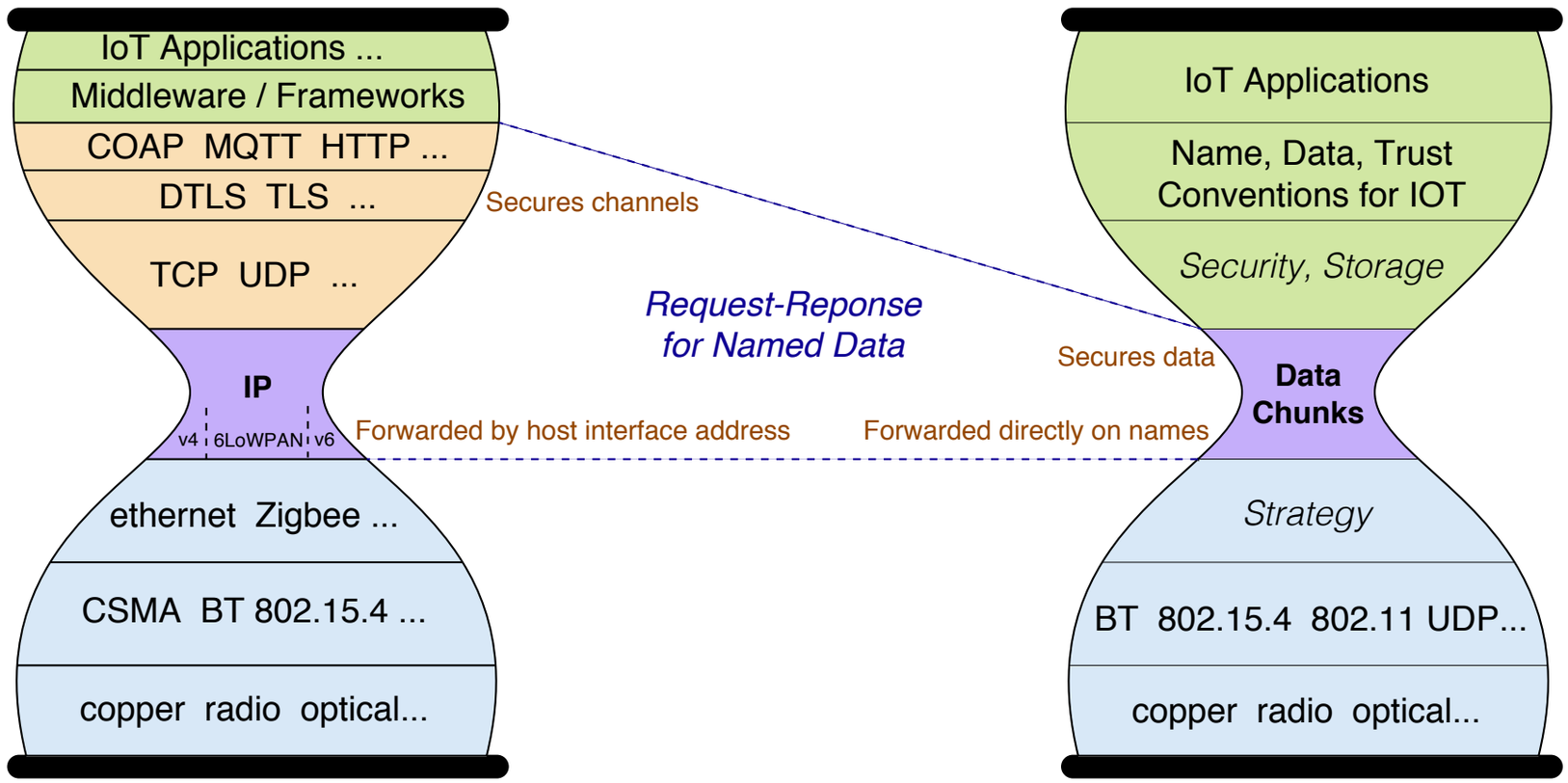
OPEN IOT/NDN RESEARCH CHALLENGES

LAN WANG, UNIVERSITY OF MEMPHIS

NAMED DATA NETWORKING OF THINGS

Naming data at network layer simplifies architecture.



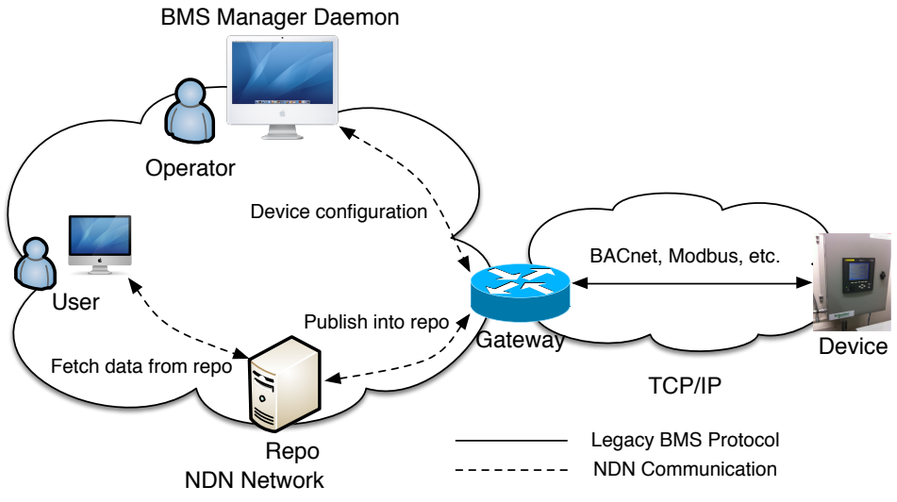
- name and retrieve data (/LivingRoom/temp)
- name and operate on “things” (/ThisRoom/fan/on)
- secure data and commands directly

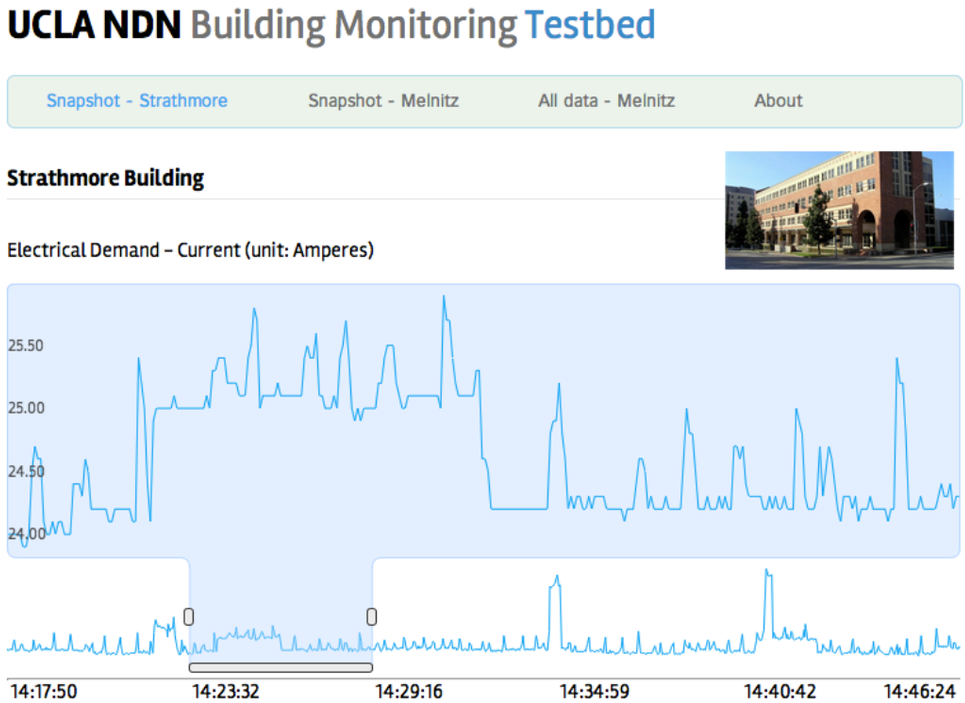
IoT/NDN Research Issues

	strengths	design issues
Naming	expressiveness	name size, routing scalability, forwarding strategy effectiveness
Data acquisition	request-response	publish-subscribe
Data retrieval efficiency	in-network storage, hop-by-hop multipath forwarding	small MTU, memory constraint
Security	data-centricity, fine-granularity access, schematized trust	computation & power constraints
Management	no IP address, meaningful names	trust model, bootstrapping devices, service discovery

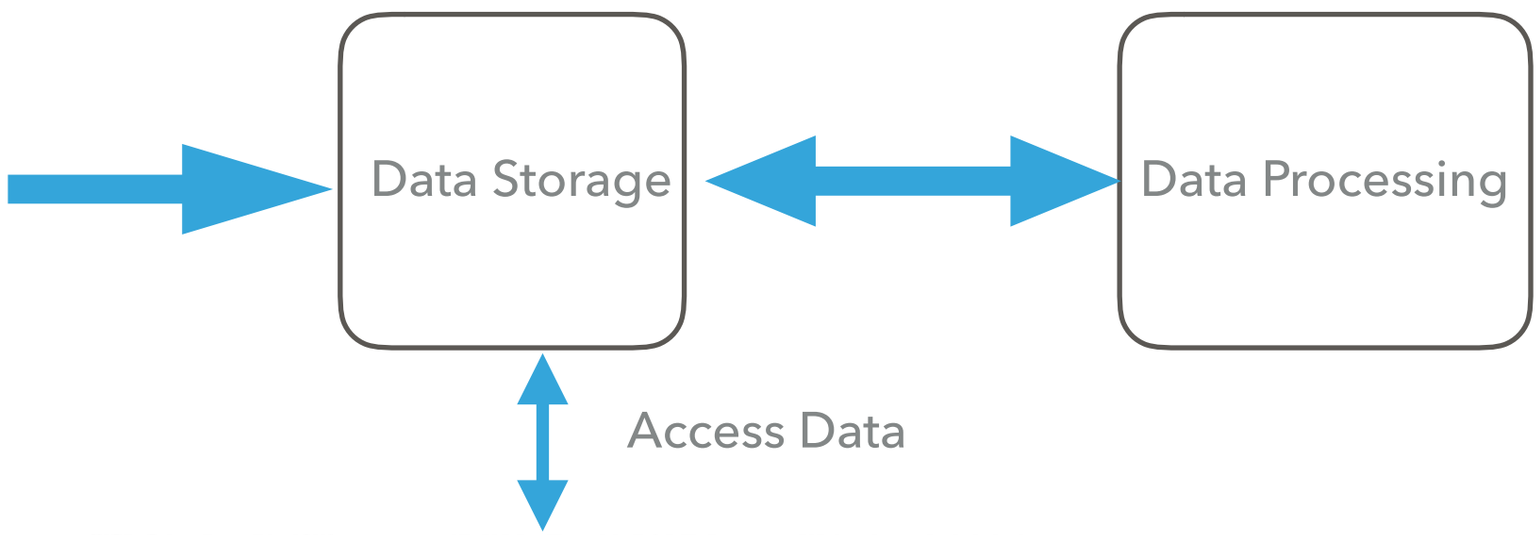
NDN Building Automation and Management

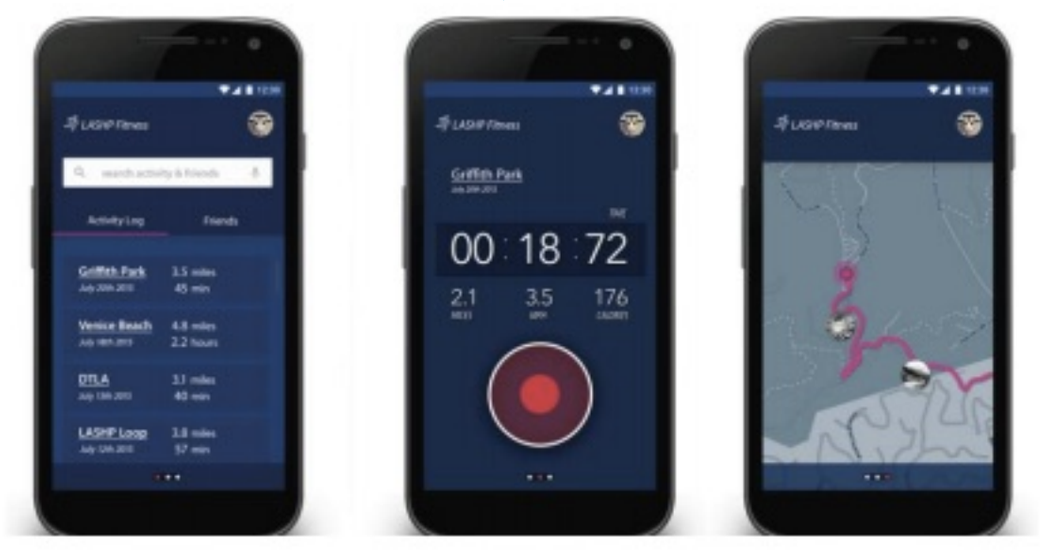
- NDN-BMS, Mini-BMS, authenticated lighting control
- Partner: UCLA Facilities Management





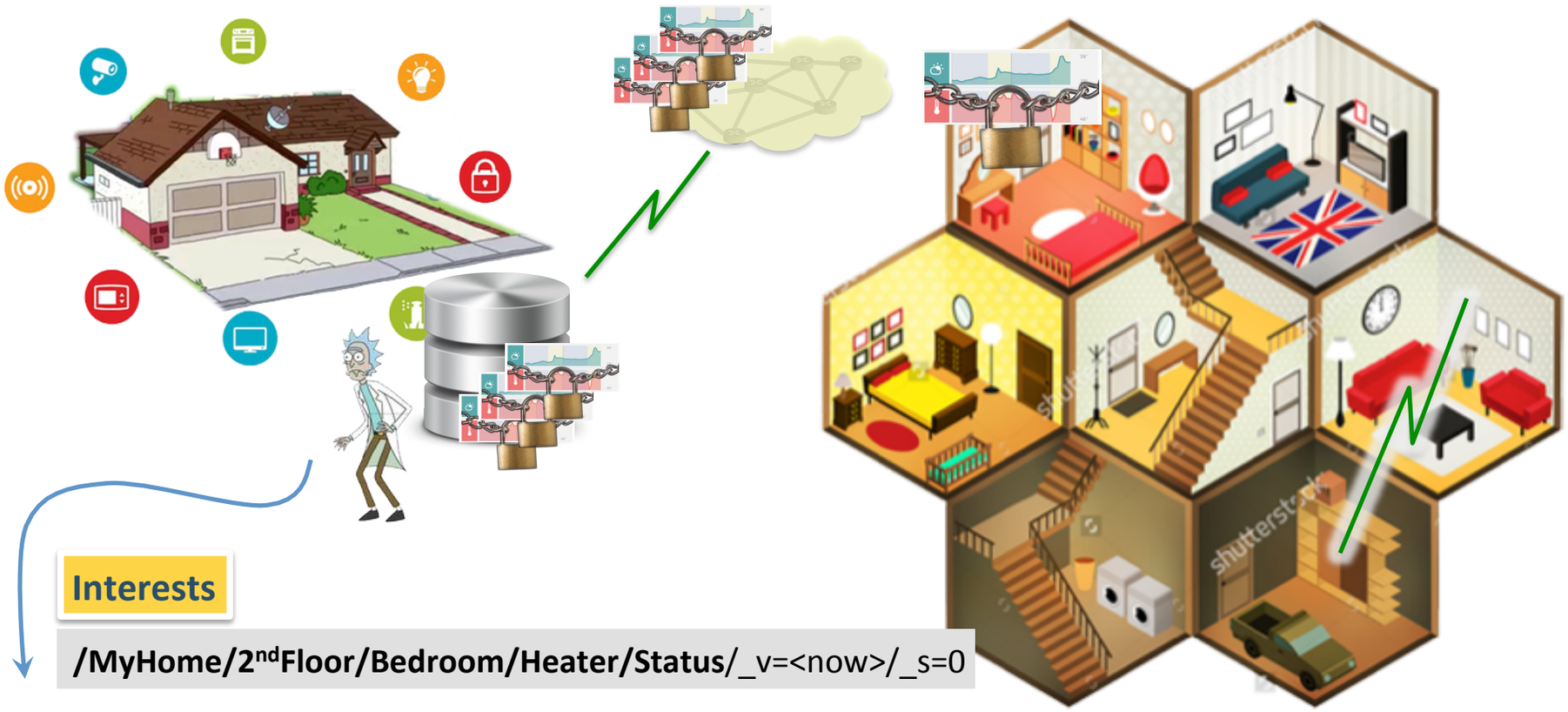
NDNFit





http://redmine.named-data.net/projects/ndnfit

NDN Smart Home



Interests

/MyHome/2nd Floor/Bedroom/Heater/Status/_v=<now>/_s=0

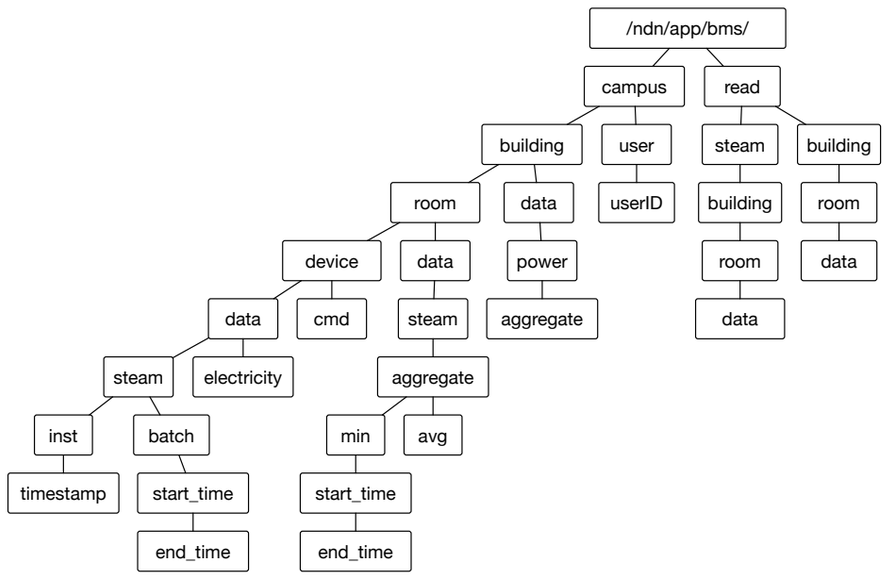
Interests

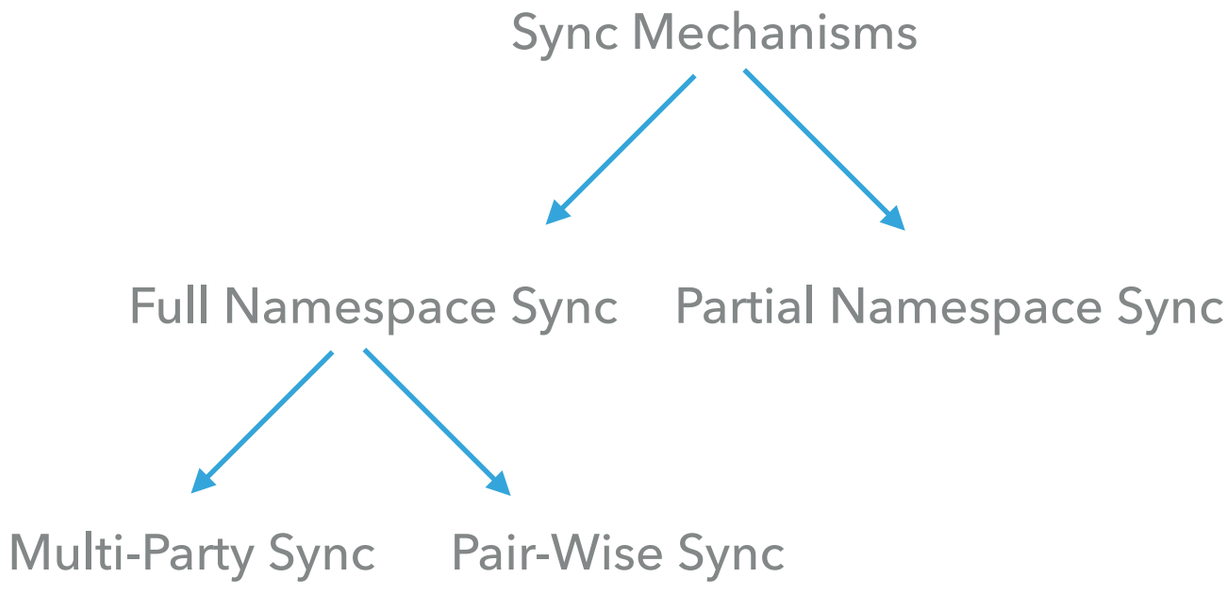
/MyHome/Garage/Lights/ON/<signature>/...

Naming and Data Acquisition

- design patterns in sample NDN IoT applications
  - naming design
  - name discovery
- synchronization mechanisms that can be combined to implement a pub-sub system
  - ChronoSync and iSync (data replication)
    - Z. Zhu, and A. Afanasyev. "Let's chronosync: Decentralized dataset state synchronization in named data networking." Proceedings of IEEE ICNP, 2013.
    - W. Fu, H. B. Abraham, and P. Crowley. "iSync: a high performance and scalable data synchronization protocol for named data networking." Proceedings of ACM ICN, 2014
  - PartialSync (publish-subscribe)
    - M. Zhang, V. Lehman, and L. Wang, PartialSync: “Efficient Synchronization of a Partial Namespace in NDN,” NDN Tech. Rep. NDN-0039, Revision 1, May 2016

BMS Name Space Design





Security for IoT in NDN

- encryption-based access control
  - W. Shang, Q. Ding, A. Marianantoni, J. Burke, and L. Zhang. "Securing Building Management Systems Using Named Data Networking." In IEEE Network, Vol. 28, no. 3, May 2014.
- authorization framework for actuation apps
  - W. Shang, Y. Yu, T. Liang, B. Zhang, and L. Zhang, "NDN-ACE: Access Control for Constrained Environments over Named Data Networking," NDN Tech. Rep. NDN-0036, Revision 1, December 2015.
- name-based access control
  - Y. Yu, A. Afanasyev, and L. Zhang, "Name-Based Access Control," NDN Tech. Rep. NDN-0034, Revision 2, Jan. 2016
- trust models in sample IoT applications

NDN Support for IoT Platforms

- NDN-IoT: toolkit for NDN dev on Raspberry Pi
  - https://github.com/remap/ndn-pi
  - simple service discovery functionality

- NDN on Arduino: minimal app for Arduino
  - https://github.com/ndncomm/ndn-btle

- RIOT OS: the friendly OS for IoT
  - https://www.riot-os.org/
  - http://irl.cs.ucla.edu/~wentao/ndn-riot-os-poster.pdf
  - NDN on RIOT coming soon

IoT/NDN Research Issues

Issues	strengths	design issues
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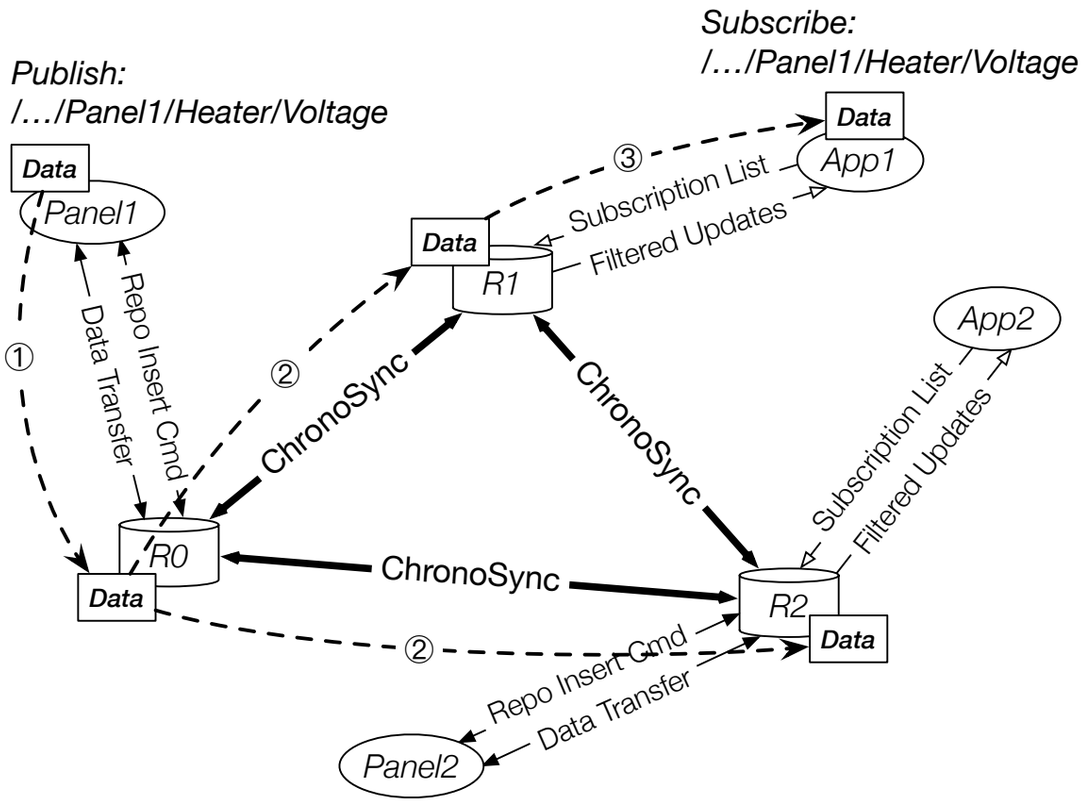
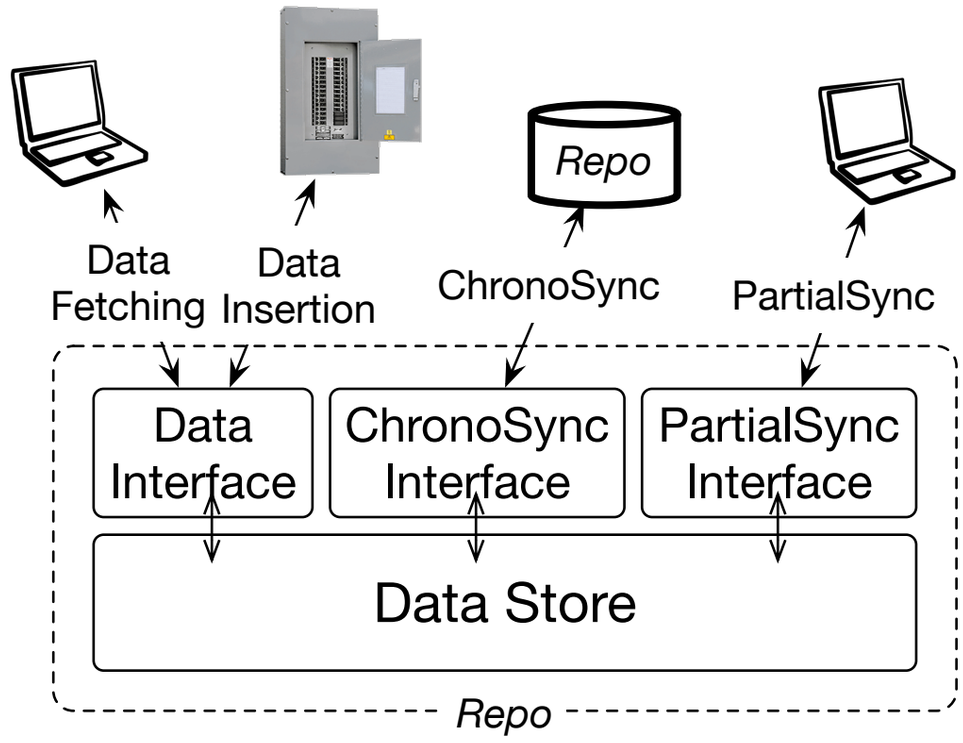
NDN/IoT Case Study: Building Management Systems

- typical BMS deployment on an enterprise campus
  - spreads across many buildings
  - tens of thousands of wired or wireless sensors
- data production characteristics
  - large amounts of data: electricity, water flow, lighting temperature, humidity, air quality, …
  - sensors: on and off, limited storage
- data consumption patterns
  - real-time and historical data
  - Users may be interested in different subsets of the data.
  - Devices may access data at different frequencies.

NDN-PS: Publish-Subscribe Communication in BMS*



Data flow in a pub-Sub group



Repo: long-term storage and pub-sub server

* W. Shang, M. Zhang, A. Afanasyev, J. Burke, L. Wang, L. Zhang, "Publish-Subscribe Communication in Building Management Systems over Named Data Networking, " under review

Example Data Names in a Pub-sub group

Pub-Sub Group Prefix:

/BigCompany/Building1/ConfRoom/Electricity

Data Streams:

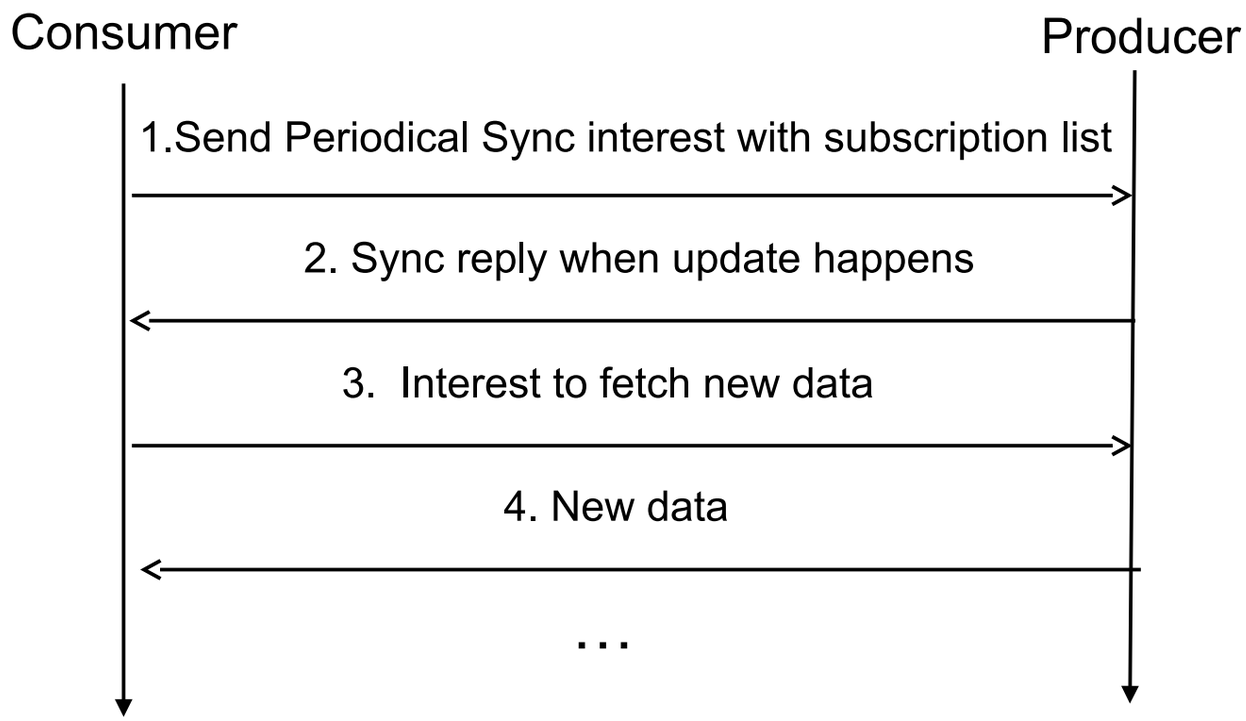
/BigCompany/Building1/ConfRoom/Electricity/Panel1/Heater/Voltage/{1,2,3,…}
/BigCompany/Building1/ConfRoom/Electricity/Panel1/Heater/Current/{1,2,3,…}
/BigCompany/Building1/ConfRoom/Electricity/Panel1/Vent/Voltage/{1,2,3,…}
/BigCompany/Building1/ConfRoom/Electricity/Panel1/Vent/Current/{1,2,3,…}
/BigCompany/Building1/ConfRoom/Electricity/Panel1/Switches/Voltage/{1,2,3,…}
/BigCompany/Building1/ConfRoom/Electricity/Panel1/Switches/Current/{1,2,3,…}
/BigCompany/Building1/ConfRoom/Electricity/Panel1/Plugs/Voltage/{1,2,3,…}
/BigCompany/Building1/ConfRoom/Electricity/Panel1/Plugs/Current/{1,2,3,…}

/BigCompany/Building1/ConfRoom/Electricity/Panel2/Projector/Voltage/{1,2,3,…}
/BigCompany/Building1/ConfRoom/Electricity/Panel2/Projector/Current/{1,2,3,…}
/BigCompany/Building1/ConfRoom/Electricity/Panel2/Speaker/Voltage/{1,2,3,…}
/BigCompany/Building1/ConfRoom/Electricity/Panel2/Speaker/Current/{1,2,3,…}
…

Each consumer can subscribe to a subset of the data streams.

PartialSync supports publish-subscribe semantics.

- Consumer expresses *subscription list* in Sync Interests.
- Producer sends matching *data names* and *producer state* in Sync Replies.
- Session-less: all context information encoded in Interest/Data names
  - Subscription list encoded in Bloom Filter, ranges or other data structures.
  - Producer state encoded in Invertible Bloom Filter.
- Consumer can sync with any producer with the data –> robustness
- Producer does not keep per-consumer state –> scalability



High-Level Message Exchanges in PartialSync

Repo Data Published in ChronoSync

Name: ***/BigCompany/Building1/ConfRoom/Electricity***/Repo1/ChronoSync/<seq#>

← *Group Prefix* →

Content: {/<Group-Prefix>/Panel1/Heater/Voltage/<seq#>,
/<Group-Prefix>/Panel1/Heater/Current/<seq#>,
/<Group-Prefix>/Panel1/Plugs/Voltage/<seq#>,
/<Group-Prefix>/Panel1/Plugs/Current/<seq#>,
…
}

Repos exchange list of their data names through ChronoSync.

Examples of BMS Certification Chains

BMS Root Key: **/BigCompany/BMS**/key

Signs

Building Key: **/BigCompany/Building1**/key

Signs

Device Key: **/BigCompany/Building1/ConfRoom/Electricity/Panel1**/key

Signs

Device Data: **/BigCompany/Building1/ConfRoom/Electricity/Panel1/Heater/Voltage**/<seq#>

BMS Data Certification Chain

BMS Root Key: **/BigCompany/BMS**/key

Signs

Department Key: **/BigCompany/DepartmentA**/key

Signs

Employee Key: **/BigCompany/DepartmentA/Alice**/key

Signs

User Device Key: **/BigCompany/DepartmentA/Alice/Phone**/key

User Device Certification Chain

BMS Root Key: **/BigCompany/BMS**/key

Signs

Building Key: **/BigCompany/Building1**/key

Signs

Pub-Sub Group Key: **/BigCompany/Building1/ConfRoom/Electricity**/key

Signs

Repo Key: **/BigCompany/Building1/ConfRoom/Electricity/Repo1**/key

Signs

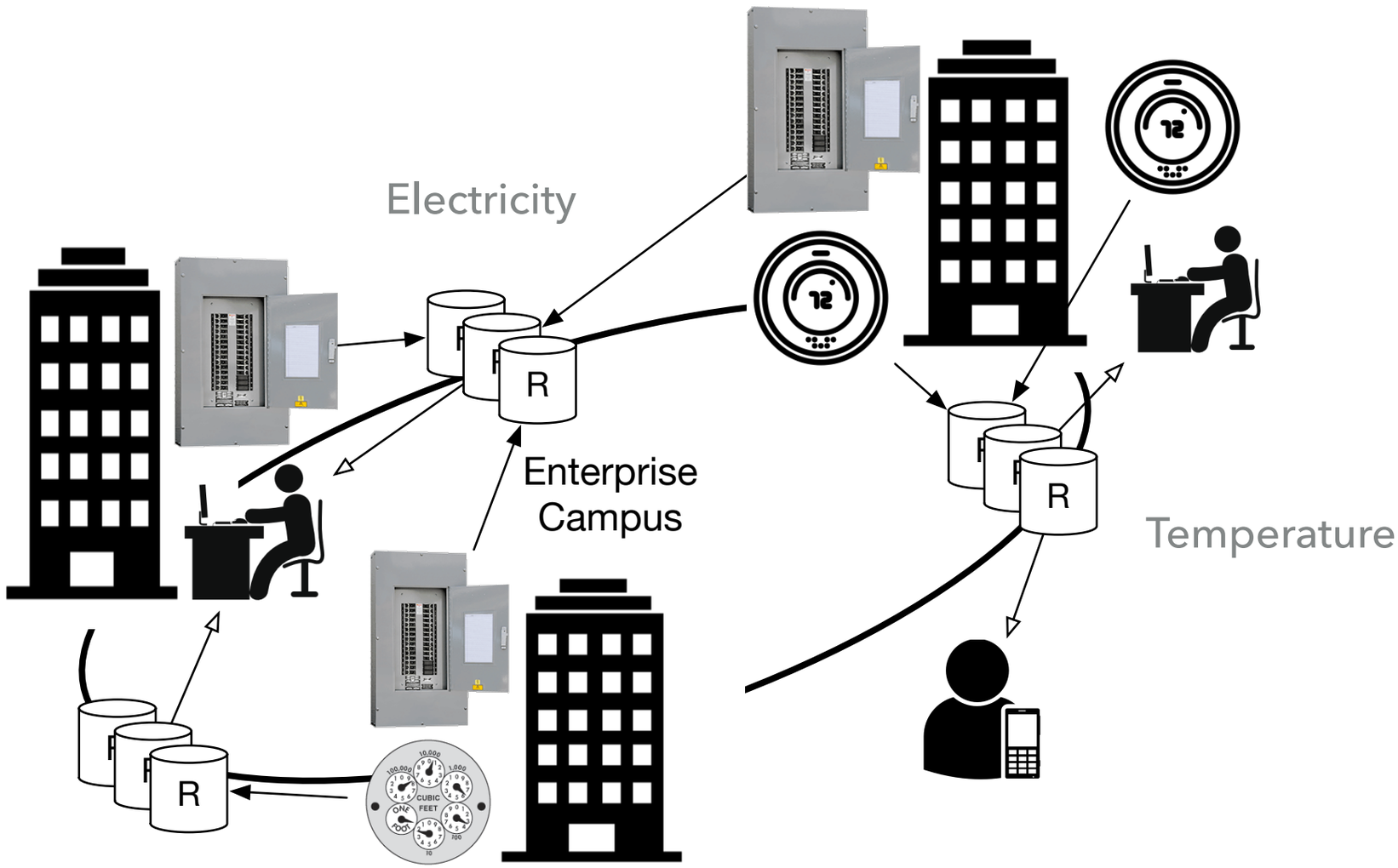
Repo Data: **/BigCompany/Building1/ConfRoom/Electricity/Repo1**/ChronoSync/<…>

or

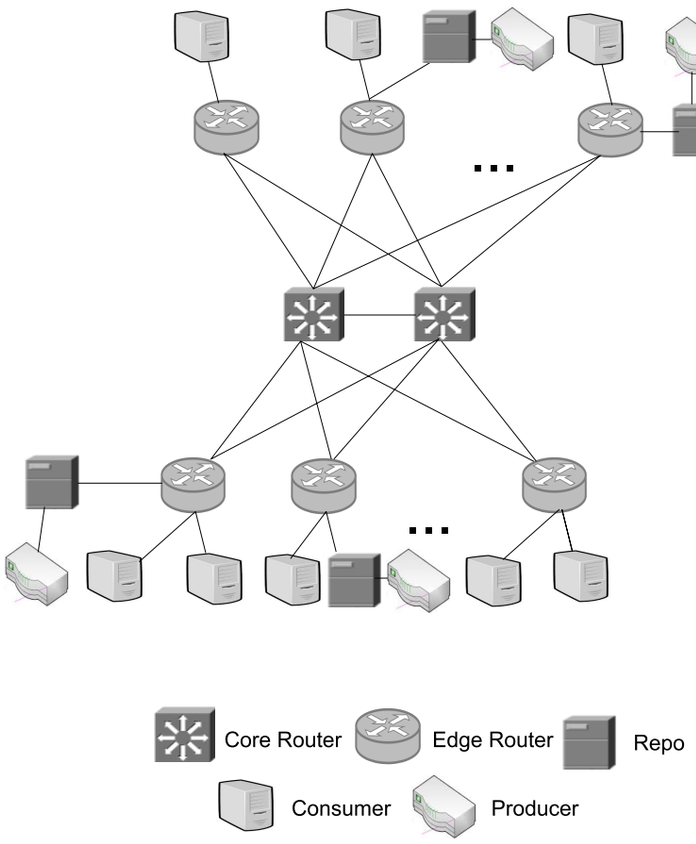
/BigCompany/Building1/ConfRoom/Electricity/Repo1/PartialSync/<…>

Repo Data Certification Chain

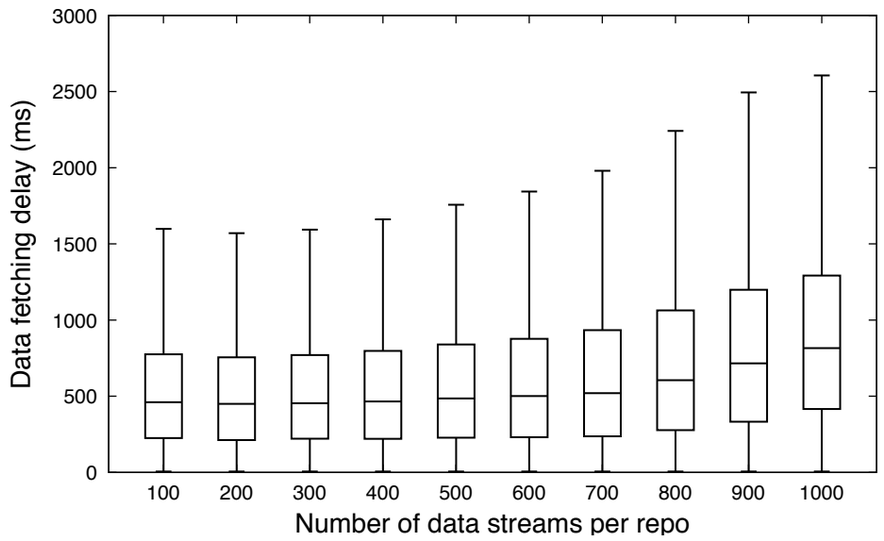
Multiple pub-sub groups store and serve different data.



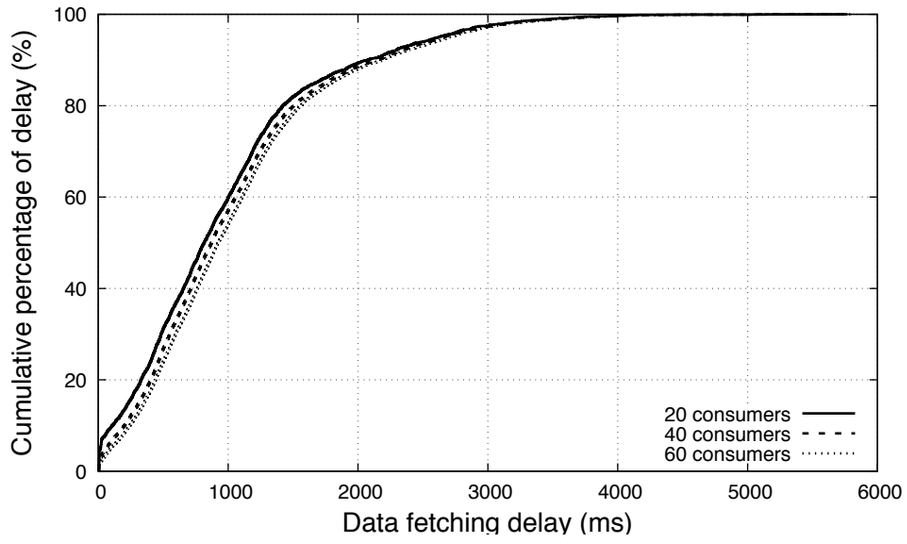
Evaluation



Evaluation Topology



Scalability under Number of Data Streams



Scalability under Number of Consumers

Conclusion

- Naming data at the network layer simplifies IoT system development.
- Ongoing NDN project efforts provide sample IoT applications and building blocks.
  - W. Shang, A. Bannis, T. Liang, Z. Wang, Y. Yu, A. Afanasyev, J. Thompson, J. Burke, B. Zhang, and L. Zhang, “Named Data Networking of Things,” First IEEE International Conference on Internet-of-Things Design and Implementation, April 2016
- Efficient and secure pub-sub system for IoT applications can be built using our building blocks.
  - W. Shang, M. Zhang, A. Afanasyev, J. Burke, L. Wang, L. Zhang, “Publish-Subscribe Communication in Building Management Systems over Named Data Networking, ” under review

More papers at http://named-data.net/publications/.