Internet security

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Thanks to:
NSF ITR–0716498
Internet insecurity

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Why doesn’t the Internet use cryptography?
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“The Internet does use cryptography! I just made an SSL connection to my bank.”
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Indeed, many connections use SSL, Skype, etc. But *most* connections don’t.
Why is there so much unprotected Internet communication?
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In fact, attackers are forging packets and exploiting buffer overflows and doing much more. Users want all of these problems fixed.
Why are typical Internet packets unencrypted and unauthenticated?
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“"It’s too easy to write Internet software that exchanges data without any cryptographic protection. Most Internet clients and servers don’t know how to make cryptographic connections."”

True for most protocols. But let’s focus on HTTP. Most HTTP servers and browsers (Apache, Internet Explorer, Firefox, etc.) support SSL.
Why is SSL used for only a tiny fraction of all HTTP connections?
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Indeed, usability is a major issue. Only $\approx 1\%$ of the Apache servers on the Internet have SSL enabled.
But let’s focus on Google.

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Why does Google actively *turn off* cryptographic protection?
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“Enabling SSL for more than a small fraction of Google connections would overload the Google servers. Google doesn’t want to pay for a bunch of extra computers. Too slow ⇒ unusable.”
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Many companies sell SSL-acceleration hardware, but that costs money too.
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Can universal crypto be usable?
The Domain Name System

nwo.nl has mail to deliver to someone@os3.nl.

Mail client at nwo.nl

“The mail server for os3.nl has IP address 145.100.96.119.”

Administrator at os3.nl

Now nwo.nl delivers mail to IP address 145.100.96.119.
Same for web browsing. nwo.nl wants to see http://www.os3.nl.

Browser at nwo.nl

“The web server www.os3.nl has IP address 145.100.96.70.”

Administrator at os3.nl

Now nwo.nl retrieves web page from IP address 145.100.96.70.
DNS software security holes: BIND libresolv buffer overflow, Microsoft cache promiscuity, BIND 8 TSIG buffer overflow, BIND 9 dig promiscuity, etc.
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But what about protocol holes?
Forging DNS packets

nwo.nl has mail to deliver to someone@os3.nl.

Mail client at nwo.nl

“The mail server for os3.nl has IP address 157.22.245.20.”

Attacker anywhere on network

Now nwo.nl delivers mail to IP address 157.22.245.20, actually the attacker’s machine.
“Can attackers do that?”
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— Yes.
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— Yes.

“Really?”
“Can attackers do that?”
— Yes.

“Really?” — Yes.
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“Really?” — Yes.

“Don’t the clients check who’s sending information?”
“Can attackers do that?” — Yes.

“Really?” — Yes.

“Don’t the clients check who’s sending information?” — Yes, but the attacker forges the sender address; as easy as forging address on a physically mailed letter.
“Is the client always listening for the address of www.os3.nl?”
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— No, but many ways for attackers to work around this:

1. Attack repeatedly.

2. Poke the client to trigger a known lookup.

3. Attack caches a long time in advance.
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4. Easy, succeeds instantly: Sniff the network.
“Doesn’t the attacker have to win a race against the legitimate DNS packets from the administrator at os3.nl?”
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— Yes, but many ways for attackers to win race:

1. Deafen the legitimate server.
2. Mute the legitimate server.
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What about cookies?

Client’s DNS query packet contains a 16-bit ID.

RFC 1035 (1987): “This identifier is copied [to the] reply and can be used by the requester to match up replies to outstanding queries.”

Traditional ID sequence: 1, 2, 3, 4, 5, etc.

More recent idea: “Hey, let’s use random IDs! Then the attacker won’t be able to forge a packet with the right ID!”
Many “random” IDs are actually quite easy to predict. Client asks for information from attacker’s servers; attacker inspects IDs, predicts subsequent IDs.


But modern cryptographic random-number generators are extremely difficult to predict.
Client can randomize 16-bit ID and 16-bit UDP source port.

Implemented and advertised in djbdns since 1999, and in PowerDNS since 2006.

Same feature added 2008.07 in emergency upgrade to BIND, Microsoft DNS, Nominum CNS, most Cisco products, etc.

New York Times headline: “WITH SECURITY AT RISK, A PUSH TO PATCH THE WEB”
Many ways for attackers to beat this randomization, even if it’s cryptographic:

1. Attack repeatedly. “An attacker who makes a few billion random guesses is likely to succeed at least once; tens of millions of guesses are adequate with a colliding attack;” etc.

2. Allocate most UDP ports to other tasks, non-reusably.
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What about serious crypto?

Cryptography can stop sniffing attackers by scrambling legitimate packets.

Cryptography is often described as protecting confidentiality: attackers can’t understand the scrambled packets.

Can also protect integrity: attackers can’t figure out a properly scrambled forgery.
Traditional cryptography requires each legitimate client-server pair to share a secret key.

Public-key cryptography has much lower requirements. (1976 Diffie–Hellman; many subsequent refinements)

Each party has one public key. Two parties can communicate securely if each party knows the other party’s public key.

1993: IETF begins “DNSSEC” project to add public-key signatures to DNS.
Paul Vixie, June 1995:

This sounds simple but it has deep reaching consequences in both the protocol and the implementation—which is why it’s taken more than a year to choose a security model and design a solution. We expect it to be another year before DNSSEC is in wide use on the leading edge, and at least a year after that before its use is commonplace on the Internet.

BIND 8.2 blurb, March 1999:

[Top feature:] Preliminary DNSSEC.

BIND 9 blurb, September 2000:

[Top feature:] DNSSEC.
Paul Vixie, November 2002:

We are still doing basic research on what kind of data model will work for DNS security. After three or four times of saying “NOW we’ve got it, THIS TIME for sure” there’s finally some humility in the picture . . . “Wonder if THIS’ll work?” . . .

It’s impossible to know how many more flag days we’ll have before it’s safe to burn ROMs . . . It sure isn’t plain old SIG+KEY, and it sure isn’t DS as currently specified. When will it be? We don’t know. . . .

2535 is already dead and buried. There is no installed base. We’re starting from scratch.
Paul Vixie, 20 April 2004, announcing BIND 9.3 beta:

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ISC will also begin offering direct support to users of BIND through the sale of annual support contracts.
Paul Vixie, 1 November 2005:

Had we done a requirements doc ten years ago . . . they might not have noticed that it would intersect their national privacy laws or business requirements, we might still have run into the NSEC3 juggernaut and be just as far off the rails now as we actually are now.
After fifteen years and millions of dollars of U.S. government grants (e.g., DISA to BIND company; NSF to UCLA; DHS to Secure64 Software Corporation), how successful is DNSSEC?

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Surveys by DNSSEC developers, last updated 2008.10.09, have found 133 *.com names with DNSSEC signatures. 116 on 2008.08.20; 133 > 116.
Why is nobody using DNSSEC?

Some of the Internet’s DNS servers are extremely busy: e.g., the root servers, the .com servers, the google.com servers.

DNSSEC tries to minimize server-side costs by precomputing signatures of DNS records.

Signature is computed once; saved; sent to many clients. Hopefully the server can afford to sign each DNS record once.
Clients don’t share the work of verifying a signature.

DNSSEC tries to reduce client-side costs through choice of crypto primitive.

DNSSEC RFCs say DSA is “10 to 40 times as slow for verification” as RSA; recommend RSA “as the preferred algorithm” for DNSSEC; suggest RSA key size of only 1024 bits for “leaf nodes in the DNS.”
I say:
1024-bit RSA is irresponsible.

2003: Shamir–Tromer et al. concluded that 1024-bit RSA was already breakable by large companies and botnets.

2003: RSA Laboratories recommended a transition to 2048-bit keys “over the remainder of this decade.” 2007: NIST made the same recommendation.
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But most users don’t know this. Why aren’t they using DNSSEC?
Effects of precomputation:

1. Pain for implementors. Hundreds of DNS tools need to be modified to precompute and store signatures.

2. Pain for administrators, far beyond a simple upgrade.

3. Reduced privacy. DNSSEC publishes all “secured” DNS records. (NSEC3: almost all.)

4. Reduced reliability, “DNSSEC suicide,” reduced denial-of-service protection, etc.
Rethinking signatures

What we’ve learned: DNSSEC precomputes public-key signatures for speed, creating severe usability problems while sacrificing security.

Can we achieve adequate speed without precomputation? Let’s change the design.
Rethinking signatures

What we’ve learned:
DNSSEC precomputes public-key signatures for speed, creating severe usability problems while sacrificing security.

Can we achieve adequate speed without precomputation?
Let’s change the design.

1. Add encryption.
Want to protect against sabotage and against espionage.
So use public-key signatures and public-key encryption.
2. Merge signing with encryption.

“Public-key signcryption” protects against forgery and eavesdropping in one step.

“Public-key authenticated encryption” is even faster.

No need to partition the algorithms into an encryption component and an authentication component. Combined algorithms are faster.
3. Merge public-key operations across multiple messages.

It’s silly for a sender to authcrypt two messages to the same recipient.

“Hybrid cryptography” is much faster.

Example: Sender generates a random AES key, authcrypts the AES key, uses the AES key to encrypt and authenticate both messages.
4. Choose sensible primitives.

256-bit elliptic-curve cryptography using public-domain software:

489069 Core 2 cycles to handle a new communication partner.

5355 cycles to encrypt and authenticate a 510-byte message.

6786 cycles to verify and decrypt a legitimate 510-byte message.

3465 cycles to reject a forged 510-byte message.
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Handling 4 trillion partners/day: under $1000000.
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Final question for today: Can this protection be pushed beyond DNS to protect every Internet packet?