Networking in the Ethos Operating System

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Part I

The current state of software

Snowden revelations

- To observers of security and privacy, none of the individual capabilities disclosed by Snowden is surprising.
- We knew how software was failing under attack
- What was shocking was the breadth of activity
- And who it was aimed at
- *We have met the enemy and he is us* –Pogo
- Pogo is right is my take away from the Snowden revelations

The current state of software (prolog)

When software meets the attacker

- it fails (almost always)
- if it doesn't fail, just attack at a different layer
- attackers have to work to make it fail
- but there is plenty of motivation to do so
- for example, US spends $60 Billion a year on intelligence
- a significant amount of it is spent on serveilance

What goes wrong?

Lots of things

- Trust: relying on those who are not reliable
- Weak security services (cryptography, authentication, ...)
- Fragile semantics (buffer overflow, integer overflow, input, ..)
- Complexity
  - to program
  - to use
  - to administer
  - to secure

Trust

- This is the one issue that users cannot avoid
- Who are your adversaries?
- Who are your friends?
- Never rely on someone else when you can do it yourself
- Ex. of trust decisions
  - What Tor nodes should you use?
  - What authentication services should you use?
  - What software should you use?
  - What hardware should you use?

Security Services

- Password authentication appropriate only on local machines
- Authorization to limit what users/programs can do
- Encryption for isolation
- Problems
  - Trust (software, hardware, data)
  - Key escrow (Denial of Service)
  - Key distribution

Fragile semantics

- Programming languages:
  input verification, buffer overflow, integer overflow
- Operating systems: race conditions, isolation failures, aliasing
- Services: isolation, authorization, authentication, encryption
- Network protocols: parsing, XSS, Injection, CSRF

These issues are designed into our software.

Complexity

- Complexity favors the attacker
- The attacker has to find one execution path to compromise
- The defender has to prevent all paths from being compromised

Today's software is unfixable

Robust software—able to withstand attacks:

- must be designed for security
- must have low complexity

Its time to start over

> *Insanity: doing the same thing over and over again and expecting different results.*
>
> Albert Einstein

Lieutenant: *I think we can handle one little girl. I sent two units, they're bringing her down now.*

Agent Smith: *No lieutenant, your men are already dead.*

The Matrix

Part II

Ethos

Ethos

- Ethos' primary purpose is to make it easy to build *robust* applications
- Ethos is a clean-slate design
- It is incompatible (with the mistakes of the past)
- It tries to avoid doing things that haven't worked in the past

It's an old habit. I spent my life trying not to be careless.

Don Corleone
The Godfather (by Mario Puzzo)

How does an OS affect application security?

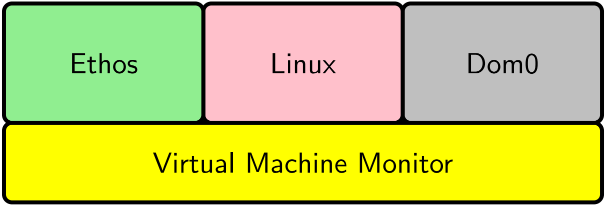
- Its part of the TCB, so its failure can destroy security
- But its impact is much more than just that
- The semantics exported by the OS determines how applications can fail
- The easiest way to see this is with a Programming Language
- A type-safe programming language cannot have buffer overflow
- Thus the system layers can have a profound impact on the types of security holes possible.
- We like to say that "Security is Semantics".

Complexity

Ethos avoids complexity to the extreme

- Because even the extreme may not enough
- One way of doing things (find the best and use that)
- Unification (make similar things look the same)
- Higher level semantics (because they fail more gracefully)
- Mindful of the pitfalls which result in security holes
- Use virtual machines for flexibility
- Modularity and information hiding
- Use declarations rather than code (because of decidability)
- Reduce cognitive load (e.g., use file system to provide privileges)

Virtual Machine Impact



- Ethos coded to one virtual machine (largely hardware independent)
- Ethos can use other OS facilities (eg. Qubes graphics)
- Your favorite OS applications can still be used
- VMs can simplify permissions and many other things

Unification examples

- Make networking very efficient so that only one networking protocol needed.
- Maximize commonality between Ethos-native and the Linux port of MinimaLT.
- The file system provides the name space for networking.
- Naming can be used to define permissions, etc.

Designed for the Internet

- Public keys are user IDs
  - Each user can have as many as they want (pseudonyms)
  - Self generated
  - Guaranteed unique (if your PRNG is not broken)
- User are added on the fly
  - With fine-grain enough authorization, this is not a problem
- Domain names
  - World-wide guaranteed unique names
  - Names which are easy to remember
- Mobile: connections are not named by their IP address/Port

Part III

Ethos Networking

Networking properties

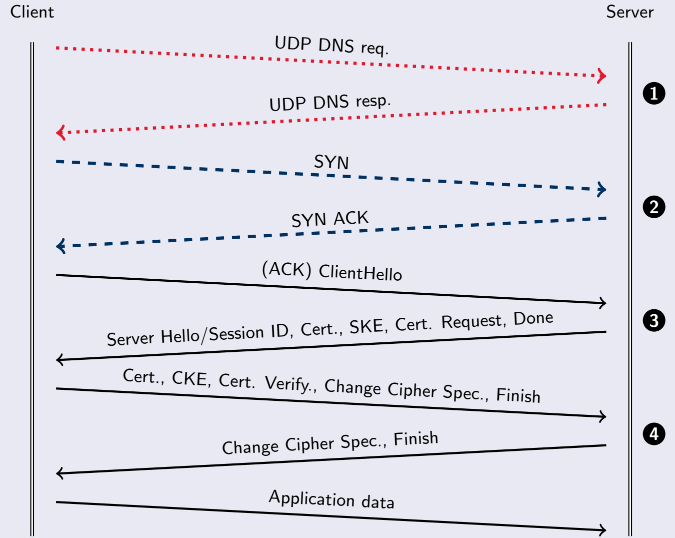
- Data on the first packet (low latency)
- All networking encrypted for confidentiality and integrity
- Ephemeral public keys used for perfect forward security
- Public key authentication of users and servers
- Tunneled to hinder traffic analysis
- Puzzles for denial-of-service protections
- Prevention of amplification attacks
- Mobile (shut down you notebook, get on a plane, open and continue connections)
- Prevent linkability of across tunnels

MinimaLT: Ethos network protocol

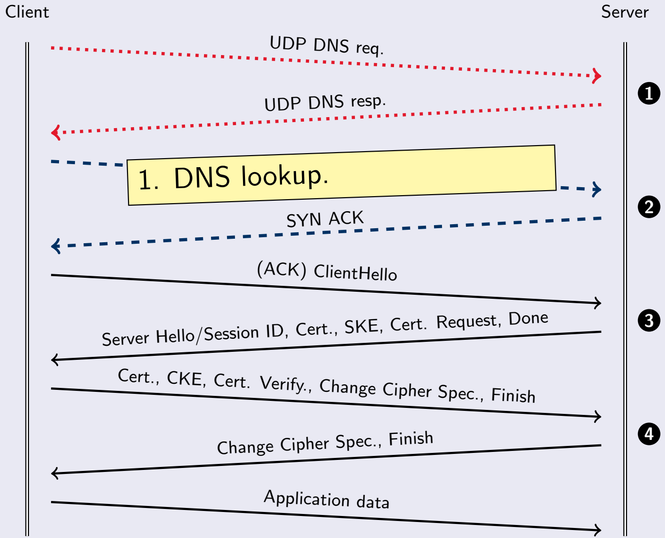
MinimaLT stands for Minimal Latency Tunneling

- ECC DH
- NaCL
- integrated with authentication servers
- implemented on Ethos and Linux

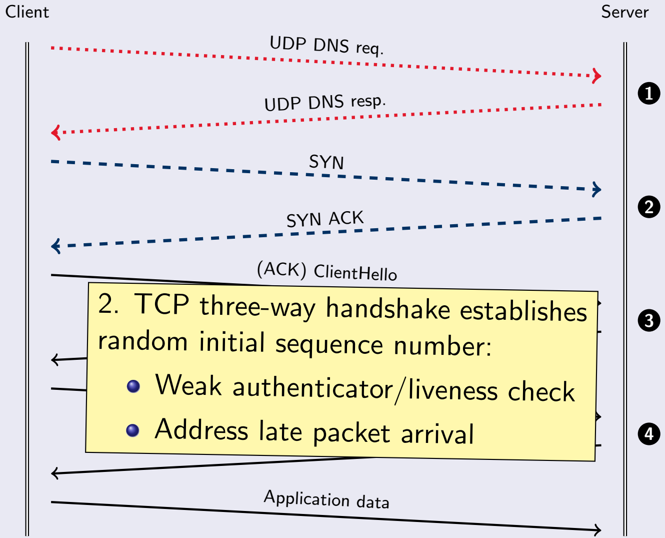
TLS: 4 round trips



TLS: 4 round trips

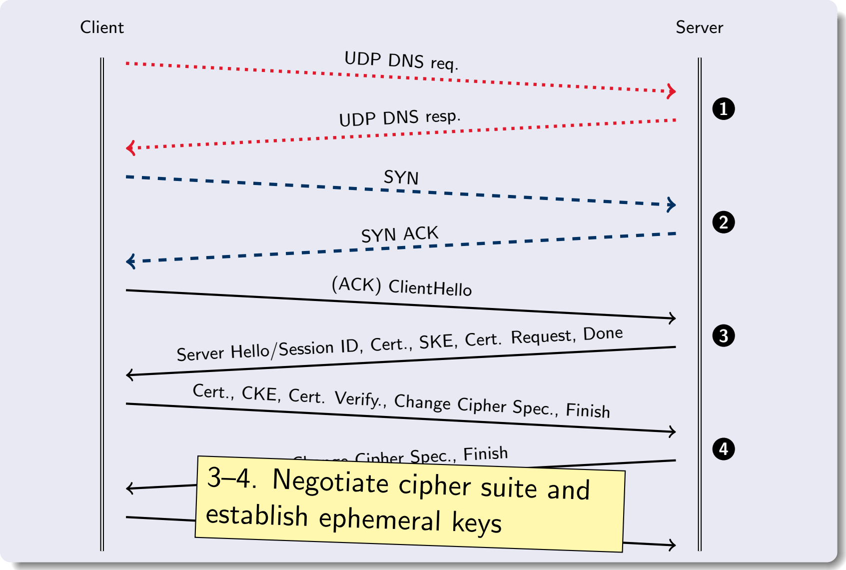


TLS: 4 round trips



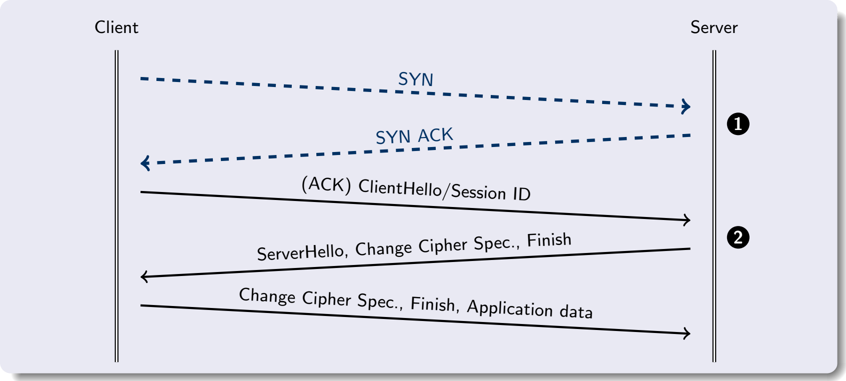
2. TCP three-way handshake establishes random initial sequence number:
- Weak authenticator/liveness check
- Address late packet arrival

TLS: 4 round trips



3–4. Negotiate cipher suite and establish ephemeral keys

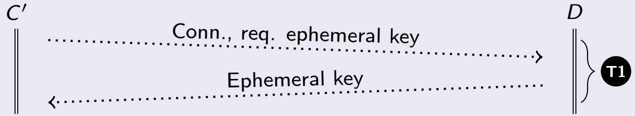
TLS (abbreviated): 2 round trips



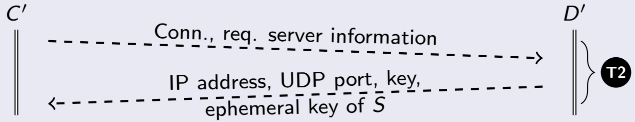
Only possible on a *reconnect*

MinimaLT round trips

Obtaining *D*'s ephemeral key (only at boot time):

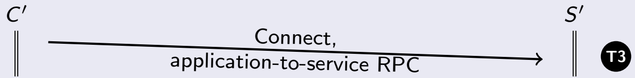


DNS-like lookup (once per host):



MinimaLT Connection Establishment

Connection establishment:



- TCP's SYN/ACK handshake unnecessary in cryptographic protocol
- One round trip for directory lookup (same as any internet protocol)
- Data goes on first packet to server in all cases
- if tunnel already established, create new connections w/i tunnel

Packet information

On the unencrypted part of the packet is

- IP and UDP for routing
- Client ephemeral public key (if tunnel initiation packet)
- Tunnel ID
- Time-based Nonce
- Encrypted payload with
  - Sequence and Acknowledge fields encrypted
  - Control fields (other than for routing) not exposed example TCP/IP RST.
  - Integrity protected

Key Rollover

- Rekeying occurs periodically (every minute)
- Key is a hash of the previous key
- Key rollover is identified by a changed tunnel ID
- Changed tunnel ID looks like a tunnel initiation packet
- Provide PFS even over long running connections

Mobility

- Tunnel is identified by a tunnel ID
- Tunnel ID is the hash of the client's ephemeral public key
- When changing IP address, simultaneously do a tunnel rekey
- Looks like a new tunnel
- Inhibits location tracking of clients

Programming

client:

```
fd = ipc("/service/messaging", "example.com")
```

server:

```
iFd = advertise("/service/messaging")
fd, user = import(iFd)
```

- Crypto is transparent
- Returns UserID to server
- Authorized by UserId
- Simpler than POSIX network APIs
- Application programmer can't screw up encryption, authentication, ...

Other issue

- Uses Sayl, a scalable authentication infrastructure
  - Scales to the Internet
  - Enables user and host authentication
  - Very efficient
- Denial of Service protections built into MinimaLT
- All information is typed, no need to
  - serialize and
  - parse
- All control messages sent by RPC
  - Start a new connection anonymously
  - Start a new connection with a pseudonym
  - Close a tunnel
  - Next tunnel ID

Part IV

Conclusion

Conclusion

- Today's widely used systems have failed under attack
- They are brittle, break disastrously
- They are unfixable, and will have to be replaced
- Need systems which are much stronger
- Ethos is designed to drive down complexity and remove pitfalls while providing strong security services
- We focused on Ethos networking here
  - Faster than unencrypted TCP/IP
  - More secure than TLS
  - Very simple