DNSSEC + DANE

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Securing DNS Cryptographically

- Securing DNS has different goals:

- DNS transaction security
  - Peer/message authentication

- DNS data security
  - Data origin authentication
  - Authenticated denial of existence

Transaction Authentication (TSIG)

- ***Idea***:
- Use signatures to secure data at zone transfer **master → slave**
- Pre shared symmetric key at each entity
- MD5 Hash used as signature

- **TSIG Resource Record:**
  (Name, Type (“TSIG”), Class (“ANY”), TTL(“0”), Length, Data(<signature>))

- Possibility to authenticate, but very complex to administrate in large domains (manual pre-sharing of keys)
  - amount of keys required:

- Main application areas:
  - Secure communication between stub resolvers and security aware caching servers *(?)*
  - Zone transfers (master → slave)
  - Combined with nsupdate in data centers, to update stale information in caches

[Vixie et. al: „RFC 2845: Secret Key Transaction Authentication for

DNS Security (DNSSEC) – Objectives

- DNS security ***objectives***:
  - End-to-end zone data *origin authentication* and integrity
  - *Detection* of data corruption and spoofing

- DNSSEC ***does not*** (want to) provide:
  - DoS-Protection *(in fact, it facilitates DoS Attacks on DNS servers)*
  - Data delivery guarantees (availability)
  - Guarantee for correctness of data (only that it has been signed by some authoritative entity)

[Eastlake: „RFC 2535: Domain Name System Security Extensions“ (obsolete)]
[Arends et. al: „RFC 4033: DNS Security Introduction and Requirements“]
[RFCs:4033,4034,4035,4310,4641]

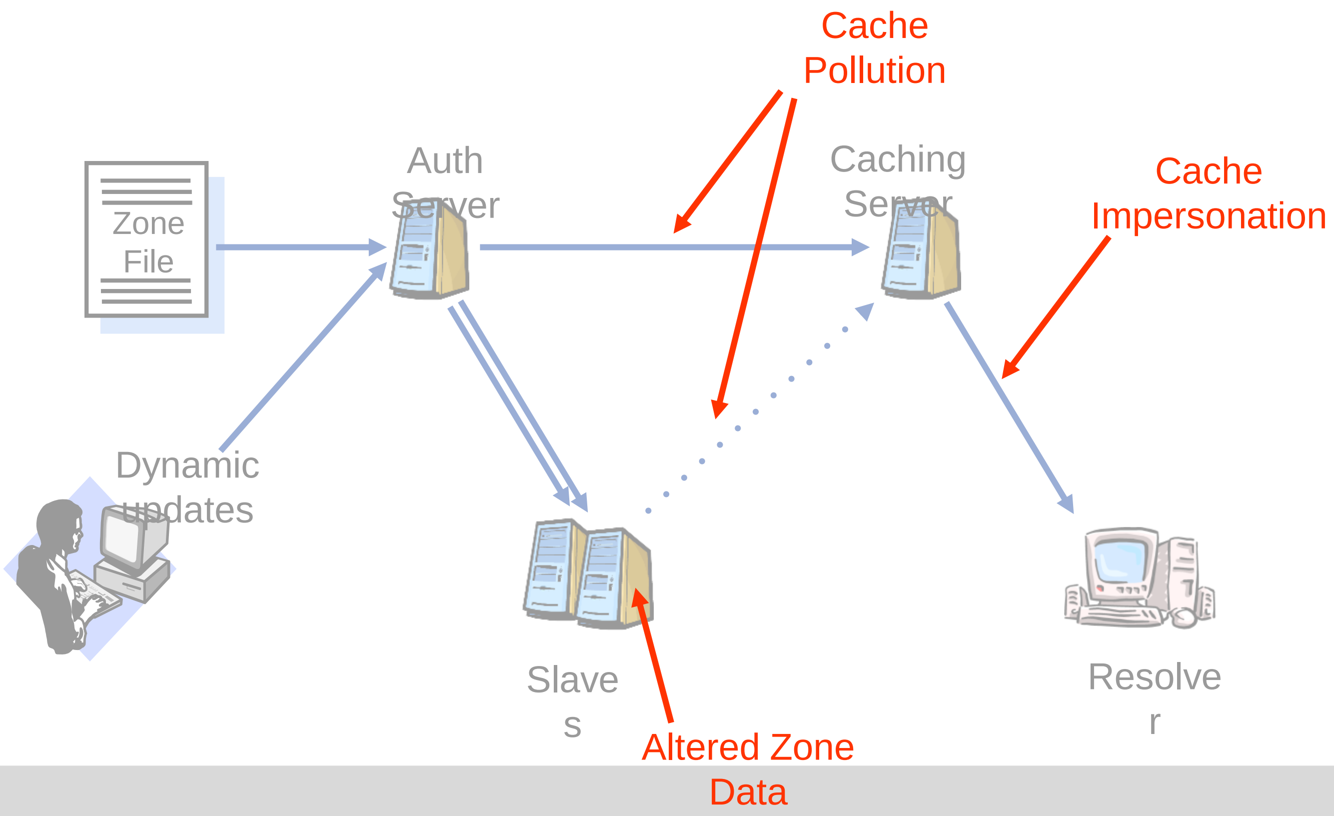
DNSSEC

- Usage of *public key cryptography* to allow for ***data origin authentication*** on a world wide scale

- **RRSets** (groups of RRs) signed with private key of authoritative entities
- **Public keys** (DNSKEYs) published using DNS

- Distinguish *zone signing key* (**ZSK**) and *key signing key* (**KSK**) (SEP-Secure Entry Point)
- Child zone keys are authenticated by parents and hence anchored trust chains established
- Only root zone key signing key (KSK) needed (manual distribution) to create complete trust hierarchy (in theory)
- How/Why shall we trust root zone key?
- Until then: islands of trust with manually shared anchor keys
- No key revocation DNSSEC keys should have short expiration date (quick rollover)

DNSSEC – Targeted Threats



DNSSEC – Means of Securing RRSets

- Goal: authenticity and integrity of Resource Record Sets
- Means:
  - Public Key Cryptography (with Trust Chains)
  - Security integrated in DNS (new RRs)

- New Resource Record Types:
  - `RRSig`: signatures of RRs
  - `DNSKEY`: public keys
  - `DS`: for trust chaining (trust anchor signs key of child zone)
  - `NSEC`: pointer to next secure name in canonical order (authenticated denial for requested zone)

DNSSEC – New Resource Records: RRSIG

- Resource Record for transmission of ***signatures***
- `RRSIG:`
  - `Name` – name of the signed RR
  - `Type` – RRSIG (46)
  - `Algorithm` – MD5(1), Diffie-Hellman(2), DSA (3)
  - `Labels` – number of labels in original RR (wildcard indication)
  - `TTL` – TTL at time of signature inception
  - `Signature Expiration` – End of validity period of signature
  - `Signature Inception` – Beginning of validity period of signature
  - `Key Tag` – ID of used key if signer owns multiple keys
  - `Signer’s Name` – Name of the signer
  - `Signature` – Actual Signature

RRSIG signature

- signature = sign(RRSIG_RDATA | RR(1) | RR(2)...)
- RRSIG_RDATA= all the fields but the signature
  Name | type | alg | labels | TTL | sig_exp | sig_inc | key tag | signer's name
- RR(i) = owner | type | class | TTL | RDATA length | RDATA

DNSSEC – New Resource Records: DNSKEY

- Resource Record containing ***public keys*** for distribution
- `DNSKEY:` (Label, Class, Type, Flags, Protocol, Algorithm, Key)

  - `Label` – Name of key owner
  - `Class` – Always: IN (3)
  - `Type` – DNSKEY
  - `Flags` – key types: Key Signing Key (257) or Zone Signing Key (256)
  - `Protocol` – Always DNSSEC (3)
  - `Algorithm` – RSA/MD5(1), Diffie-Hellman(2), DSA/SHA-1(3), elliptic curves(4), RSA/SHA-1(5)
  - `Key` – Actual key

DNSSEC – New RRs: Delegation Signer (DS)

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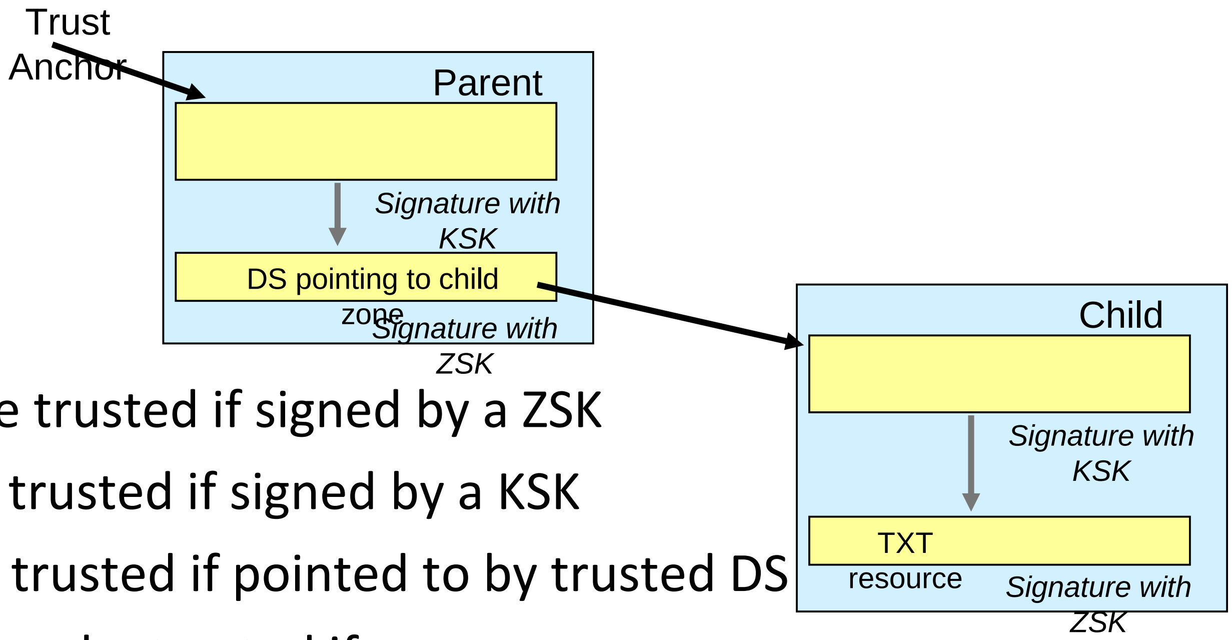
- DS contains ***hash-value of DNSKEY*** of the name server of a sub zone
- Together with NS Resource Record, DS is used for trust chaining
- `DS`: (Name, Type, Key Tag, Algorithm, Digest Type, Digest)
  - `Name` – Name of the chained sub zone
  - `Type` – DS
  - `Key Tag` – Identification of the hashed key
  - `Algorithm` – RSA/MD5(1), Diffie-Hellman(2), DSA(3) (of referred DNSKEY)
  - `Digest Type` – SHA-1(1), SHA-256(2)
  - `Digest` – Actual value of hashed DNSKEY

DNS – Authority Delegation and Trust Chaining



- Data can be trusted if signed by a ZSK
- ZSK can be trusted if signed by a KSK
- KSK can be trusted if pointed to by trusted DS
- DS record can be trusted if
  - Signed by parents ZSK
  - Signed by locally configured trusted key

DNS – Authority Delegation and Trust Chaining (Example)

Trusted Key
(locally configured)

Parent
Zone

```
child        NS      ns.child
             DS            (…) <KSK-id>
             RRSIG        DS (…) parent.
```

Child
Zone

```
@NS
             ns
             DNSKEY      (…) <KSK-id>
             DNSKEY      (…) <ZSK-id>
             RRSIG       dnskey (…)<KSK-id> parent.
             RRSIG       dnskey (…)<ZSK-id> child.parent.

ns           A           10.5.1.2
             RRSIG       A (…) <ZSK-id> child.parent.

www          A           10.5.1.3
             RRSIG       A (…) <ZSK-id> child.parent.
```

DNSSEC – New Resource Records: NSEC

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- Next Secure (NSEC) gives information about the next zone / sub domain in canonical order (last entry points to first entry for the construction of a closed ring)
- Gives the ability to prove the non-existence of a DNS entry: *Authenticated Denial*

- `NSEC` (Name, Type, Next Domain)
  - `Name` – Name of the signed RR
  - `Type` – NSEC (47)
  - `Next Domain` – Name of the next domain in alphabetical order

- *Allows adversary to crawl entire name zone ("zone walking")*

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DNSSEC – New RRs: NSEC3 (1)

- Successor to NSEC: NSEC3 and NSEC3PARAM
- Uses hashed domain names to make zone walking more difficult
- Hashing based on salt and multiple iterations to make dictionary attacks more difficult

- NSEC3
  - `Name` – Name of the signed RR
  - `Type` – NSEC3 (50)
  - `Hash Algorithm` – SHA-1 (1)
  - `Flags` – To Opt-Out unsigned names
  - `Iterations` – Number of iterations of Hash Algorithm
  - `Salt Length` – Length of the salt value
  - `Salt` – Actual salt value
  - `Hash Length` – Output length of hash function
  - `Next Hashed Owner Name` – Next Hash of domain name in alphabetical order

DNSSEC – New RRs: NSEC3 (2)

- Potential advantage: Salting and hashing does not allow for easily deducting hostnames from zone walks

- Problem:
  - Hostnames usually have very low entropy (to remember them)
  - Easy dictionary attacks - despite the usage of salts & iterations
  - But not used heavily anyways:
    - .: Uses NSEC
    - .com: No salt, No iterations
    - .de: Static salt BA5EBA11, 15 Iterations

DNSSEC: NSEC5 / Record Type Denial

- Provide authenticated denial of existence without leaking names requires online signing.
- Providers do not want to trust the DNS servers with keys…

- Cloudflare Record Type Denial
- Send positive response but deny requested record type

DNSSEC Issues

- Pro's:
  - DNSSEC allows to prevent unauthorized/spoofed DNS records

- Con's:
  - Added complexity (signing, checking, key distribution) **eases DoS attacks** on DNS servers
  - Zones need to be signed completely (performance challenge for large companies or registries)
  - Authenticated denial with NSEC gives the possibility to "walk" the chain of NSEC and to gain knowledge on the **full zone content** (all zones/ sub domains) in O(N) ==> NSEC3, …
  - Distribution of anchor keys still a **manual task** (allows for human error, social engineering)

Deployment:

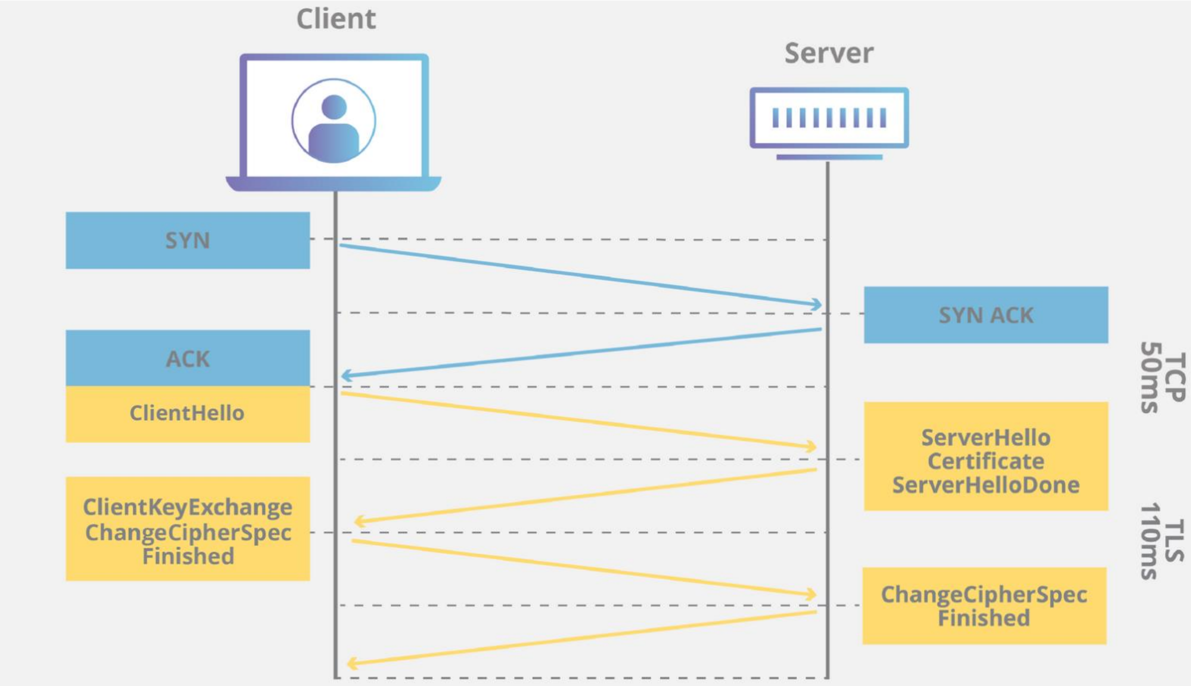
- http://www.secspider.net/islands.html
- https://blog.apnic.net/2017/12/06/dnssec-deployment-remains-low/
- https://stats.labs.apnic.net/dnssec/XA

TLS authentication

- Many applications use the certificate-based authentication in Transport Layer Security (TLS)
    - allow clients to authenticate server.
    - allow server and client to agree upon acceptable ciphersuite
- Typically, authentication is based on PKIX certificate chains rooted in certificate authorities (CAs)
- What are the challenges in PKIX?
    - trust roots are configured out of band (depend on vendors)
    - DoS attacks to block certificate status verification
    - trusted CAs may be attacked and misbehave

TLS authentication

- Authentication is often based on PKIX certificate chains rooted in certificate authorities (CAs)

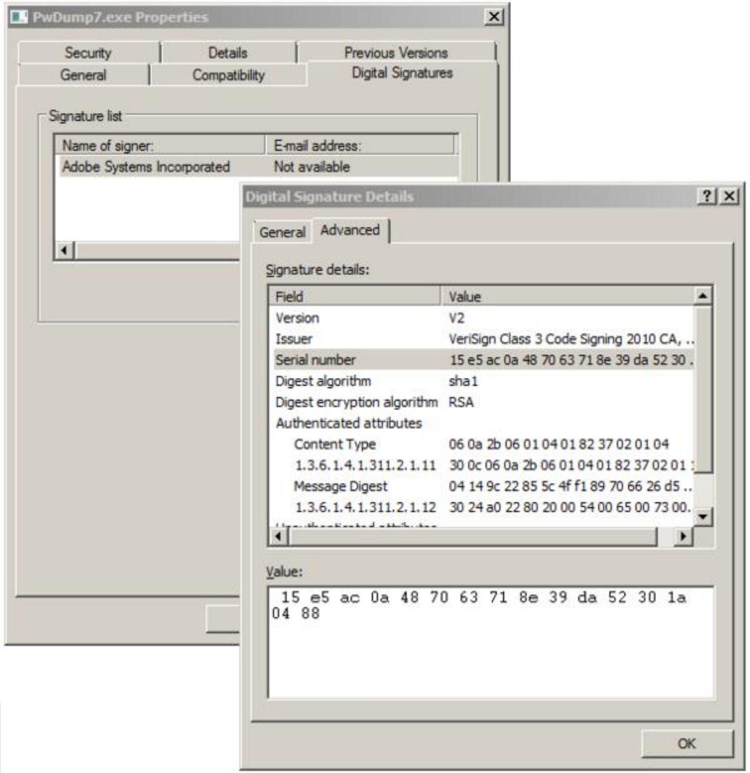


PKIX challenges

- trust roots are configured out of band (depend on vendors)
- DoS attacks to block certificate status verification
- verification path building
- trusted CAs may be attacked and misbehave
- ...

Certificates (privkey)stolen

- Adobe, Microsoft developer, ...



CAs attacked

- Comodo: fraud certs to mail.google.com, login.skype.com, addons.mozilla.org
- ...

Date	Incident	Target	Reason
Jan 25 2011	**Stuxnet** Stuxnet driver is discovered to be signed with a valid certificate belonging to Realtek Semiconductor Corps. On July 16 2011, Verisign revokes Realtek Semiconductor Corps certificate.[1]	Realtek	Stolen Certificate
Mar 24 2011	**Comodo** As a revenge for Stuxnet, an Iranian Hacker forges fake certificates for google email services.[2]	COMODO	Vulnerability in Enrollment
Aug 29 2011	**Diginotar** A user named finds a certificate warning about a revoked SSL certificate Google services. The certificate was issued on July 10th by Dutch DigiNotar. The fake certificate was forged by Comodo Hacker, and revoked immediately.[3]	DigiNotar	Non Disclosed Web Vulnerability
Sep 6 2011	**Diginotar, Globalsign and StartCom** The real extent of the Diginotar breach becomes clear: 531 bogus certificates issued including Google, CIA, Mossad, Tor. Comodo Hacker also claims to own four more CAs, among which GlobalSign which precautionally suspends issuance of certificates. Another one StartCom was able to avoid the hack since its CEO was sitting in front of HSM, although the attacker claims to own emails, DB and Customer data.[4]	DigiNotar, GlobalSign, StartCOM	N/A
Sep 7 2011	**Symantec** As a consequence of Comodo Hackler's claims, Symantec releases a statement to reassure their customers their infrastructure has been audited and it is not compromised.[5]	Symantec	N/A
Sep 7 2011	**Thawte** Panic is spreading on the Certification Authority industry. Thawte publishes a similar announcement than Symantec after an erroneous report from a Dutch Government agency according to which the Security firm had been breached.[6]	thawte	N/A
Sep 9 2011	**GlobalSign** After suspending issuing certificates, GlobalSign finds evidence of a breach to the web server hosting the www website. The breached web server has always been isolated from all other infrastructure and is used only to serve the www.globalsign.com website.[7]	GlobalSign	Breach on Web Site
Oct 19 2011	**Duqu** Researchers discover that Duqu, the son of Stuxnet, masks itself as legitimate code using a driver file signed with a valid digital certificate. The certificate belongs to a company headquartered in Taipei, identified by F-Secure, as C-Media Electronics Incorporation. The certificate was set to expire on August 2, 2012, but authorities revoked it on Oct. 14, shortly after Symantec began examining the malware.[8]	Cmedia	Stolen Certificate?
Nov 3 2011	**Digicert Malaysia (not to be confused with US based Digicert)** Mozilla announces to revoke another intermediate signing certificate used by a registrar in Malaysia, DigiCert Sdn. Bhd. (not to be confused with US based DigiCert) which had issued 22 weak certificates (RSA 512) to the Malaysian government that could lead to abuse or compromise. Entrust stated that two of the certificates issued were used to sign malware used in a spear phishing attack against another Asian certificate authority. Three other certificates were also involved, but were not issued by DigiCert Sdn. Bhd.[9]	digicert	N/A
Nov 4 2011	**Getronics (KPN Certification Authority)** After Diginotar, another Dutch certificate authority, KPN, stops issuing digital certificates as a precaution after finding an attack DDoS tool during an audit on a server in its Web infrastructure. The tool may have been there for as long as four years.[10]	kpn	DDoS Tool on the a Web Server
Nov 14 2011	**Malaysian Agricultural Research and Development Institute** F-Secure detects a malware signed with a Governmental Signing Key belonging to mardi.gov.my which is part of the Government of Malaysia: Malaysian Agricultural Research and Development Institute. According the information received from the Malaysian authorities, this certificate has been stolen "quite some time ago".[11]		Stolen Certificate
Dec 8 2011	**Gemnet** Another Dutch Certification Authority breached: security firm Gemnet suffers a data breach including administrative credentials. Parent company KPN has suspended sister company Gemnet CSP's certificate signing operations.[12]	Gemnet	No Password on the phpMyAdmin portal

paulsparrows.wordpress.com

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TLS authentication and DNSSEC

- Remember DNSSEC:
  - links a key to a domain name
  - allows online access to signed keys
  - keys associated to a domain must be signed by a key in the parent domain
  - TLS server name
  - verification path easier to build
  - hierarchical control
- DNS-Based Authentication of Named Entities (DANE) supports TLS using DNSSEC
  - DANE provides information about the cryptographic credentials associated with a domain
  - Clients can increase the level of assurance they receive from the TLS handshake process
  - Not only https but any application

DANE certificate usages

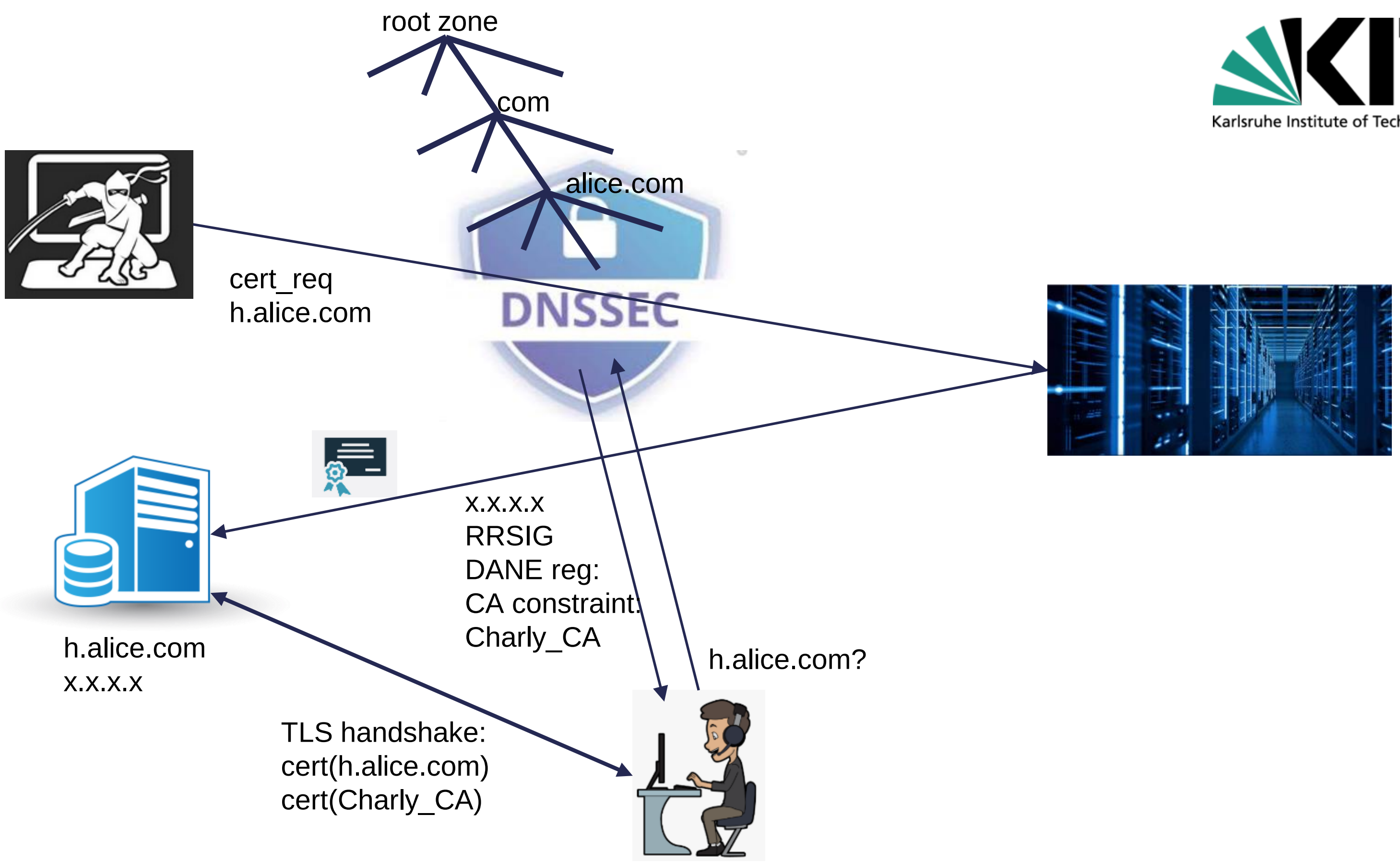
- Let Alice be the
  - operator of a TLS-protected application service on the host h.alice.com, and
  - the administrator of the corresponding DNS zone.

- Let Bob be a client connecting to h.alice.com.

- Let Charlie be a well-known CA that issues certificates with domain names as identifiers.

- Given those actors, let's review DANE certificate usages:
  - CA constraints (PKIX-TA)
  - Service certificate constraints (PKIX-EE)
  - Trust anchor (DANE-TA)
  - Domain-issued certificates (DANE-EE)

PKIX-TA



root zone
com
alice.com
DNSSEC
cert_req
h.alice.com
x.x.x.x
RRSIG
DANE reg:
CA constraint:
Charly_CA
h.alice.com?
h.alice.com
x.x.x.x
TLS handshake:
cert(h.alice.com)
cert(Charly_CA)

CA constraints: PKIX-TA

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- Alice has a cert issued by Charly to h.alice.com
    - Alice fears that an attacker gets a cert issued by another well known CA to h.alice.com
        - Clients would accept it since it is valid
    - Alice wants all the clients to accept only Charly’s issued certs for h.alice.com
    - In the TLS handshake
        - the server includes Charlie's cert in the server Certificate message's certificate_list
    - Charly should also check the CA Constraint in Alice domain prior to issue the cert

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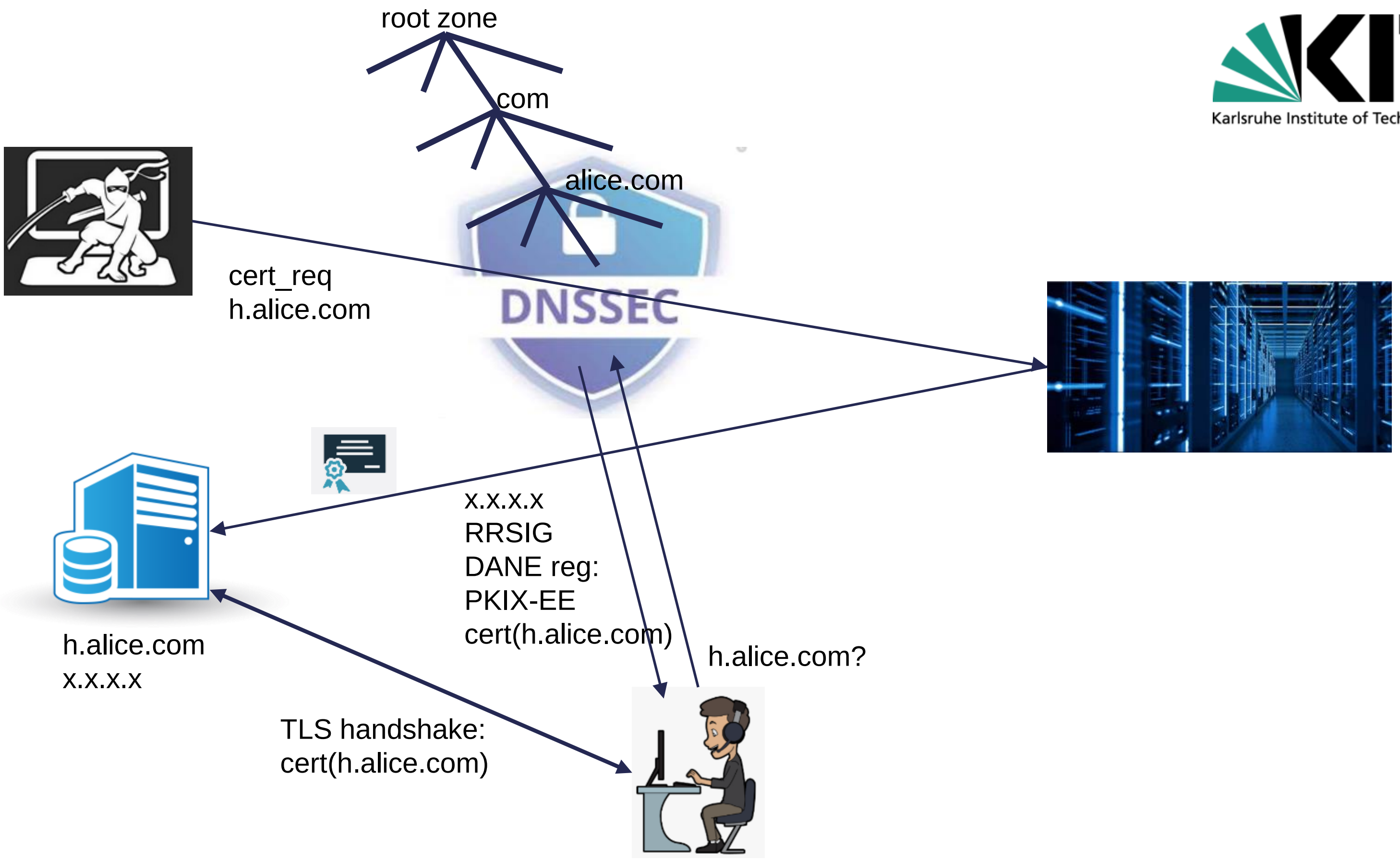
PKIX-EE



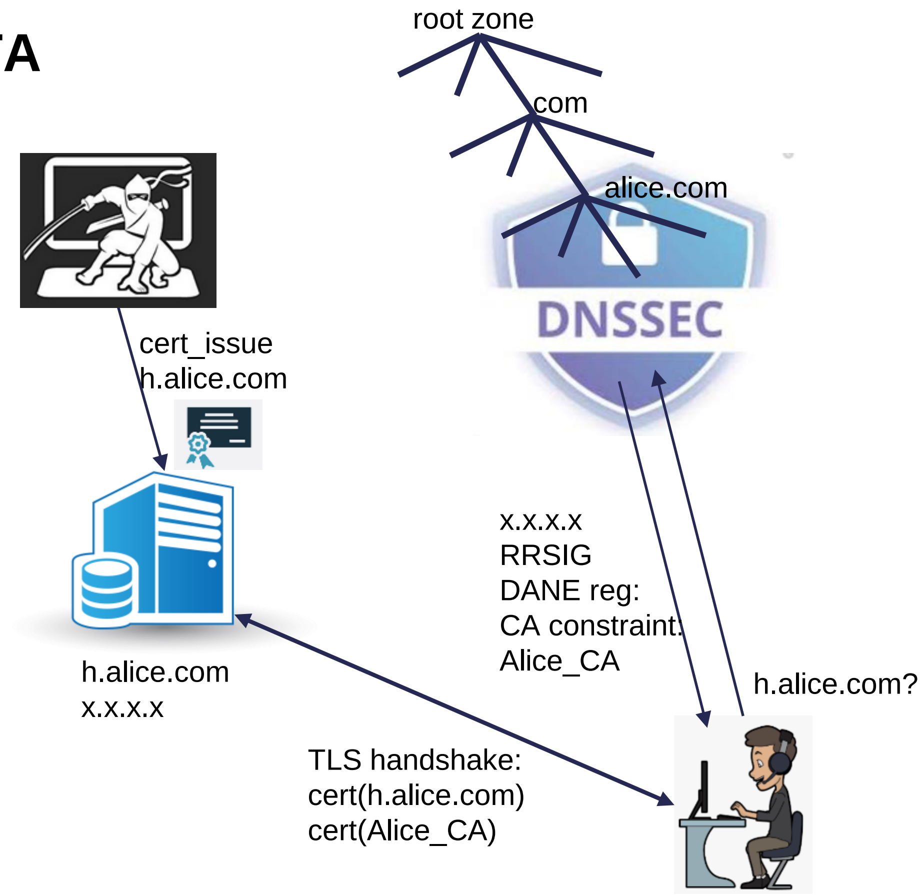
root zone
com
alice.com
DNSSEC
cert_req
h.alice.com
x.x.x.x
RRSIG
DANE reg:
PKIX-EE
cert(h.alice.com)
h.alice.com?
h.alice.com
x.x.x.x
TLS handshake:
cert(h.alice.com)

Service Certificate Constraints: PKIX-EE

- Alice has a cert issued by Charly to h.alice.com
  - Alice fears that an attacker gets another cert issued by Charly to h.alice.com
    - Clients would accept it since it is valid
  - Alice wants all the clients to accept only the present cert she had been issued by Charly
  - in the TLS handshake
    - the server includes the cert issued by Charlie as the first in the certificate_list

- Similar as in CA Constraints, a successful attacker would need to
  - take control of DNS zone
  - tamper with the dnssec records
  - have a valid cert issued by Charly
  - modify the DANE records accordingly

DANE-TA


root zone
com
alice.com
DNSSEC
cert_issue
h.alice.com
h.alice.com
x.x.x.x
x.x.x.x
RRSIG
DANE reg:
CA constraint:
Alice_CA
h.alice.com?
TLS handshake:
cert(h.alice.com)
cert(Alice_CA)

Trust Anchor Assertion (DANE-TA) and Domain-Issued Certificates (DANE-EE)

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- Alice runs her own CA to issue certificates to applications and hosts in her domain
  - Alice wants all the clients to accept only the certificates issued by her
  - in the TLS handshake
    - the server includes Alice’s self-signed CA cert as the first in the certificate_list
  - Besides adding the self-signed cert as a trust anchor, Alice can add it as CA Constraints
    - This way clients will only accept Alice issued certificates for the domain

- Such a trust anchor can be also used in the previous scenarios as a prerequisite for Charly to issue a cert to h.alice.com
  - The CA can check if the cryptographic key linked to the domain has been used to sign the certificate request or can be used to validate the signing key.

- How this relates to the use case where Alice wants to use a little known certificate autority?

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Delegated Services

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- Suppose Oscar operates h.alice.com on behalf of Alice.
- Oscar has control over certificates to present in TLS handshakes for h.alice.com.

a. Alice has the A/AAAA records in her DNS and can sign them along with the DANE record, Oscar and Alice need tight coordination if the addresses and/or the certificates change.

a. Alice delegates a sub-domain name to Oscar, and has no control over the A/AAAA, DANE, or any other pieces under Oscar's control.

a. Alice can put DANE records into her DNS server but delegate the address records to Oscar's DNS server.
    - Alice controls the usage of certificates
    - Oscar is free to move the servers around as needed
    - Coordination only needed when the certificates change (Always?)

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TLSA record

- DANE performs its functions defining a new DNSSEC Resource Record named the TLSA
- The TLSA record gives information about a host in the domain:
  a. the certificate usage: PKIX-TA (0), PKIX-EE(1), DANE-TA(2), DANE-EE(3)
  b. the selector: the full cert (0) or just the public key info (1)
  c. the matching type: Full (0), SHA2-256 (1), SHA2-512 (2)
  d. data: full value or digest of the certificate or subject public key as determined by the matching type and selector

Example of PKIX-TA CERT SHA2-512:

    _443._tcp.h.alice.com. TLSA 0 0 2 {blob}

Other proposals for DANE

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- DANE can also be used for other purposes:
  a. Distributing OpenPGP public keys RFC 7929
  b. Associate Certificates with Domain Names for S/MIME RFC 8162
  c. SMTP transport security RFC 7672

- Other resources:
  a. https://weberblog.net/how-to-use-danetlsa/
  b. https://weberblog.net/pgp-key-distribution-via-dnssec-openpgpkey/
  c. https://dnssec-validator.cz/pages/documentation.html