Perspectives: Improving SSH-style authentication using multi-path probing

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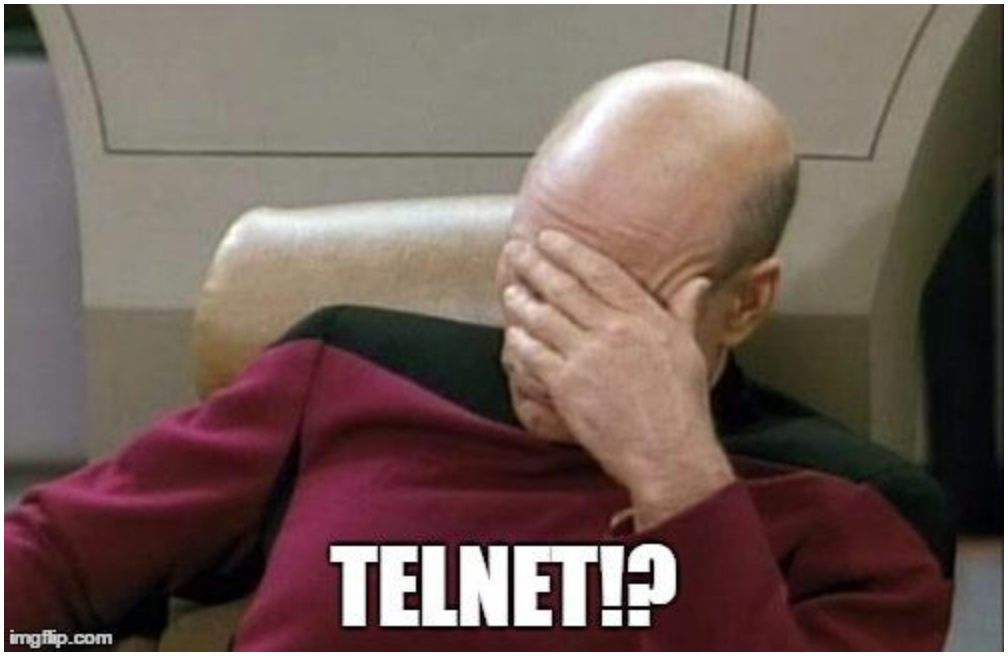
CS 598 - COMPUTER SECURITY IN THE PHYSICAL WORLD

In the beginning of times..

- Telnet
- r* services (rlogin, rsh)
- Weak (or no) authentication
- Communication in the clear

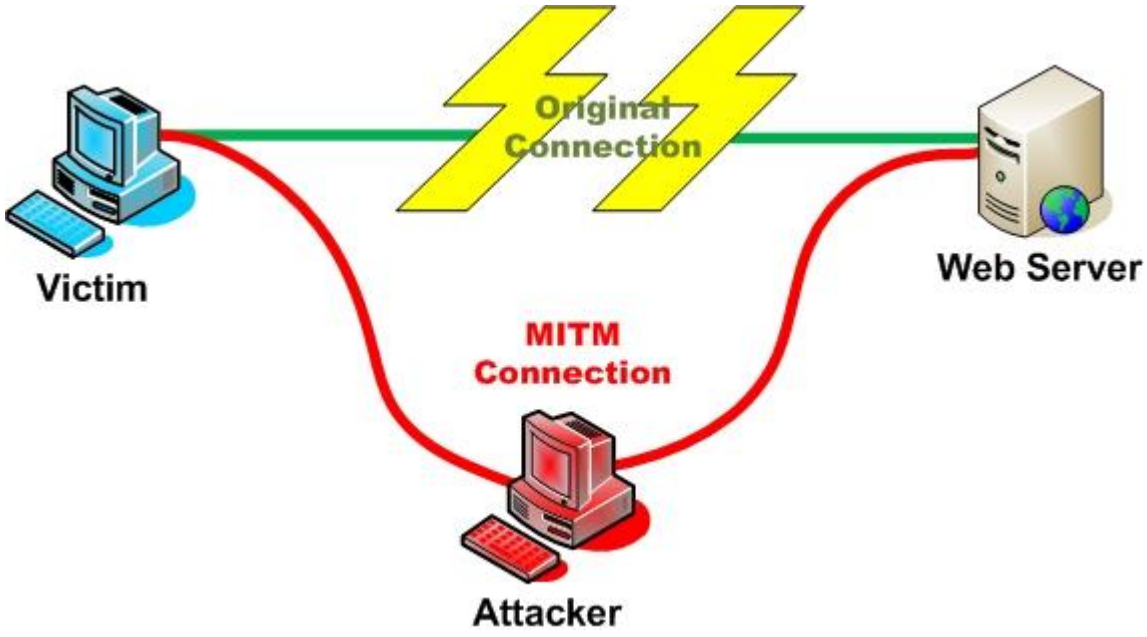


Enter SSH/SSL

- Provided the cryptographic elements to build a tunnel for confidential data transport with checked integrity

However..

- SSH/SSL authentication based on asymmetric cryptography
- Diffie-Hellman key exchange subject to MITM attack.



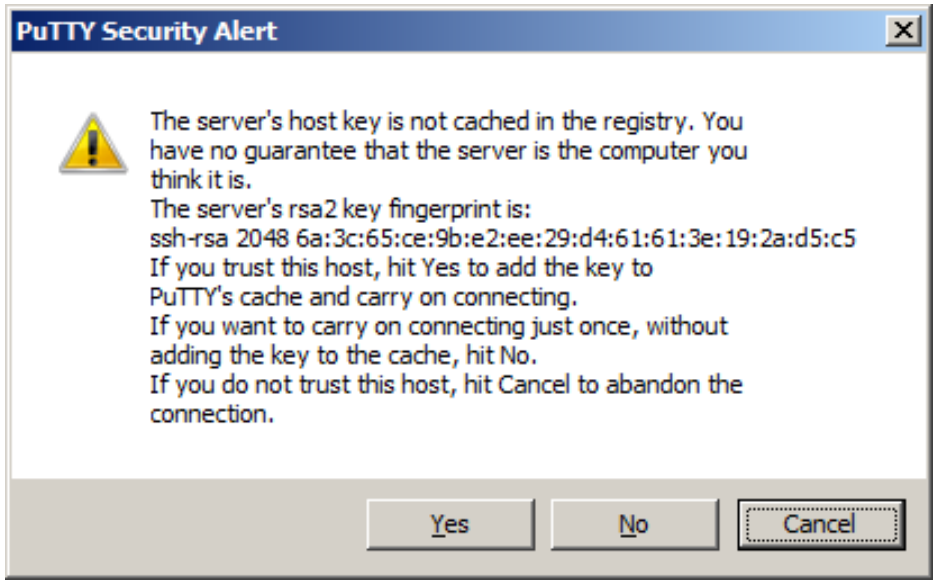
Should I be worried about MitM?

- Recent trends increase MitM vulnerability
  - Other hosts on a wireless can spoof ARP/DNS.
    (e.g., ARPIFrame worm)
  - Access points/home routers may be poorly administered or have known vulnerabilities.
    (e.g., "Pharming" attacks)
- These attacks are automated & profit driven

Obtaining Authentic Public Keys

Two standard approaches to handling MitM attacks:

- Public Key Infrastructure (e.g., Verisign certs)
- Trust on first use (TOFU) mechanism



Trust-on-first-use Authentication

1) Assume no adversary on first connection, cache key
2) If key changes*, panic!

Seems insecure, why use it?

- Unlike PKI, it's simple & cheap.
- No manual work when adding a server, just plug-and-play.

*SSH keys do change legitimately

Goals of this paper

- Significantly improve attack resistance for Tofu

- Keep simple SSH-style deployment model.

Key observation for SSH

With Tofu, clients face a security decision:

- When first connecting to a server.
- Any time a key mismatch is detected.

But Tofu gives little/no helpful information!

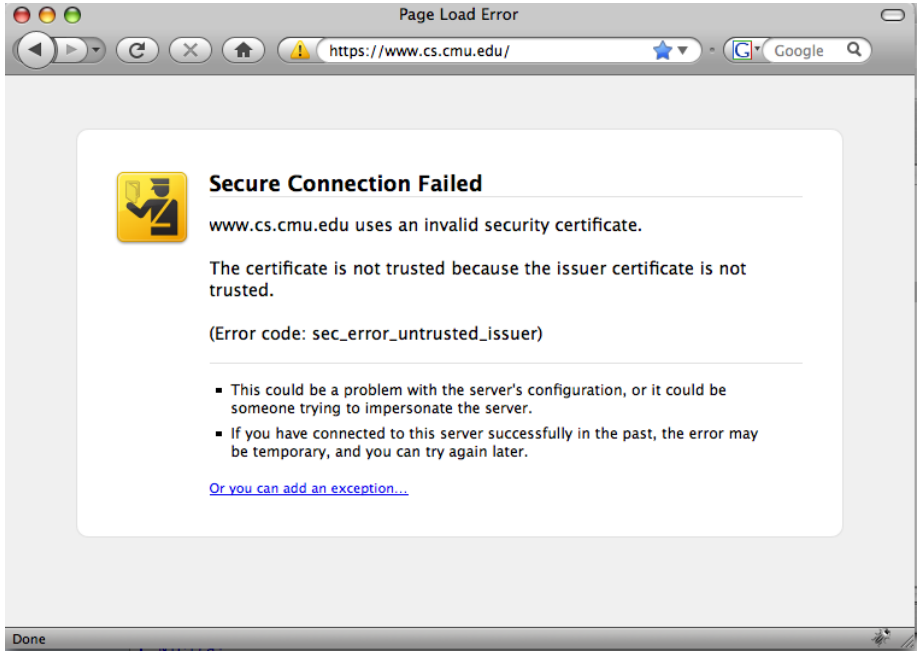
```
The authenticity of host 'host.domain.com (192.168.74.49)' can't be established.
RSA key fingerprint is 07:fd:fb:9b:03:a2:b4:e8:b3:c9:0f:0b:db:43:1c:1a.
Are you sure you want to continue connecting (yes/no)?
```

or

```
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@    WARNING: REMOTE HOST IDENTIFICATION HAS CHANGED!     @
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
IT IS POSSIBLE THAT SOMEONE IS DOING SOMETHING NASTY!
Someone could be eavesdropping on you right now (man-in-the-middle attack)!
It is also possible that the DSA host key has just been changed.
The fingerprint for the DSA key sent by the remote host is
4c:68:03:d4:5c:58:a6:1d:bd:17:13:84:14:48:ba:99.
Please contact your system administrator.
```

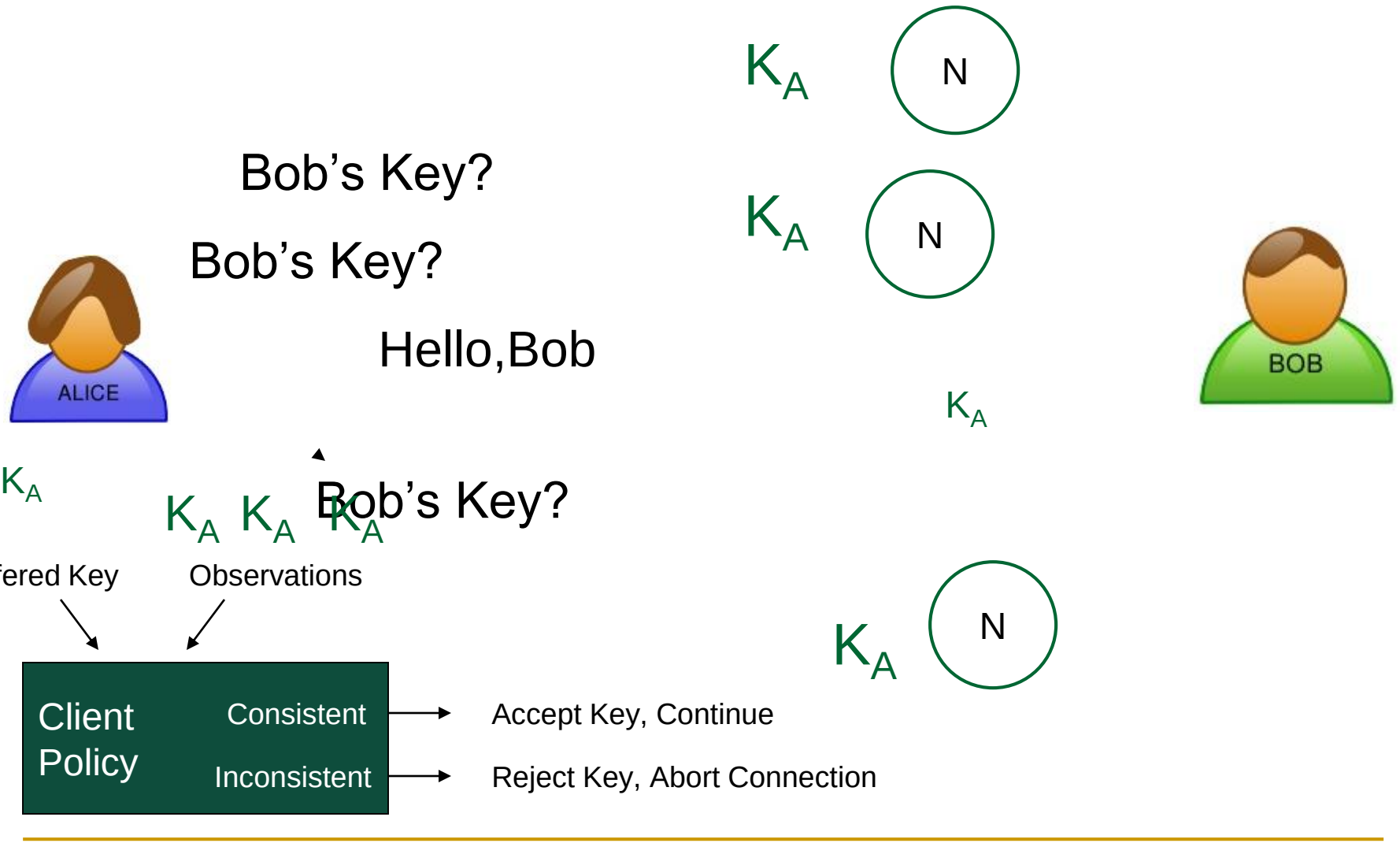
Key observation for SSL

- Difficult for users to validate new/changed keys with self-signed certs.
- Frequent spurious warnings “train” users to ignore ALL warnings



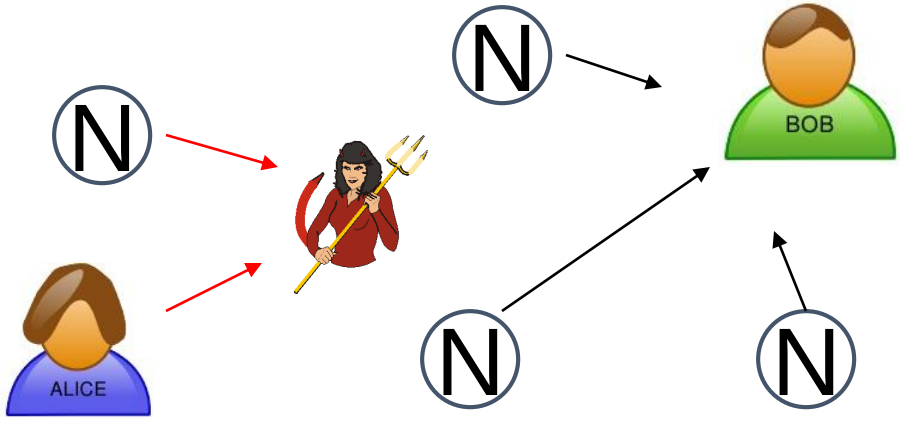
Perspectives provides additional data to distinguish between an attack and a spurious warning.

Perspectives Overview



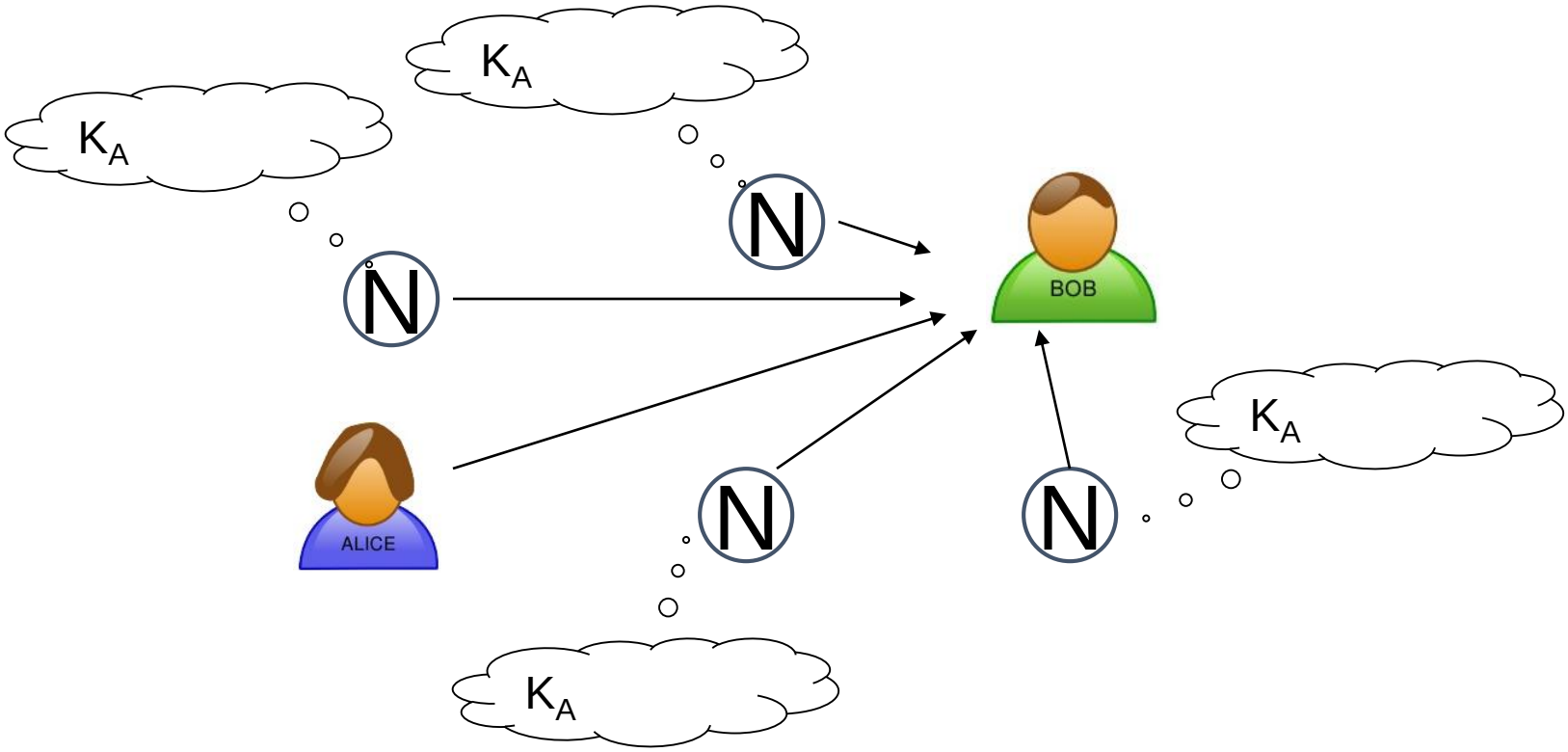
Spatial Resistance

Multiple vantage points to circumvent localized attackers



Temporal Resistance

Key history raises alarm even if all paths are compromised.



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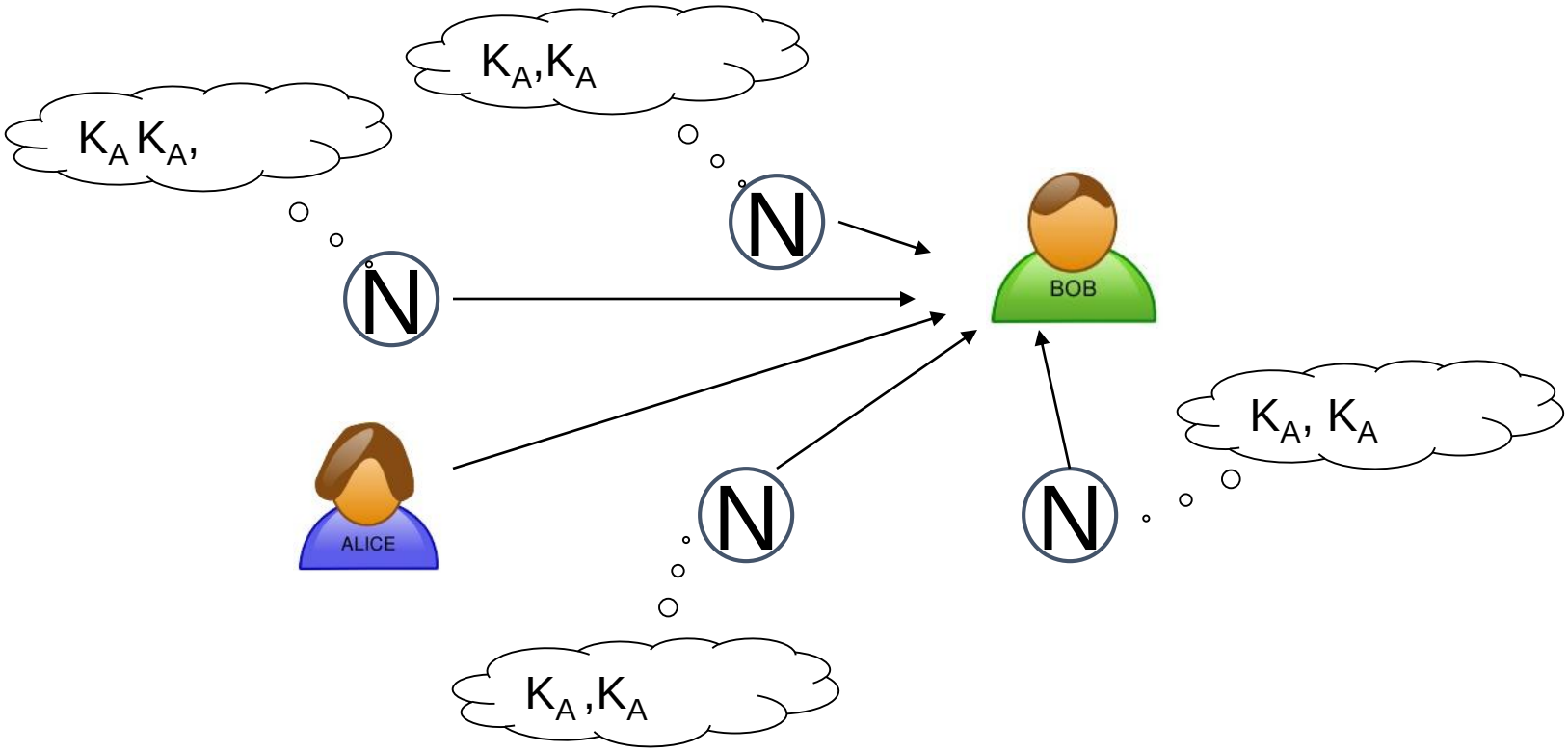

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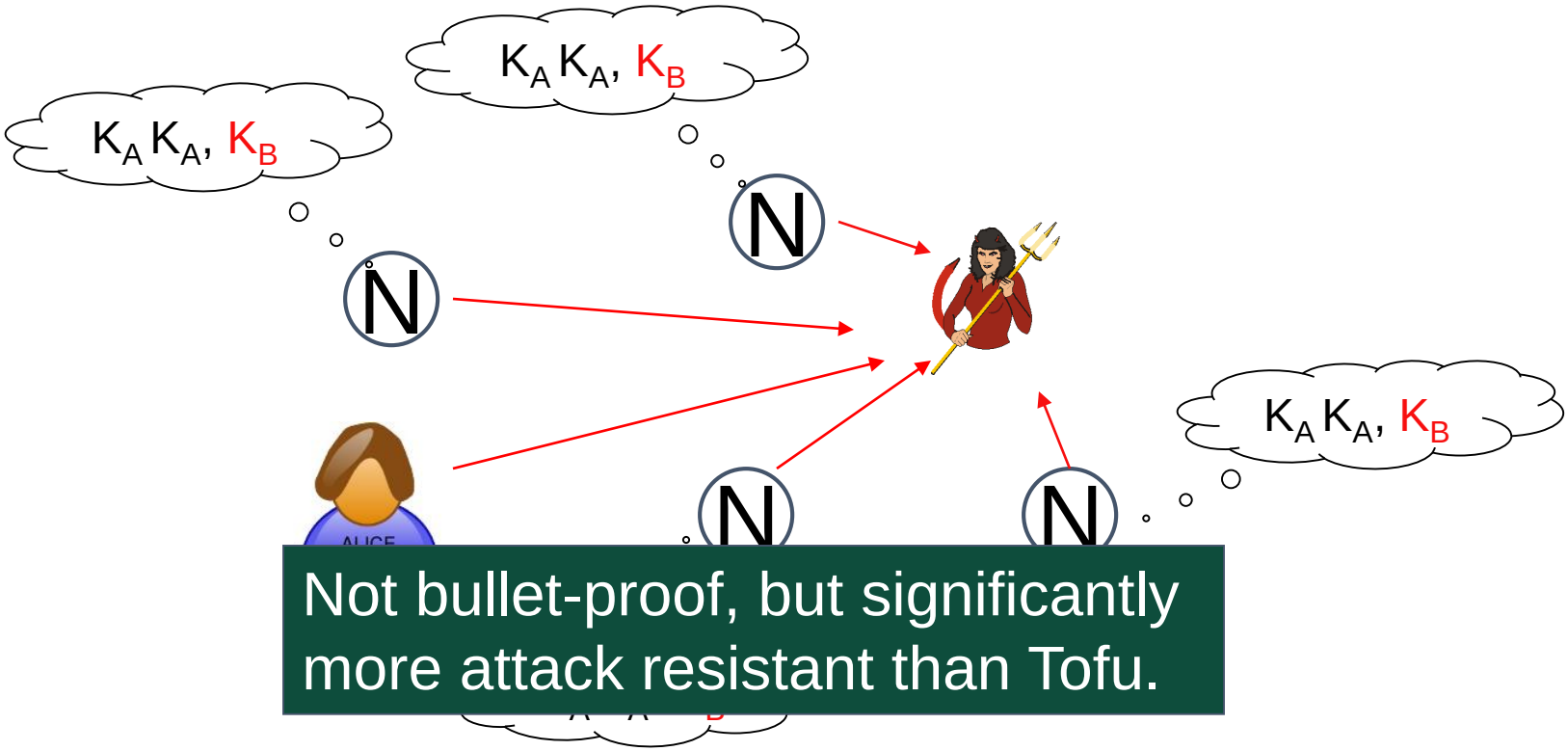


Not bullet-proof, but significantly more attack resistant than Tofu.

Perspectives Design

- Who runs these network notaries?
- How do notaries probe servers?
- How do clients use notary data to accept or reject a key?

Who runs notary servers?

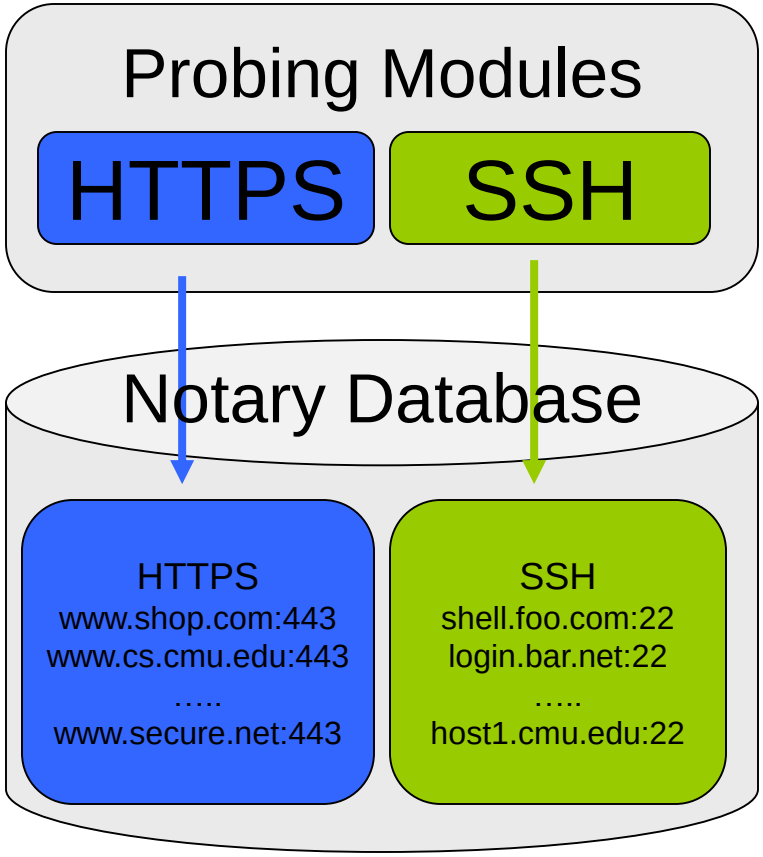
- A “community deployment” with universities, ISPs, or hosting providers volunteering to host a single notary.
  - Public traceroute & looking-glass servers
  - Academic network testbeds like PlanetLab and RON.

- Design assumes notaries are only “semi-trusted”.

- Clients regularly download “notary list” to bootstrap.

  [notary ip, notary public key]
  [notary ip, notary public key]
  ……
  [notary ip, notary public key]

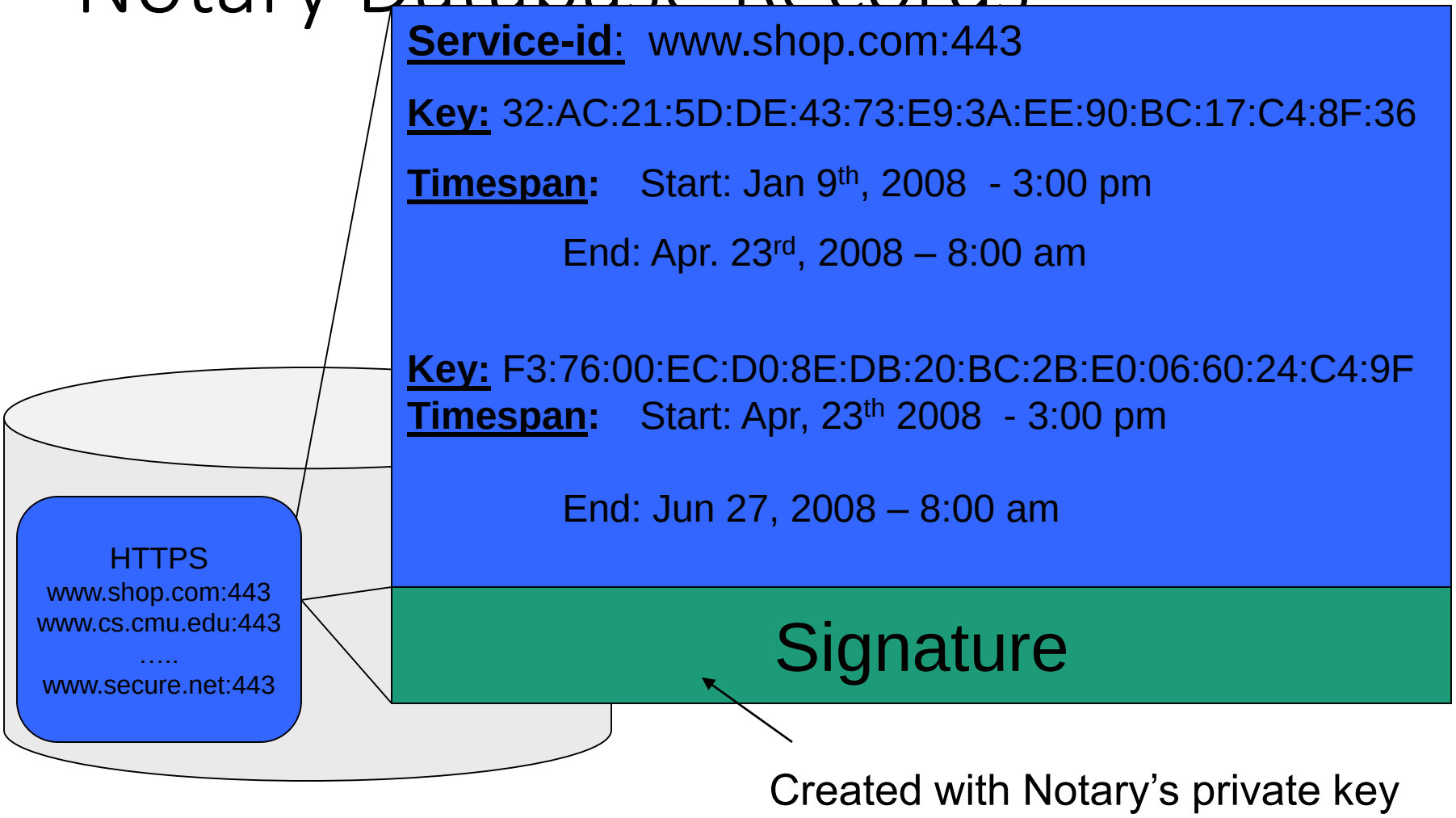
How do notaries monitor keys?



- Probing modules mimic client.

- Notary regularly (e.g. daily) probes each service listed in database and updates its info.

Notary Database Records



Compromised notaries?

Data redundancy

- Each notary acts as a *shadow server* for several other notaries.
- *A shadow server* stores an immutable record of each observation made by another notary.
- Whenever a client receives a query reply from a notary, it can also check and compare reply history with one or more of that notary's shadow servers

Client Policies to accept/reject a key.

- Test spatial and temporal “consistency”.

- Many possible approaches to policies:

  - Manual (power users)

    or

  - Automatic (normal users)

Manual Key Policies: Power Users

Give sophisticated users more detailed info than Tofu.

- 6/6 notaries have consistently seen the offered key from this service over the past 200 days.
- 4/6 notaries currently see a different key!
- All notaries have seen the offered key for the past 8 hours, but previously all consistently saw key Y!

Automated Key Policies: Normal Users

quorum: minimum notary agreement needed to consider a key valid.

Notary #1	Notary #2	Notary #3	Notary #4	Notary #5
K_A	K_A	K_A	K_B	K_A

If offered key is K_A: if Q <= 80% then Accept
else then Reject

Automated Key Policies: Normal Users

Quorum must be a fraction of the total number of queried notaries, not responses received.

Notary #1	Notary #2	Notary #3	Notary #4	Notary #5
K_A	K_A	K_A	K_B	K_A

Adversary on client link can selectively drop notary replies.

Automated Key Policies: Normal Users

- Define “quorum duration” : given quorum threshold,
  the length of time a particular key has held quorum.

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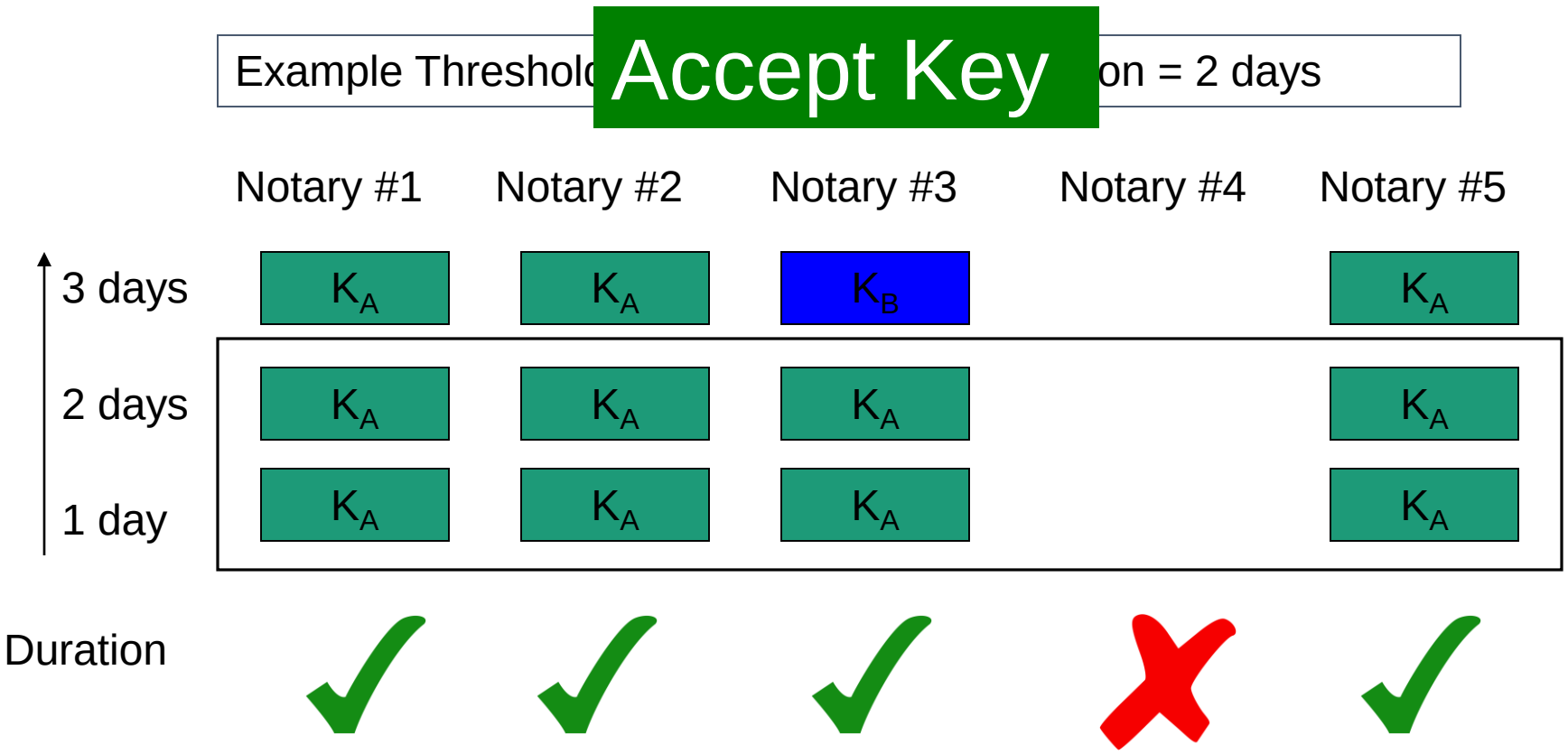
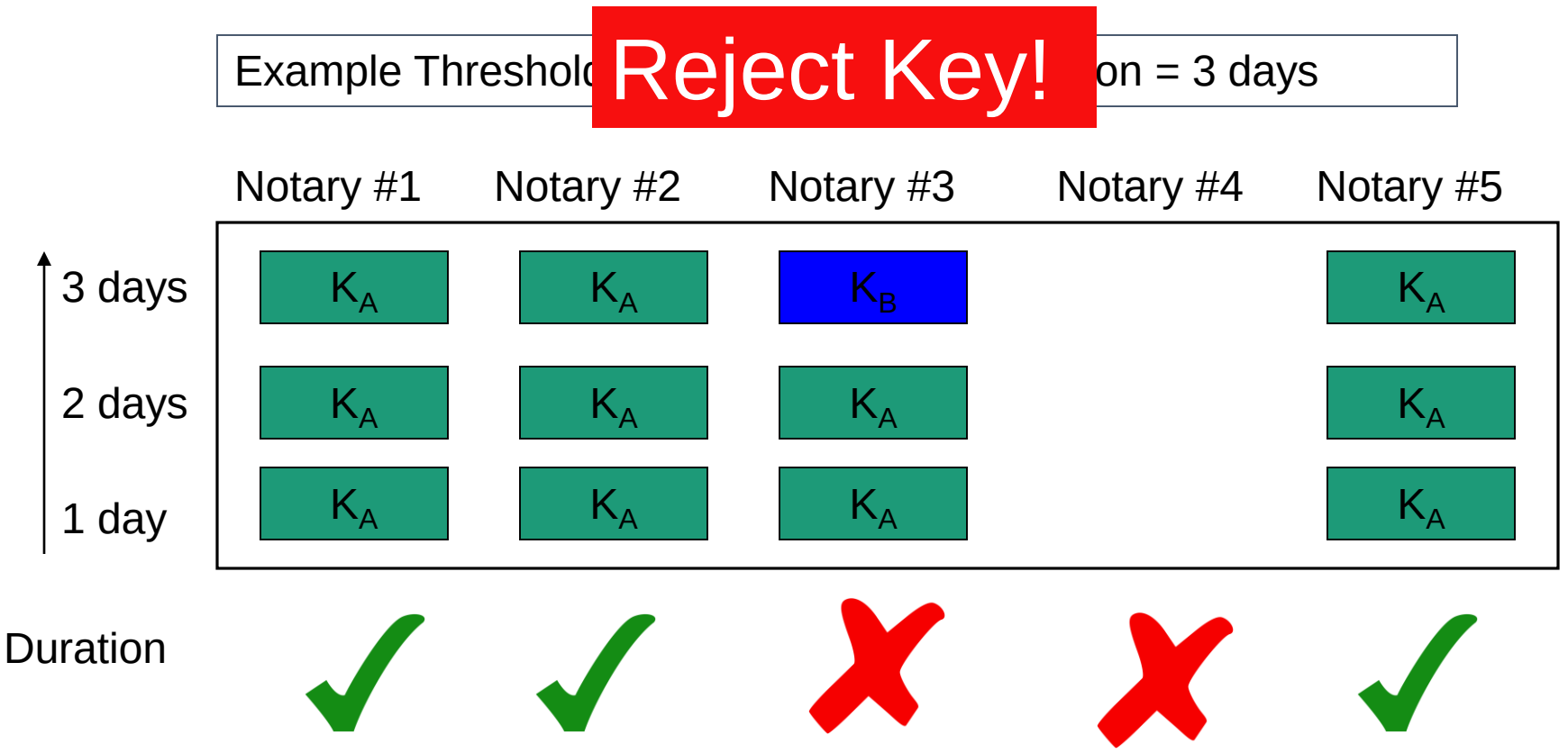


Key Policies: Normal Users

- Define "quorum duration" : given quorum threshold, the length of time a particular key has held quorum.



Security vs. Availability

- Fundamental network authentication trade-off:

  Clients gain security at the cost of availability (i.e., rejecting a key and disconnecting).

- quorum/quorum duration" encode this trade-off:
  - Higher quorum threshold is more secure:

    => but client is more likely to reject valid key due to notary compromise or failure.
  - Higher quorum duration threshold is more secure:

    => but client rejects valid servers with new keys.

Contrast with PKI

- Perspectives allows each client to individually make a security vs. availability trade-off.

- In contrast a traditional PKI applies a single criteria for all clients.

Security Analysis

		Tofu		Perspectives
Compromise	**DoS**	**MitM**	**DoS**	**MitM**
L_{client}	**X**	**X**	**X**	**safe**
L_{server}	**X**	**X**	**X**	**temporal safe**
$k \cdot n_m$	**safe**	**safe**	$k > (n - q)$: **X** $k \leq (n - q)$: **safe**	**safe**
$L_{server} + L_{client}$	**X**	**X**	**X**	**temporal safe**
$L_{client} + k \cdot n_m$	**X**	**X**	**X**	$k \geq (q + q \cdot r)$: **X** $k \geq q$: **temporal safe** $k < q$: **safe**
$L_{server} + k \cdot n_m$	**X**	**X**	**X**	$k \geq (q + q \cdot r)$: **X** $k < (q + q \cdot r)$: **temporal safe**
$L_{server} + L_{client} + k \cdot n_m$	**X**	**X**	**X**	$k \geq (q + q \cdot r)$: **X** $k < (q + q \cdot r)$: **temporal safe**

Discussion Questions

- Contributions?
  - Do you think something like this can be deployed currently?
- Limitations?
- Thoughts on scalability?
- Thoughts on notaries impacting user privacy? They are still ‘semi-trusted’
  - Factor in proxies, DNS?
- If you really care about privacy, why not choose the PKI path (it’s worth the hassle!)