Cryptographic Standards and Protocols

An Overview

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Overview

- Kerberos
- X.509
- X.500
- IPv6
- SSL
- TLS
- IPSec

Kerberos

- Kerberos is a network authentication protocol. It is designed to provide strong authentication for client/server applications by using secret-key cryptography.
- Before a network connection is opened between two entities, Kerberos establishes a shared secret key through a Ticket Granting Server (TGS) that is used for authenticating the parties in the subsequent communications
- Versions of Kerberos also have extensions to utilize public/private keys for authentication
- Versions 4 and 5 (RFC 1510) are in use today
  - v4 has technical deficiencies
    - http://www.isi.edu/div7/publication_files/evolution_of_kerberos.pdf

Category: Authentication

Kerberos

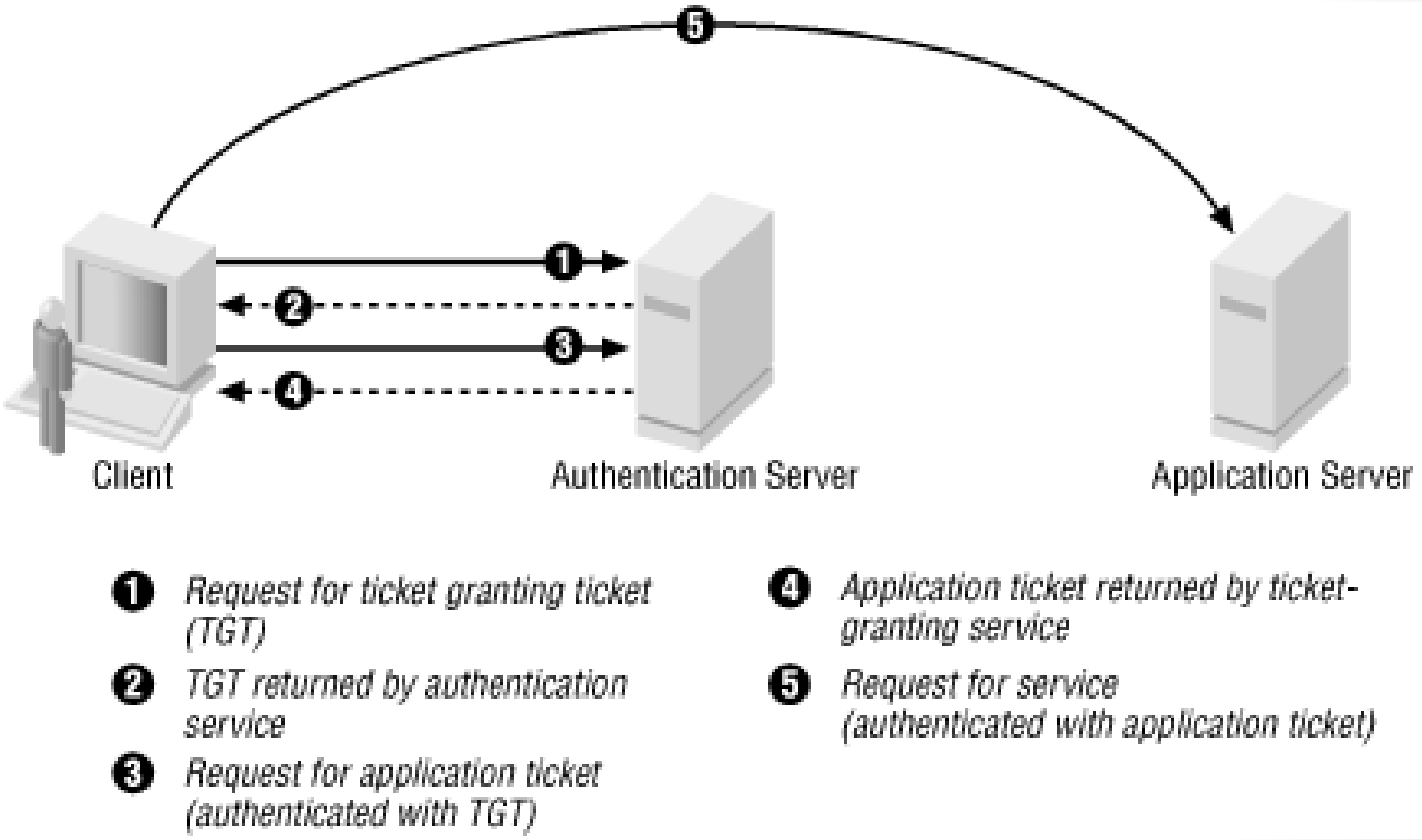
- It provides a centralized private-key third-party authentication in a distributed network
  - Allows users access to services distributed through a network without needing to trust all workstations
  - All trust is handled through a central authentication server
    - Implemented using an authentication protocol based on Needham-Schroeder

Kerberos

- Kerberos environment consists
  - A Kerberos server
  - A number of clients, all registered with the server
  - Application servers, sharing keys with the Kerberos server
    - Termed a realm
  - Typically a single administrative domain
    - If multiple realms, their Kerberos servers must share keys and trust

  - Authentication Server (AS)
    - Users initially negotiate with AS to identify self
    - AS provides a non-corruptible authentication credential
      - Ticket Granting Ticket (TGT)
    - Ticket Granting server (TGS)
      - Users subsequently request access to other services from TGS on basis of users TGT
    - Uses a complex protocol using DES

Kerberos



5
1
2
3
4
Client
Authentication Server
Application Server
1 Request for ticket granting ticket (TGT)
2 TGT returned by authentication service
3 Request for application ticket (authenticated with TGT)
4 Application ticket returned by ticket-granting service
5 Request for service (authenticated with application ticket)

X.509

- To facilitate the identification and security of keys in PKI, a Certificate Authority (CA) is used to authenticate the public key by digitally signing it
  - This is known as a digital certificate
- The validation and invalidation process (authentication) of digital certificates is handled by the Certificate Authority, and is governed by the X.509 de-facto standard.
  - Specifies the semantics of certificates and certificate revocation lists for the Internet PKI

Category: Authentication

X.500

- The X.500 standard is a global directory service that is based on a replicated distributed database
- Programs access the directory services using the X/Open Directory Service (XDS) APIs.
- The XDS API's permit programs to read, compare, update, add, and remove directory entries; list directories; and search for entries based on attributes, while authenticating these activities.
- There are varieties of X.500 products (i.e. Directory Access Protocols) available, and the latest version is LDAP.
  - Lightweight Directory Access Protocol (LDAP) provides the same functions as DAP except it reduces overheads through bypassing much of the session and presentation layers using Distinguished Names (DN)

LDAP

- The Lightweight Directory Access Protocol is an open, vendor-neutral, industry standard application protocol for accessing and maintaining distributed directory information services over an Internet Protocol network.
- Directory services play an important role in developing intranet and Internet applications by allowing the sharing of information about users, systems, networks, services, and applications throughout the network.
  - provide any organized set of records
  - often with a hierarchical structure such as a corporate email directory
- A common usage of LDAP is to provide a single-sign-on where one password for a user is shared between many services

http://www.ietf.org/rfc/rfc4511.txt

Category: Authentication

LDAP

- LDAP Data Interchange Format (LDIF)

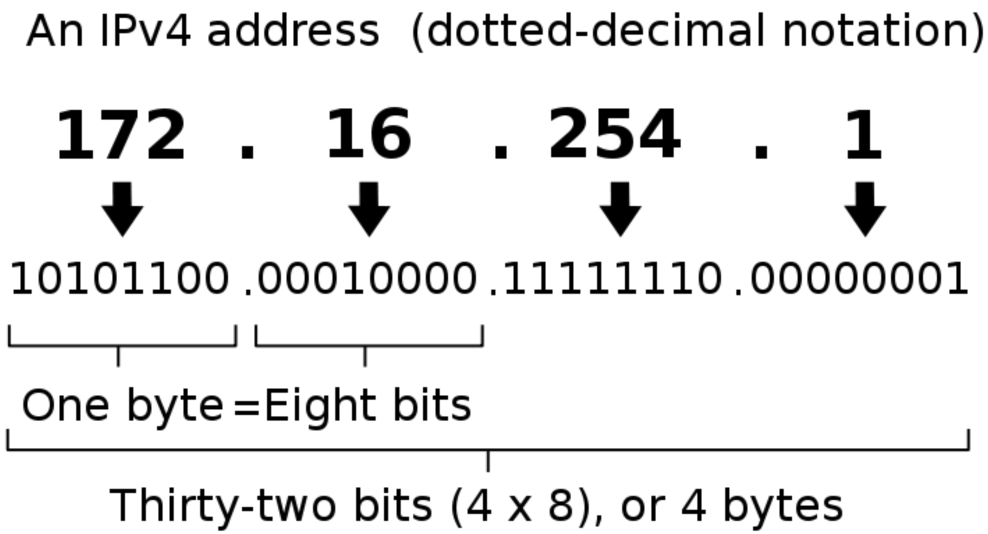
```
dn: cn=John Doe,dc=example,dc=com
cn: John Doe
givenName: John
sn: Doe
telephoneNumber: +1 888 555 6789
telephoneNumber: +1 888 555 1232
mail: john@example.com
manager: cn=Barbara Doe,dc=example,dc=com
objectClass: inetOrgPerson
objectClass: organizationalPerson
objectClass: person
objectClass: top
```

IPv6

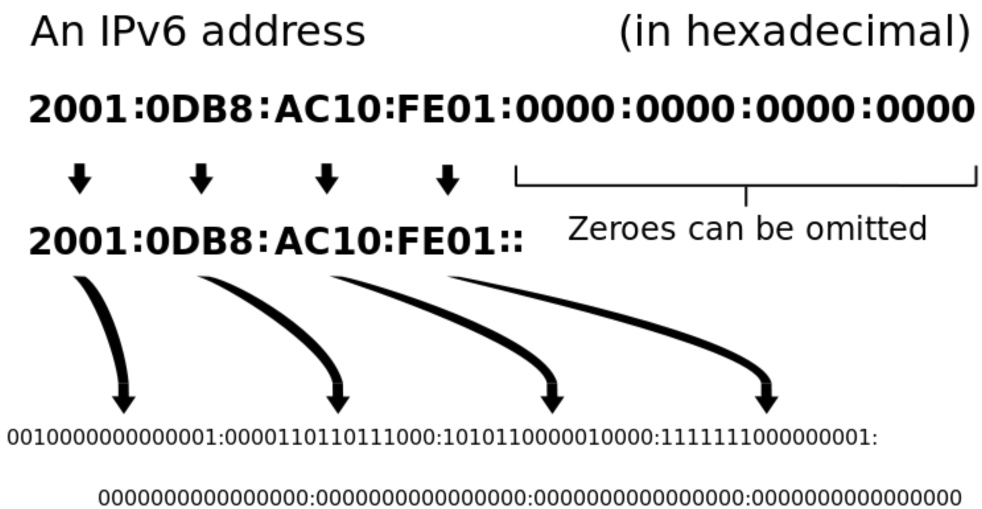
- The proposed standard Internet Protocol version 6 (IPv6) is the next generation of IP and will eventually replace IPv4.
  - Currently being transitioned throughout the Internet and is backward compatible with version 4.
- IPv6 provides the following added features
  - An increase from the 32-bit address space to 128-bit
  - Provisions for unicast, multicast, and anycast
  - An extension Authentication Header (AH) which provides authentication and integrity (without confidentiality) to IPv6 datagrams
  - An IPv6 Encapsulating Security Header (ESH) which provides integrity and confidentiality to datagrams

http://tools.ietf.org/html/rfc2460

IPv6



Source: https://upload.wikimedia.org/wikipedia/commons/7/74/Ipv4_address.svg



Source: https://en.wikipedia.org/wiki/File:Ipv6_address_leading_zeros.svg

IPv6

<table>
<caption>Fixed header format</caption>
<tr><th>Offsets</th><th>Octet</th><th colspan="8">0</th><th colspan="8">1</th><th colspan="8">2</th><th colspan="8">3</th></tr>
<tr><th>Octet</th><th>Bit</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th><th>28</th><th>29</th><th>30</th><th>31</th></tr>
<tr><td>0</td><td>0</td><td colspan="4">Version</td><td colspan="8">Traffic Class</td><td colspan="20">Flow Label</td></tr>
<tr><td>4</td><td>32</td><td colspan="16">Payload Length</td><td colspan="8">Next Header</td><td colspan="8">Hop Limit</td></tr>
<tr><td>8</td><td>64</td><td colspan="32" rowspan="4">Source Address</td></tr>
<tr><td>12</td><td>96</td></tr>
<tr><td>16</td><td>128</td></tr>
<tr><td>20</td><td>160</td></tr>
<tr><td>24</td><td>192</td><td colspan="32" rowspan="4">Destination Address</td></tr>
<tr><td>28</td><td>224</td></tr>
<tr><td>32</td><td>256</td></tr>
<tr><td>36</td><td>288</td></tr>
</table>

SSL

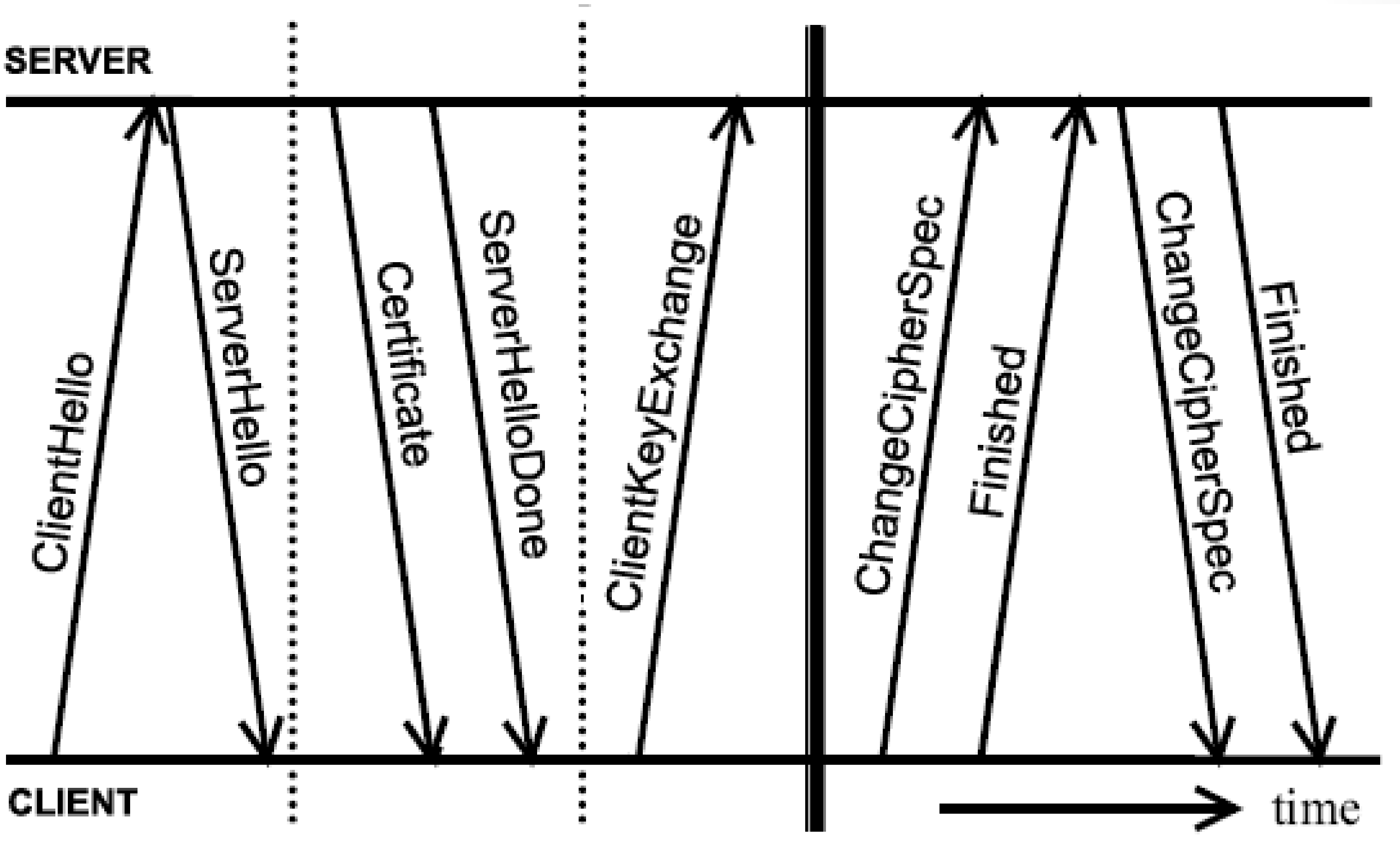
- Secure Socket Layer (SSL) is a security socket connection that provides a security layer at the transport level between the TCP/IP transport and sockets.
- The objective is to securely transmit from one site to another without involving the applications that invoke it
- The SSL protocol provides a certificate-based server authentication, private client-server communications using Rivest-Shamir-Adleman (RSA) encryption and message integrity checks.
- The SSL client generates a secret key for one session that is encrypted using the server's public key.
  - The session key is forwarded to the server and used for communication between the client and the server.

http://tools.ietf.org/html/rfc6101

SSL

- Basic properties
  - The connection is private.
    - Encryption is used after an initial handshake to define a secret key.
    - Symmetric cryptography is used for data encryption.
      - DES, 3DES, RC4
  - The peer's identity can be authenticated using asymmetric, or public key, cryptography.
    - RSA, DSS
  - The connection is reliable.
    - Message transport includes a message integrity check using a keyed Message Authentication Code (MAC) [RFC2104].
    - Secure hash functions (e.g., SHA, MD5) are used for MAC computations.

SSL


SERVER
CLIENT
ClientHello
ServerHello
Certificate
ServerHelloDone
ClientKeyExchange
ChangeCipherSpec
Finished
ChangeCipherSpec
Finished
time

Transport Layer Security (TLS)

- "TLS versions 1.0, 1.1, and 1.2, and SSL 3.0 are very similar" [http://tools.ietf.org/html/rfc5246, The Transport Layer Security (TLS) Protocol, Version 1.2, 2008].
  - There are many minor differences between these protocols, but browsers and servers are often configured to "rollback" to an earlier protocol in this family – if their communication partner requests this.
  - Attackers may exploit the differences and the rollbacks, see https://www.ietf.org/proceedings/84/slides/slides-84-tls-4.pdf
- Most experts advise against using the older protocols.
  - Qualys deprecates any browser that accepts SSL2.0, see https://www.ssllabs.com/ssltest/viewMyClient.html and https://www.ssllabs.com/projects/rating-guide/
- "SSL/TLS is a deceptively simple technology.
  - "It is easy to deploy, and it just works . . . except that it does not, really.
  - The first part is true—SSL is easy to deploy—but it turns out that it is not easy to deploy correctly." [https://www.ssllabs.com/projects/best-practices/]

Wikipedia's Current Advice on Cipher Selection in SSL/TLS

Cipher			Protocol version						Status
Type	Algorithm	Strength (bits)	SSL 2.0	SSL 3.0 [n 1][n 2][n 3][n 4]	TLS 1.0 [n 1][n 3]	TLS 1.1 [n 1]	TLS 1.2 [n 1]	TLS 1.3 (Draft)	
Block cipher with mode of operation	AES GCM[24][n 5]	256, 128	N/A	N/A	N/A	N/A	Secure	Secure	Defined for TLS 1.2 in RFCs
	AES CCM[25][n 5]		N/A	N/A	N/A	N/A	Secure	Secure	
	AES CBC[n 6]		N/A	N/A	Depends on mitigations	Secure	Secure	N/A	
	Camellia GCM[26][n 5]	256, 128	N/A	N/A	N/A	N/A	Secure	Secure	
	Camellia CBC[27][n 6]		N/A	N/A	Depends on mitigations	Secure	Secure	N/A	
	ARIA GCM[28][n 5]	256, 128	N/A	N/A	N/A	N/A	Secure	Secure	
	ARIA CBC[28][n 6]		N/A	N/A	Depends on mitigations	Secure	Secure	N/A	
	SEED CBC[29][n 6]	128	N/A	N/A	Depends on mitigations	Secure	Secure	N/A	
	3DES EDE CBC[n 6]	112[n 7]	Insecure	Insecure	Low strength, Depends on mitigations	Low strength	Low strength	N/A	
	GOST 28147-89 CNT[23]	256	N/A	N/A	Secure	Secure	Secure		Proposed in RFC drafts
	IDEA CBC[n 6][n 8]	128	Insecure	Insecure	Depends on mitigations	Secure	N/A	N/A	Removed from TLS 1.2
	DES CBC[n 6][n 8]	56	Insecure	Insecure	Insecure	Insecure	N/A	N/A	
		40[n 9]	Insecure	Insecure	Insecure	N/A	N/A	N/A	Forbidden in TLS 1.1 and later
	RC2 CBC[n 6]	40[n 9]	Insecure	Insecure	Insecure	N/A	N/A	N/A	
Stream cipher	ChaCha20-Poly1305[33][n 5]	256	N/A	N/A	N/A	N/A	Secure	Secure	Defined for TLS 1.2 in RFCs
	RC4[n 10]	128	Insecure	Insecure	Insecure	Insecure	Insecure	N/A	Prohibited in all versions of TLS
		40[n 9]	Insecure	Insecure	Insecure	N/A	N/A	N/A	
None	Null[n 11]	-	N/A	Insecure	Insecure	Insecure	Insecure	Insecure	Defined for TLS 1.2 in RFCs

http://en.wikipedia.org/wiki/Transport_Layer_Security, 27 July 2016

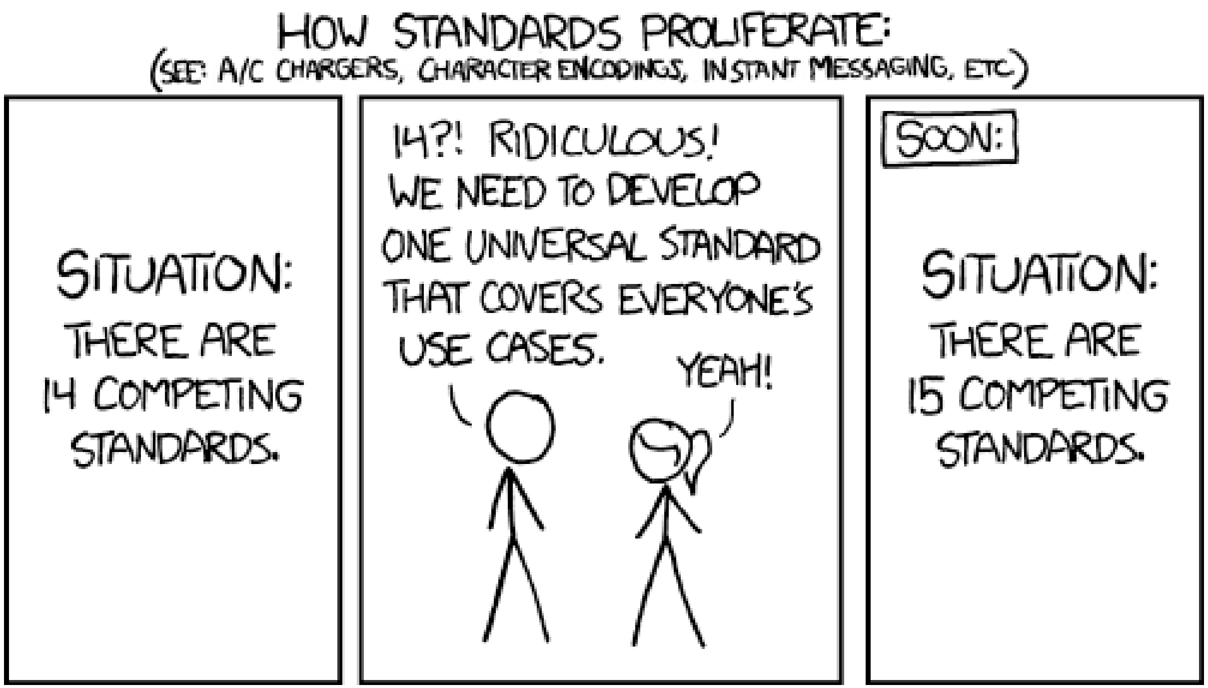
Wikipedia's Earlier Advice on Cipher Selection in SSL/TLS

Cipher			Protocol version				
Type	Algorithm	Strength (bits)	SSL 2.0	SSL 3.0 [note 1][note 2][note 3]	TLS 1.0 [note 1][note 3]	TLS 1.1 [note 1]	TLS 1.2 [note 1]
Block cipher with mode of operation	AES CBC[note 4]	128, 256	N/A	N/A	Depends on mitigations	Secure	Secure
	AES GCM[21][note 5]		N/A	N/A	N/A	N/A	Secure
	AES CCM[22][note 5]		N/A	N/A	N/A	N/A	Secure
	CAMELLIA CBC[23][note 4]	128, 256	N/A	N/A	Depends on mitigations	Secure	Secure
	CAMELLIA GCM[24][note 5]		N/A	N/A	N/A	N/A	Secure
	SEED CBC[25][note 4]	128	N/A	N/A	Depends on mitigations	Secure	Secure
	ARIA CBC[26][note 4]	128, 256	N/A	N/A	Depends on mitigations	Secure	Secure
	ARIA GCM[26][note 5]		N/A	N/A	N/A	N/A	Secure
	IDEA CBC[note 4][note 6]	128	Insecure	Depends on mitigations	Depends on mitigations	Secure	N/A
	3DES EDE CBC[note 4]	112[note 7]	Insecure	Low strength, Depends on mitigations	Low strength, Depends on mitigations	Low strength	Low strength
	DES CBC[note 4][note 6]	56	Insecure	Insecure	Insecure	Insecure	N/A
		40[note 8]	Insecure	Insecure	Insecure	N/A	N/A
	RC2 CBC[note 4]	40[note 8]	Insecure	Insecure	Insecure	N/A	N/A
Stream cipher	CHACHA20+POLY1305[30][note 5]	256	N/A	N/A	N/A	N/A	Secure
	RC4[note 9]	128	Insecure	Insecure	Insecure	Insecure	Insecure
		40[note 8]	Insecure	Insecure	Insecure	N/A	N/A
no encryption	NULL	-	N/A	Insecure	Insecure	Insecure	Insecure

http://en.wikipedia.org/wiki/Transport_Layer_Security, 1 August 2014

A Lighthearted View

- Question at https://www.schneier.com/blog/archives/2013/02/really_clever_t.html:
  - “It's probably fair to say that TLS has accrued too many options and versions to remain secure overall.
  - “Time to throw it out and build a new protocol that avoids all the problems identified with TLS over the years.
  - “Who'll go first?”
- Answer: … Time for obligatory xkcd: http://xkcd.com/927/



IPSec

- Short for IP Security, a set of protocols developed by the IETF to support the secure exchange of packets at the IP layer.
  - IPsec has been deployed widely to implement Virtual Private Networks (VPNs).
- For IPsec to work, the sending and receiving devices must share a public key.
  - Internet Security Association and Key Management Protocol/Oakley (ISAKMP/Oakley) protocol.
  - Allows the receiver to obtain a public key and authenticate the sender using digital certificates.

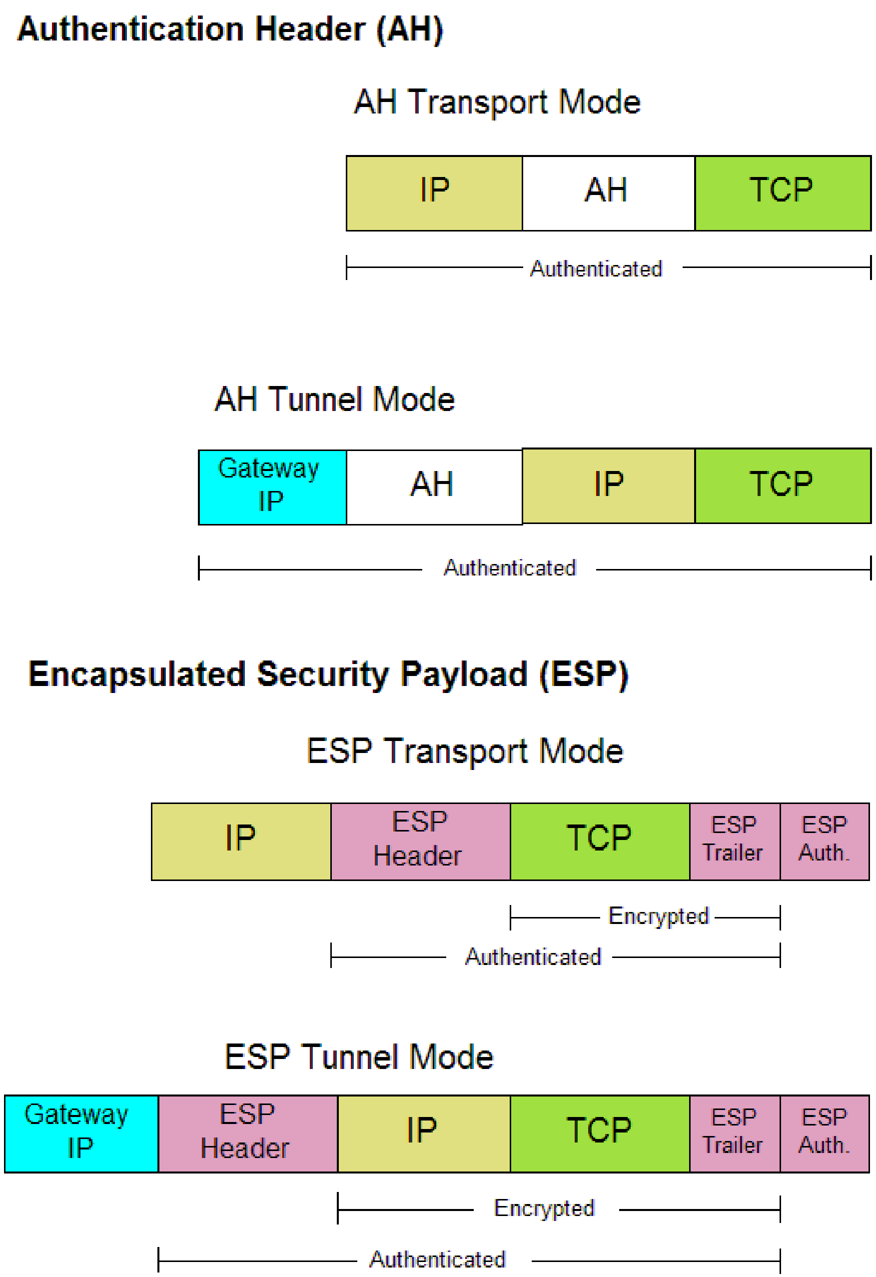
http://tools.ietf.org/html/rfc4301

Category: Data Confidentiality

IPSec

- IPSec may be used to protect one or more paths between two of any combination of hosts and/or security gateways (routers, firewalls, etc).
  - This is facilitated through the use of its Authentication Header (AH), and its Encapsulating Security Payload (ESP), both of which are algorithm independent.
  - The AH is used to authenticate the origin of the packets and the ESP encapsulating the content within the packets
- IPsec supports two encryption modes
  - Transport mode encrypts only the data portion (payload) of each packet, but leaves the header untouched.
  - Tunnel mode encrypts both the header and the payload.
  - On the receiving side, an IPSec-compliant device decrypts each packet.

IPSec


Authentication Header (AH)
AH Transport Mode
IP
AH
TCP
Authenticated
AH Tunnel Mode
Gateway IP
AH
IP
TCP
Authenticated
Encapsulated Security Payload (ESP)
ESP Transport Mode
IP
ESP Header
TCP
ESP Trailer
ESP Auth.
Encrypted
Authenticated
ESP Tunnel Mode
Gateway IP
ESP Header
IP
TCP
ESP Trailer
ESP Auth.
Encrypted
Authenticated

IPSec

- IKE-Related Output (VeriSign CA enrollment)

```
dt1-45a#show crypto key mypubkey rsa
% Key pair was generated at: 11:31:59 PDT Apr 9 1998
Key name: dt1-45a.cisco.com
 Usage: Signature Key
 Key Data:
  305C300D 06092A86 4886F70D 01010105 00034B00 30480241 00C11854 39A9C75C
  4E34C987 B4D7F36C A058D697 13172767 192166E1 661483DD 0FDB907B F9C10B7A
  CB5A034F A41DF385 23BEB6A7 C14344BE E6915A12 1C86374F 83020301 0001
% Key pair was generated at: 11:32:02 PDT Apr 9 1998
Key name: dt1-45a.cisco.com
 Usage: Encryption Key
 Key Data:
  305C300D 06092A86 4886F70D 01010105 00034B00 30480241 00DCF5AC 360DD5A6
C69704CF 47B2362D 65123BD4 424B6FF6 AD10C33E 89983D08 16F1EA58 3700BCF9
  1EF17E71 5931A9FC 18D60D9A E0852DDD 3F25369C F09DFB75 05020301 0001
```

http://www.cisco.com/c/en/us/support/docs/security-vpn/ipsec-negotiation-ike-protocols/16439-IPSECpart8.html

Final Thoughts

- Many many many more protocols and standards than presented here…
  - You can spend an entire lifetime on this stuff
    - Because many have…
- Lots of discussion….which is the point.
  - These protocols are based on standards
    - Standards can be vague, biased or ineffective
- Don’t take anything as the absolute unchanging truth
  - Read the source material e.g. http://www.ietf.org/