

ICN Privacy and Name based Security

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<http://mm.aueb.gr/presentations/2014-ICN-Privacy-Tutorial.pdf>



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+MSc, undergraduate students

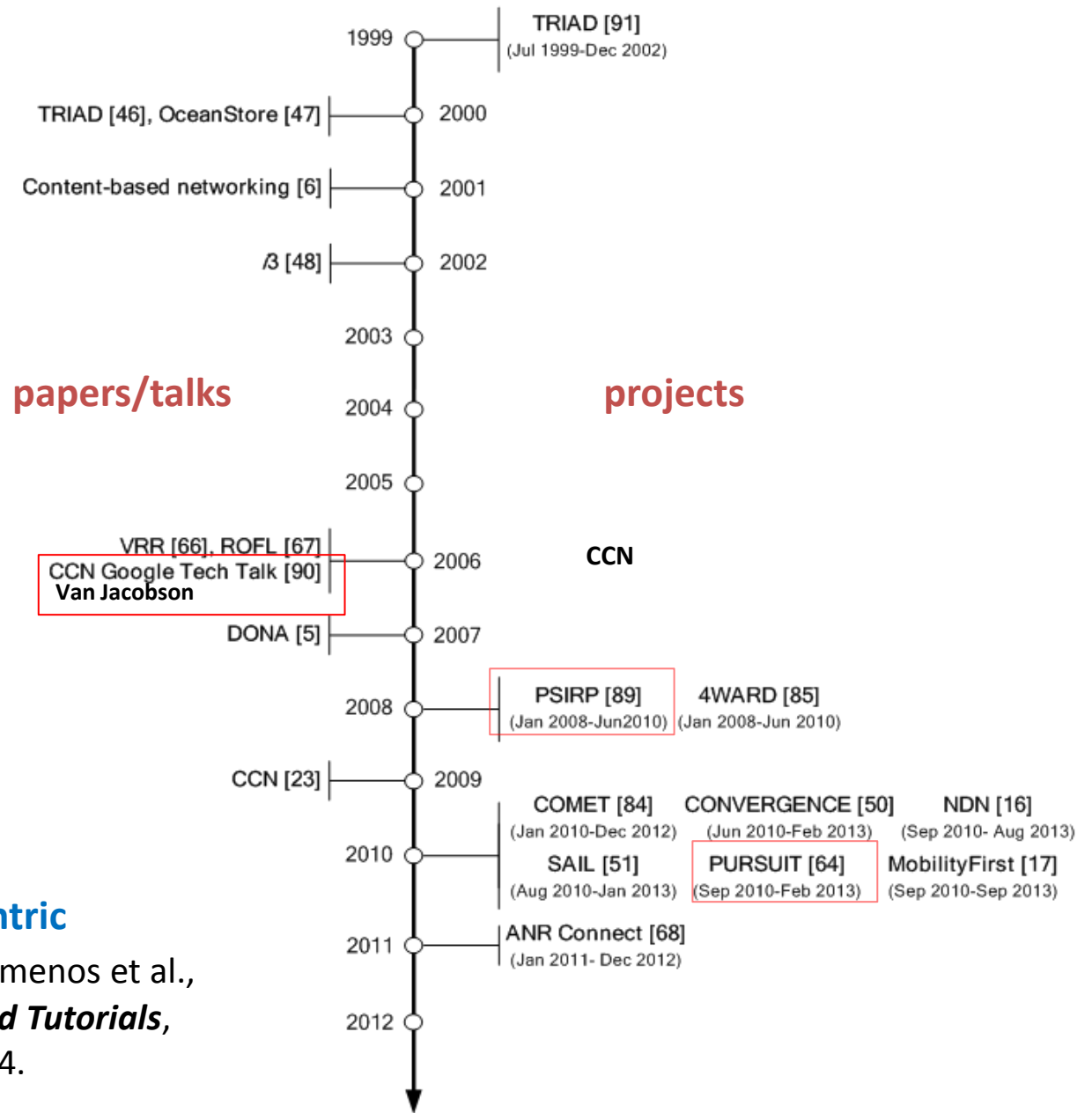
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ICN timeline



“A Survey of Information-Centric Networking Research,” G. Xylomenos et al., *IEEE Communications Surveys and Tutorials*, vol. 16, no. 2, pp. 1024-1049, 2014.

Mobile Multimedia Lab @ AUEB

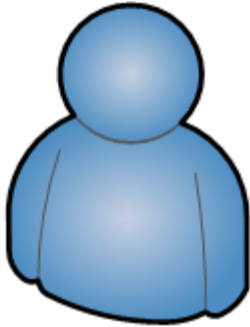
Relevant Research Projects

- **PSIRP**: Publish Subscribe Internet Routing Paradigm
 - FP7 ICT STREP, 2008-2010
 - **the basis**
- **PURSUIT**: Publish Subscribe Internet Technologies
 - FP7 ICT STREP, 2010-2013
 - revisiting, extending, above and below the internet layer
- **Euro-NF**: Anticipating the Network of the Future—From Theory to Design
 - FP7 ICT NoE, 2008-2012
 - various topics, including network architecture
- **EIFFEL**: Evolved Internet Future For European Leadership
 - FP7 ICT SSA, 2008-2010; Think-Tank continued
 - June 2011 TT: *Information-Centric Networking*
- **φ SAT**: The Role of Satellite in Future Internet Services
 - ESA (ARTES 1), 2011-2013
- **I-CAN**: Information-Centric Future Access Networks
 - NSRF (Greece), 2014-2015



A REFERENCE ICN MODEL

The data owner entity

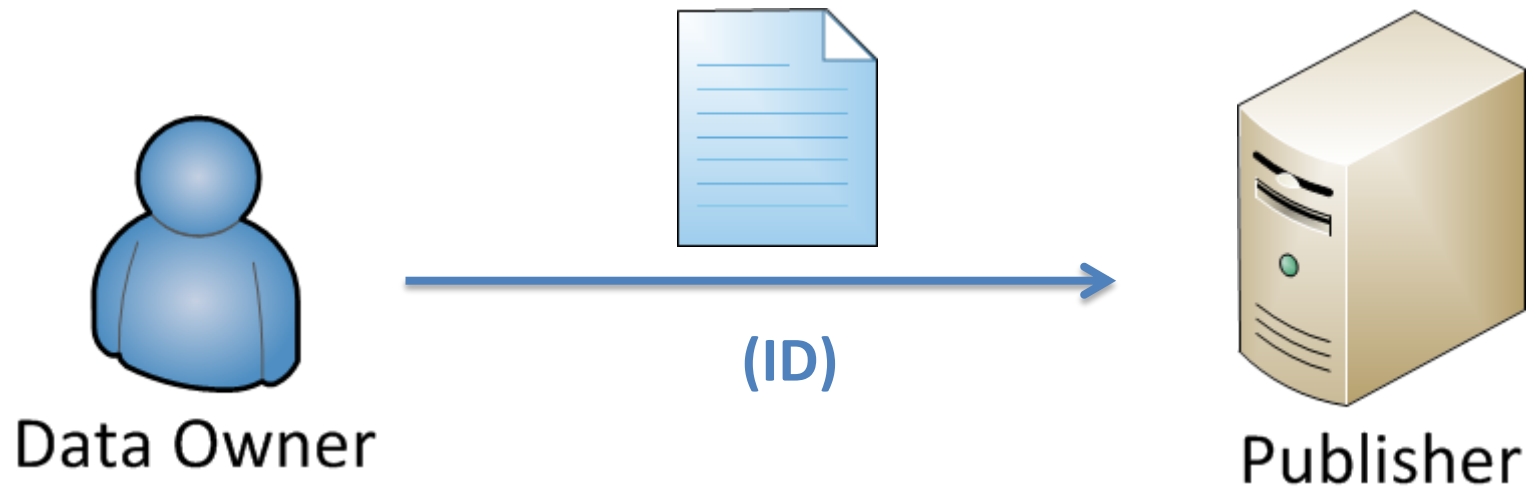


Data Owner

- Real world entity
- Owns a content item that wants to disseminate

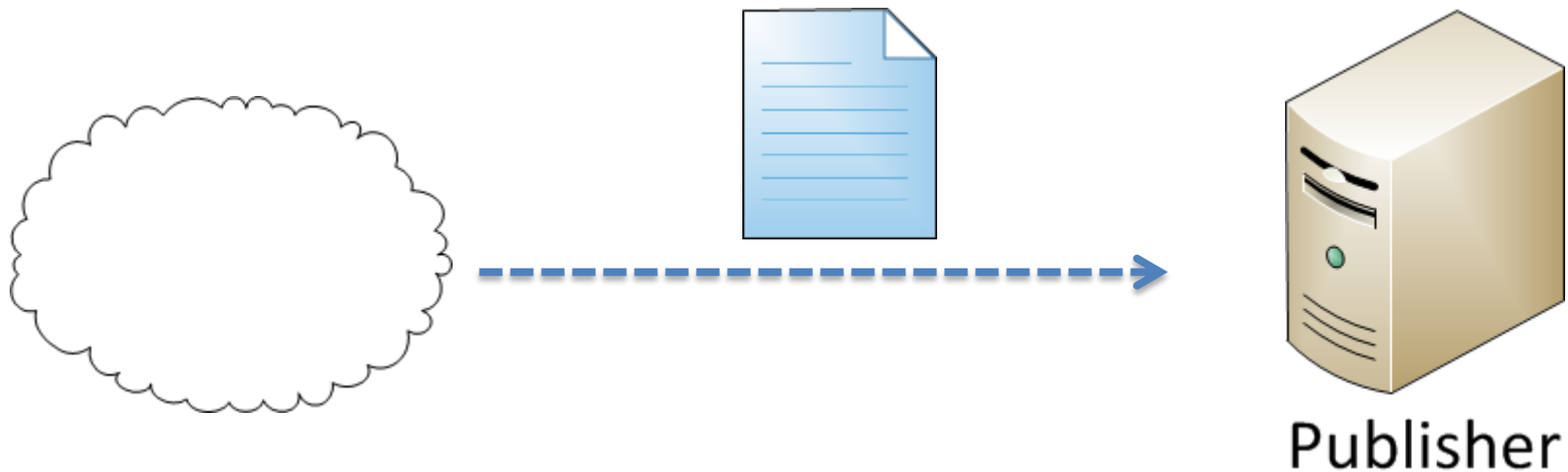
ID assignment and content storage

The data owner assigns a unique identifier to a content item and **Stores** it at a publisher



Opportunistic content storage

A publisher may receive an item from multiple sources

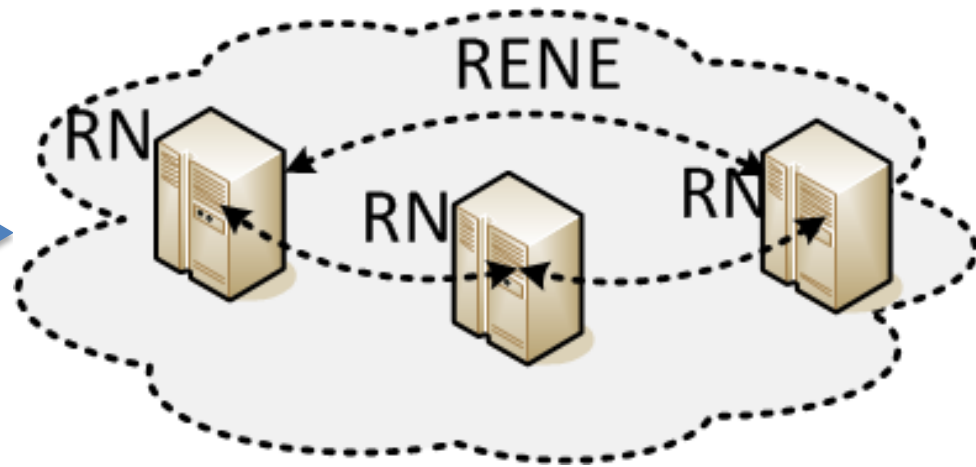


Content advertisement

A publisher **Advertises** a content item to the **Rendezvous Network**

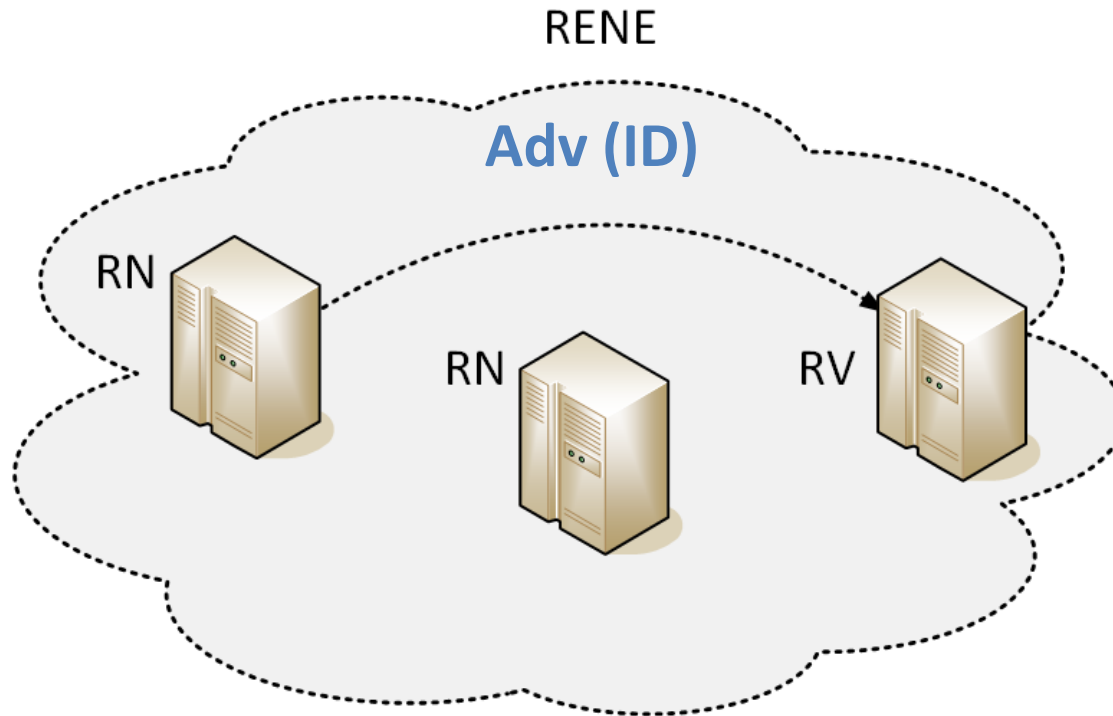


Publisher

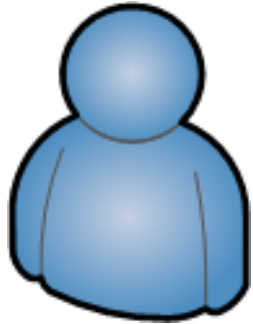


Storing content advertisements

The advertisement is stored in one or more **RendezV**ous points



The subscriber entity

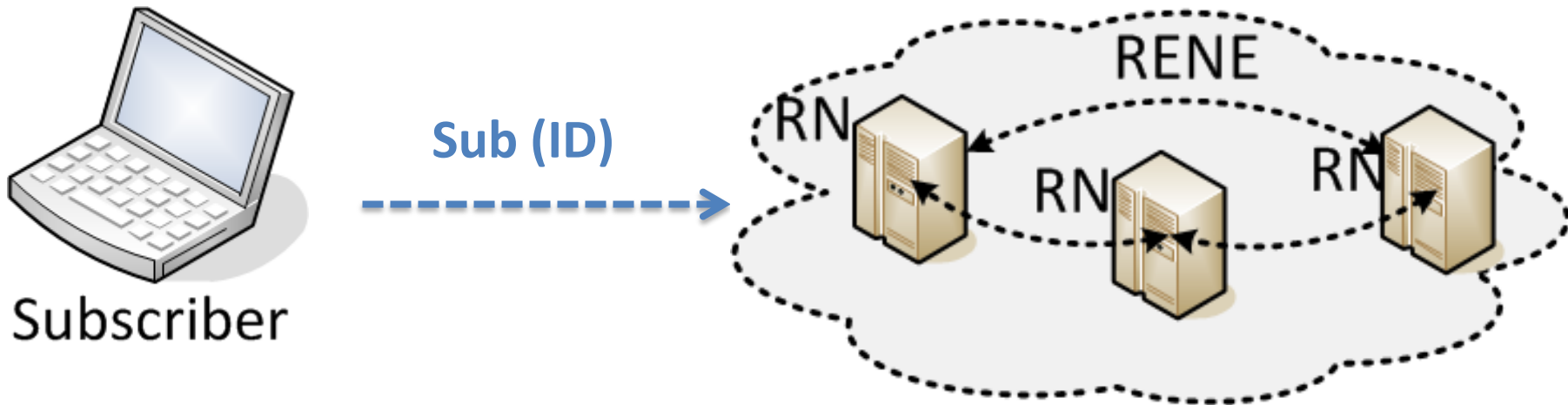


Subscriber

- The device of a real world entity that is interested in a content item

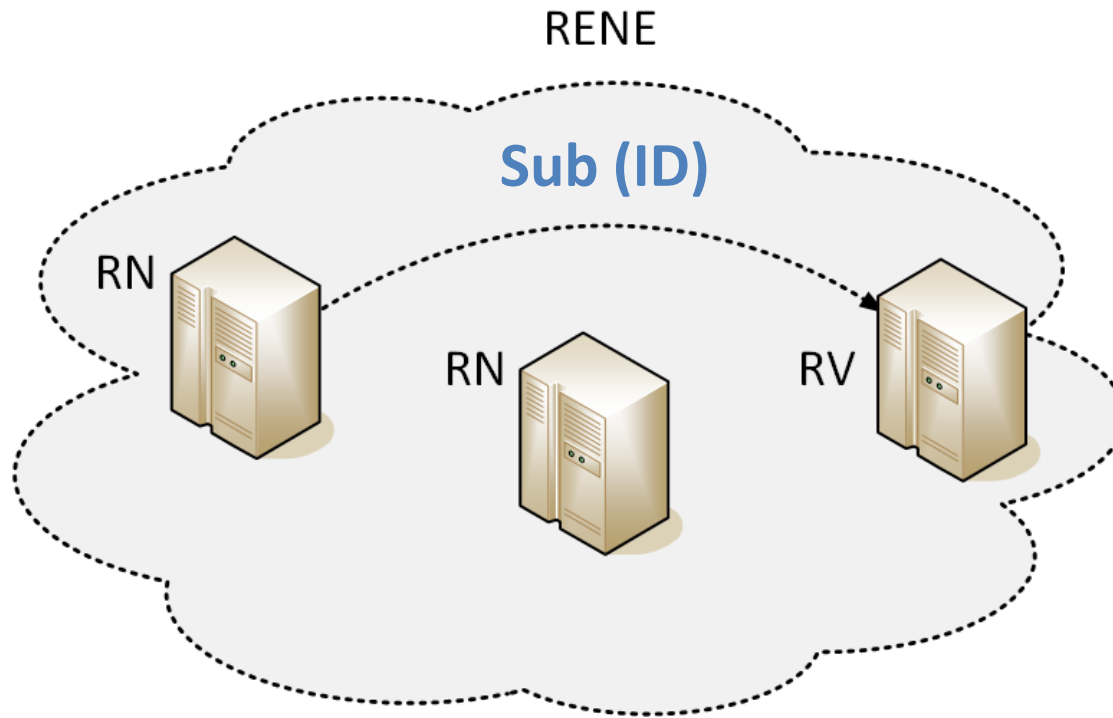
Subscription for content

A subscriber **Subscribes** for a content item



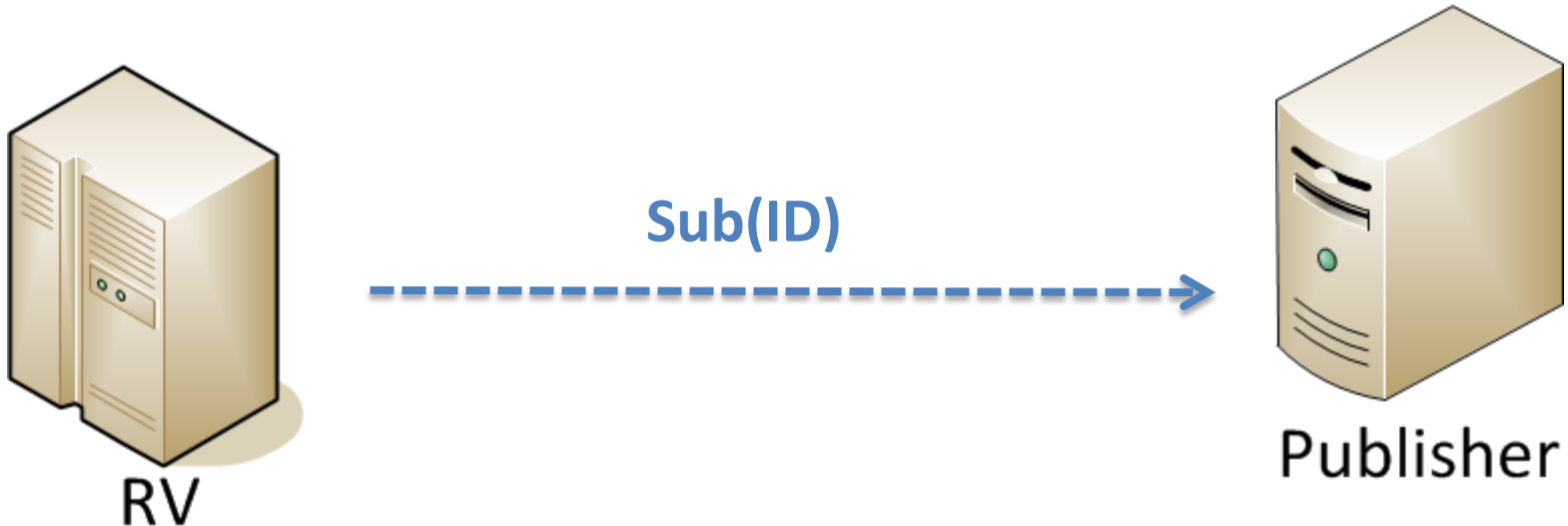
Subscription forwarding

The subscription is rooted at the RENE...



Subscription forwarding

...to a Publisher (after the matching)



Content forwarding

The Publisher **Forwards** the item to the Subscriber



Publisher



Subscriber

Introduction

ICN PRIVACY

ICN Privacy: a myth to bust (?)

- ICN inherently preserves user's privacy
 - Endpoints are decoupled
 - Subscription and Advertisement messages do not contain sensitive information
 - Forwarding techniques that do not reveal packet destination(s)
 - zFilters (PSIRP/PURSUIT)
 - crumb based(CCN/NDN)

But ICN packets reveal more information...

???



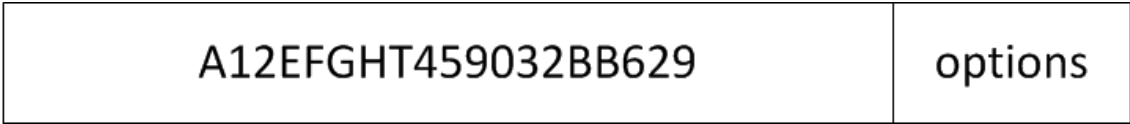
195.251.120.16	210.120.99.88	options
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!!!

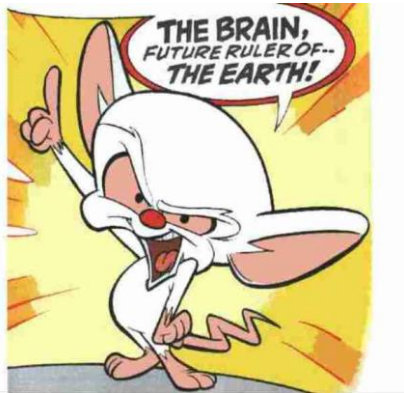
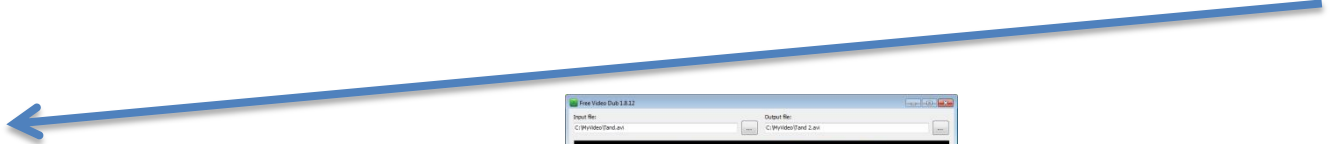
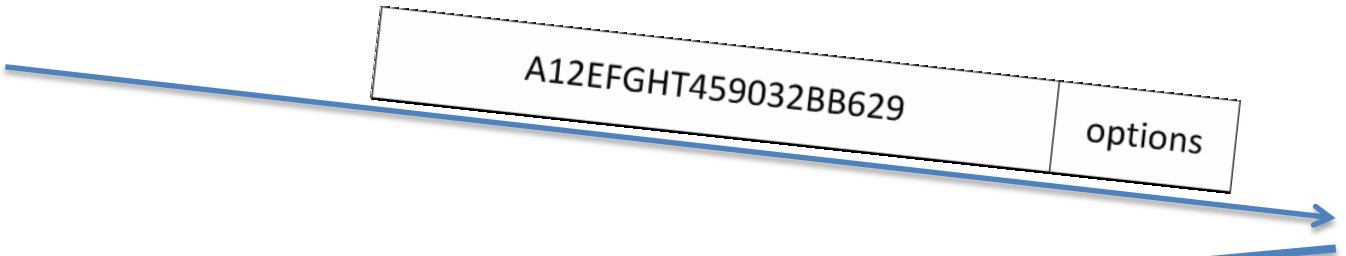


economy/stock/ftse-20/apple/price	options
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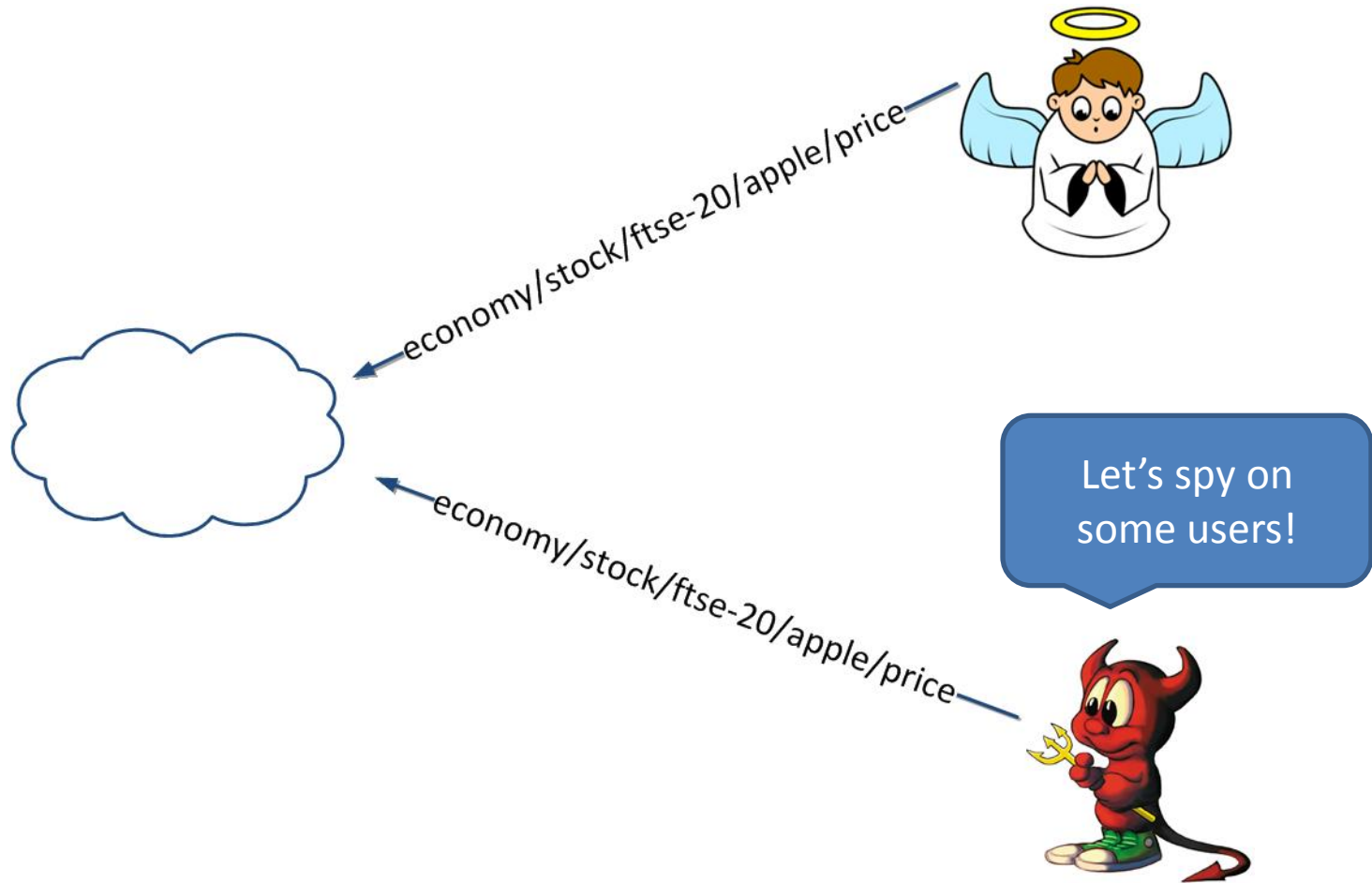
...even if packet header is scrambled...



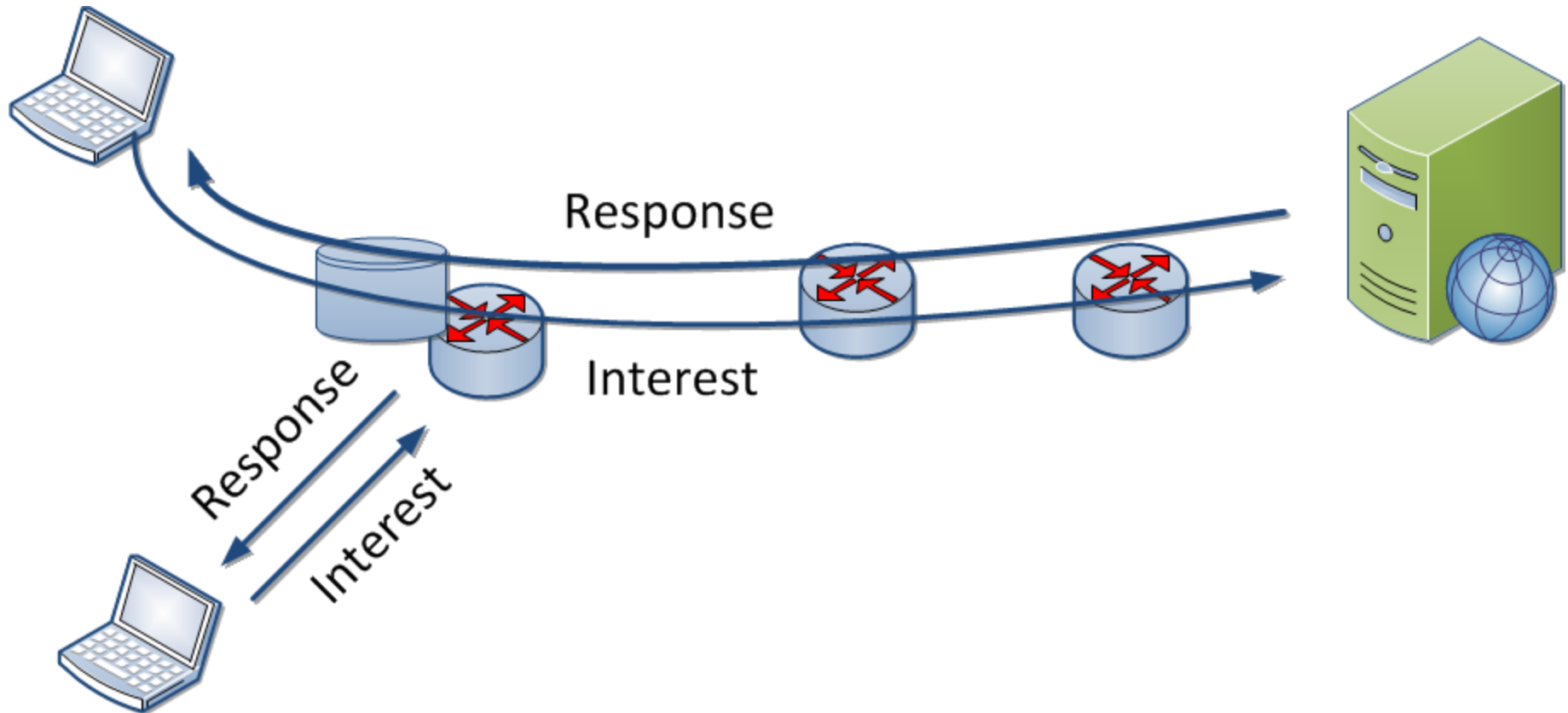
...it is easier to **replay** it and receive the corresponding content



...everybody can be a publisher...

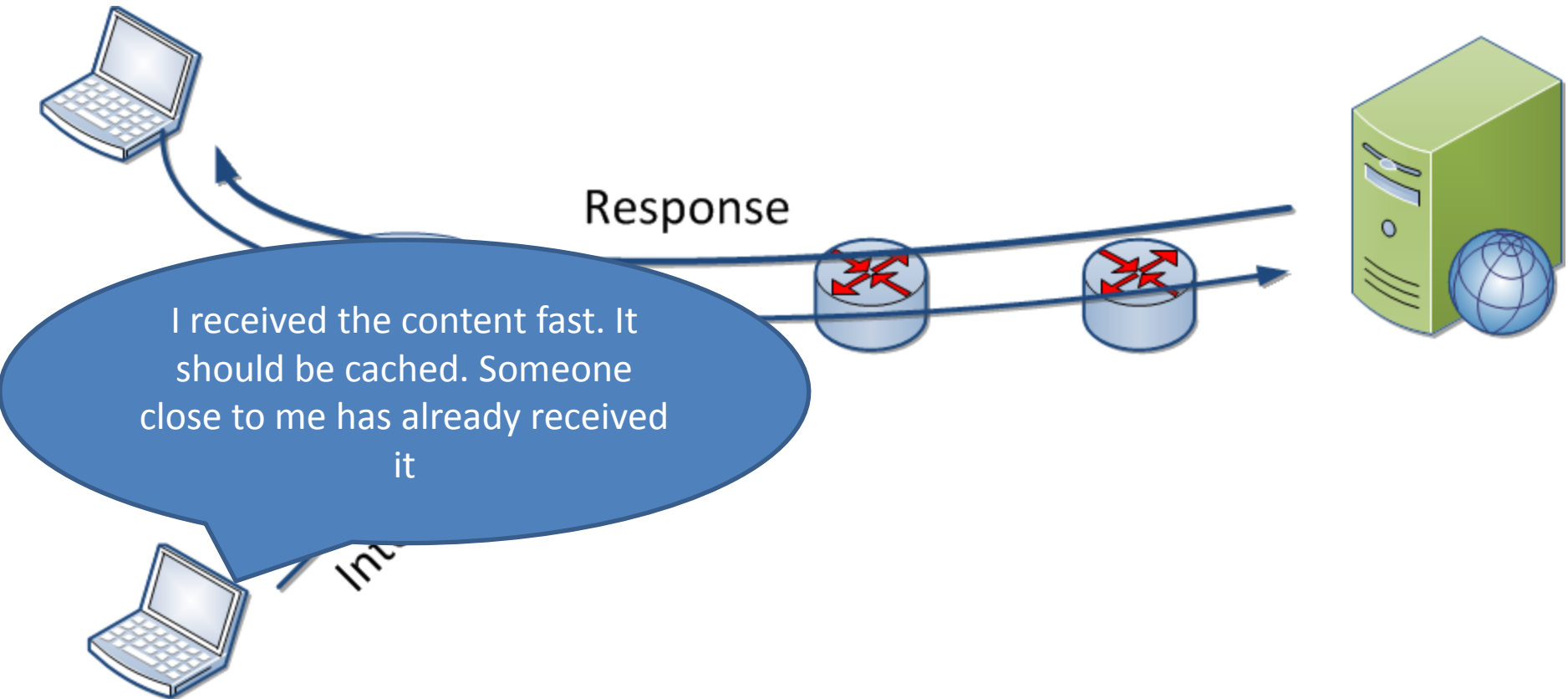


...and some old privacy attacks are upgraded*....



*T. Lauinger et al., “Privacy risks in named data networking: what is the cost of performance?,” ACM SIGCOMM *Computer Communication Review* 42, no. 5 (2012): 54-57.

...and some old privacy attacks are upgraded*....



*T. Lauinger et al., “Privacy risks in named data networking: what is the cost of performance?,” ACM SIGCOMM *Computer Communication Review* 42, no. 5 (2012): 54-57.

The devil is in the (implementation) details

- “We represent this by having P(ublisher) digitally sign the mapping from his chosen name”*
- “PLA divides this problem into two distinct parts: binding a user's traffic to that user's cryptographic identity, and binding the user's cryptographic identity to their real identity”**

*D. Smetters, V. Jacobson, “**Securing Network Content**”, PARC Tech Report, October 2009.

** D. Lagutin and S. Tarkoma, “**Cryptographic signatures on the network layer - an alternative to the ISP data retention,**” IEEE ISCC 2010.

The devil is in the (implementation) details

- “We represent this by having P(ublisher) dig **Possibly Censorship** g from his chosen name”*
- “PLA divides this problem into two distinct par **Possibly** traffic to that user's cry **Surveillance** and binding the user's cryptographic identity to their real identity”**

*D. Smetters, V. Jacobson, “**Securing Network Content**”, PARC Tech Report, October 2009.

** D. Lagutin and S. Tarkoma, “**Cryptographic signatures on the network layer - an alternative to the ISP data retention,**” IEEE ISCC 2010.

A Threat Model*

ICN PRIVACY

* N. Fotiou, S. Arianfar, M. Särelä, and G.C. Polyzos, “**A Framework for Privacy Analysis of ICN Architectures**,” *Privacy Technologies and Policy*, Springer, Lecture Notes in Computer Science, no. 8450 (2014): 117-132.

Adversaries

Location
Local
Arbitrary

Role
Owner
Subscriber
Publisher
Rendezvous Node
Observer
Authority

Mode of operation
Active
Passive
Honest-but-Curious

Privacy attacks*

- 3 Main Categories:
 - Monitoring attacks
 - Aim at learning the preferences of subscribers
 - Decisional interference attacks
 - Censorship
 - Invasion attacks
 - Affect privacy related information of a target in order to cause (not necessarily privacy related) harassment
 - Try to lure a subscriber to subscribe for a content item, or make a RV believe that a subscriber is interested in something

* Based on: D.J. Solove, “**A taxonomy of privacy**,” *University of Pennsylvania Law Review* (2006): 477-564.

Monitoring attacks

- Surveillance
 - Collect information about a target
- Interrogation
 - Force a target to give information in order to use a service
 - e.g., a RN that accepts only digitally signed advertisements
- Identification
 - Link collected information to a particular target
- Breach of confidentiality and disclosure
 - Revelation of information by a third party
 - If that party was considered trusted then breach of confidentiality occurs

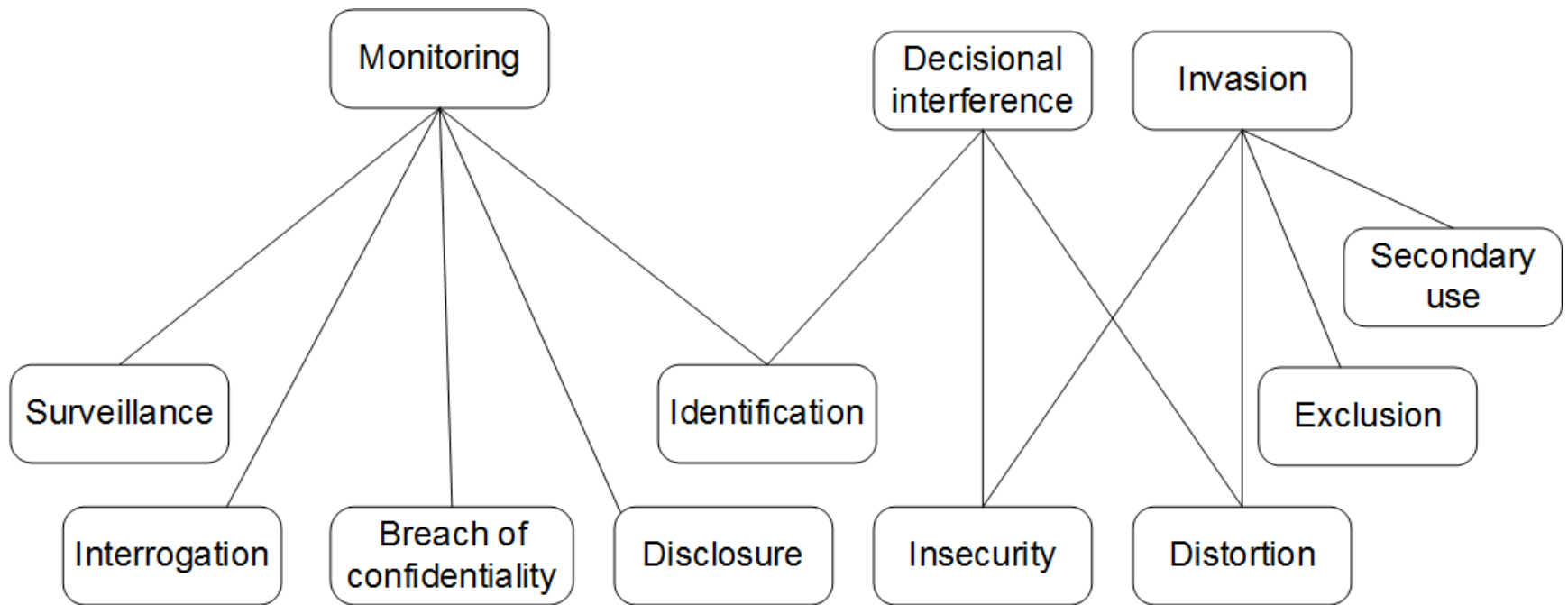
Decisional interference attacks

- Successful Identification is a prerequisite
- Insecurity
 - Manipulation of a “data pool”
 - e.g., manipulation of the state of a RN
- Distortion
 - Manipulate or delete an “information flow”
 - e.g., a subscription message

Invasion attacks

- Insecurity and Distortion
 - Also used for making a subscriber receive something never requested
- Exclusion
 - Prevents a target from removing a record about him in a “data pool”
 - e.g., to prevent a subscriber from withdrawing a subscription
- Secondary use
 - (Re-)Use of previously collected information
 - e.g., repetition of a subscription message

Attacks



Privacy solutions

ICN PRIVACY

Entropy-based*

- It does not modify underlay architecture
- It makes “hard” for an adversary to guess subscriber preferences
 - Unobservability

* S. Arianfar, T. Koponen, B. Raghavan, and S. Shenker, “**On preserving privacy in content-oriented networks,**” Proc. ACM SIGCOMM workshop on Information-Centric Networking (2011): 19-24.

Outline

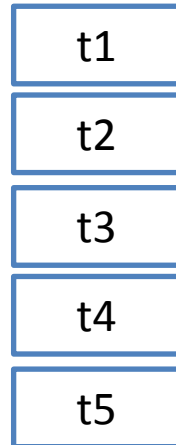
- Subscriber and Publisher share some knowledge about the content
- Publisher splits the content in chunks and assigns an **Id** to each chunk
- An adversary's goal is to censor content based on its Id

Design



Publisher

Target File t



Design



Publisher

Target File t	Computed Ids per block
t1	$H(t,1)$
t2	$H(t,2)$
t3	$H(t,3)$
t4	$H(t,4)$
t5	$H(t,5)$

Design



Publisher

Target File t Cover File c



Design



Publisher

Target File t Cover File c Computed Ids per block

t1	c1	$H(c,1)$
t2	c2	$H(c,2)$
t3	c3	$H(c,3)$
t4	c4	$H(c,4)$
t5	c5	$H(c,5)$
	c6	$H(c,6)$

Design

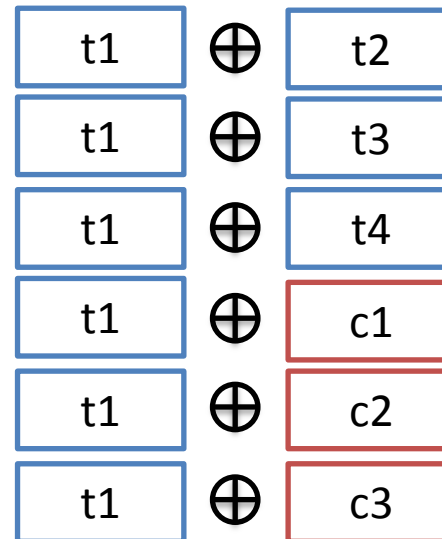


Publisher

Target File t Cover File c



New “chunks” by XORing blocks

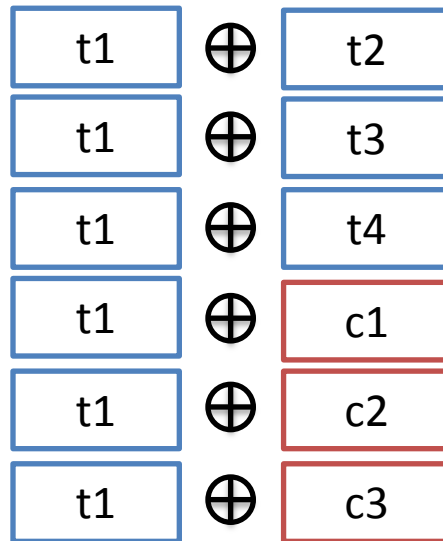


Design



Publisher

New “chunks”



Computed Ids per chunk

$H(H(t,1), H(t,2))$

$H(H(t,1), H(t,3))$

$H(H(t,1), H(t,4))$

$H(H(t,1), H(c,1))$

$H(H(t,1), H(c,2))$

$H(H(t,1), H(c,3))$

Design



Subscriber

$\text{Sub}(H(H(t,1), H(c,1)))$



$\text{Sub}(H(H(t,1), H(c,2)))$



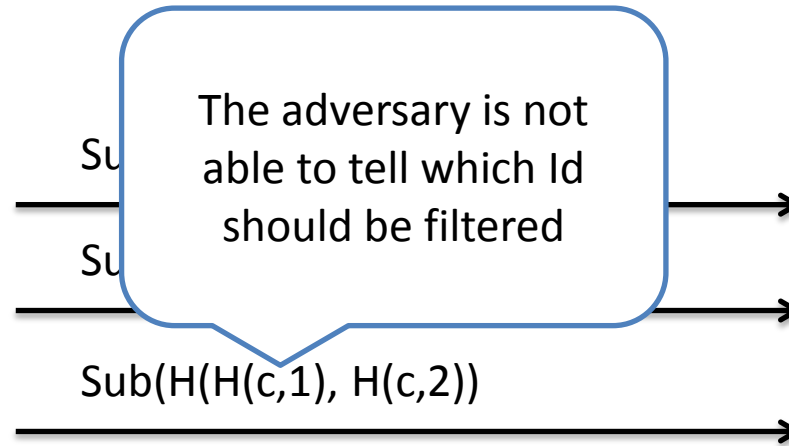
$\text{Sub}(H(H(c,1), H(c,2)))$



Design



Subscriber



Mix networks-based*

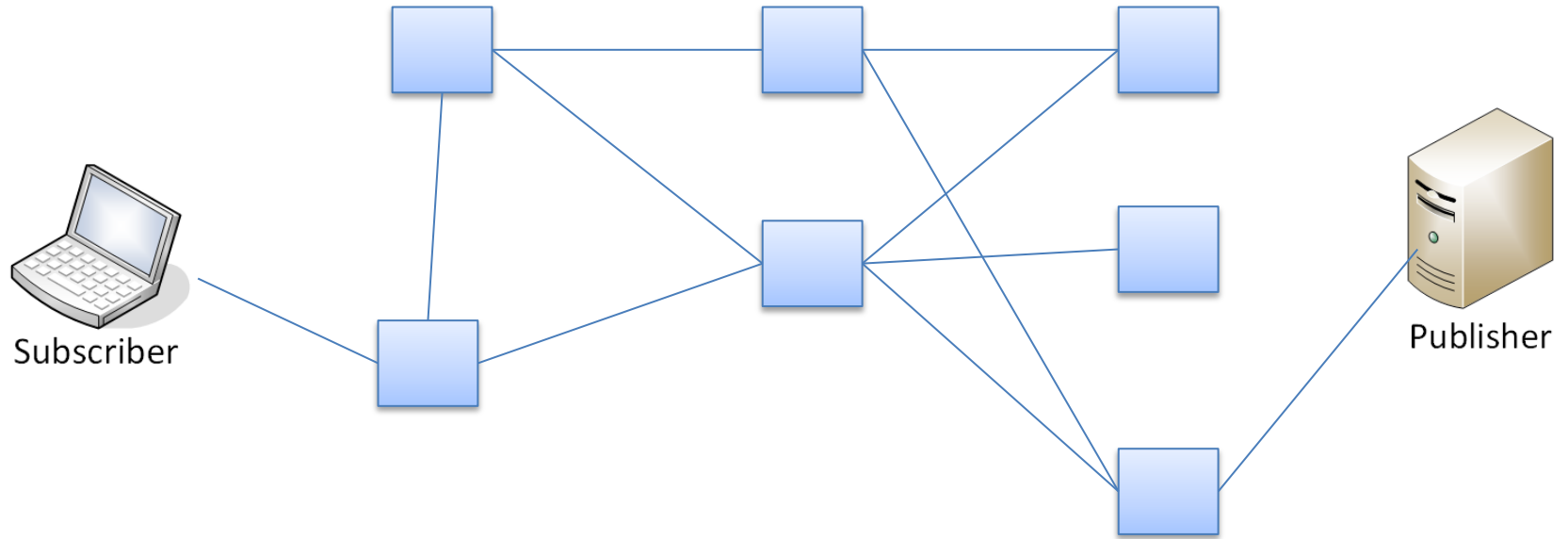
- An adaptation of onion routing for ICN (NDN)
- The identity of the subscriber is hidden
 - Anonymity
- Subscriptions and content packets cannot be “linked”
 - Unlinkability

* S. DiBenedetto, P. Gasti, G. Tsudik, and E. Uzun, “**ANDaNA: Anonymous named data networking application**,” Proc. Network and Distributed System Security Symposium (NDSS 2012)

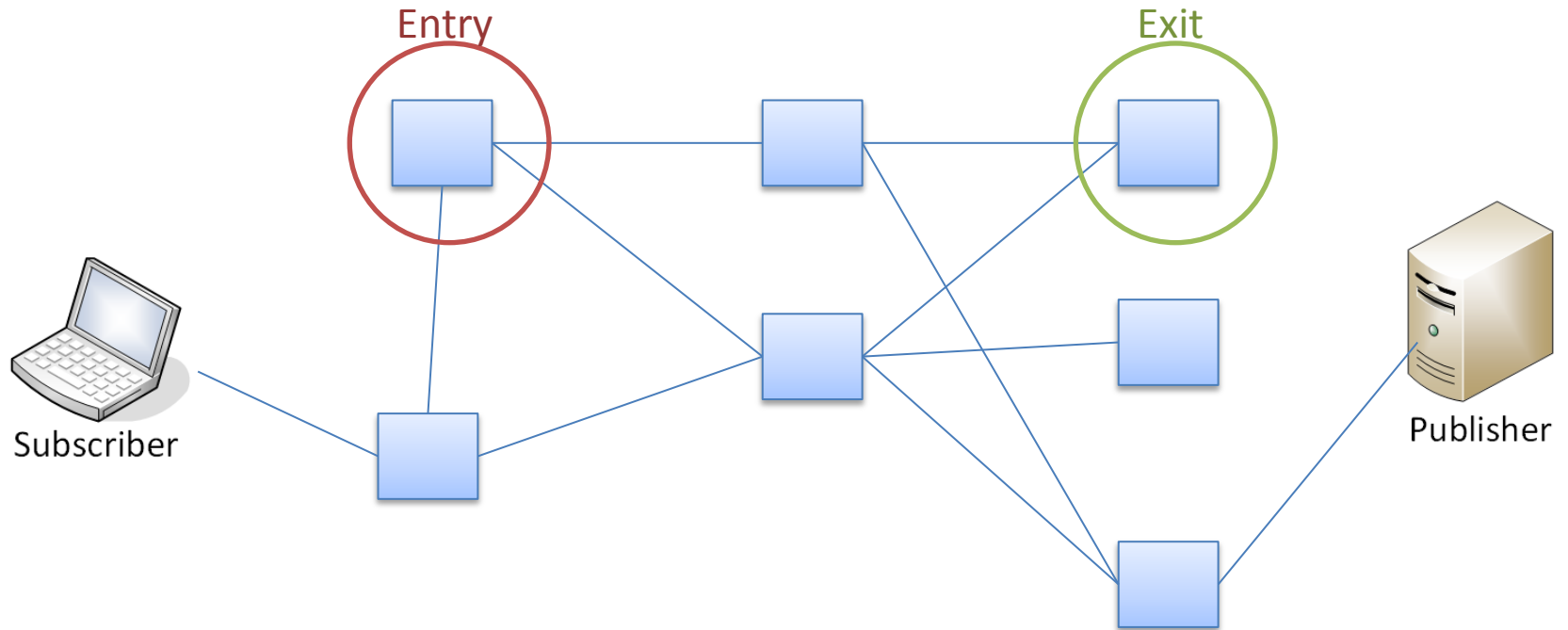
Outline

- Multiple concentric layers of encryption
- Every message is routed through a chain of at least two “anonymizing routers” (ARs)
- Each router removes a layer of encryption and forwards the message to the next hop

Design



Design



Design



Subscriber

- Sub(ID)

Design



Subscriber

- $E_{\text{exit}}(\text{Sub}(\text{ID}), K2)$

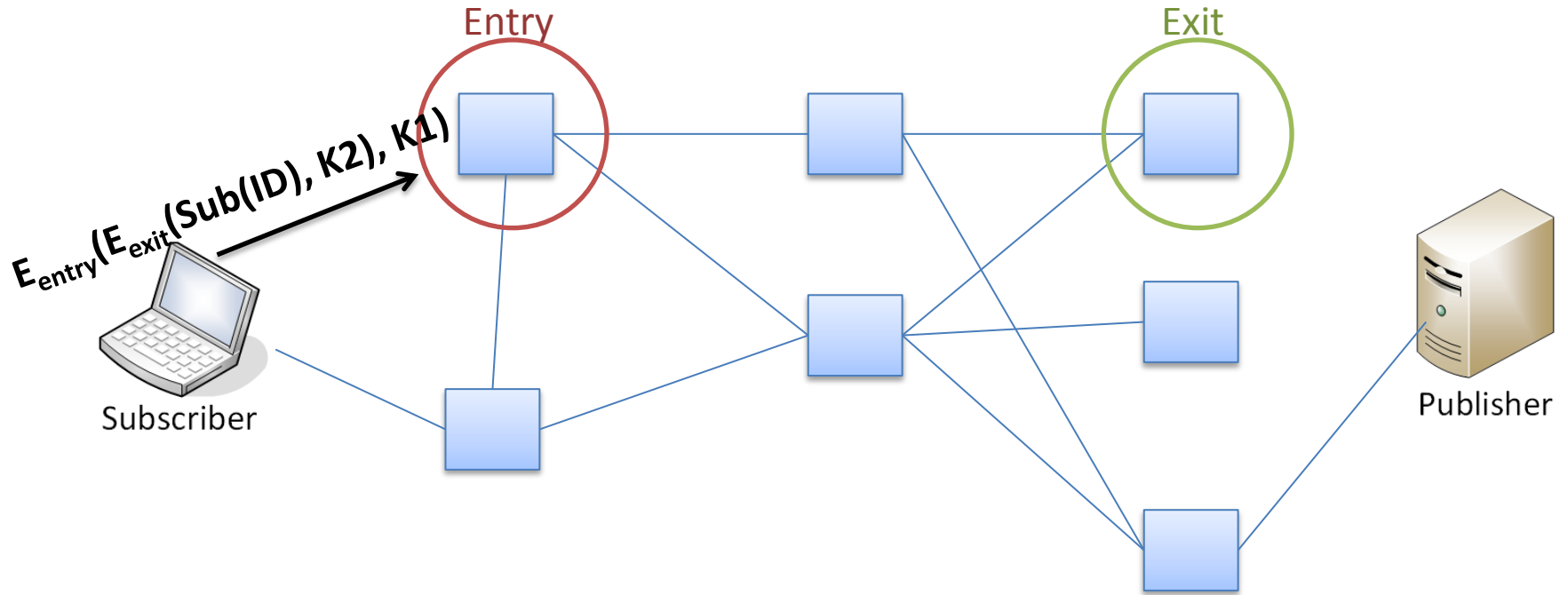
Design



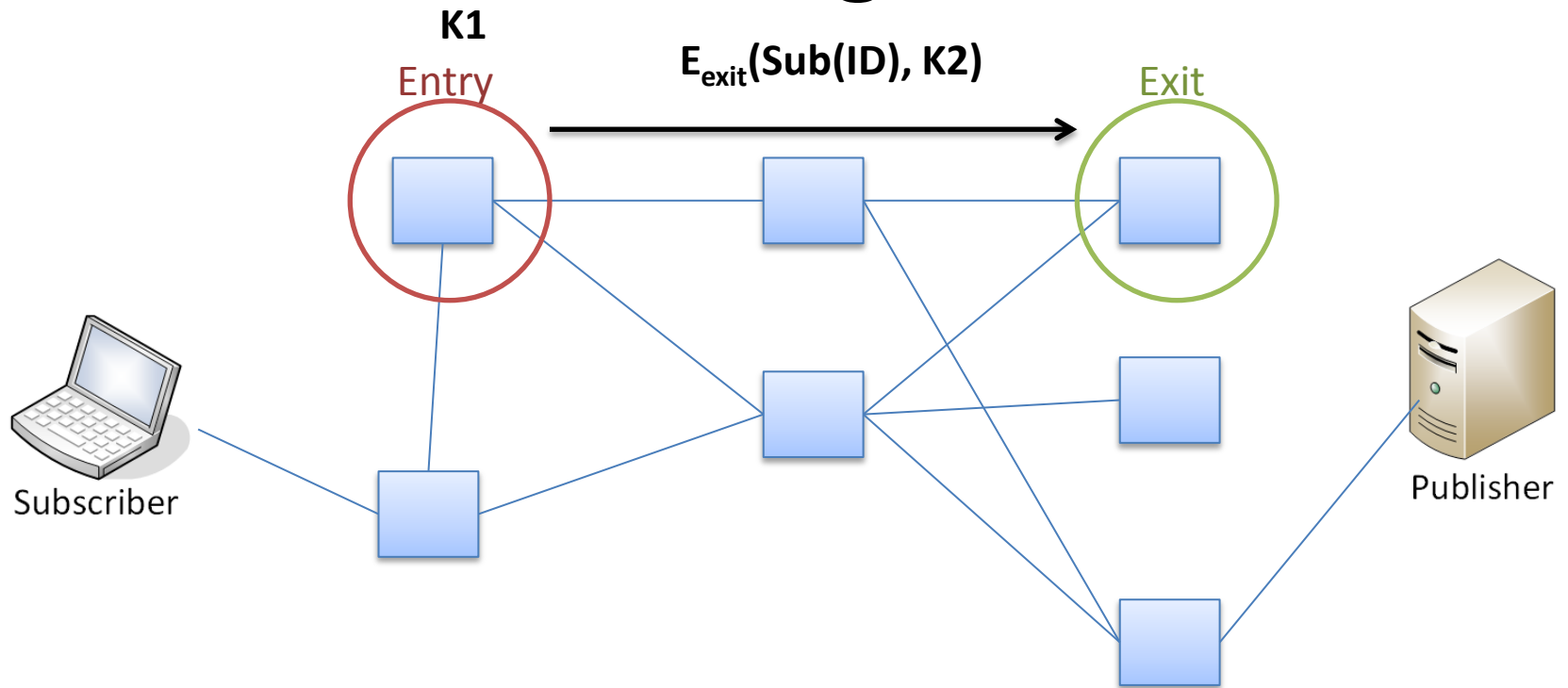
Subscriber

- $E_{\text{entry}}(E_{\text{exit}}(\text{Sub}(\text{ID}), K2), K1)$

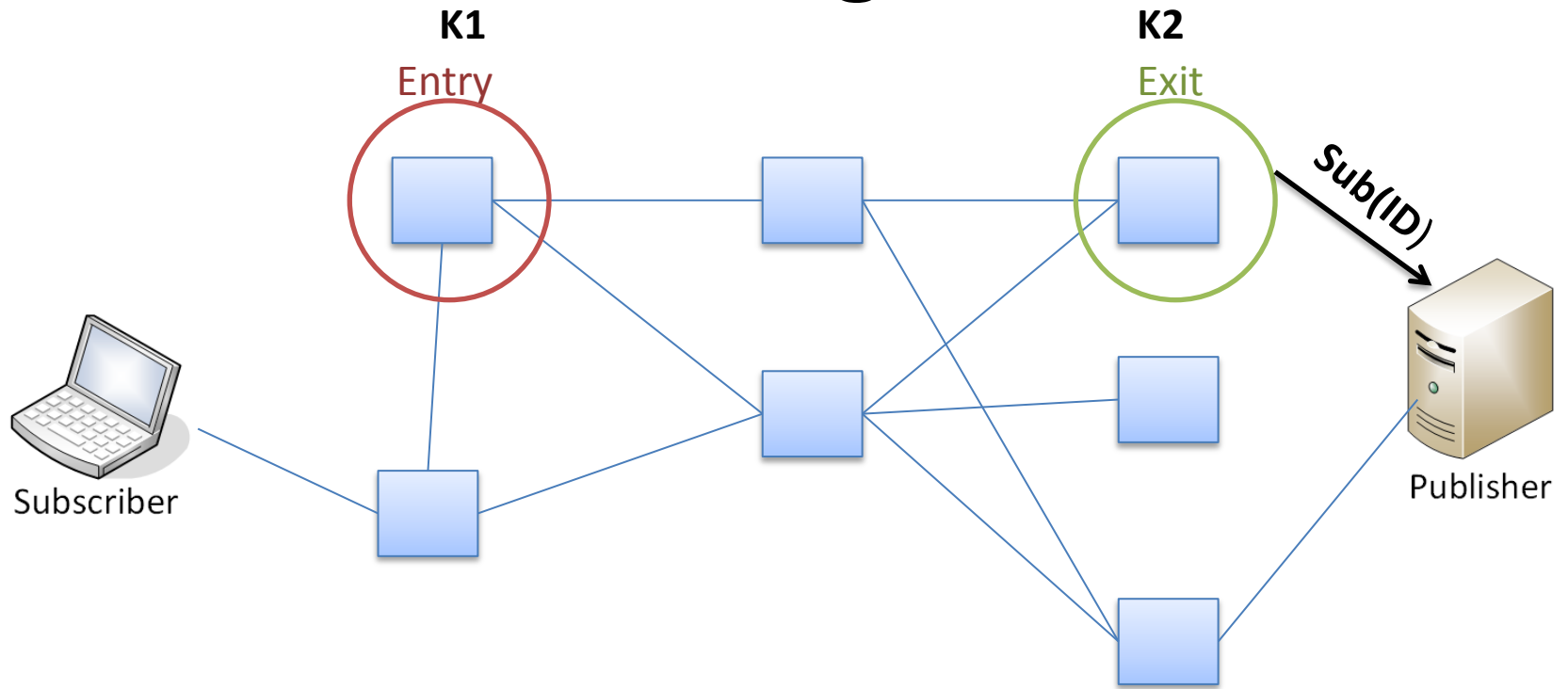
Design



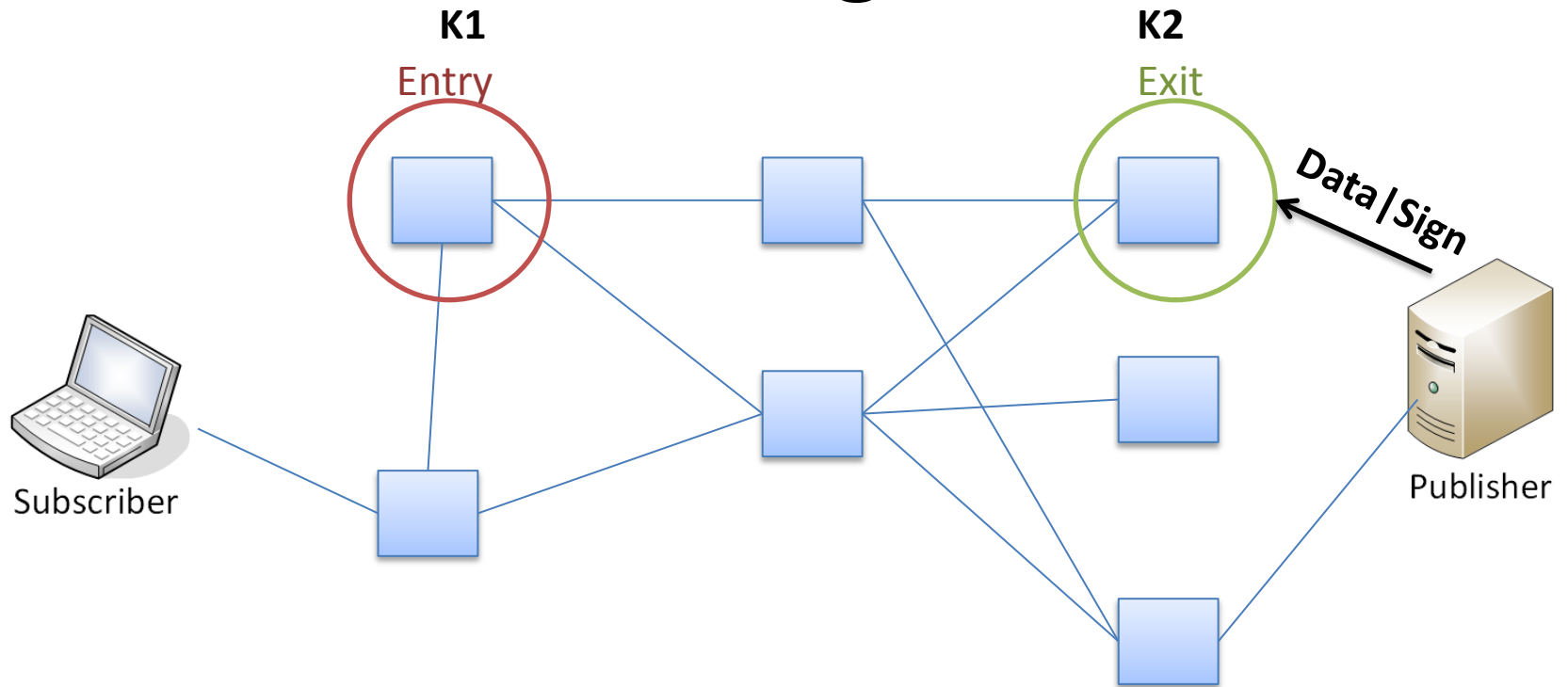
Design



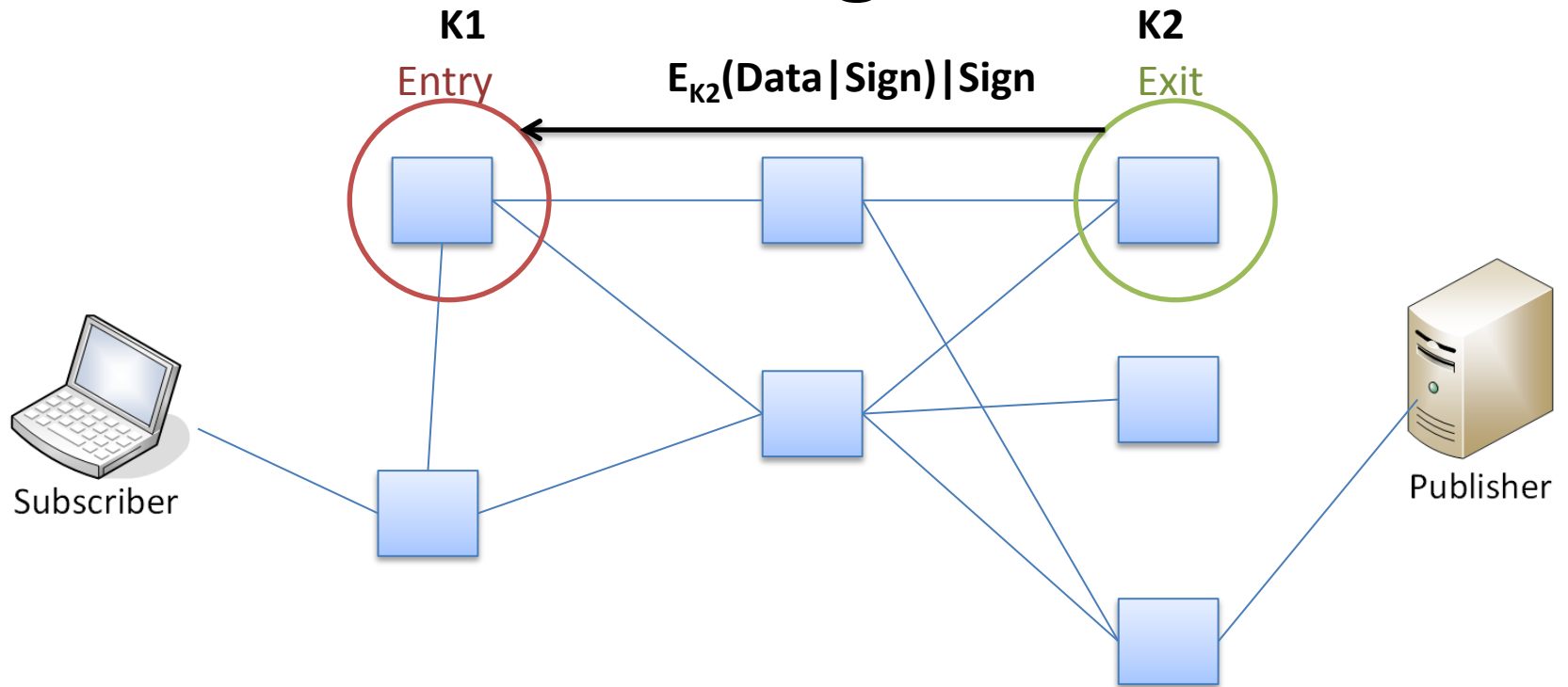
Design



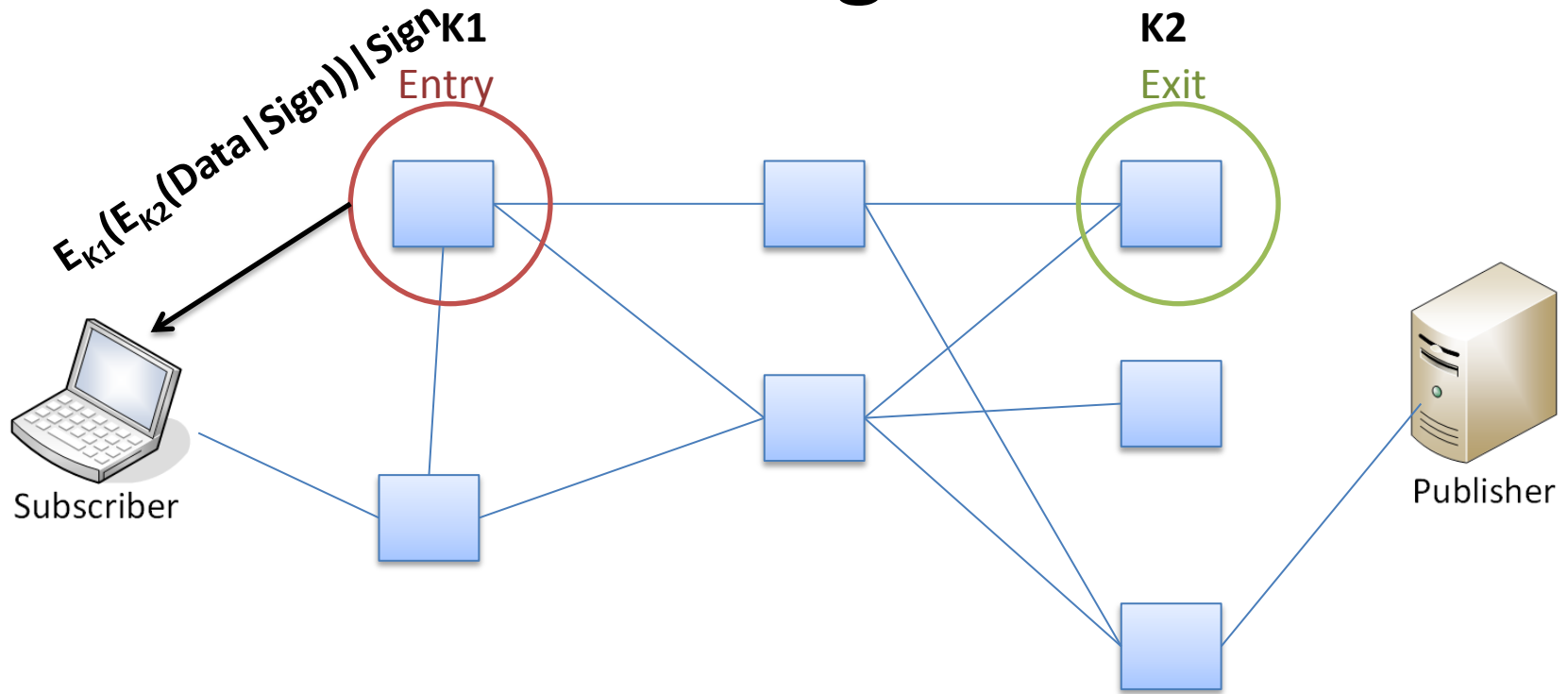
Design



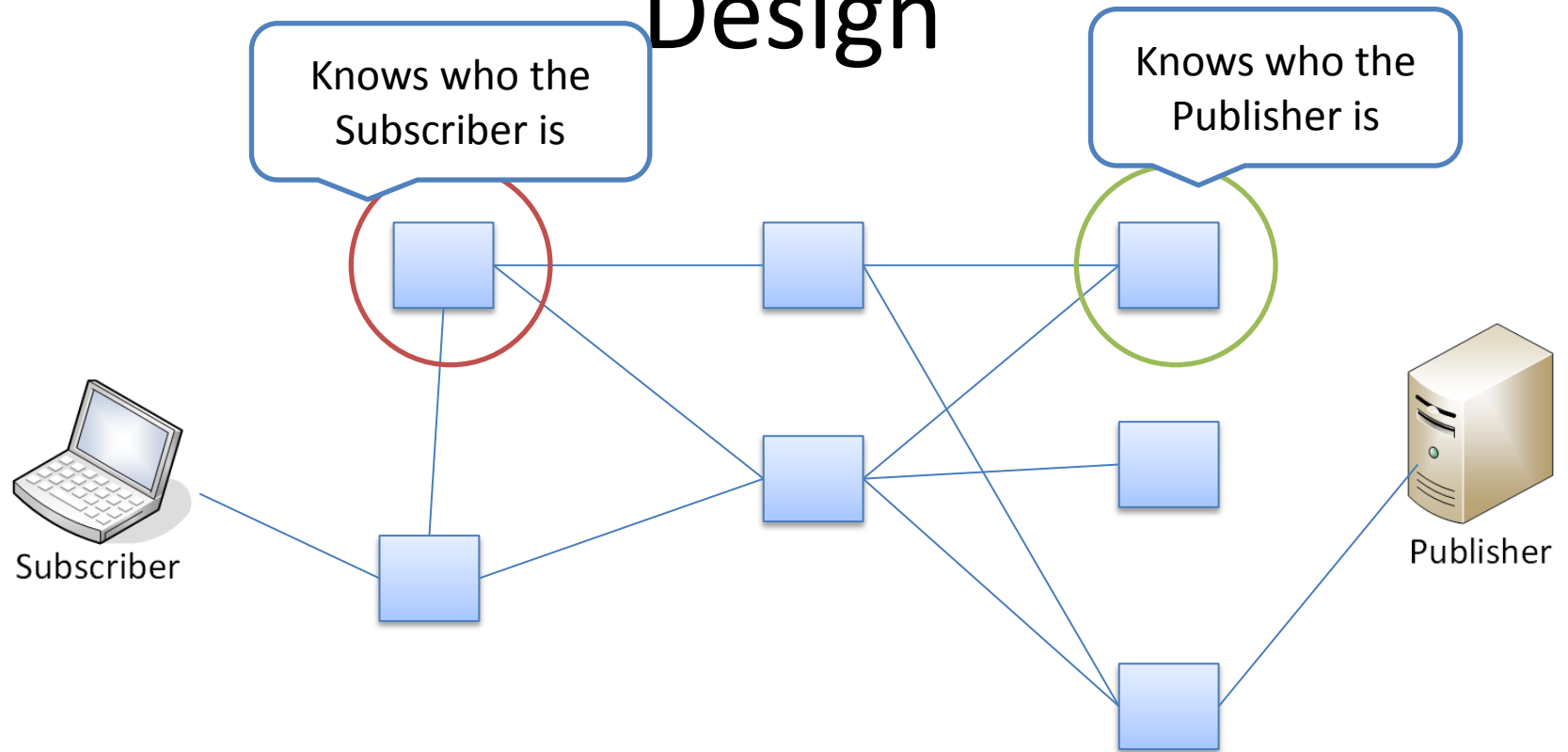
Design



Design



Design



Homomorphic encryption-based*

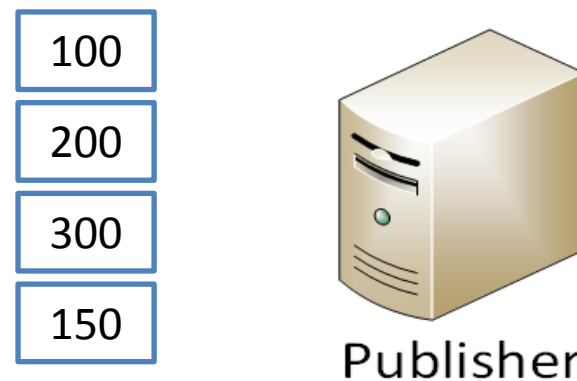
- A subscriber is able to request a content item, a publisher is able to send it, nobody learns what the subscriber asked and what the publisher responded
 - Not even the publisher!
 - Unobservability
- Subscriber identity is not hidden
- Based on the Paillier cryptosystem

* N. Fotiou et al., “Enhancing information lookup privacy through homomorphic encryption,” *Security and Communication Networks*, Wiley, vol. 7, no. 4, (2014): 700-713

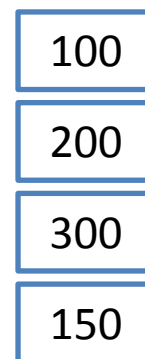
(A very high level) Introduction to the Paillier cryptosystem

- Probabilistic:
 - $E(1) \neq E(1)$
- Homomorphism:
 - $E(a) * E(b) = E(a + b)$
 - $E(a)^k = E(a) * E(a) * \dots (k \text{ times}) \dots E(a) = E(k * a)$

(A very high level) PIR scheme



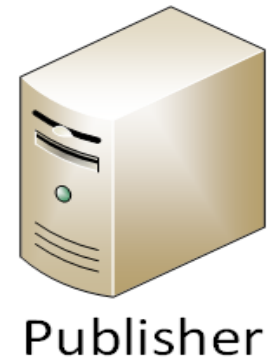
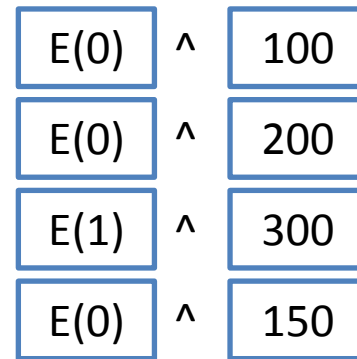
(A very high level) PIR scheme



(A very high level) PIR scheme



(A very high level) PIR scheme



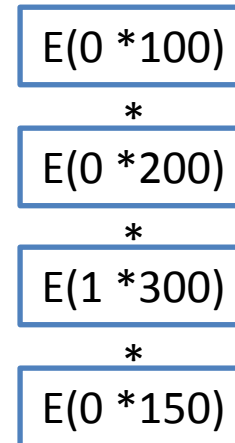
(A very high level) PIR scheme



$E(0 * 100)$
 $E(0 * 200)$
 $E(1 * 300)$
 $E(0 * 150)$



(A very high level) PIR scheme



(A very high level) PIR scheme



Subscriber

$$E(0 * 100 + 0 * 200 + 1 * 300 + 0 * 150)$$



Publisher

(A very high level) PIR scheme



$E(300)$



Pros and Cons

- Unobservability is guaranteed by the underlay cryptographic primitives
- Computationally intensive
- Communication overhead

Introduction

NAME-BASED SECURITY

Content-related security requirements

- Confidentiality
 - A content item can be viewed only by the intended recipients
- Integrity
 - A content item has not been modified
- Authenticity
 - A content item is what I asked
- Provenance verification
 - The sender of a content item can be verified

Solutions

NAME-BASED SECURITY

Authenticating Named Content*

- Common ways to satisfy content-related security requirements are:
 - Use content hash as a name
 - Use names of the form “Publisher_key || Label” **
- Authenticating Named Content aims at achieving the same properties by using names of any form

* D. Smetters, V. Jacobson, “**Securing Network Content**,” PARC Tech. Report, (2009).

** Ghodsi et al., “**Naming in Content-Oriented Architectures**,” In Proc. of SIGCOMM ICN Workshop, (2011).

Design

- Content is made available in the network as a mapping triplet $(N, C, \text{Sign}_p(N,C))$
 - N: An arbitrary name chosen by the publisher for a content item
 - C: The hash of the content data
 - $\text{Sign}_p(N,C)$: The digital signature of the concatenation of N and C using Publisher's private key

Building a “network of trust”

- N may also include an “indication” about P (e.g., a domain name) which can be mapped to a certificate using PKI
- N may be mapped to a N' (instead of C)
 - “secure reference”

Identity-Based Encryption*

- Public key cryptography, where the public key is an arbitrary string
 - www.example.com, foo@example.com, alice
- Identity-Based Signature schemes also exist

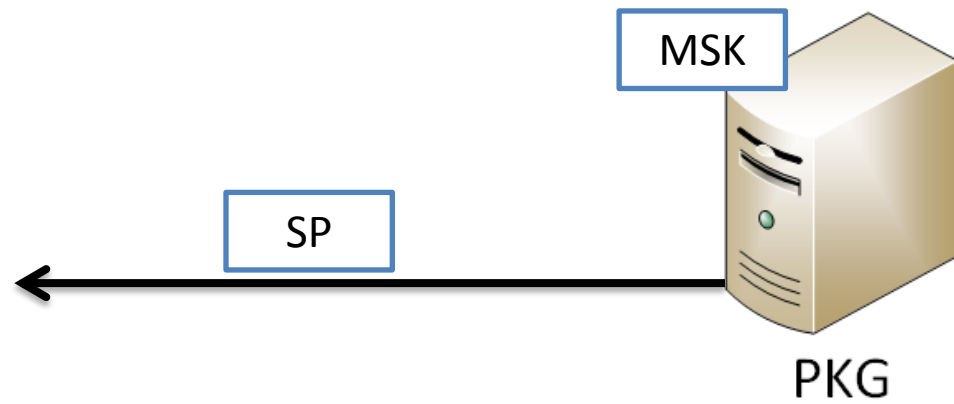
* X. Zhang et al., “Towards name-based trust and security for content-centric network,” Proc. ICNP 2011

IBE Setup

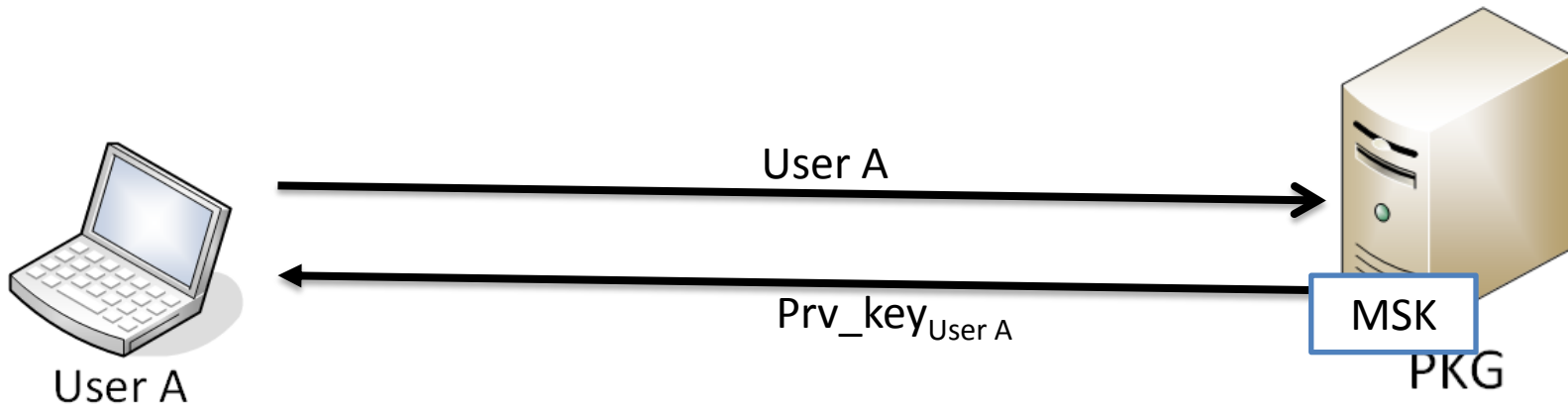


PKG

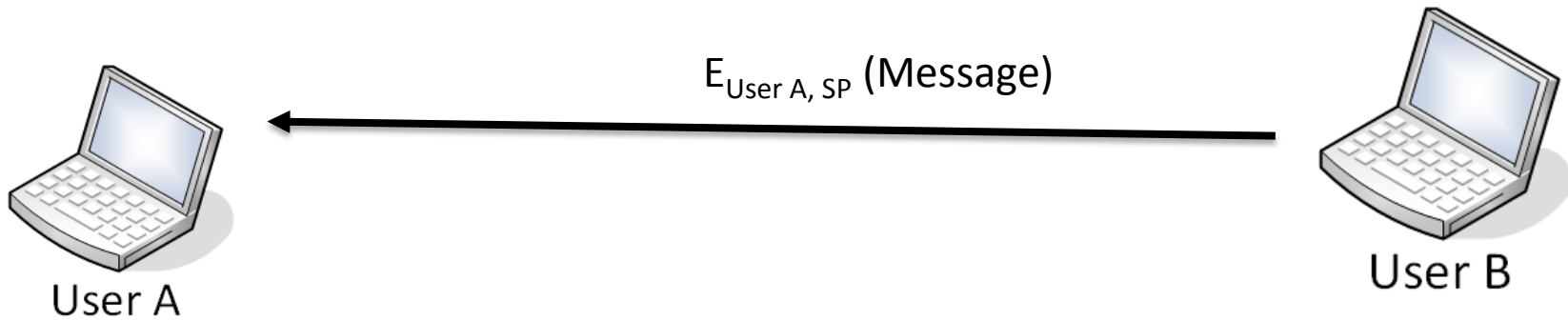
IBE Setup



IBE Key generation



IBE Encryption



Name-based security using IBE

- SP are transmitted using the PKI
- Confidentiality:
 - Encrypt content using as key the identity of the receiver
- Integrity, Authenticity, Provenance verification:
 - Identifiers of the form
“publisher identity | content identity”
 - Sign the content using IBS and the private key that corresponds to the content identifier

Discussion

- Hierarchical Identity Based Encryption
 - even more possibilities
- Key escrow by PKG
- Key revocation is an issue
 - identities should be “revocable”
 - use as key:
identity | | something
 - where something is: serial number, date, ...,

FURTHER READING

Privacy

- H.C. Hsiao et al., “**LAP: Lightweight anonymity and privacy**,” Proc. IEEE Symposium on Security and Privacy 2012, pp. 506-520
- G. Acs et al., “**Cache Privacy in Named-Data Networking**,” Proc. 33rd IEEE International Conference on Distributed Computing Systems (ICDCS), pp. 41-51, 2013
- A. Chaabane et al., “**Privacy in content-oriented networking: threats and countermeasures**,” ACM SIGCOMM *Computer Communication Review*, vol. 43, no. 3, pp. 25-33, 2013
- M. Ion, J. Zhang, and E.M. Schooler, “**Toward Content-centric Privacy in ICN: Attribute-based Encryption and Routing**,” ACM SIGCOMM *Computer Communication Review*, vol. 43, no. 4, pp. 513-514, 2013

Access Control

- N. Fotiou, G. F. Marias, and G. C. Polyzos, “**Access control enforcement delegation for information-centric networking architectures,**” ACM SIGCOMM Computer Communication Review, vol. 42, no. 4, pp. 497-502, 2012
- V. Jacobson et al. “**Custodian-based information sharing,**” IEEE *Communications Magazine*, vol. 50, no. 7, pp. 38-43, 2012
- S. Misra, R. Tourani, and N. E. Majd, “**Secure content delivery in information-centric networks: design, implementation, and analyses,**” Proc. 3rd ACM SIGCOMM workshop on Information-Centric Networking , pp. 73-78, 2013
- C.A. Wood and E. Uzun, “**Flexible End-to-End Content Security in CCN,**” Proc. IEEE Consumer Communications and Networking Conference, 2014

Content-related security

- C. Dannewitz et al., “**Secure naming for a network of information,**” Proc. IEEE INFOCOM Workshops 2010, pp. 1-6, 2010
- W. Wong, and P. Nikander, “**Secure naming in information-centric networks,**” Proc. ACM Re-Architecting the Internet Workshop (ReARCH), pp. 1-6, 2010
- C. Ghali, T. Gene, and E. Uzun, “**Needle in a Haystack: Mitigating Content Poisoning in Named-Data Networking,**” Proc. NDSS Workshop on Security of Emerging Networking Technologies (SENT), 2014
- N. Fotiou, G. F. Marias, and G. C. Polyzos, “**Fighting spam in publish/subscribe networks using information ranking,**” Proc. 6th EURO-NF Conference on Next Generation Internet (NGI), pp. 1-6, 2010

Infrastructure availability

- M. Sarela et al., “**Forwarding anomalies in Bloom filter-based multicast,**” Proc. IEEE INFOCOM, pp. 2399-2407, 2011
- M. Xie, I. Widjaja, and H. Wang, “**Enhancing cache robustness for content-centric networking,**” Proc. IEEE INFOCOM, pp. 2426-2434, 2012
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Concluding remarks

- ICN-IP relationship
 - Some of the techniques are adapted for ICN from the existing IP networks
 - More generally, many of techniques are also applicable to the existing IP networks
 - Same for threats and objectives
 - but there are also differences
- Important open issues
 - **Performance trade offs**
 - on a concrete system
 - Caching vs. Privacy vs. Confidentiality
 - **Governance and authorities**
 - On non random identifiers (human readable)
 - e.g., details on naming
 - **Shared responsibility** for important decisions or actions, departure from single TTP models
 - Bitcoin vs Certificates/PKI
 - Byzantine agreement,...
 - **“NSA free” architectures**
 - Global policies
 - Traffic engineering

Thank you

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