

# Supporting Mobility\* in Named Data Networking

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\* In the context of the globally connected infrastructure

# Outline

- ◇ IP mobility problem and range of the solutions
- ◇ NDN mobility problem: take another detailed look
- ◇ Summary of all published papers on the subject
  - How many different ways to support NDN producer mobility
- ◇ What we learn from all the above

# IP Mobility: Range of the Solutions

- ◇ Goal: **delivering packets to a mobile node**
- ◇ The core idea of all solutions: reaching a moving destination through a rendezvous mechanism
  - Dynamic Routing: mobile informs all routers
    - ◇ Connexion<sup>1</sup>
  - Mapping: mobile reports its current address to RP
    - ◇ Mobile IP, BackToMyMack<sup>2</sup>, ILNP<sup>3</sup>
  - Tracing: mobile builds a path from RP to itself
    - ▷ Cellular IP<sup>4</sup>
    - ▷ MSM-IP (sparse mode)<sup>5</sup>
  - Geo-routing
    - ▷ Special case apps
    - ▷ Landmark routing

[1] [https://en.wikipedia.org/wiki/Connexion\\_by\\_Boeing](https://en.wikipedia.org/wiki/Connexion_by_Boeing)

[2] S. Cheshire, Z. Zhu, R. Wakikawa, and L. Zhang, "Understanding Apple's back to my mac (BTMM) service," RFC 6281, 2011.

[3] R. Atkinson and S. Bhatti, "Identifier-locator network protocol (ILNP) architectural description," RFC 6740, November 2012.

[4] A. G. Valkó, "Cellular IP: A new approach to internet host mobility," SIGCOMM CCR, vol. 29, no. 1, pp. 50–65, 1999.

[5] J. Mysore and V. Bharghavan, "A new multicasting-based architecture for Internet host mobility," in MobiCom '97, 1997.

# NDN Mobility Problem

- ◇ Goal: **Retrieve data while either/both consumer and producer may be moving**
- ◇ First understand how consumer mobility supported naturally
- ◇ Then figure out how to support producer mobility

# Consumer Mobility

- ◇ **“How to return requested data to a moving consumer”**
- ◇ Assumes the network knows where to forward the interest
- ◇ Leverages stateful interest forwarding, leaving behind a breadcrumb trace for data to follow
- ◇ Mobile can always re-express interests after moving to rebuild the breadcrumb

# Producer Mobility

- ◇ **“How to forward Interest towards the data created by a moving publisher (MP)”**
- ◇ Solution: design rendezvous mechanisms for interests to meet data generated by the MP
- ◇ Rendezvous with the MP
  - interests “chase” MP to retrieve data from it
- ◇ Rendezvous with data
  - data can be moved/provisioned in “stationary” place

# Identified Producer Mobility Approaches

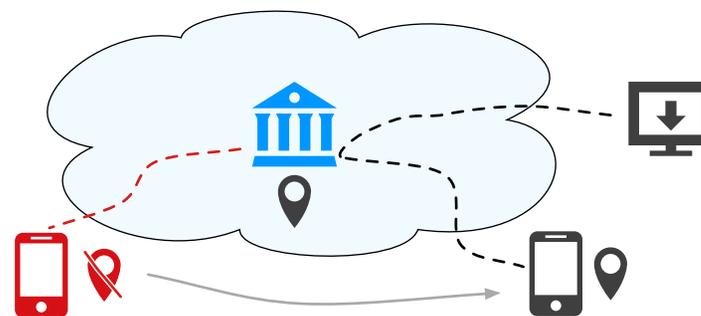
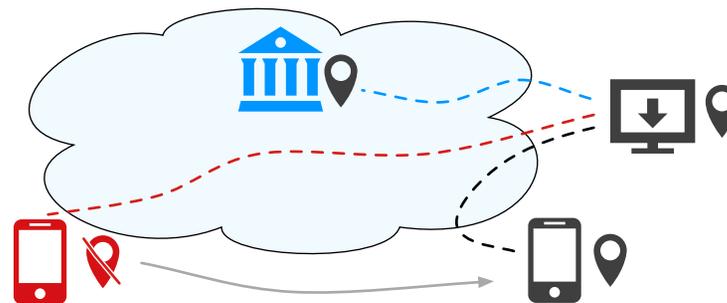
<b>Chase Mobile Producer</b>	
<b>Mapping</b>	The MP reports to the RP routable name(s) through which its data can be retrieved
<b>Tracing</b>	The MP creates a “breadcrumb trail” from the RP back to itself, that Interests can follow
<b>Rendezvous Data</b>	
<b>Data depot</b>	The MP moves its data to a known stationary depot
<b>Data spot*</b>	Data is produced in a stationary region by any MP in that region

# MP Chasing: Mapping

- ◇ MP report its current “routable prefix” to the RP
- ◇ 2 specific questions:
  - What RP does?
  - How to carry the routable prefix in an interest packet?

# RP may do different things

- ◇ Offer Mapping service only<sup>1,2,3</sup>
  - MP can publish data under any namespace
    - ▷ /a/family/photos/photo1.jpg
  - Consumers look up MP's data name to find routable prefix that can be used to forward interest to MP directly\*
    - ▷ /a/family/... => /att/lte/...
- ◇ Behave like a Home agent<sup>4,5,6</sup>
  - MP publishes under HA's prefix
    - ▷ /timewarner/.../a/family/...
  - 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.

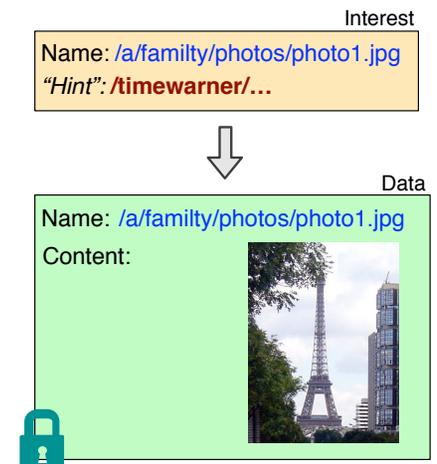
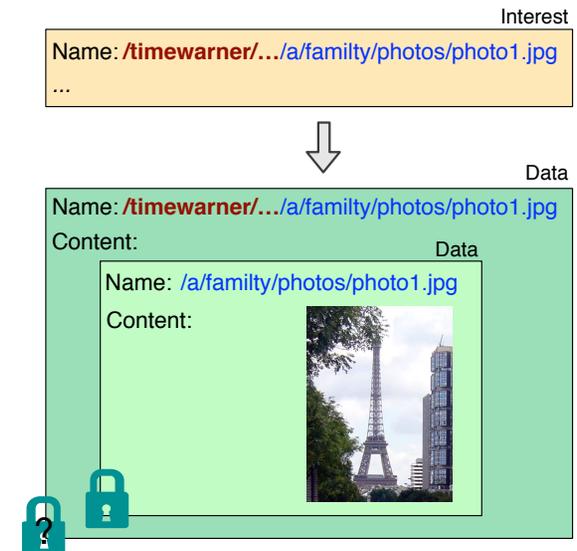
[6] D.-h. Kim, J.-h. Kim, Y.-s. Kim, H.-s. Yoon, and I. Yeom, "Mobility support in content centric networks," in ICN '12, 2012.

\* Interests can get satisfied before reaching MP

# How to get Interests to the MP

- ◇ Concatenate routable prefix with (unroutable) data names<sup>1,2,3,4,5</sup>
  - Interests can be forwarded in standard way
  - Change interest names: reply data must bear the same name as interest => have to make a new data packet with new (?) signature
  - If data reachable via two or more routable prefixes: can only select one to use
- ◇ carry routable name as “hints” in interests<sup>1,5,6,7</sup>
  - Original data names & signature preserved
  - Multiple hints possible
  - Require changes to the forwarding lookup
  - Need measures against potential abuse

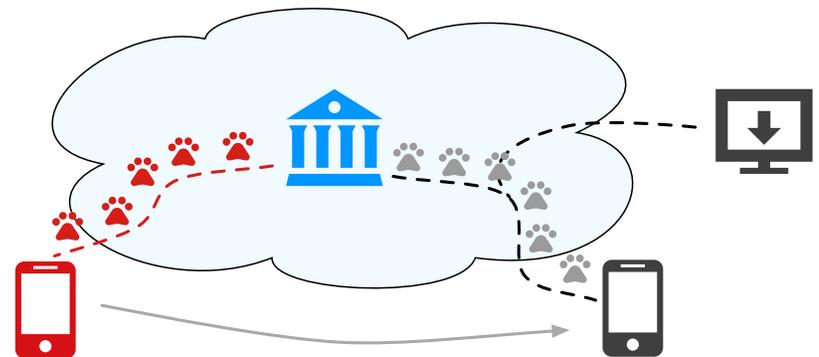
[1] D. Li and M. C. Cuah, “SCOM: A Scalable Content Centric Network Architecture with Mobility Support,” in IEEE MSN, 2013.  
[2] J. Lee, S. Cho, and D. Kim, “Device mobility management in content-centric networking,” IEEE Commun. Magazine, 2012.  
[3] R. Ravindran, S. Lo, X. Zhang, and G. Wang, “Supporting 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 NDN 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<sup>1,2,3,4,5</sup>
  - MP sends interests towards RP to create “breadcrumb path” to get interest
  - Traces can be concatenated<sup>3,4</sup>
  - Consumer Interests can take shortcuts

- ◇ Design choices:
  - Trace-state-in-FIB<sup>1,2,3,4</sup>
  - trace-state-in-PIT<sup>5</sup>



[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.

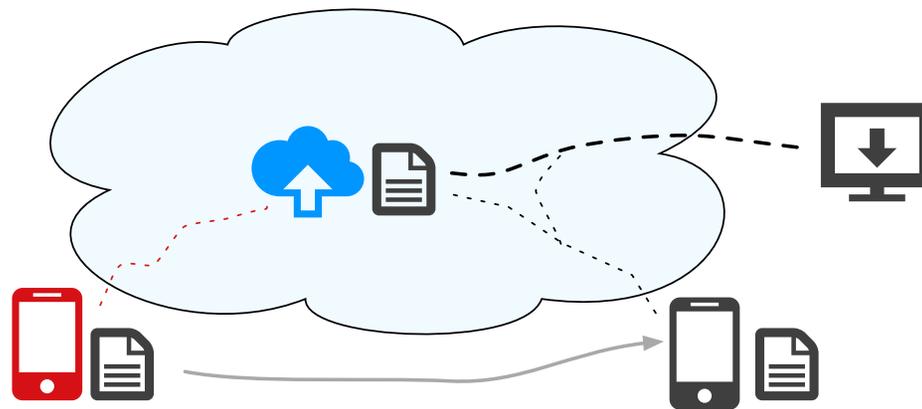
[3] D.Han, M.Lee, K.Cho, T.T.Kwon, and Y.Choi, “PMC: Publisher Mobility Support for Mobile Broadcasting in Content Centric Networks,” ASIA Future Internet 2012 Summer School, 2012.

[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

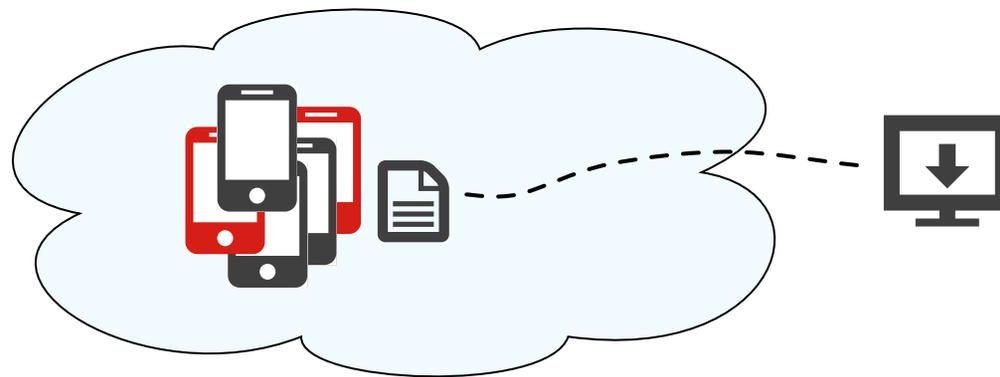
- ◇ Move the data generated by MP to a “stationary” place<sup>1</sup>
  - MP uploads data once it is produced
    - ▷ e.g., using trace-in-PIT upload protocol
  - Interests for data can take shortcuts
    - ▷ Meet cached data
    - ▷ Cross path with traces



[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



# Tradeoffs of Different Approaches

- ◇ Depot
  - Hide mobility from all consumers
  - Still need either mapping or tracing for data upload
- ◇ 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	<ul style="list-style-type: none"><li>• Interest format</li><li>• Forwarding processing</li></ul>	<ul style="list-style-type: none"><li>• Increased forwarding complexity</li><li>• Additional management<ul style="list-style-type: none"><li>• protocol to obtain routable names</li></ul></li></ul>
Mapping + name prepending	<ul style="list-style-type: none"><li>• Optional changes in forwarding processing (e.g., data decap)</li></ul>	<ul style="list-style-type: none"><li>• Changed data (e.g., data encap)</li><li>• Network forced to forward interests towards the selected directions</li></ul>
Trace-in-FIB	<ul style="list-style-type: none"><li>• Update "tentative" FIB when receiving trace interests</li><li>• Look both FIBs when processing ordinary interests</li></ul>	<ul style="list-style-type: none"><li>• In-network state that needs to be refreshed<ul style="list-style-type: none"><li>• pure overhead if no one is fetching</li></ul></li><li>• Potential security complications<ul style="list-style-type: none"><li>• e.g., by creating /google trace</li></ul></li></ul>
Trace-in-PIT	<ul style="list-style-type: none"><li>• Use PIT state (trace) to forward interests when requested</li></ul>	<ul style="list-style-type: none"><li>• In-network state that needs to be refreshed<ul style="list-style-type: none"><li>• pure overhead if no one is fetching</li></ul></li></ul>

# 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, least cost(?)
    - ▷ all kinds of depots possible (facebook, company data depot, personal home depot)
  - use tracing to upload data from MP to depot
  - Use mapping to reach MP upon request
    - ▷ one mapping system

# Future work needed

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