Tryst: The Case for Confidential Service Discovery

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Local service discovery (SD)

Used to find:
- 802.11 networks
- consumer electronics
- local services
- other applications

How SD is done today

iTunes "Bob" is here — Connect to "Bob"

Is iTunes "Bob" here? — "Bob" is here

Services send **announcements** and/or clients send **probes**
(typically via unencrypted broadcast)

Important properties:
- *Plug-and-play networking*
  - Can proceed automatically without user input
- *Disconnected operation*
  - Requires only communication medium between client and service

Problem 1: SD reveals inventory

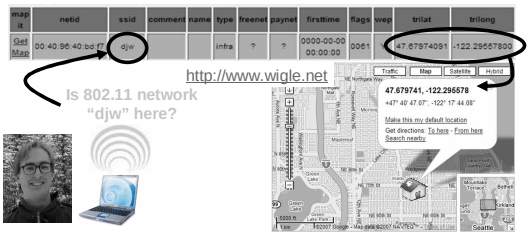
- The devices I have
  Problem: "Phone pirates in seek and steal mission" [Cambridge Evening News 2005]
- The applications I am running
  Problem: "Apple Mac OS X mDNSResponder buffer overflow vulnerability" [CERT 2007]

Problem 2: SD reveals identity

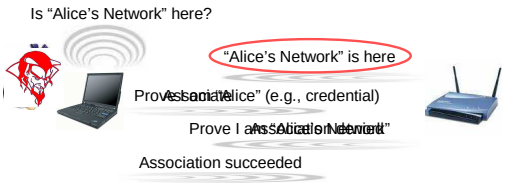
- Announcements expose explicit identifiers
  Problem: Some services are private and want to be hidden
  Problem: Mobile "services" vulnerable to tracking

Problem 3: SD reveals history

- Probes can reveal services you have used
  Problem: Network names can be correlated with location (e.g., using a wardriving database)



Problem 4: SD is not authenticated



- Authentication occurs only after SD
  - **Problem**: Anyone can elicit a response, even if they are not trusted to access the service

Solution requirements

Desired properties:

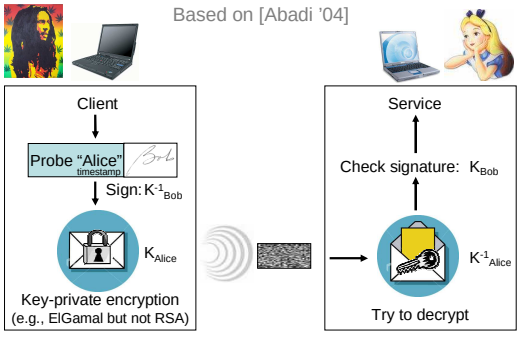
- *Confidentiality*
  - Hide contents that reveals type
  - Hide sender
  - Hide intended recipients
- *Authenticity*
  - Offer proof of identity

Challenges:

- Exposing information *only* to trusted clients/services
- Clients *and* services may want to hide from third parties
- Plug-and-play networking, disconnected operation

A public key protocol

Based on [Abadi ’04]



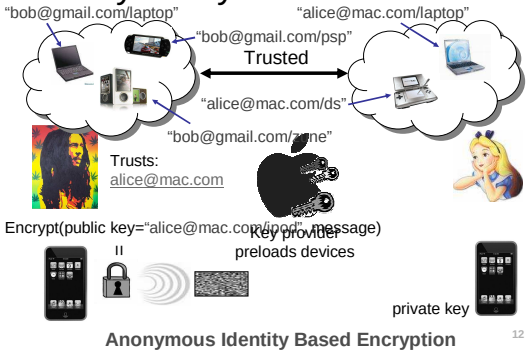
Problems

- Must obtain public keys for new services/clients
  - May be disconnected during discovery
  - Don’t want to involve extra user action
- Must try to decrypt *every* message
  - Public key decryption is slow (>100ms on typical AP)
    ⇒ adds jitter to relaying of other messages
  - 168x slower than 802.11 line-rate even on laptops
    ⇒ susceptible to low-rate denial-of-service attacks

Observations

- Must obtain public keys for new services/clients
  - Will have some relationship with those we trust
  - Can trust new services/clients in trusted domains
- Must try to decrypt *every* message

Tryst: key establishment



Anonymous Identity Based Encryption

Observations

- Must obtain public keys for new services/clients
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- Must try to decrypt *every* message
  - Common case is to *re*discover known services
  - Can negotiate a secret symmetric key the first time

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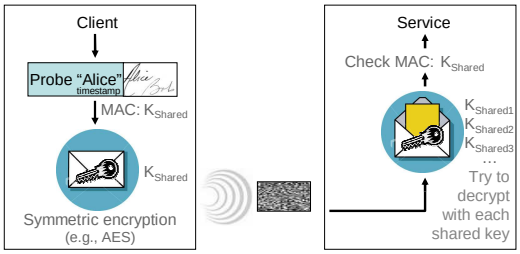
Tryst: a symmetric key protocol



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- Must try to decrypt *every* message
  - Common case is to *re*discover known services
  - Can negotiate a secret symmetric key the first time
  - Linkability at short timescales is usually OK
  - Can use temporary *unlinkable* addresses

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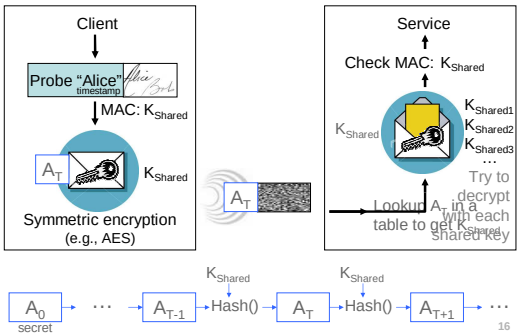
Tryst: a symmetric key protocol



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Conclusions

- Ubiquitous clients *and* services may want privacy
- Service discovery exposes inventory, identity, and history
- Tryst helps enable *confidential* service discovery
- Outstanding challenges
  - Hiding other side channels (physical layer, message timing, size)
  - Other mechanisms to automatically establish keys
  - More efficient broadcast probes

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Backup Slides

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Other key establishment methods

- Certificates (e.g., secure websites)
  - Neither client nor service can offer certificate first!
- Pairing (e.g., Bluetooth peripherals)
  - Can not always physically identify service
  - *User* must perform discovery before *device* does!
- Discovery is also used to find *unknown* services
  - We want to automatically expand the trust horizon
  - Tryst mechanisms:
    - New services in trusted domains
    - New services trusted transitively

Anonymous identity based encryption

[Boneh & Franklin '01]

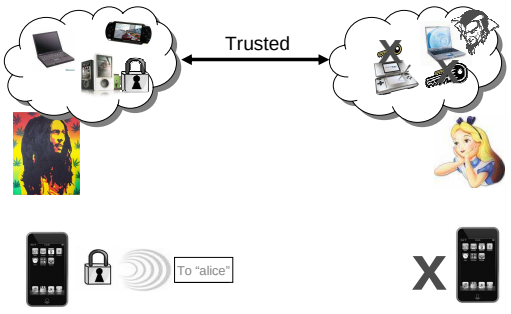
PublicParams, MasterSecret = **Setup** ()
(publicly published; known only by key provider)

ciphertext = **Encrypt** ($K_{AliceiPod}$, PublicParams, plaintext)
||
"alice@mac.com/ipod"

plaintext = **Decrypt** ($K^{-1}_{AliceiPod}$, PublicParams, ciphertext)
||
Extract("alice@mac.com/ipod", MasterSecret)

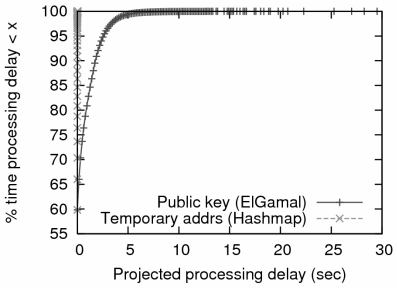
- Some assumptions over traditional public key crypto
  - *Alice and Bob trust key provider not to reveal secret keys to third parties*
    - Can instead trust that no t of n providers collude (use threshold crypto)
    - May also be able act as their own key providers (anonymity unproven)
  - *Revoking my public key implies changing my identity since identity = key*
    - Can instead use temporary identities ("alice@mac.com/ipod.nov.2007")
- Only need to use protocol until first discovery

Tryst: key establishment



Strawman Solution

Projected probe processing delay



Rough simulation based on:

- SIGCOMM 2004 (wifi probes)
- Soekris "AP" (265Mhz Geode)
- GnuPG crypto (~150ms/pkt)

Protocol message volume

- Each message encrypted for one recipient

⇒ As many messages as intended recipients
- Typically OK: E.G., 90% of WiFi clients probe for fewer than 12 unique network names [OSDI 2006 WiFi trace]

- Future work:
  - Efficient protocol to broadcast probes to many recipients

Key problem: messages can be linked

- Consistent naming enable correlation of SD messages
- Opaque names prevent some problems…
  but not all:
  - Example: location can be correlated with other databases

Related work

- **SmokeScreen** [Cox '07] – access control for discovering friends
  - Similar to symmetric key protocol
  - Uses online social network to exchange secret keys
- **SSDS** [Czerwinski '00] – secure service discovery architecture
  - Relies on trusted infrastructure
  - Not necessarily confidential
- **Broadcast Encryption** [Fiat '93] – encrypt message to many users
  - Making this private is an open problem
- **JFK** [Aiello '93] – efficient Internet key exchange
  - No service privacy …
  - … *or* not resilient to man-in-the-middle attacks

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SD is widely used

- **Example 1**: Application Protocols (OSDI 2006)

Protocol Name	Devices (%)
NetBIOS	530 (69.9)
mDNS	270 (35.6)
UPnP SSDP	260 (34.3)
SLP	106 (14.0)
Microsoft Office v.X	50 (6.6)
Internet Printing Protocol	8 (1.1)
TiVo Beacon Protocol	8 (1.1)
Dantz Retrospect	8 (1.1)
LiveTribe SLP	6 (0.8)
BakBone NetVault	4 (0.5)
Other	31 (4.1)
Any Protocol	685 (90.4)

- **Example 2**: **85%** devices send WiFi discovery probes (SIGCOMM 2004)

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Problem 3: SD reveals history

- Probes can reveal services you have used

  Problem: Network names can be correlated with location (e.g., using a wardriving database)

23% of devices at SIGCOMM 2004 probed for an name that WiGLE isolates to one city

All 4 known home networks located to within 2 blocks

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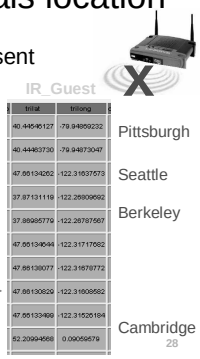
Problem 5: SD reveals location

- The fact that my service is present
  - **Problem**: Common practice to disable WiFi annoucements to (try to) hide access points [O'Reilly 802.11 Guide]
- Where my service is located
  - **Problem**: Knowledge of network name at one site can tell you where other sites are [WiGLE Wardriving Database]



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Problem 6: SD reveals social contacts

- Emerging social devices also offer "services"
  - **Microsoft Zune**: music sharing service
  - **PSP, Nintendo DS**: multiplayer gaming service

- Service discovery exposes social contacts

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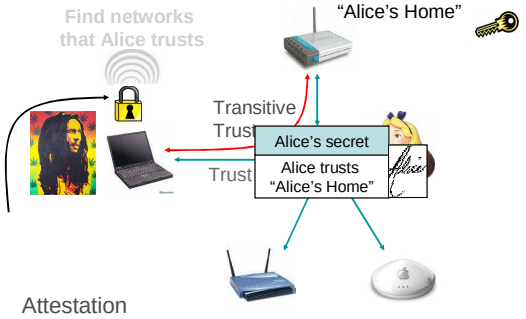
New services transitively trusted



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Old Slides

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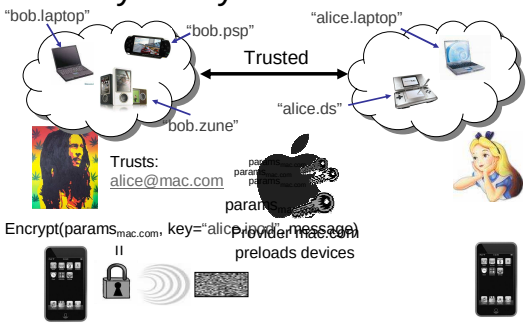
Tryst: key establishment



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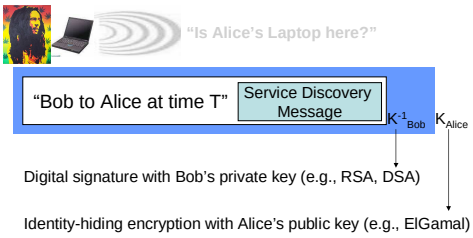
Public Key Protocol

- Existing theoretical public key protocol [Abadi '04]



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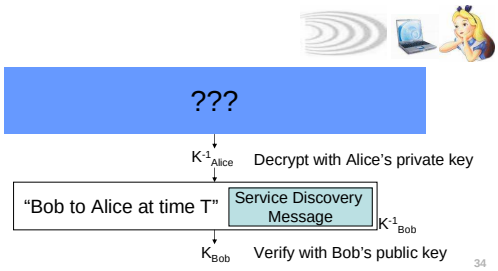

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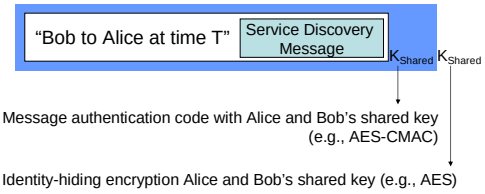
Symmetric Key Protocol



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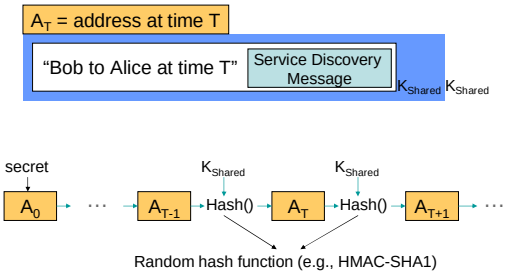

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