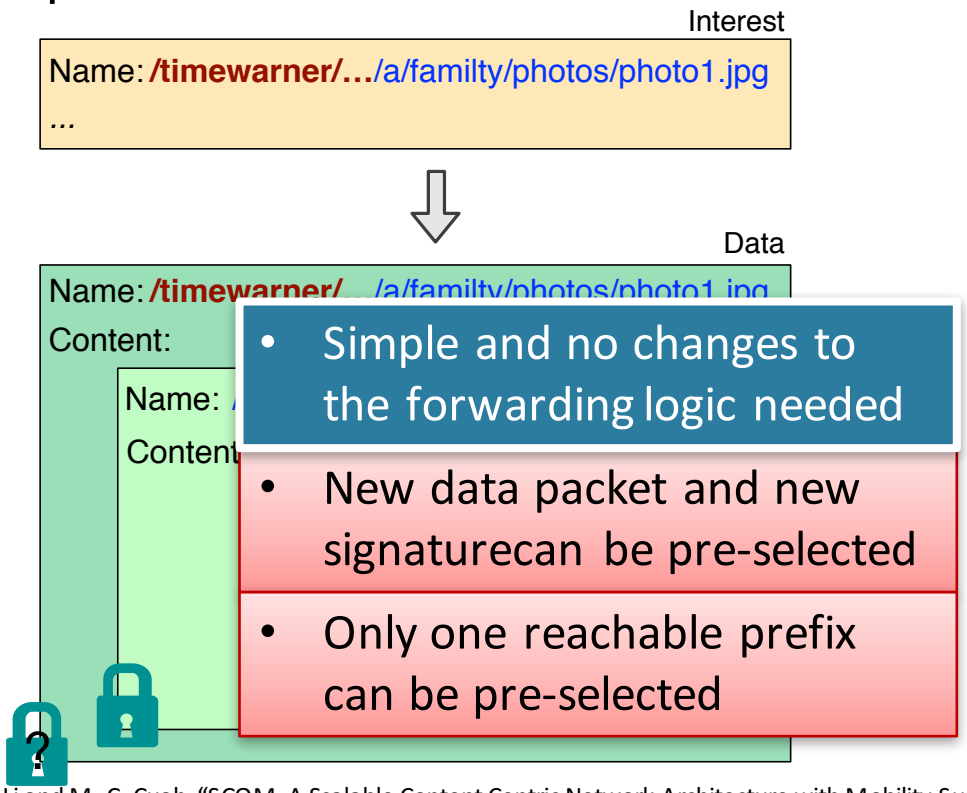


[1] A. Afanasyev, C. Yi, L. Wang, B. Zhang, and L. Zhang, "SNAMP: Secure namespace mapping to scale NDN forwarding," in IEEE Global Internet Symposium '15, 2015.
[2] J. Lee, S. Cho, and D. Kim, "Device mobility management in content-centric networking," IEEE Commun. Magazine, 2012.
[3] R. Ravindran, S. Lo, X. Zhang, and G. Wang, "Supporting seamless mobility in named data networking," IEEE ICC, 2012.
[4] F. Hermans, E. Ngai, and P. Gunningberg, "Global source mobility in the content-centric networking architecture," in NoM '12, 2012.
[5] J. Lee, S. Cho, and D. Kim, "Device mobility management in content-centric networking," IEEE Commun. Magazine, 2012.
[6] D.-h. Kim, J.-h. Kim, Y.-s. Kim, H.-s. Yoon, and I. Yeom, "Mobility support in content centric networks," in ICN '12, 2012.

* Interests can get satisfied before reaching MP

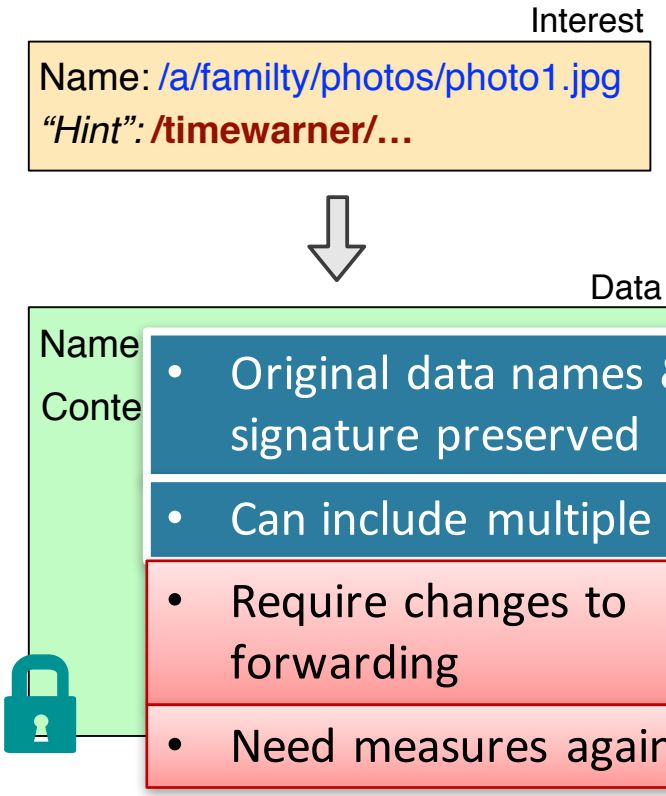
How to Carry the Reachable Prefix in Interests

- Concatenate prefixes[1,2,3,4,5]



- Simple and no changes to the forwarding logic needed
- New data packet and new signaturecan be pre-selected
- Only one reachable prefix can be pre-selected

- Carry "hints" [1,5,6,7]

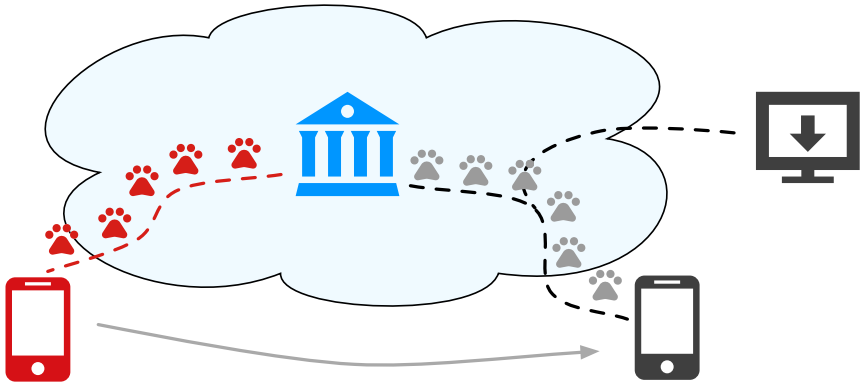


- Original data names & signature preserved
- Can include multiple hints
- Require changes to forwarding
- Need measures agains abuse

[1] D. Li and M. C. Cuah, "SCOM: A Scalable Content Centric Network Architecture with Mobility Support," in IEEE MSN, 2013.
[2] J. Lee, S. Cho, and D. Kim, "Device mobility management in content-centric networking," IEEE Commun. Magazine, 2012.
[3] R. Ravindran, S. Lo, X. Zhang, and G. Wang, "Supporting seamless mobility in named data networking," IEEE ICC, 2012.
[4] D.-h. Kim, J.-h. Kim, Y.-s. Kim, H.-s. Yoon, and I. Yeom, "Mobility support in content centric networks," in ICN '12, 2012.
[5] A. Afanasyev, "Addressing Operational Challenges in Named Data Networking Through NDNS Distributed Database," Ph.D. dissertation, ULCA, 2013.
[6] A. Afanasyev, C. Yi, L. Wang, B. Zhang, and L. Zhang, "SNAMP: Secure namespace mapping to scale NDN forwarding," in IEEE Global Internet Symposium '15, 2015.
[7] F. Hermans, E. Ngai, and P. Gunningberg, "Global source mobility in the content-centric networking architecture," in NoM '12, 2012.

MP Chasing: Tracing

- Use stateful forwarding to bring back interests[1,2,3,4,5]
  - MP sends interests towards RP to create "breadcrumb path" to get interest
  - Traces can be concatenated[3,4]
  - Consumer Interests can take shortcuts

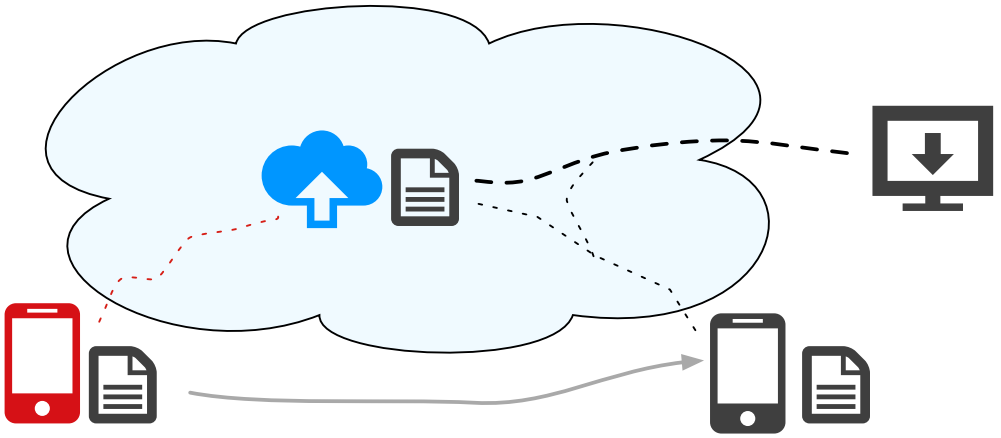


- Design choices:
  - Trace-state-in-FIB[1,2,3,4]
  - trace-state-in-PIT[5]

[1] D.-h. Kim, J.-h. Kim, Y.-s. Kim, H.-s. Yoon, and I. Yeom, "Mobility support in content centric networks," in ICN '12, 2012.
[2] L. Wang, O. Waltari, and J. Kangasharju, "MobiCCN: Mobility support with greedy routing in Content-Centric Networks," Globecom, 2013.
[3] D. Han, M. Lee, K. Cho, T. T. Kwon, and Y. Choi, "PMC: Publisher Mobility Support for Mobile Broadcasting in Content Centric Networks," ASIA Future Internet 2012 Summer School, 2012.
[4] J. Augé, G. Carofiglio, G. Grassi, L. Muscariello, and G. Pau, "Anchor-less Producer Mobility in ICN," in ACM ICN'15, 2015, pp. 189–190.
[5] Y. Zhang, H. Zhang, and L. Zhang, "Kite: A mobility support scheme for NDN," in ACM ICN'14, 2014, pp. 179–180.

Data Rendezvous: Data Depot

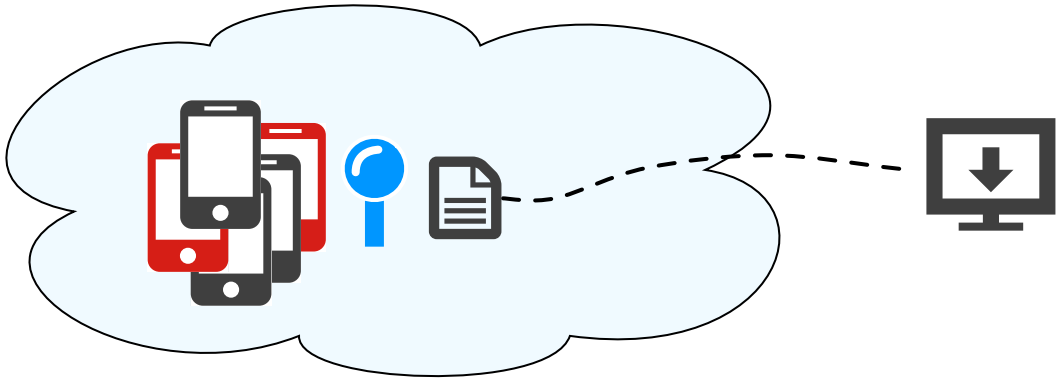
- Move the data generated by MP to a "stationary" place[1]
  - MP uploads data once it is produced
    - e.g., using trace-in-PIT upload protocol
  - Interests for data can take shortcuts
    - Meet cached data
    - Cross path with traces



[1] V. Jacobson et al., "Custodian-based information sharing," IEEE Communications Magazine, vol. 50, no. 7, pp. 38–43, 2012.

Data Rendezvous: Data Spot

- "Same" data can be produced by multiple MPs "on the spot"
  - Road traffic monitoring
  - "/I405/CA /Westwood/traffic/Jan9,2015-8pm")
- Interests "rendezvous" data either via geo-routing or through road-side units announcing prefixes into the global routing table



[1] G. Grassi, D. Pesavento, G. Pau, L. Zhang, R. Vuyyuru, and R. Wakikawa, "VANET via Named Data Networking," in NoM, 2014.

Tradeoffs of Different Approaches

- Depot
  - Hide mobility from all consumers
  - Still need either mapping or tracing to move data
- Mapping
  - Keep MP movement info at one place only
  - If lots consumers: everyone has to do lookup
- Tracing
  - All nodes along the path involved, need period refreshes
  - If no one fetches data, pure overhead
  - Active data fetching makes it more feasible
- Spot
  - Anybody can send interests directly asking for data
  - Works for special case applications
  - May have issues with malicious producers on the spot

Tradeoffs for Architectural Changes

Approach	Changes	Cost

Mapping + hint	• Interest format
	• Forwarding processing
		• Increased forwarding complexity
		  • security mechanisms
		• Additional management
		  • protocol to obtain routable names

Mapping + name prepending	• Optional changes in forwarding processing (e.g., data decap)	• Changed data (e.g., data encap) • Network forced to forward interests towards the selected directions

Trace-in-FIB	• Update "tentative" FIB when receiving trace interests
	• Look both FIBs when processing ordinary interests
		• In-network state that needs to be refreshed
		  • pure overhead if no one is fetching
		• Potential security complications
		  • e.g., by creating /google trace

Trace-in-PIT	• Use PIT state (trace) to forward interests when requested	• In-network state that needs to be refreshed • pure overhead if no one is fetching

Summary

- Producer mobility requires a means to rendezvous interests with data
  - Routing (scaling issue), mapping, tracing, data depot
- Our analysis suggests the need for a combination of solutions
  - data depot + mapping / tracing
    - all kinds of depots possible (facebook, company data depot, personal home depot)
  - Mapping / tracing to move data to the depot

Future work needed

- Identify implications and additional costs for tracing approaches
- Experiment with different applications designs to gain better understanding about the tradeoffs