Name-Based Access Control

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What we have so far…

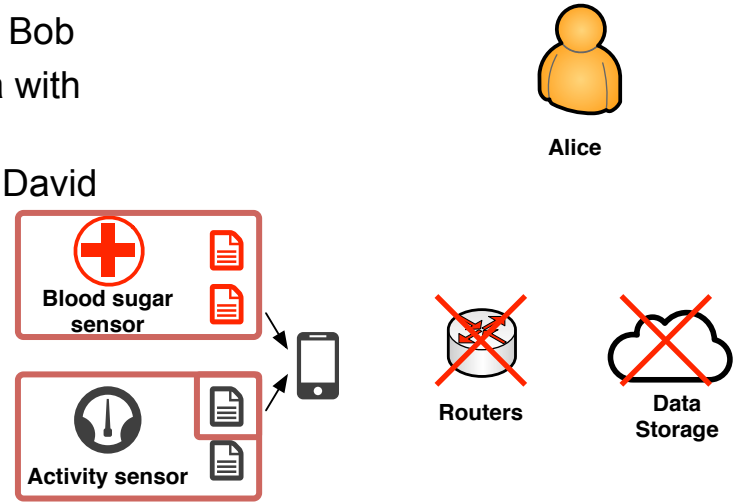
- Facilitating data retrieval over the network
  - Synchronization as the new transport paradigm in NDN
- Making data verifiable independently from where data is retrieved
  - Trust schema as a new mechanism to specify application-level trust model
- Can we also have location-independent content confidentiality?

What you will get next…

- Content-based confidentiality
  - the other part of content-based security
  - confidentiality stays with content, no dependency on the content delivery system
- End-to-end confidentiality
  - the “end” of application-level communication
    - more general, including multi-party communication
  - not the “end” of a connection
- Differential confidentiality
  - granting data access at fine granularities
- Multi-party access control system
  - coordinate access control among multiple data producers and consumers

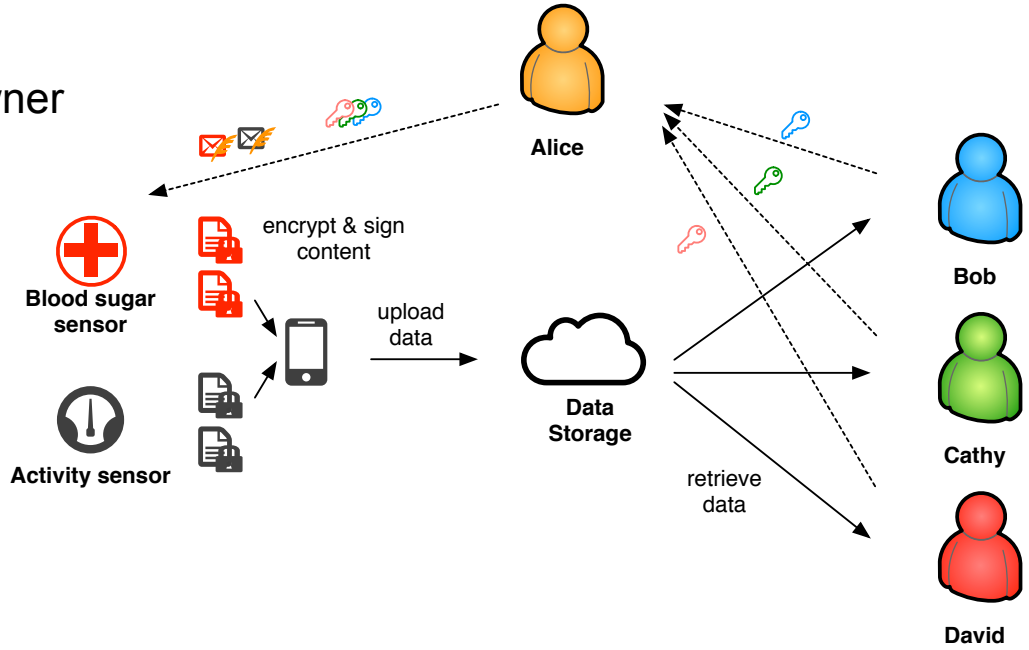
Application Scenario

- Alice collects her health data through a fit application
- Alice wants to share different health data with different people
  - share her daily activity data with Bob
  - occasionally share her step data with Cathy
  - share her blood sugar data with David after each meal
- No one except content owner (Alice), producers (sensors), and authorized consumers (e.g., Bob) can see the data



Content-Based Access Control

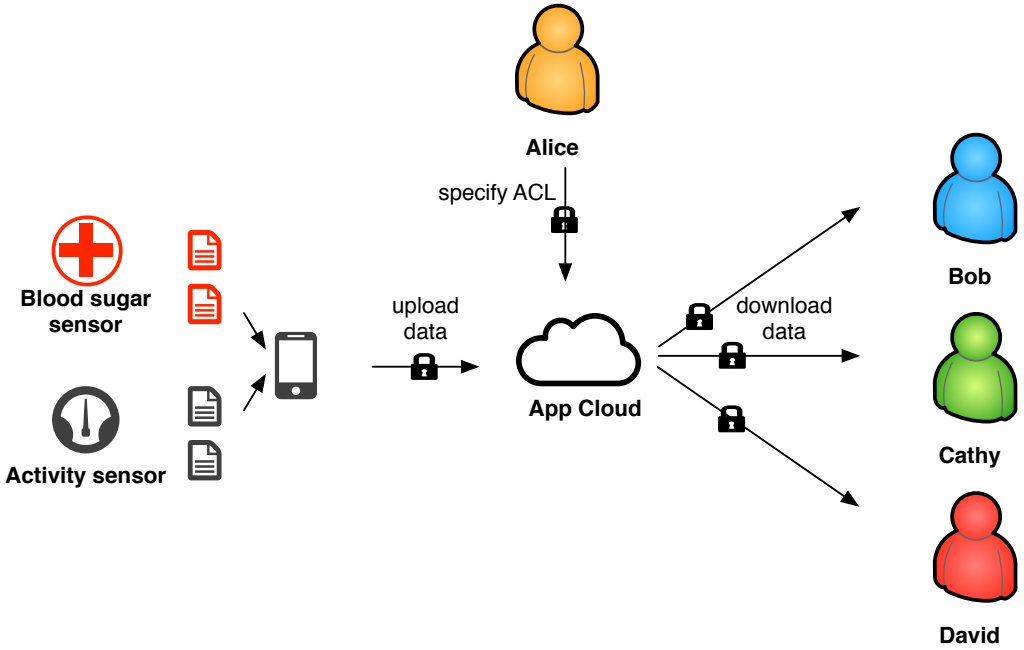
- Data owner (Alice) enforces access control on data directly
  - independent from data container (storage, channels)
- Write access
  - produce data on behalf of owner
  - issue signing certificate
- Read access
  - encrypt data
  - distribute decryption key
- Data container is a pure storage
  - the only always-online entity



Container-Based Access Control

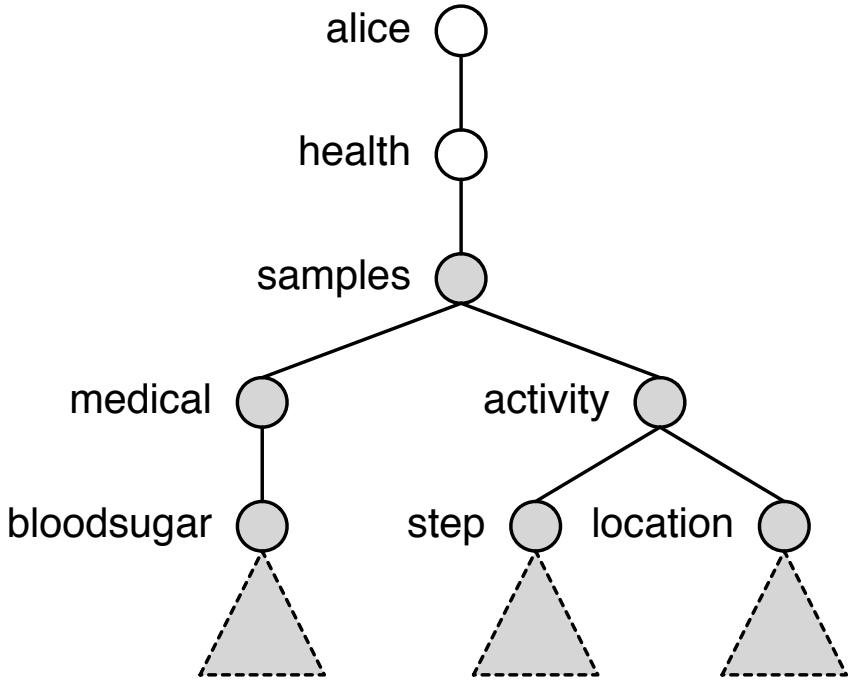
- Data owner relies on a container (e.g., application server) to enforce access control

- Limitations
  - data owner has to trust the container
  - container must understand ACL semantics
  - container must be able to authenticate entities
  - content must be delivered over a secure channel



Privilege: Data Namespace

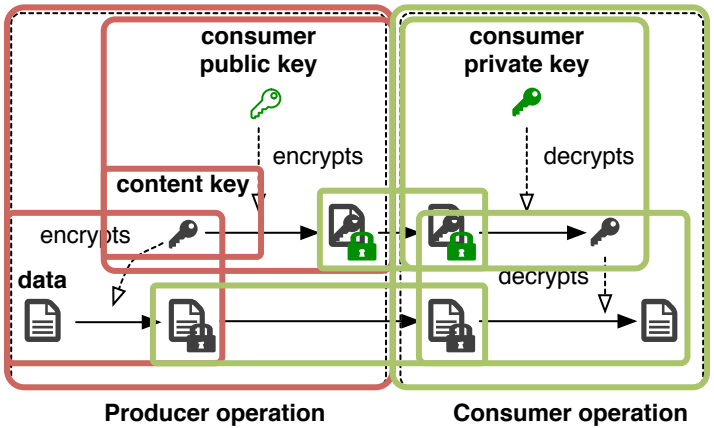
- Producers can produce data under its own namespace
  - blood sugar sensor:
    - /alice/health/samples/medical/bloodsugar
  - activity sensor
    - /alice/health/samples/activity
- Consumers can only read data under the authorized namespace
  - data owner may enforce further restriction
    - e.g., data produced during certain time periods, or at certain locations



Simple Encryption-Based Read Access

- Producer side
  - creates a content key
    - e.g., /alice/health/samples/activity/location/C-KEY
  - encrypt data using content key
  - encrypt content key using the encryption key of authorized consumers
    - e.g., /bob/health/access/E-KEY

- Consumer side
  - retrieve encrypted data
  - retrieve encrypted content key
  - decrypt content key
    - e.g., /bob/health/access/D-KEY
  - decrypt data
  - as long as data is available

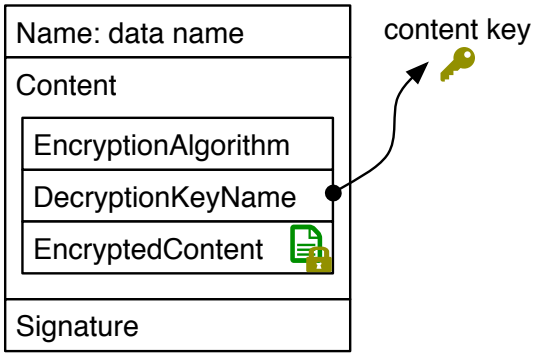


Encrypted Content Format

- Data packet must carry enough information for authorized consumers to decrypt content

- Experiment as application semantics
  - content encoding (not a part of architecture yet)

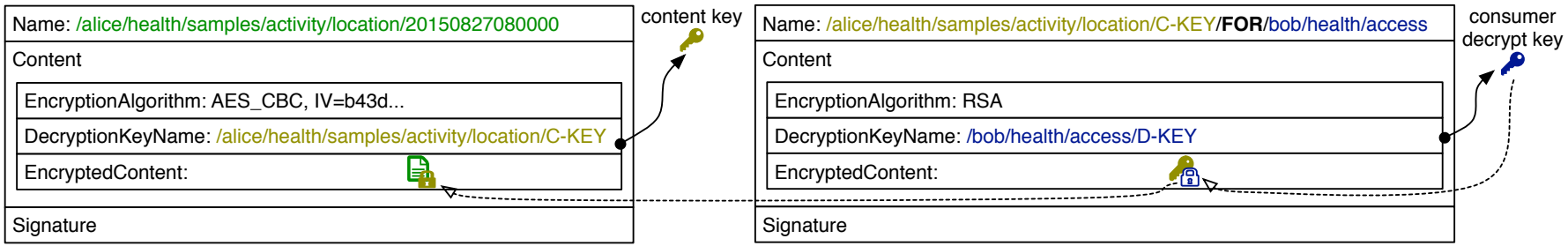
- EncryptedContent TLV contains three sub-TLVs:
  - EncryptionAlgorithm
    - may also algorithm-specific fields, e.g., Initial Vector
  - DecryptionKeyName
    - used by the consumer to retrieve the decryption key
  - EncryptedContent



- When a data has more than one encrypted copies
  - each encrypted copy is an independent data packet
  - naming convention: /<content_name>/**FOR**/<decrypt_key_name>

Decryption Chain

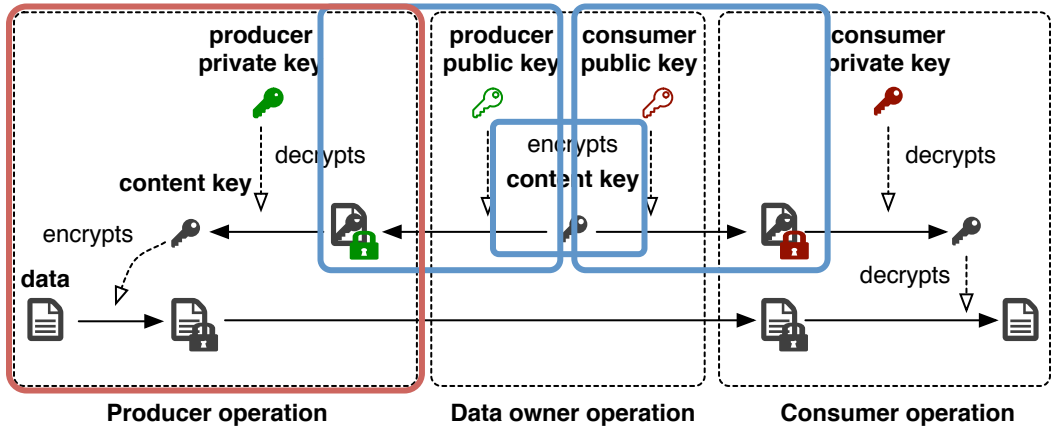
- Consumer Bob extracts DecryptionKeyName
  - /alice/health/samples/activity/location/C-KEY
- C-KEY is encrypted, construct an interest by appending its own name
  - /alice/health/samples/activity/location/C-KEY/**FOR**/**bob/health/access**
- The interest will bring back a content key encrypted using one of Bob's public key



Delegated Data Production

- In some scenarios, data owner may delegate the data production to others
  - e.g., Alice gives her activity sensors to produce data on her behalf.
  - delegated producer may not know the authorized consumers

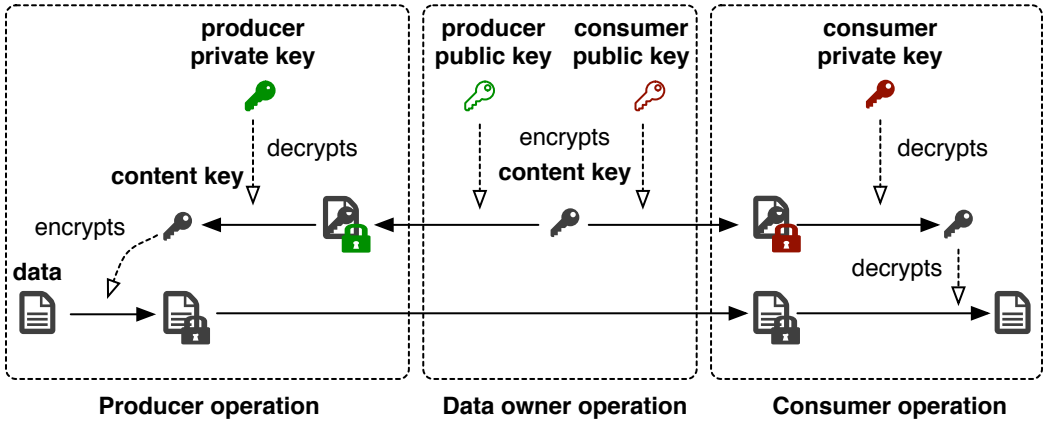
- Data owner should be able to direct the content encryption at the producer side
  - create a content key
  - publish the key encrypted with both producer and consumer keys
  - producer retrieves content key and encrypt content



Limitations in Distributed Production

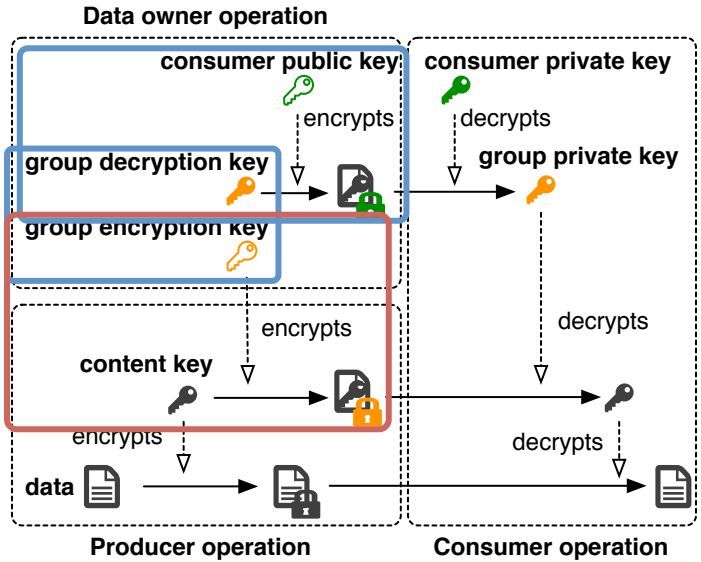
- Producer cannot produce data without fetching the content key
- Data owner has to be online all the time to keep producing content key
- Data owner has to be aware of all the potential producers
  - because content key must be encrypted using producer's public key

- **Can we decouple data production from access control?**
- Producer is free to encrypt content
- Data owner is free to grant access



Name-Based Read Access Control

- Data owner create a pair of public/private key instead of a content key
  - the name of public key defines a read access scope
  - any producer that produces data in the access scope should encrypt data through the public key (group encryption key)
  - any consumer that obtains the private key (group decryption key) can read the data in access scope
- Producer creates its own content key
  - encrypt data using its own content key
  - encrypt content key with appropriate group encryption key

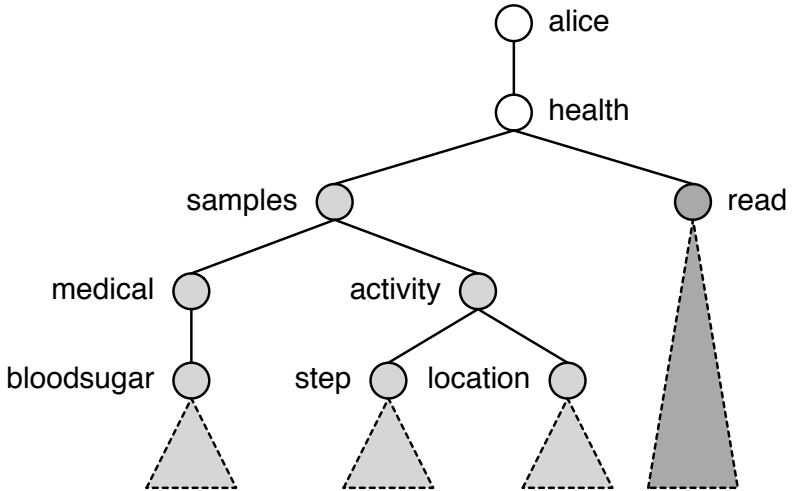


Group Key Namespace

- Only data owner is allowed to create group key

- Group keys are named under a separate namespace
  - /alice/health/**read** vs /alice/health/**samples**
  - so that data producers are not allowed to create group keys

- Group key namespace replicate data namespace
  - /alice/health/**read**/activity
  - /alice/health/**read**/medical/bloodsugar



Group Key Naming Convention

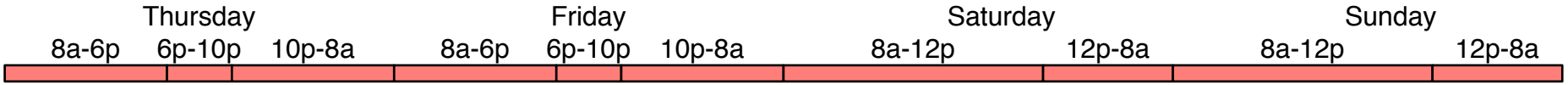
- Key name defines the access scope

- Group encryption key
  - /<data_prefix>/**E-KEY**/<additional_restriction>
  - data_prefix: describe the prefix of data to encrypt
  - additional_restriction: further classify encrypted data
    - e.g., producing timestamp, geo-location
  - A producer can tell which content key should be encrypted using the group encryption key according to the key name

- Group decryption key
  - /<data_prefix>/**D-KEY**/<additional_restriction>/**FOR**/<consumer_key_name>
  - consumer_key_name: the name of consumer key that can decrypt the group key
  - uniquely identify one copy of encrypted group key

How to retrieve group encryption key?

- Case 1: continuous data production
  - e.g., health sensors produce data all the time
  - data owner needs to generate group encryption keys that can cover all the time



  - data owner can encode time information into additional_restriction portion of key name
    - /<data_prefix>/**E-KEY**/<start_ts>/<end_ts>
    - e.g., /alice/health/read/activity/**E-KEY**/20150930160000/20150930180000
  - a producer once retrieve an encryption key, it knows the starting timestamp of next encryption key thus it can send interest
    - /alice/health/read/activity/**E-KEY**/20150930180000
    - and retrieve next encryption key,
      - e.g., /alice/health/read/activity/**E-KEY**/20150930180000/20151001000000

- Case 2: arbitrary additional restriction
  - data owner create a sync group for encryption keys, and all producers join the sync group

Data Type Granularity

- Data owner may also specify a variety of data_prefixes for different access granularity
  - Alice may share her activity data with Bob, but only share her step data with Cathy
    - Bob can access both location and step data, while Cathy can access step data only
  - two group keys:
    - /alice/health/read/activity/D-KEY → Bob
    - /alice/health/read/activity/step/D-KEY → Cathy

- Producer also need to track encryption keys with different granularities
  - Alice's activity sensor needs to track
    - /alice/health/read/activity/step/E-KEY/…
    - /alice/health/read/activity/E-KEY/…
    - /alice/health/read/E-KEY/…
  - when sync is used, encryption keys of the same granularity forms a data set to synchronize between data owner and producers

Example: Data Owner

- Alice wants to share her activity data during 4pm-6pm Sep. 30, 2015 with her friend Bob

- Create an encryption key:
  - /alice/health/read/activity/**E-KEY**/20150930160000/20150930180000
  - signed by Alice's key, so that her activity sensor can authenticate the E-KEY.

- Encrypt the decryption key using Bob's public key
  - /alice/health/read/activity/**D-KEY**/20150930160000/20150930180000/**FOR**/bob/health/access
  - signed by Alice's key, so that Bob can authenticate the D-KEY.

Example: Producer

- Alice's activity sensor produce step data at time 17:00 Sep. 30, 2015
  - /alice/health/samples/activity/steps/201509301700
- Create a content key
  - /alice/health/samples/activity/steps/**C-KEY**/20150930170000
  - encrypt step data using the content key
  - signed by sensor's key
- Time of the step data falls between the interval of 4pm-6pm
  - encrypt the content key using the group encryption key
  - /alice/health/samples/activity/steps/**C-KEY**/20150930170000/**FOR**/alice/health/samples/activity/**D-KEY**/20150930160000/20150930180000/
  - signed by sensor's key

Example: Consumer

- Bob retrieve Alice's step data: /alice/health/samples/activity/steps/201509301700
  - data contains the decryption key name:
    - /alice/health/samples/activity/steps/**C-KEY**/20150930170000
- Bob knows Alice share the activity data with him: /alice/health/read/activity
  - send an interet for the content key encrypted using the group key for
    - /alice/health/samples/activity/steps/**C-KEY**/20150930170000/**FOR**/alice/health/samples/activity
  - Bob does not have to specify the full name of the group decryption key
- When encrypted content key is retrieved
  - Bob learns the exact name of the group decryption key from the packet payload:
    - /alice/health/read/activity/**D-KEY**/20150930160000/20150930180000
  - send another interest for the group decryption key encrypted using Bob's key
    - /alice/health/read/activity/**D-KEY**/20150930160000/20150930180000/**FOR**/bob/health/access
- Decrypt the group decryption key using its own private key, and then decrypt the content key and sync data

Post-fact Access Granting

- It is necessary to grant access to data that has been produced long time ago

- Data owner should always retain a copy of content key
  - it is resource consuming to store a copy at the data owner side
  - data owner only needs to create a super group key
    - /alice/health/read/E-KEY
  - data owner keep the decryption key to itself
  - all producers under the data namespace will encrypt every content key using the encryption key
  - when a data owner needs to grant the access later
    - retrieve the encrypted content key
    - re-encrypt the content key with the authorized consumer's encryption key.

What to expect in next step?

- An application library will be available in next NDN platform release
- Convert key exchange between data owner and producers to identity-based encryption (or attribute-based encryption)
- Enable forward secrecy: decouple consumer private key with content key
  - minimize the damage when a private key is compromised later
- Revoke access that has been granted & prevent unauthorized access granting
  - controlled functional encryption
- Future work
  - Name privacy
  - Read auditing
  - Secure multi-party computing

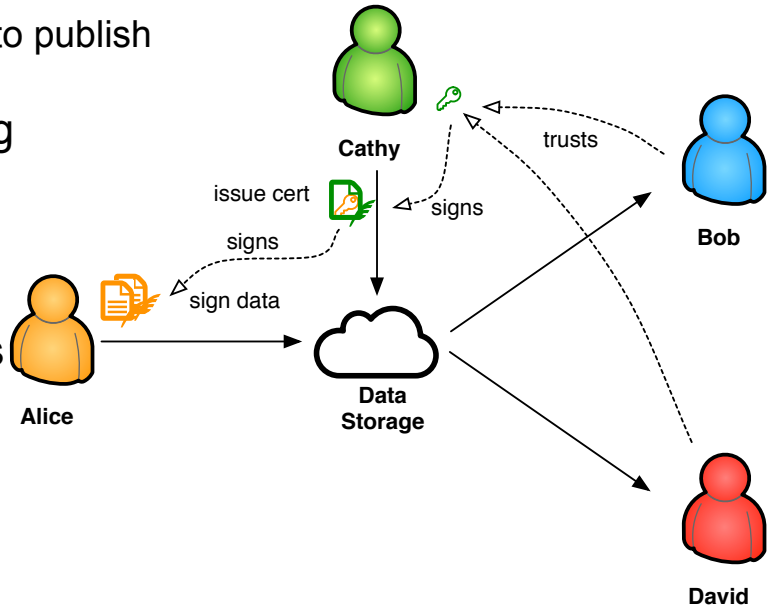
Conclusion

- Content-based confidentiality
  - true “end-to-end” confidentiality
- Differential confidentiality
  - leveraging hierarchical namespace
  - multi-dimensional access control
- Effective access control
  - separate access control apart from data production
- Still many open questions

Q & A

Content-Based Write Access Control

- Write access
  - endorse one to produce data on behalf of data owner
    - a channel owner may allow all participants to publish sync data on behalf of the channel owner
  - data modification is equivalent to producing a new version of data
- Enforce write access
  - data owner issues certificates to producers
  - data consumer authenticates data
    - discard data produced by non-authorized producers
- Granularity
  - through the name of producer certificate



Write Access Example

- The owner a chat channel “demo” owns the channel’s sync data namespace
  - /ndn/multicast/CHAT/CHANNEL/demo

- The owner may issue each participant a channel specific certificates (channel user certificate)

- With trust schema, consumers will accept sync data produced by user with a valid channel user certificate

- Any other chat channel related data (e.g., channel description) will not be accepted if the producer is a channel user