Off-the-Record Messaging: Useful Security and Privacy for IM

Digital Security Seminar
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The challenge

Researchers have had a hard time getting their work in security and privacy technologies to benefit real people.

- It's hard to use!
- It's hard to get!
- It doesn't work!

The goal

- At the end of the day, what matters is that the technologies we produce actually improve people's lives in some way!

- Our goal is to create what we call **Useful Security and Privacy Technologies**.

Useful Security and Privacy

- There are four major aspects to such technologies:
  - Usability
  - Deployability
  - Effectiveness
  - Robustness

- We'll quickly look at what these all mean.

Usability

- Usability is the best known of these properties.
- We not only mean it in the sense of user interfaces, and “usable security”, however.
- For example, if a privacy technology causes your web browsing to slow to an unacceptable crawl, that's an unusable technology.

Deployability

- But making a technology easy to use isn't enough!
- It also has to be *reasonable* to use.
  - If users have to change their:
    - operating systems
    - web browsers
    - instant messaging clients
  - then they won't want to use your technology.

Effectiveness

- Of course, even assuming the users *have* the technology, it needs to do them some good.

- All too often, we see that many proposed, and even widely deployed, security systems have major flaws.
  - Peer review, analysis
  - Not only of the design, but also the implementation

Robustness

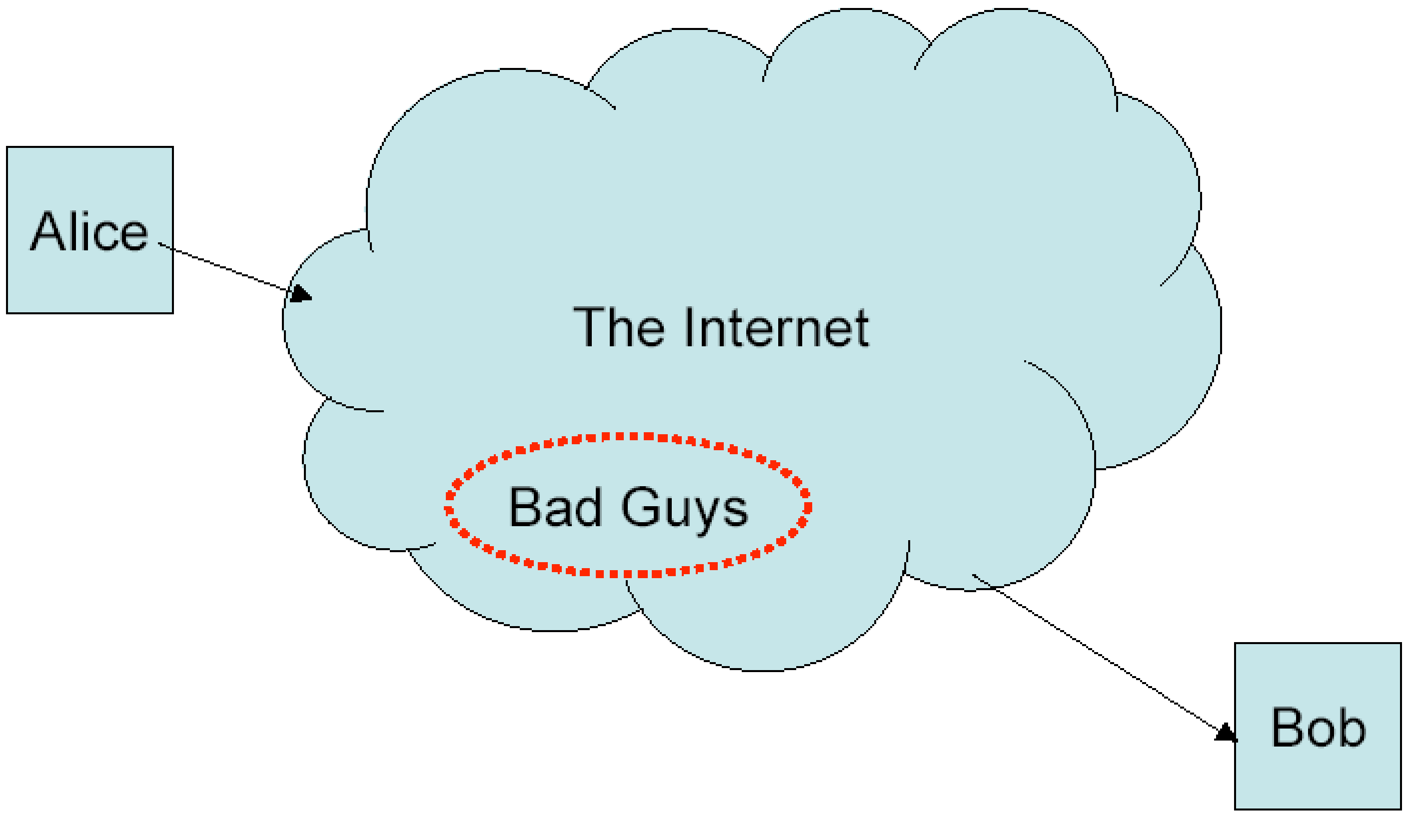
- Many times, security technologies work only so long as everything goes “according to plan”.
  - Small deviations from the assumptions made by designers can cause the systems to fail catastrophically!
- But:
  - Users forget passwords
  - Their computers are compromised by malware
  - They misunderstand security-relevant messages
  - They fall victim to phishing attacks
  - etc.

An example

- Alice and Bob want to communicate privately over the Internet.

- Generous assumptions:
  - They both know how to use PGP
  - They both know each other's public keys
  - They don't want to hide the *fact* that they talked, just what they talked about

Threat model

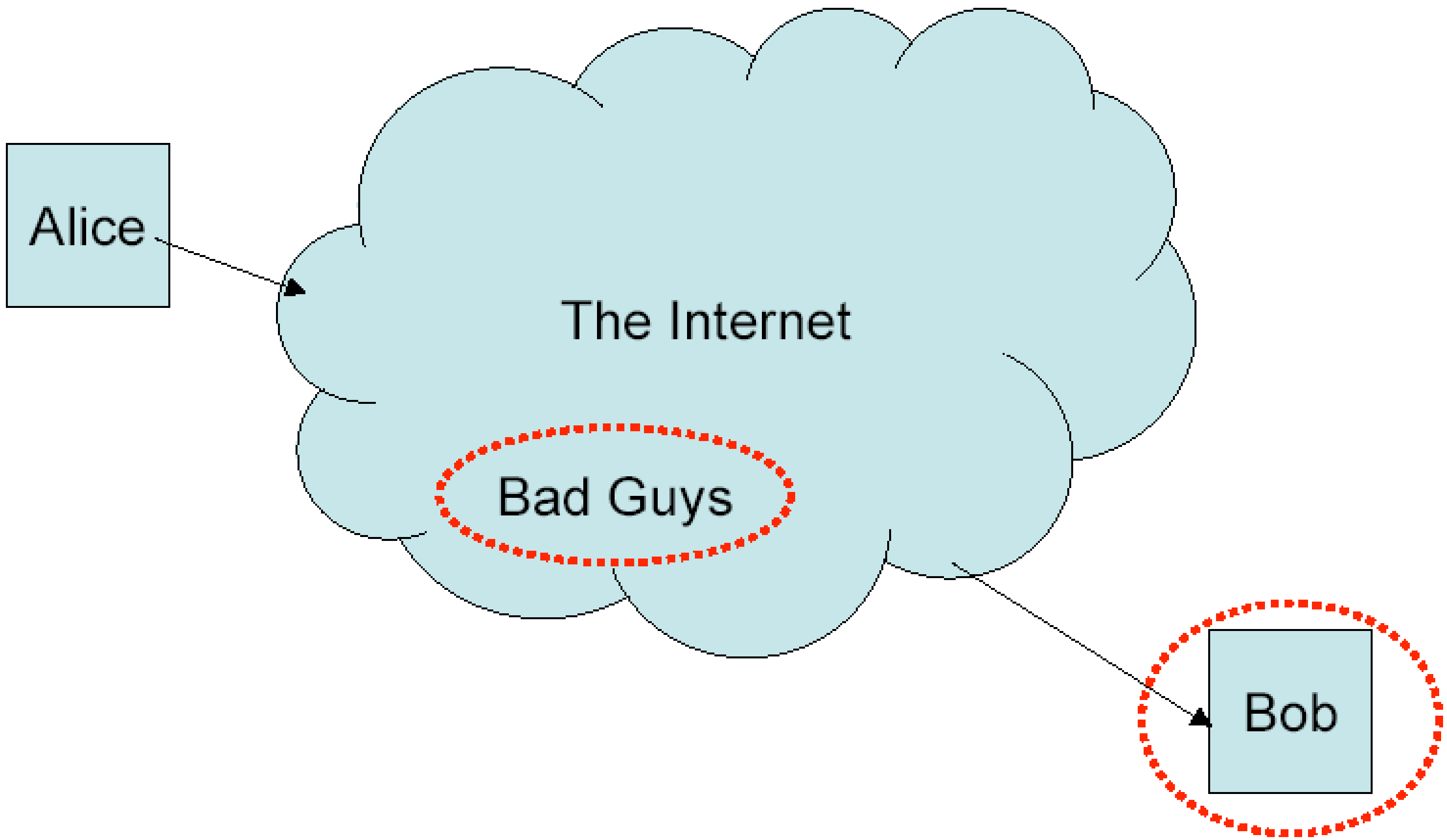


Solved problem

- Alice uses her private signature key to sign a message
  - Bob needs to know who he's talking to
- She then uses Bob's public key to encrypt it
  - No one other than Bob can read the message
- Bob decrypts it and verifies the signature

- Pretty Good, no?

Threat model



Plot twist

- Bob's computer is stolen by “bad guys”
  - Criminals
  - Competitors
  - Subpoenaed by the RCMP
- Or just broken into
  - Virus, trojan, spyware, etc.
- **All** of Bob's key material is discovered
  - Oh, no!

The Bad Guys can...

- Decrypt past messages
- Learn their content
- Learn that Alice sent them
- And have a mathematical **proof** they can show to anyone else!

- How private is that?

What went wrong?

- Bob's computer got stolen?
- How many of you have never...
  - Left your laptop unattended?
  - Not installed the latest patches?
  - Run software with a remotely exploitable bug?
- What about your friends?

What really went wrong

- PGP creates lots of incriminating records:
  - Key material that decrypts data sent over the public Internet
  - Signatures with proofs of who said what
- Alice had better watch what she says!
  - Her privacy depends on Bob's actions

Casual conversations

- Alice and Bob talk in a room
- No one else can hear
  - Unless being recorded
- No one else knows what they say
  - Unless Alice or Bob tells them
- No one can **prove** what was said
  - Not even Alice or Bob
- These conversations are “off-the-record”

We like off-the-record conversations

- Legal support for having them
  - Illegal to record conversations without notification
- We can have them over the phone
  - Illegal to tap phone lines
- But what about over the Internet?
  - Instant Messaging (IM) “feels” like a personal conversation
  - If only it were so!

Crypto tools

- We have the tools to do this
  - We've just been using the wrong ones
  - (when we've been using crypto at all)

- We want **perfect forward secrecy**

- We want **deniable authentication**

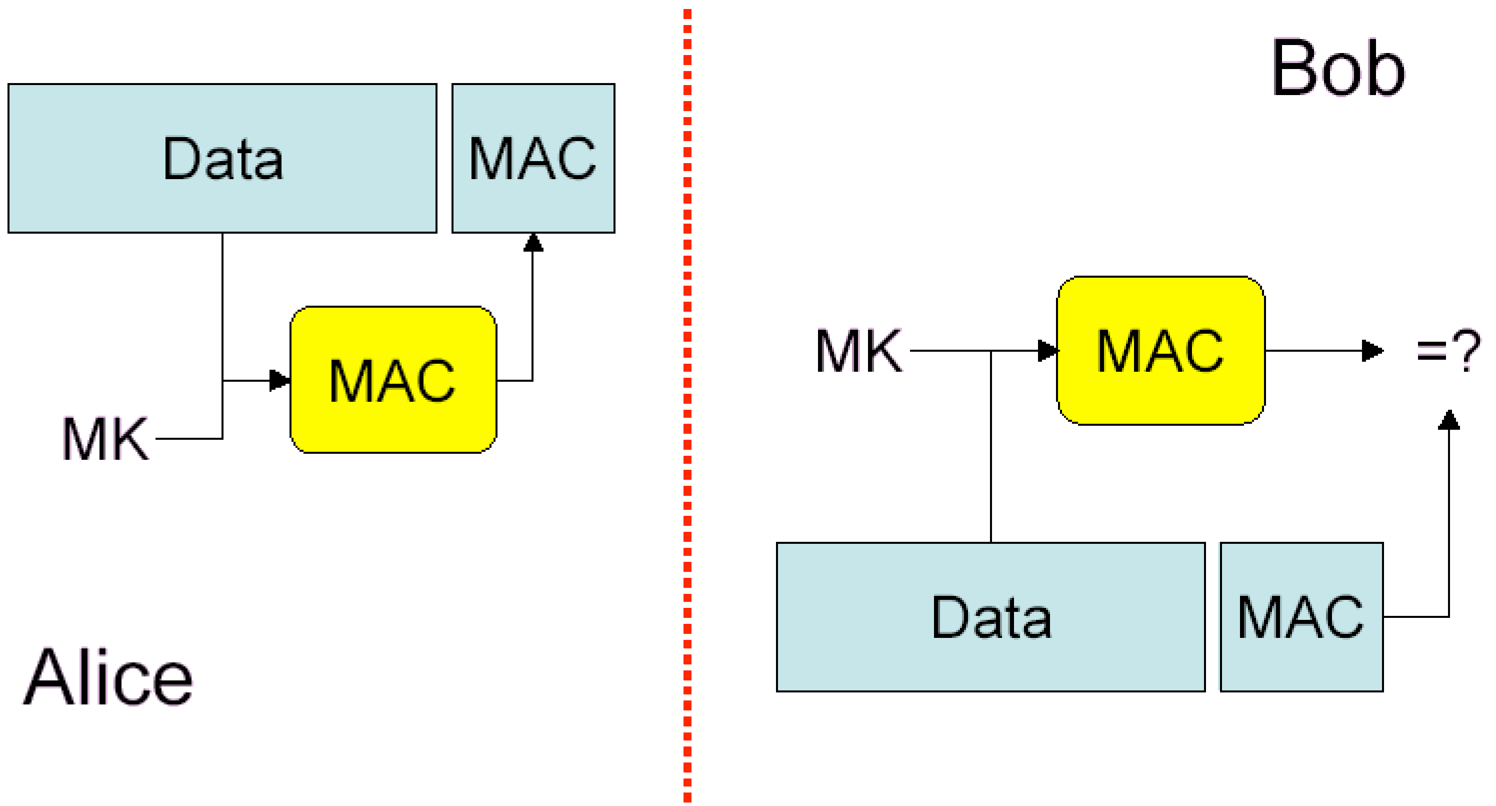
Perfect forward secrecy

- Future key compromises should not reveal past communication
- Use a short-lived encryption key
- Discard it after use
  - Securely erase it from memory
- Use long-term keys to help distribute and authenticate the short-lived key

Deniable authentication

- Do **not** want digital signatures
  - Non-repudiation is great for signing contracts, but undesirable for private conversations
- But we **do** want authentication
  - We can't maintain privacy if attackers can impersonate our friends
- Use **Message Authentication Codes** (MACs)

MAC operation



No third-party proofs

- Shared-key authentication
  - Alice and Bob have the same MK
  - MK is required to compute the MAC
- Bob cannot prove that Alice generated the MAC
  - He could have done it, too
  - Anyone who can verify can also forge
- This gives Alice a measure of deniability

Off-the-Record Messaging protocol

- Rough sketch of protocol
  - Details on our web page
- Assume Alice and Bob know each other's public keys
  - These keys are long-lived, but we will only use them as a building block
  - Use “ssh-style” approach: users are warned the first time they see a particular key; keys are verified thereafter

Step 1: Authenticated Key Exchange

- We use a variant of the SIGMA protocol as the AKE.
  - The same protocol that's used in IKE (part of IPsec)

- Use plain (unauthenticated) Diffie-Hellman to set up a channel
- Sign a MAC on fresh data to prove your identity and that you know the shared secret

Details of SIGMA

$$
\begin{aligned}
A &: \quad x \in_R 2^{320}, r \in_R 2^{128} \\
A \rightarrow B &: \quad E_r\left(g^x\right), \text{Hash}\left(g^x\right) \\
B &: \quad y \in_R 2^{320} \\
B \rightarrow A &: \quad g^y \\
A &: \quad s = \left(g^y\right)^x \\
A \rightarrow B &: \quad r, \mathrm{E}_{h_1(s)}\left(A, \text{sig}_A\left(\text{MAC}_{h_2(s)}\left(g^x, g^y, A\right)\right)\right) \\
B &: \quad s = \left(g^x\right)^y \\
B \rightarrow A &: \quad \mathrm{E}_{h_3(s)}\left(B, \text{sig}_B\left(\text{MAC}_{h_4(s)}\left(g^y, g^x, B\right)\right)\right)
\end{aligned}
$$

Step 2: Message transmission

- Compute EK=Hash(s), MK=Hash(EK)

$$A \to B \quad : \quad E_{EK}(M), \mathrm{MAC}_{MK}(E_{EK}(M))$$

- The encryption is AES in Counter mode
- Bob verifies MAC using MK, decrypts M using EK
- Confidentiality and authenticity are assured

Step 3: Re-key

- As often as possible, Alice and Bob pick new x',y'

$$A \rightarrow B \quad : \quad g^{x'}, \mathrm{MAC}_{MK}\left(g^{x'}\right)$$

$$B \rightarrow A \quad : \quad g^{y'}, \mathrm{MAC}_{MK}\left(g^{y'}\right)$$

$$A, B \quad : \quad s' = g^{x'y'}$$

- Compute EK'=Hash(s'), MK'=Hash(EK')
- Alice and Bob securely erase s, x, y, and EK
  - Perfect forward secrecy

Step 4: Publish MK

- Alice and Bob do not need to forget MK
- They no longer use it for authentication
- In fact, they publish the old MK along with the next message
  - This lets anyone forge messages, but only past ones
  - Provides extra deniability

Deniability

- OTR offers many layers of deniability:
  - During the AKE:
    - The signature only proves that Alice has used OTR at some point in the past, not even with any particular person
  - During message transmission:
    - Bob can't prove to Charlie that the messages he gets are coming from Alice, even though he himself is assured of this
  - After the fact:
    - AES Counter mode allows messages to be altered once the MAC key is published
    - Entire new messages, or whole transcripts, can in fact be forged
- It's not more deniable than plaintext, of course!

Using these techniques

- Using these techniques, we can make our online conversations more like face-to-face “off-the-record” conversations
- But there's a wrinkle:
  - These techniques require the parties to communicate *interactively*
  - This makes them unsuitable for email
  - But they're still great for instant messaging!

Off-the-Record Messaging

- Off-the-Record Messaging (OTR) is software that allows you to have private conversations over instant messaging, providing:
- Encryption
  - Only Bob can read the messages Alice sends him
- Authentication
  - Bob is assured the messages came from Alice

Off-the-Record Messaging

- Perfect Forward Secrecy
  - Shortly after Bob receives the message, it becomes unreadable to anyone, anywhere
- Deniability
  - Although Bob is assured that the message came from Alice, he can't convince Charlie of that fact
  - Also, Charlie can create *forged transcripts* of conversations that are every bit as accurate as the real thing

Off-the-Record Messaging

- Availability of OTR:
  - It's built in to Adium X (a popular IM client for OSX)
  - It's a plugin for gaim (a popular IM client for Windows, Linux, and others)
    - With these two methods, OTR works over almost any IM network (AIM, ICQ, Yahoo, MSN, etc.)
  - It's a proxy for other Windows or OSX AIM clients
    - Trillian, iChat, etc.
  - Third parties have written plugins for other IM clients
    - Miranda, Trillian, Kopete

Is OTR Useful?

- OTR is easy to use
  - The software automatically notices when Alice and Bob both support OTR, and automatically protects their conversations.
  - The IM servers just pass encrypted messages back and forth between Alice and Bob, unaware that anything unusual is going on.

Is OTR Useful?

- OTR is easy to deploy
  - You probably don't have to change your IM client to use OTR.
  - In fact, your IM client might support OTR already!
  - It's also part of many standard OS distributions.

Is OTR Useful?

- It works
  - Peer-reviewed design
  - Open-source implementation
- Robust against failures
  - Preserves security in the face of simple failures
  - Preserves deniability in the face of major failures

Is OTR Useful?

- OTR is a good example of a Useful Security and Privacy Technology.
- Tens of thousands of people are using OTR to protect their IM conversations.

Future directions

- More flexible key verification
  - When Alice first talks to Bob, she will be presented with a fingerprint

    B0A09015 B20564FB 71E1AFEE 8FC1A8F1 EEAA6379
  - How does she know if this is the correct one, or if there's a MITM?
  - She needs to determine this out-of-band, through some other authenticated channel
    - She can phone Bob, and have him read it to her (and recognize his voice)
    - Bob can put a PGP-signed message containing his OTR fingerprinton his web page

More flexible key verification

- Alice and Bob can arrange a shared secret, and compare them without revealing any information except whether the secrets match.
  - This way, they can meet before they've both installed OTR, and still be able to maintain security and privacy.
  - Alice and Bob each end up computing

$$w^{(s_A - s_B)}$$

for a random value w.

Private chats for groups

- What if more than two people want to have a private chat room?
  - What does "deniability" mean in this situation?
    - That you can claim you weren't part of the chat at all?
    - That you can claim someone else in the chat wrote a particular message?
  - Are people in the chat assured of the actual author of a message?
    - Or just that someone in the room said it?
  - Can you do it without effectively setting up person-to-person private conversations for each pair of people in the room?

Comparison to other systems

- gaim-encryption
  - Encryption and authentication
  - No deniability or perfect forward secrecy
  - Like PGP with signatures
- Trillian SecureIM
  - Encryption with perfect forward secrecy
  - No authentication at all
- SILC
  - Completely separate network
  - Share messages (securely) with SILC server, or
  - Pre-shared long-term secret, or
  - Peer-to-peer communication (hard with NATs)

For more information

- For more information about OTR, see our web page:

http://otr.cypherpunks.ca/