

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
 - ◇ Connexion¹
 - Mapping: mobile reports its current address to RP
 - ◇ Mobile IP, BackToMyMack², ILNP³
 - Tracing: mobile builds a path from RP to itself
 - ▷ Cellular IP⁴
 - ▷ MSM-IP (sparse mode)⁵
 - Geo-routing
 - ▷ Special case apps
 - ▷ Landmark routing

[1] 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

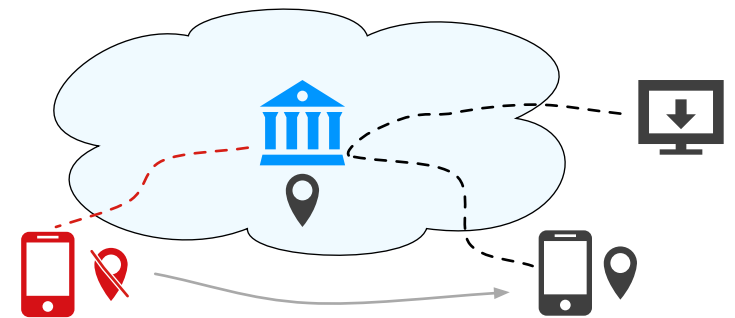
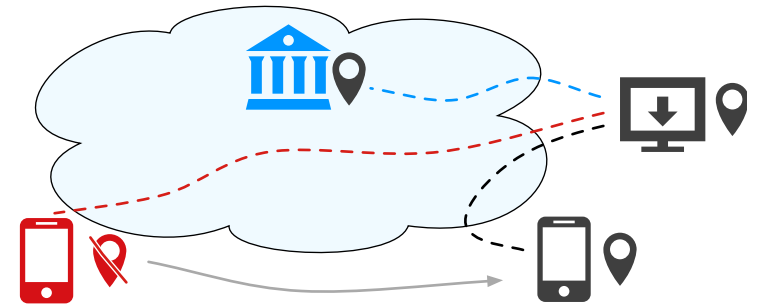
Chase Mobile Producer	
Mapping	The MP reports to the RP routable name(s) through which its data can be retrieved
Tracing	The MP creates a “breadcrumb trail” from the RP back to itself, that Interests can follow
Rendezvous Data	
Data depot	The MP moves its data to a known stationary depot
Data spot*	Data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

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^{1,2,3}
 - 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^{4,5,6}
 - MP publishes under HA's prefix
 - ▷ /timewarner/.../a/family/...
 - Consumer interests reach HA, HA forwards towards MP*



* Interests can get satisfied before reaching 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.

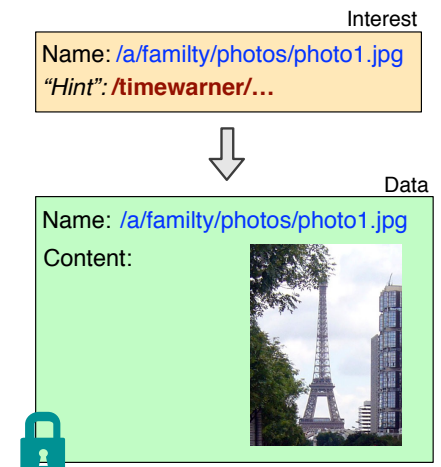
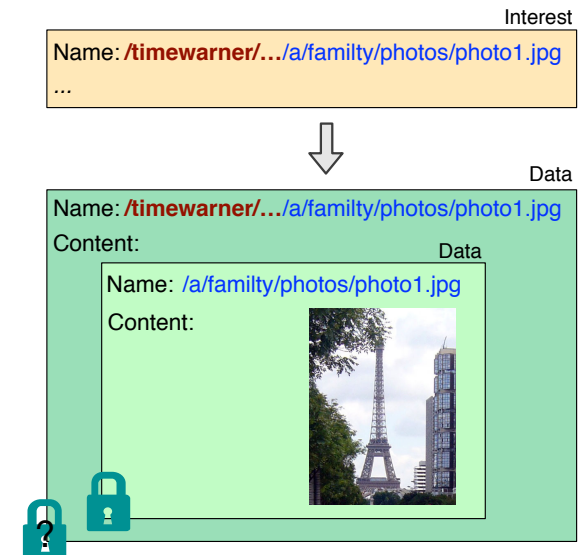
[5] J. Lee, S. Cho, and D. Kim, "Device mobility management in content-centric networking," IEEE Commun. Magazine, 2012.

[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.

How to get Interests to the MP

- ◇ Concatenate routable prefix with (unroutable) data names^{1,2,3,4,5}
 - 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^{1,5,6,7}
 - Original data names & signature preserved
 - Multiple hints possible
 - Require changes to the forwarding lookup
 - Need measures against potential abuse

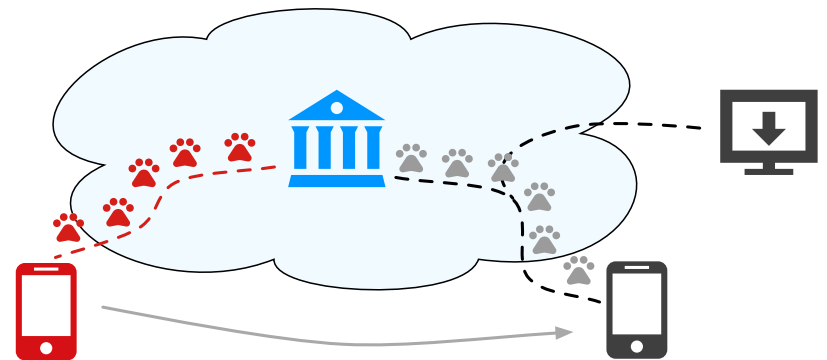
[1] D. Li and M. C. Cuah, “SCOM: A Scalable Content Centric Network Architecture with Mobility Support,” in IEEE MSN, 2013.
[2] J. Lee, S. Cho, and D. Kim, “Device mobility management in content-centric networking,” IEEE Commun. Magazine, 2012.
[3] R. Ravindran, S. Lo, X. Zhang, and G. Wang, “Supporting 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^{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-PIT⁵



[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.

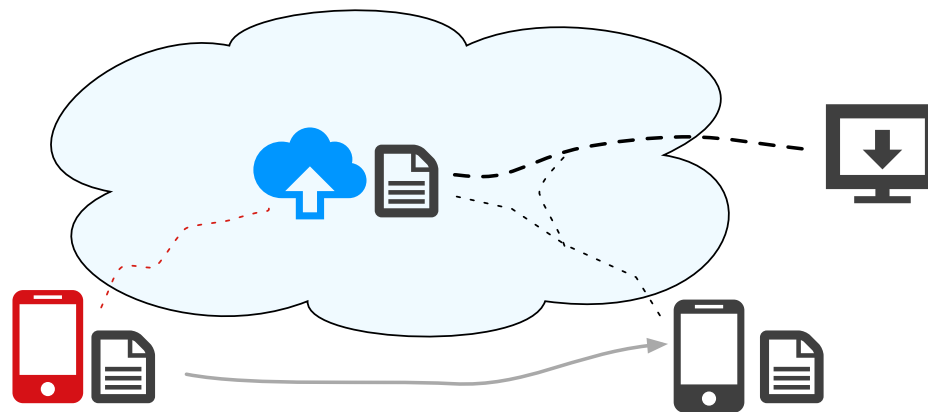
[3] D.Han, M.Lee, K.Cho, T.T.Kwon, and Y.Choi, “PMC: Publisher Mobility Support for Mobile Broadcasting in Content Centric Networks,” ASIA Future Internet 2012 Summer School, 2012.

[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

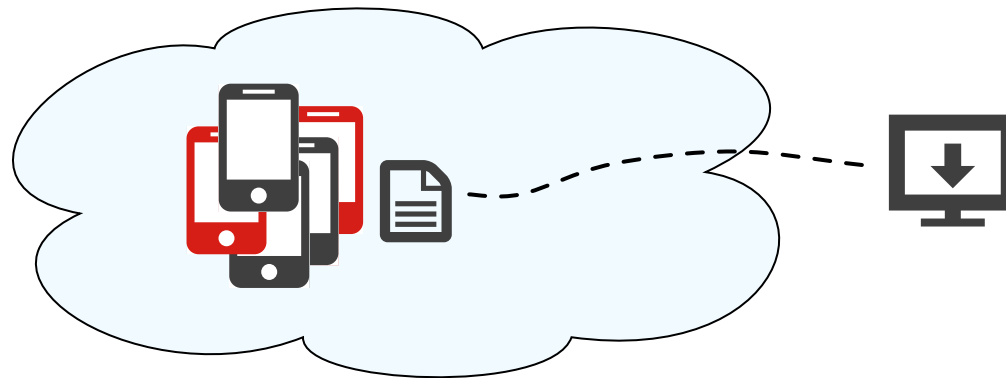
- ◇ Move the data generated by MP to a “stationary” place¹
 - MP uploads data once it is produced
 - ▷ e.g., using trace-in-PIT upload protocol
 - Interests for data can take shortcuts
 - ▷ Meet cached data
 - ▷ Cross path with traces



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