Some Lessons Learned from Designing the Resource PKI

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May 2007

Address and Routing Security

- The basic security questions that need to be answered are:
  - Is this a valid address prefix?
  - Who injected this address prefix into the network?
  - Did they have the necessary credentials to inject this address prefix?
  - Is the forwarding path to reach this address prefix an acceptable representation of the network’s forwarding state?
  - Can I trust my routing peer / customer / transit ISP to deliver me accurate information?

- Can these questions be answered **reliably**, **quickly** and **cheaply**?

A Resource Validation Framework

- To use a framework to support validation of attestations about addresses and their use

- Queries made within this validation framework should include
  - the **authenticity** of the **address object**
  - the **authenticity** of the **origin AS** of an advertisement
  - the **explicit authority** from the address holder to the AS holder that permits an **originating routing announcement** from that AS
  - the **authenticity** of the **AS path** information representing reachability to the address object. i.e. is the next hop address a valid forwarding action for this address prefix?

Choices, Choices, Choices

- As usual, there is no shortage of potential technologies that could conceivably support such a validation framework
  - Certificate Extensions
  - Attribute Certificates
  - Internet Routing Registries++
  - Signed bindings
  - Signed reports
  - The DNS

Design Principles for a Validation Framework

- **Don’t force any party to claim to be authoritative beyond its actual authority and knowledge**
- Use existing standards
- No new organizations in novel trust roles
- Leverage existing roles and authorities
- Don’t ignore existing processes and functions
- Offer incremental improvements to existing work procedures
- Allow highly reliable and trustable outcomes to be achieved efficiently

What is a **P**ublic **K**ey **I**nfrastructure?

- Public/private key pairs can be used for encryption and digital signatures

- Digital signatures can be used to validate the integrity and authenticity of a message

  By using the public key, I can confirm that the message has not been tampered with and the message was originated by the owner of the matching private key

- The integrity of the signature validation depends on the knowledge of the public key owner

- A public key is just a bit sequence

  But:

  - **WHOSE** bits?
  - **WHERE** can these bits be used?
  - **WHEN** can these bits be considered valid?

- A Public Key Infrastructure is intended answer these questions

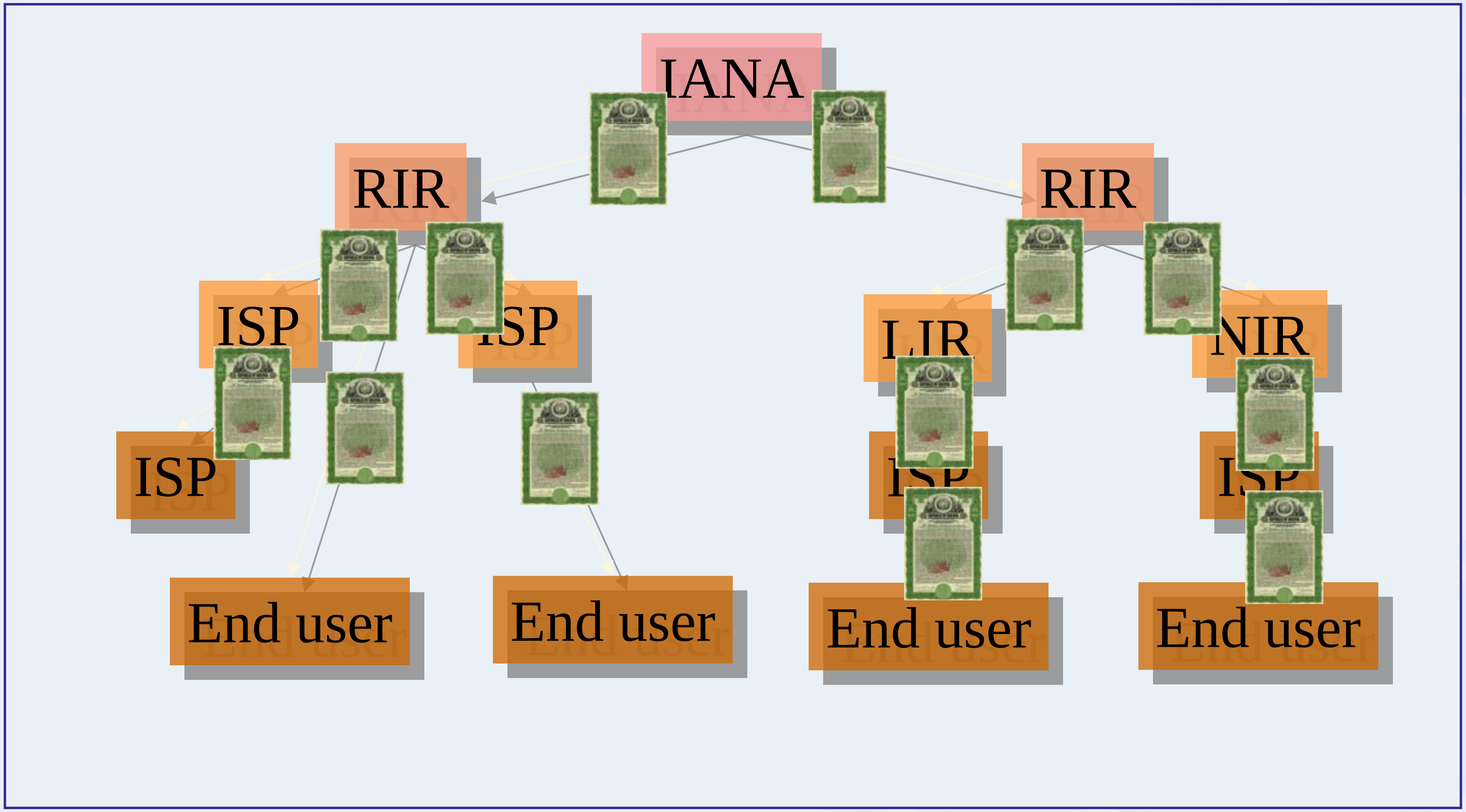
PKI Rooted Hierarchy

- Explicitly avoid various forms of web of trust models, and use deterministic uniform validation methods based on a combination of issuer subject chains and resource extensions
- Exploit and mirror address allocation hierarchy
  - Each CA in the hierarchy can only validly make attestations and generate certificates about resources that have been delegated to them from the parent CA in the hierarchy
  - Exploit existing authoritative data regarding resource distribution

Modelling the Environment

- Use an **X.509 + PKIX certificate hierarchy** aligned to address distribution points
- The certificate “topic” is the resources allocated from the issuer to the subject at this distribution point
- Certificates allow for the generation of subordinate certificates at delegation distribution points
- Validation of a certificate entails a backwards walk towards the root of the distribution hierarchy
- Revocation can model the return of a resource prior to the termination of the current certificate’s validity period

The Resource PKI



The Resource PKI

Its not just another technology project

- Requires organizational, procedural and legal inputs
- Draws upon many skills to design
- Highly complex space

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Issues

- Certificate Requests and Issuance
- Identification of the parties
- Retrieval of certificates by Relying Parties
- Validation of Signatures
- Revocation of Certificates
- Trust Anchor Models

Properties of the Resource PKI

What is the intended use case for this RPKI?

- Validation of attestations about rights-of-use and title?
  - On-demand intermittent single signature validation
  - Can tolerate some amount of visible state transition
  - Outcomes are related to supporting a level of confidence
  - Relying parties do not necessarily require high performance from validation

AND / OR

- Validation of routing protocol updates?
  - In the worst case this could require comprehensive validation across the entire RPKI, within very demanding time constraints, by many replying parties at the same time
  - Real time validation performance
  - Limited / no tolerance for invalid transitional states

Resource Certificates

Resources are not necessarily permanently bound to an identity

- I may have a “right-of-use” for a resource today, but not tomorrow
- While most forms of identity-based PKIs have stable certificate products, there is the potential for greater levels of “churn” in resource certificates
- Relying parties need to constantly refresh their knowledge of the current overall RPKI state
- Efficient repository structures may be critical if there are ~ 20,000 independent publishers and ~300,000 products to sync against constantly

Certificate Revocation Lists

- Often regarded as the weakest part of the X.509 framework
- CRLs must be issued regularly, must be kept up to date and must be available to relying parties
- Preventing access to a CRL is one of the weaknesses of the RPKI
  - Leads to false positives in validation
- CRLs are used whenever a party no longer has a “right-of-use” over a resource
  - Issue a new certificate with a smaller resource set
  - Revoke the previous certificate
- Design question:
  - Must a CRL be signed with the same private key that was used to sign the certificate that is being revoked?

Certificate Revocation Lists

- Tradeoffs with CRLs and Certificates
  - Smaller validity intervals
    - Reduce CRL size
    - Increase certificate issuance loads
    - Less stable certificates
  - Longer validity intervals
    - CRL bloat
    - More stable certificates

Repository Model

- How do you publish certificates and digitally signed statements?
  - Simple publication process

  Or
  - Ease of use by relying parties for validation
- Single repository model?
  - Critical single resource
  - Potential single point of failure of the entire RPKI
  - Issues of object name uniqueness
  - Issues of management of access control
- Multiple repository model?
  - Each CA publishes in its own repository
  - Issues of name persistence in backward and forward pointers in certificates
  - More complex operations for maintenance of local certificate cache by relying parties

Repositories and Relying Party Access

- How to reference published certificates?
  - In this case it’s a URL
  - A URL with what access method?
    - How many access tools does an relying party need to have at hand?
    - What is the optimal case for access?
      - Fast object retrieval
      - Efficient retrieval of altered objects
    - Optimise for access operations for the server or the client?
- Vulnerabilities
  - Can detect attempts of third party alteration and insertion
  - What about third party disruption by denial?
    - Should the access channel be protected?
      - What are the overheads?
    - Should a repository include a manifest as well as a CRL?
      - A signed list of what should be available in the repository
      - What happens in a denial attack on the manifest?
      - Are there “manifest” PKI standards?

The Identity Bootstrap Question

How does an issuer know that they are certifying the same party as the resource recipient?

- Good question!
- The “its magic” option
  - Somehow, somewhere, sometime in the past, some form of entity-based trust relationship based on key exchange was established between resource issuer and resource recipient
  - This can then be used to establish a key to validate the certificate request as coming from the same entity as the resource recipient

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Trust Anchor Models

- What / who are the trust anchors for this RPKI?
  - *Standard answer*: the choice of trust anchors is made by a relying party as a local configuration task
  - *In practice*, proposed Trust Anchors are provided with the distribution of relying party toolkits
    - IE: Tools -> Internet Options -> Content -> Certificates -> Trusted Root CAs
    - Trust anchors should be (relatively) stable
  - *Pragmatic answer #1*: the root of the resource distribution hierarchy: IANA
    - But what if we get into a DNSSEC-styled impass over signing at the “root” of the hierarchy?
  - *Pragmatic answer #2*: Use RIR-issued self-signed certificates as trust anchors with delegated resources
    - But these certificates will change as blocks are passed to the RIRs (i.e. monthly!)
    - So how can this regularly updated trust anchor material be distributed to all potential relying parties?

Key Rollover

Is hard!

- How quickly can you re-issue all subordinate certificates with the new key?
  - How far down the hierarchy do you need to re-issue?
- How quickly can you revoke products signed with the old key?
- Are there intermediate states that create unintentional invalidity of signed products?

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Digitally Signed Products

- How can you “revoke” an authority granted through a signed authority document?
  - Signed objects are not certificates
    - No lifetime
    - No CRL
    - No …
- Propose to use “one-off” keys and end-entity certificates
  - Generate a key pair
  - Generate an end-entity certificate for this key pair
  - Publish the certificate
  - Sign the object with the private key
  - Destroy the key pair

What have we learned so far?

- There's an entirely new terminology universe in the X.509 certificate space!
  - Dark Rites of Initiation into the security world appear to be necessary!

- X.509 certificate specifications appear to include a vast repertoire of extensions with elastic semantics
  - choose carefully!

- There is limited PKI deployment experience out there
  - each PKI development exercise is a learning experience

- Distributed authority models are very challenging to design in a robust manner
  - Think carefully about the model of synchronization across a realm of multiple issuers and multiple repositories with dynamic authoritative information

What have we learned so far?

- Resource Certificates are a means to an end, not an end in and of them selves
  - make the certificate work to suit the business model rather than the reverse

- This is not an exercise that is done lightly
  - considerable investment in expertise, tools, documentation, and navel-gazing over process is useful

- Outcomes need to represent superior choices for players
  - Risk mitigation is an ephemeral and diverse motive for widespread adoption
  - Better, faster, and cheaper solutions tend to produce better adoption motivations

- Good (and Useful) security in a very diverse environment is a very challenging objective

Thank You

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