Most Common Cryptography Mistakes

4/7/2014

Encrypted credit card numbers

76	06	93	93	2b	8f	4b	c6	ec	e2	b3	d7	a1	09	f7	
76	06	9a	95	27	84	4f	c1	ef	e2	bb	df	a5	0a	f3	
71	01	9a	93	2b	85	41	ca	e2	e9	ba	df	a0	01	fa	26
76	05	9d	99	2b	84	4a	ca	e8	e1	b7	d7	a5	08	f4	
71	04	98	98	22	8b	49	c0	ed	e1	b0	d7	a8	08	f6	22
71	05	93	94	22	8d	4a	c7	eb	e5	b0	df	a8	09	f3	23
70	02	9d	93	23	8c	4f	c4	e2	e8	bb	d0	a7	08	f6	20

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76	05	9d	99	2b	84	4a	ca	e8	e1	b7	d7	a5	08	f4	
71	04	98	98	22	8b	49	c0	ed	e1	b0	d7	a8	08	f6	22
71	05	93	94	22	8d	4a	c7	eb	e5	b0	df	a8	09	f3	23
70	02	9d	93	23	8c	4f	c4	e2	e8	bb	d0	a7	08	f6	20

ASCII: …, ‘3’ = 0x33, ‘4’ = 0x34, ‘5’ = 0x35, …

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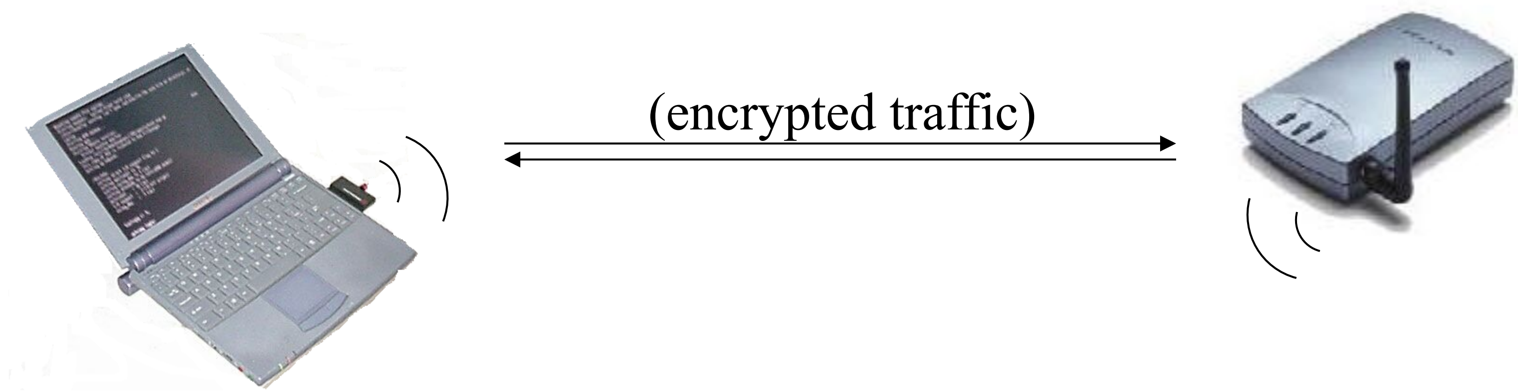
ASCII: ‘0’ = 0x30, …, ‘7’ = 0x37, ‘8’ = 0x38, ‘9’ = 0x39

#7: Don’t re-use nonces/IVs

- Re-using a nonce or IV leads to catastrophic security failure.

WEP



- Early method for encrypting Wifi: WEP (Wired Equivalent Privacy)
  - Share a single cryptographic key among all devices
  - Encrypt all packets sent over the air, using the shared key
  - Use a checksum to prevent injection of spoofed packets

WEP - A Little More Detail

$IV, \quad P \oplus RC4(K, IV)$

- WEP uses the RC4 stream cipher to encrypt a TCP/IP packet (P) by xor-ing it with keystream (RC4(K, IV))

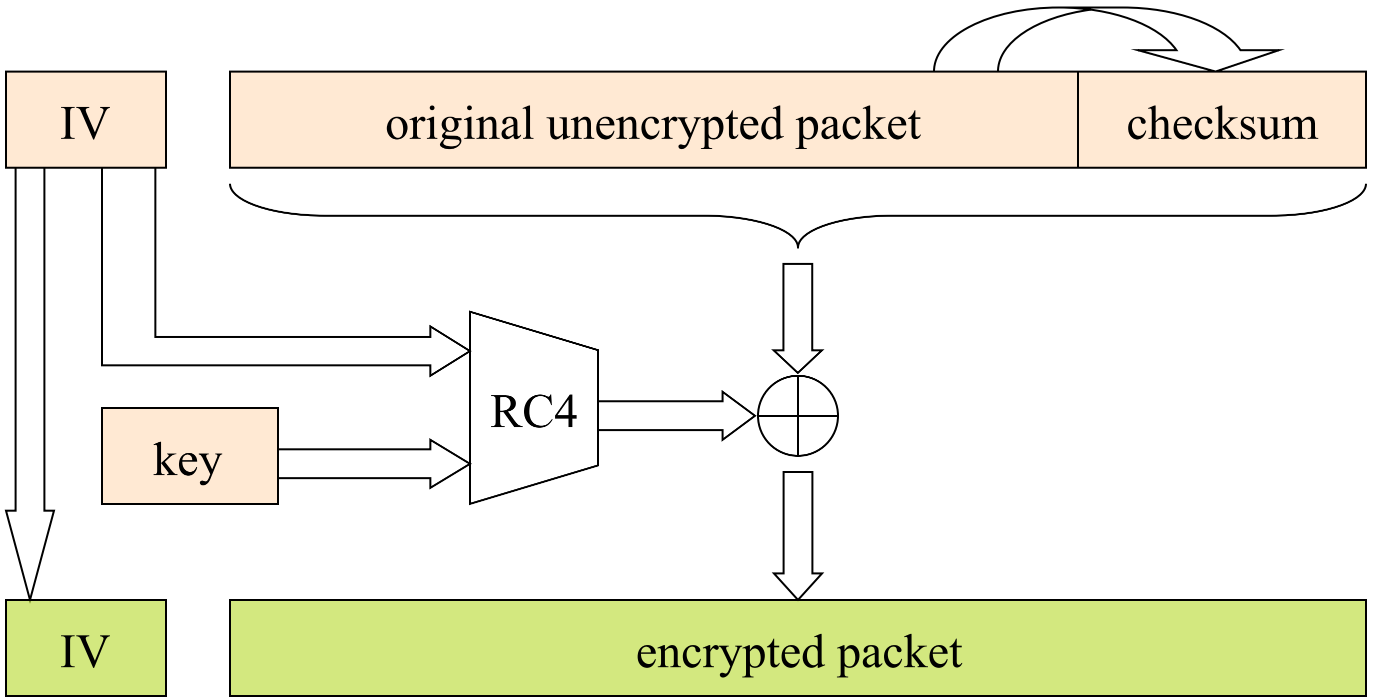
A Risk of Keystream Reuse

IV, $P \oplus RC4(K, IV)$

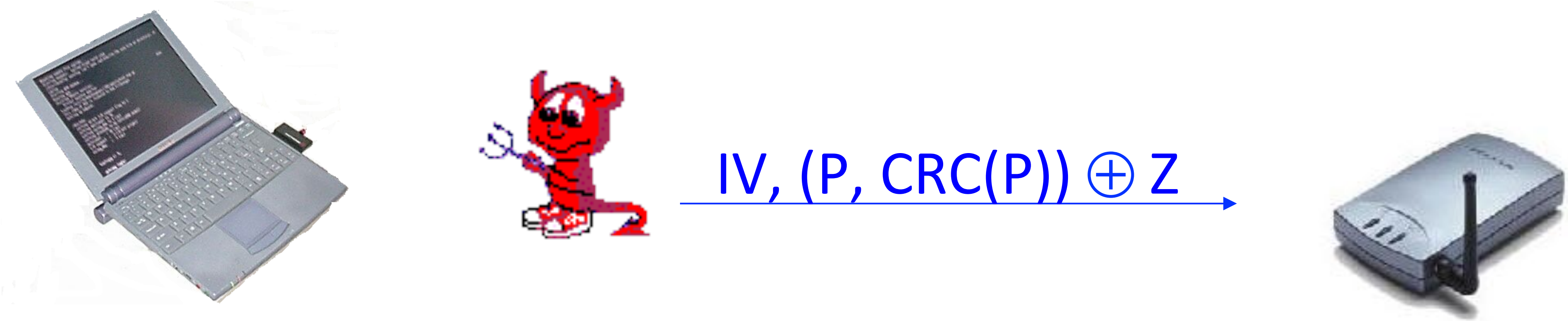
IV, $P' \oplus RC4(K, IV)$

- In some implementations, IVs repeat.
  - If we send two ciphertexts (C, C’) using the same IV, then the xor of plaintexts leaks ($P \oplus P' = C \oplus C'$), which might reveal both plaintexts
- Lesson: Don’t re-use nonces/IVs

WEP -- Even More Detail

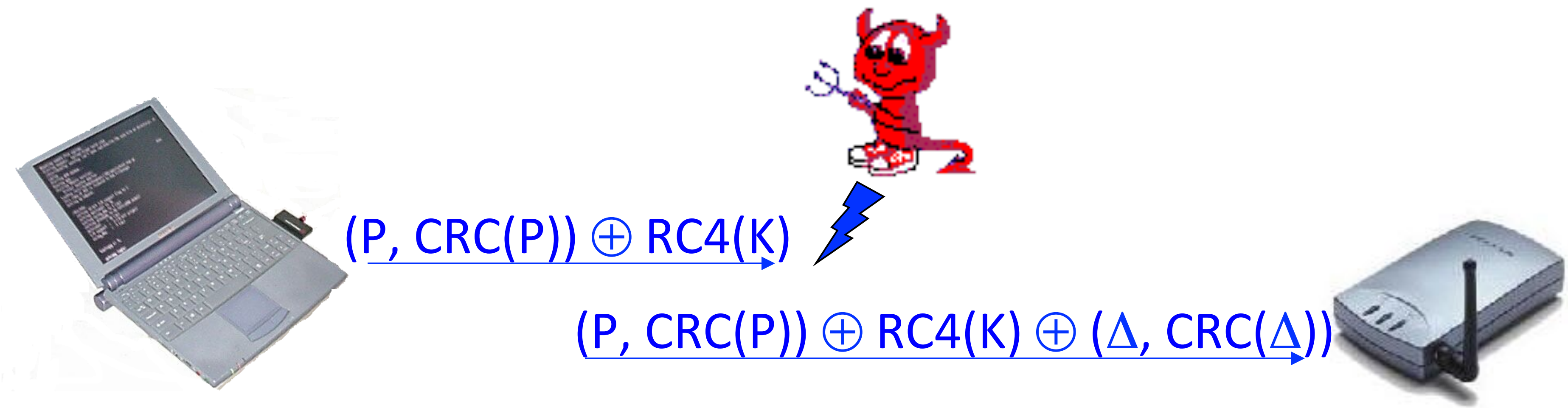


Attack #2: Spoofed Packets



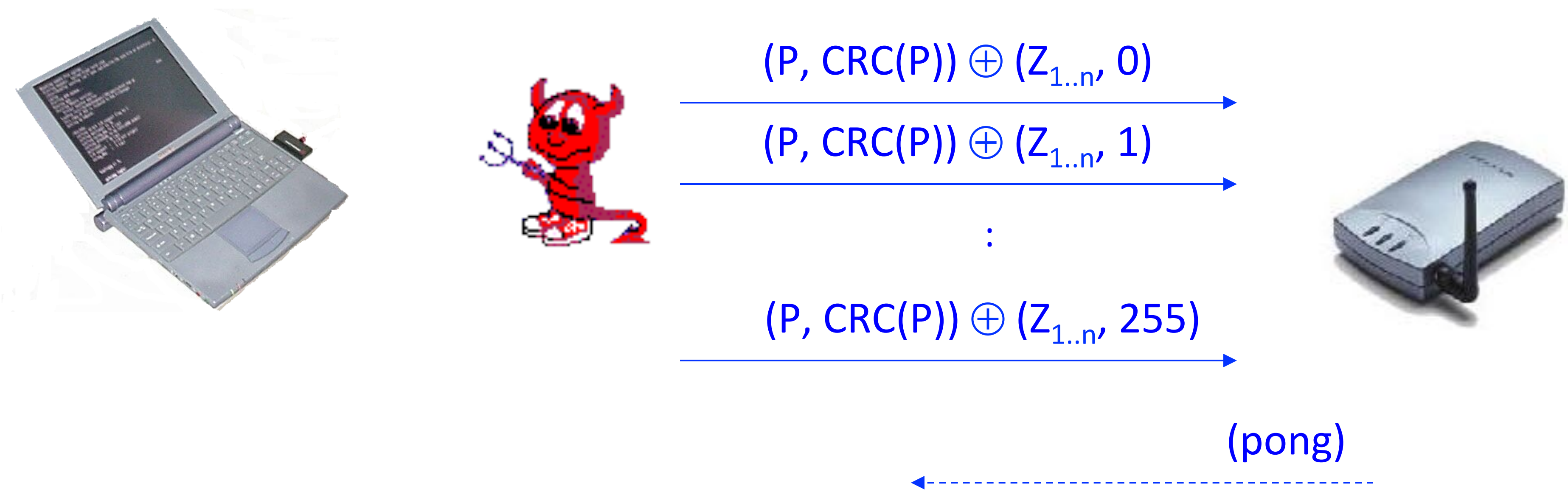
- Attackers can inject forged 802.11 traffic
  - Learn Z = RC4(K, IV) using previous attack
  - Since the CRC checksum is unkeyed, you can then create valid ciphertexts that will be accepted by the receiver

Attack #3: Packet Modification



- CRC is linear
  - ⇒ $CRC(P \oplus \Delta) = CRC(P) \oplus CRC(\Delta)$
    - ⇒ the modified packet ($P \oplus \Delta$) has a valid checksum
- ➤ Attacker can tamper with packet (P) without breaking RC4

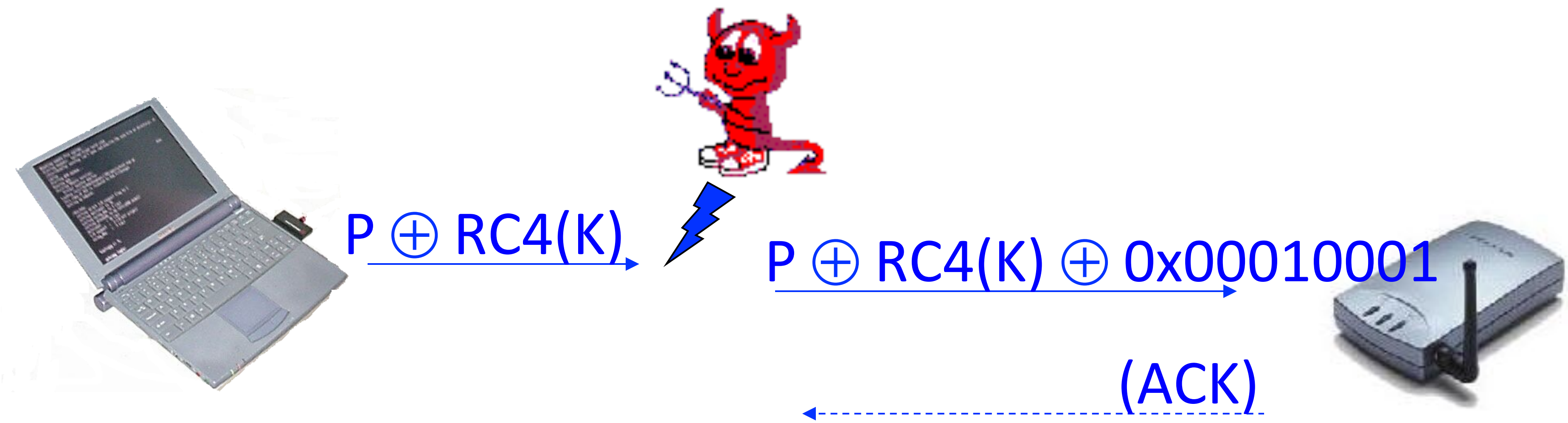
Attack #4: Inductive Learning



- Learn $Z_{1..n}$ = RC4(K, IV)$_{1..n}$ using previous attack
- Then guess Z_{n+1}; verify guess by sending a ping packet ((P, CRC(P))) of length n+1 and watching for a response
- Repeat, for n=1,2,…, until all of RC4(K, IV) is known

Credits: Arbaugh, et al.

Attack #5: Reaction Attacks



- TCP ACKnowledgement returned by recipient
  ⇔ TCP checksum on modified packet (P ⊕ 0x00010001) is valid
  ⇔ wt(P & 0x00010001) = 1

➤ Attacker can recover plaintext (P) without breaking RC4

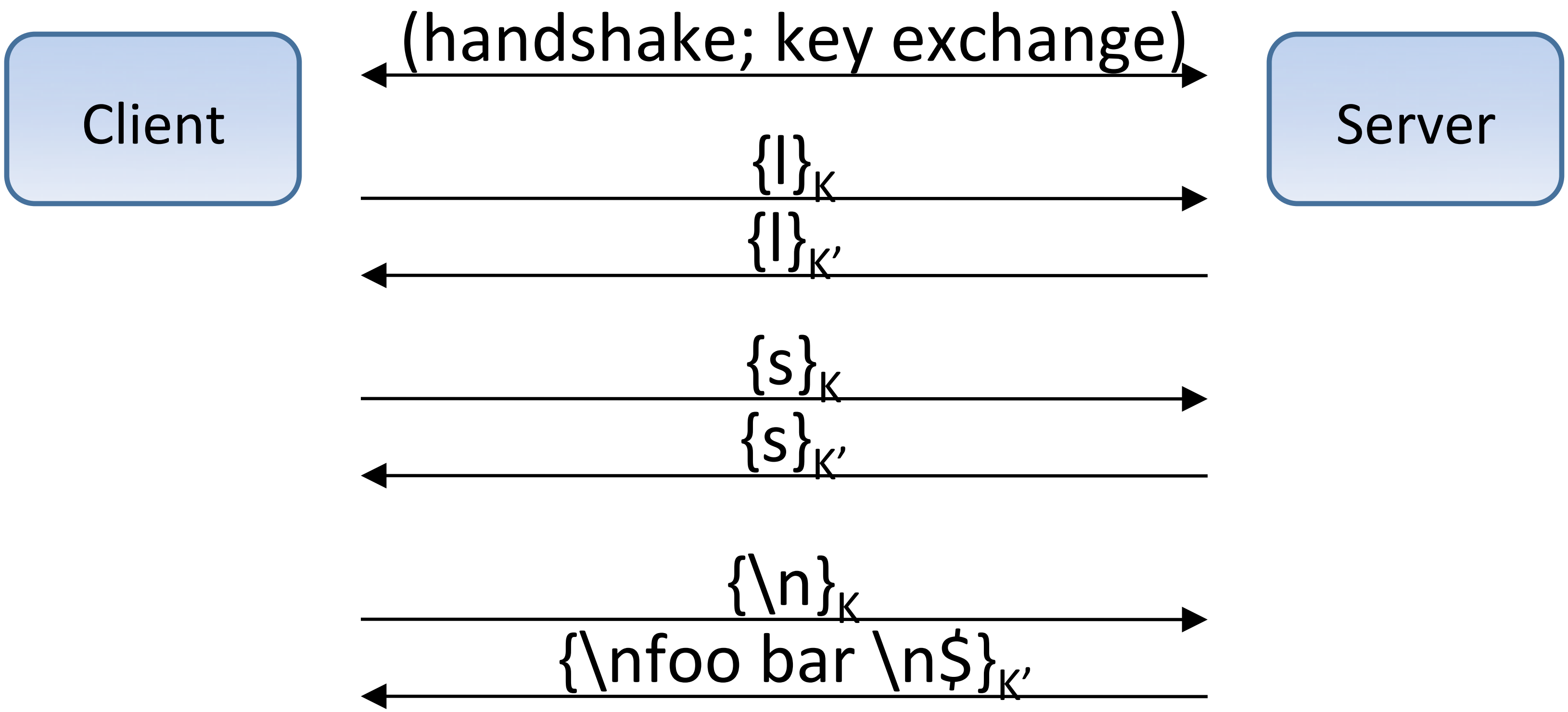
#7: Key Re-use

- Don’t re-use keys for both encryption and authentication.
- Don’t re-use keys for both encryption and signing.
- Don’t use same key for both directions.

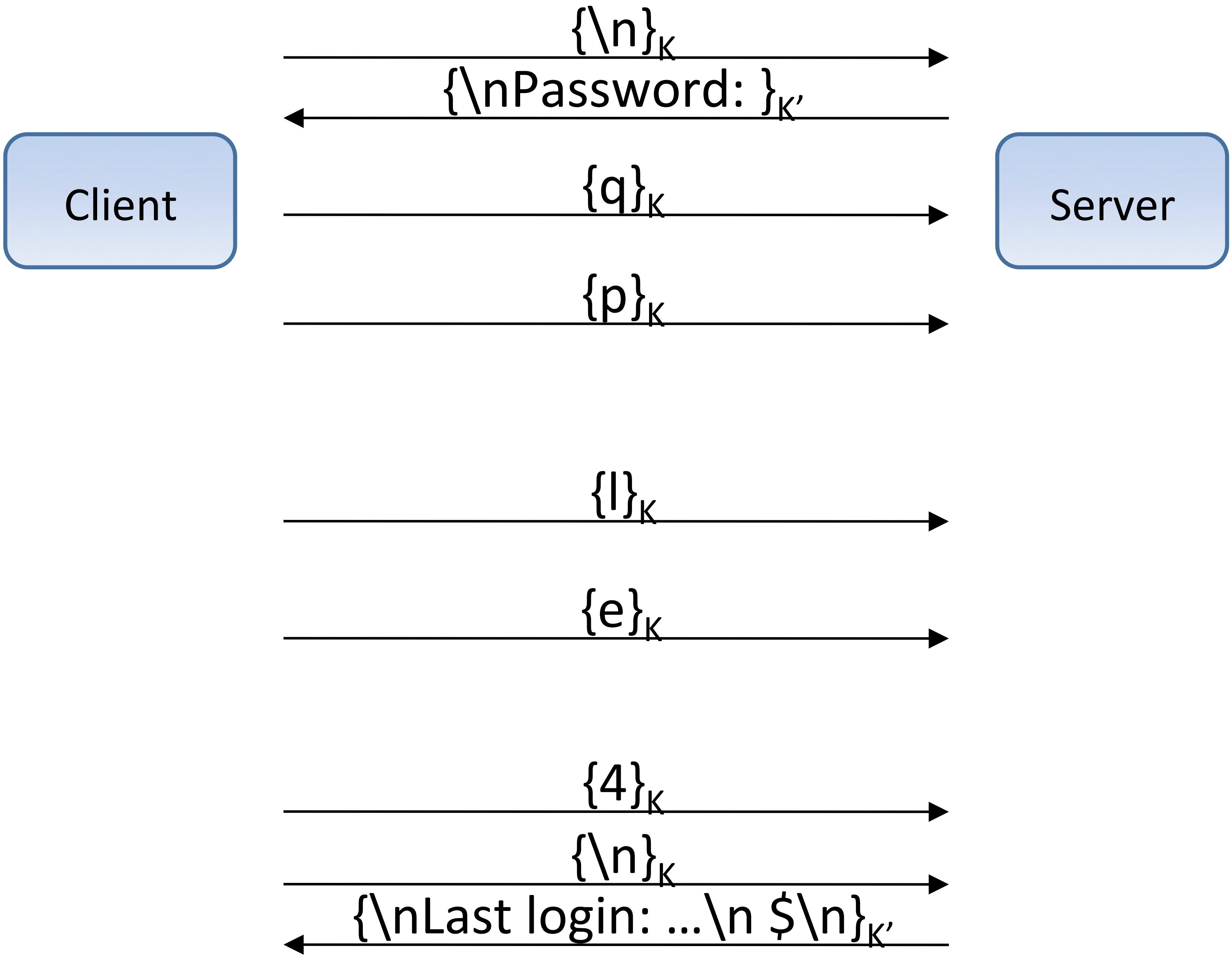
#8: Traffic Analysis is Still Possible

- Encryption doesn't hide sender, recipient, length, or time of message. ("meta-data")

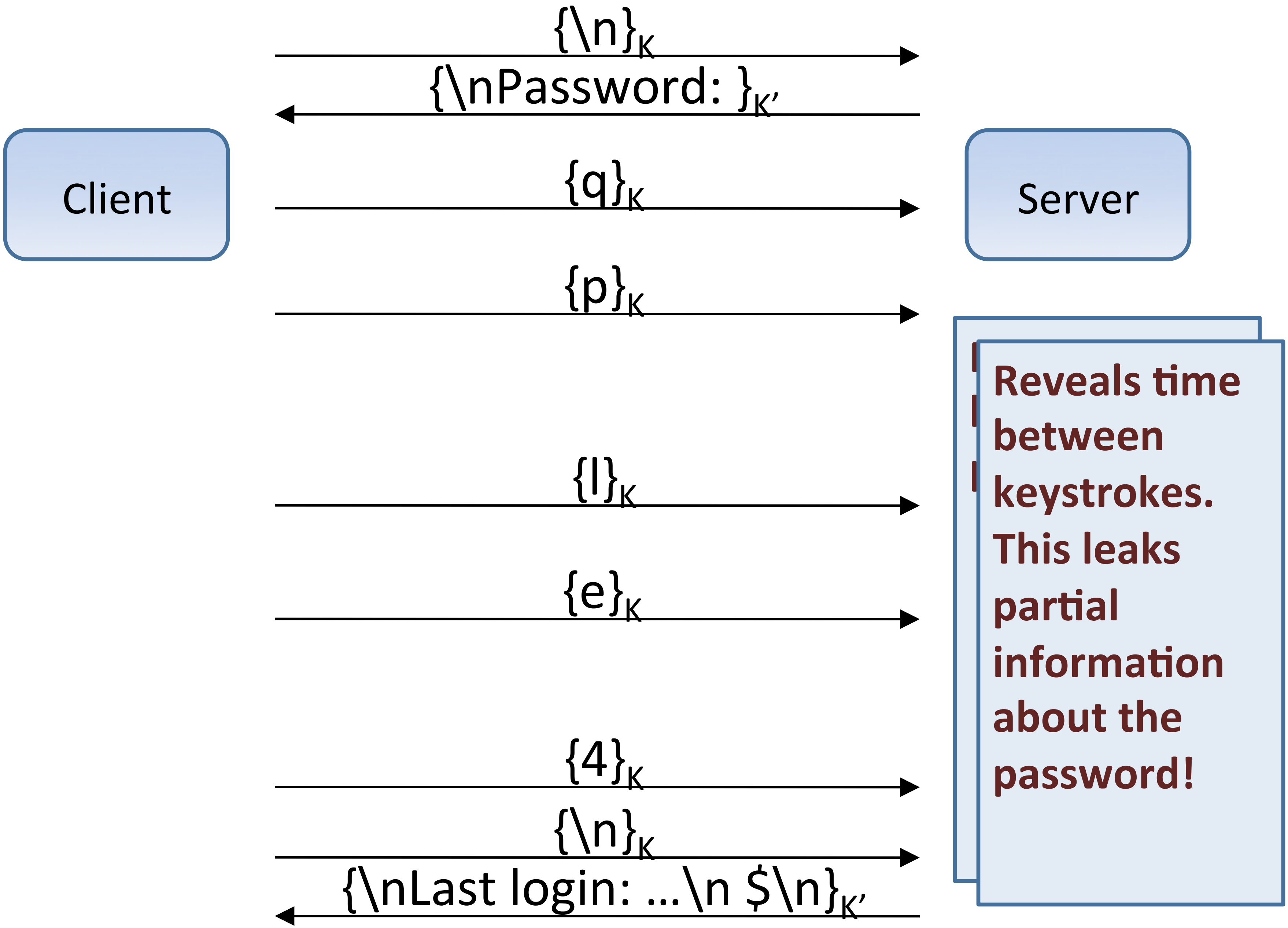
SSH


Client
Server
(handshake; key exchange)
{l}_K
{l}_K'
{s}_K
{s}_K'
{\n}_K
{\nfoo bar \n$}_K'

SSH



SSH



{\n}K
{\nPassword: }K'
Client
{q}K
Server
{p}K
{l}K
{e}K
{4}K
{\n}K
{\nLast login: …\n $\n}K'
Reveals time between keystrokes. This leaks partial information about the password!

Lessons Summarized

- Don’t design your own crypto algorithm.
- Use authenticated encryption (don’t encrypt without authenticating).
- Use crypto-quality random numbers.
- Don’t derive crypto keys from passphrases.
- Be secure by default.
- Be careful with concatenation.
- Don’t re-use nonces/IVs. Don’t re-use keys for multiple purposes.
- Encryption doesn’t prevent traffic analysis (“metadata”).

Meta-Lessons

- Cryptography is hard.
- Hire an expert, or use an existing system (e.g., SSL, SSH, PGP).
- But: Most vulnerabilities are in applications and software, not in crypto algorithms.

Securing Internet Communication: TLS

CS 161: Computer Security

Prof. David Wagner

April 7, 2013

Today's Lecture

- Applying crypto technology in practice
- Goal #1: overview of the most prominent Internet security protocol
  - SSL/TLS: transport-level (process-to-process) on top of TCP
    - Secures the web via HTTPS
- Goal #2: cement understanding of crypto building blocks & how they're used together

Building Secure End-to-End Channels

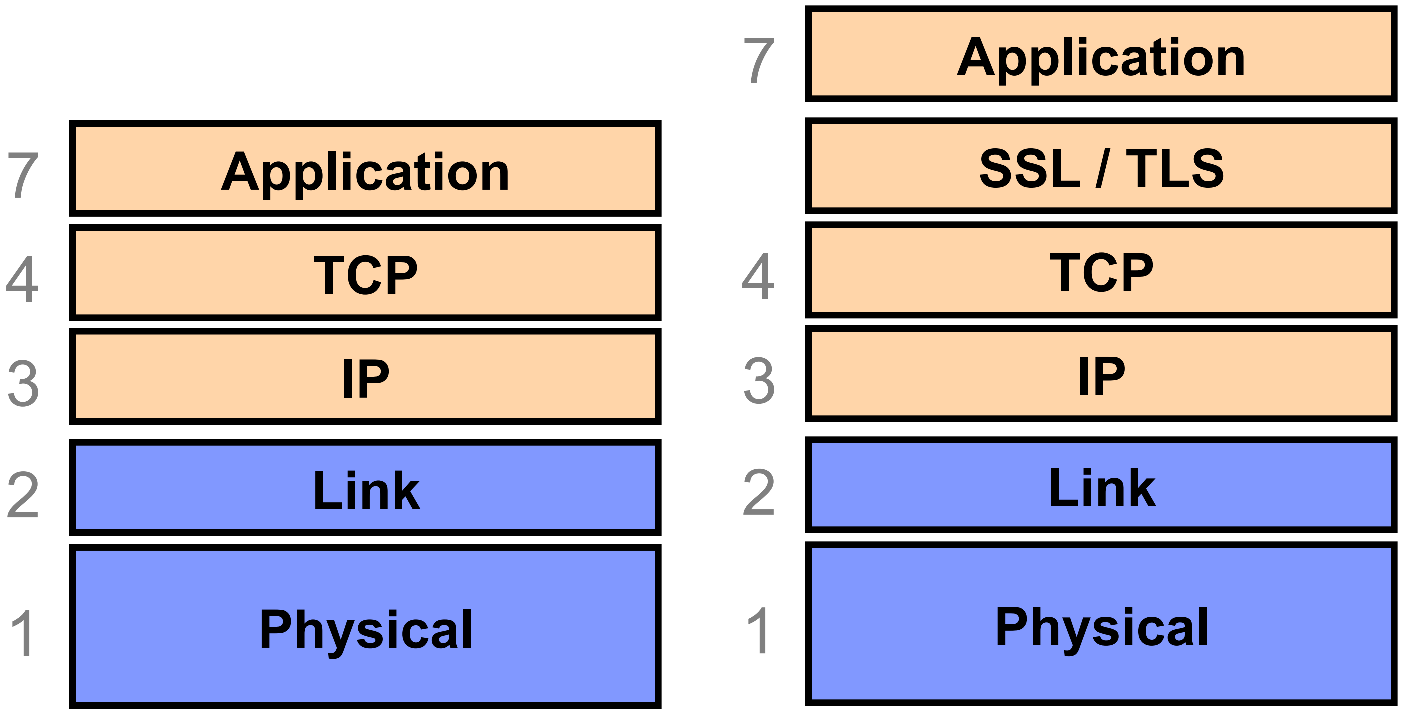
- *End-to-end* = communication protections achieved all the way from originating client to intended server
  - With no need to trust intermediaries
- Dealing with threats:
  - Eavesdropping?
    - Encryption (including session keys)
  - Manipulation (injection, MITM)?
    - Integrity (use of a MAC); *replay protection*
  - Impersonation?
    - Signatures

(What's missing?
Availability …)

Building A Secure End-to-End Channel: SSL/TLS

- SSL = *Secure Sockets Layer* (predecessor)
- TLS = *Transport Layer Security* (standard)
  - Both terms used interchangeably
- Notion: provide means to secure *any* application that uses TCP

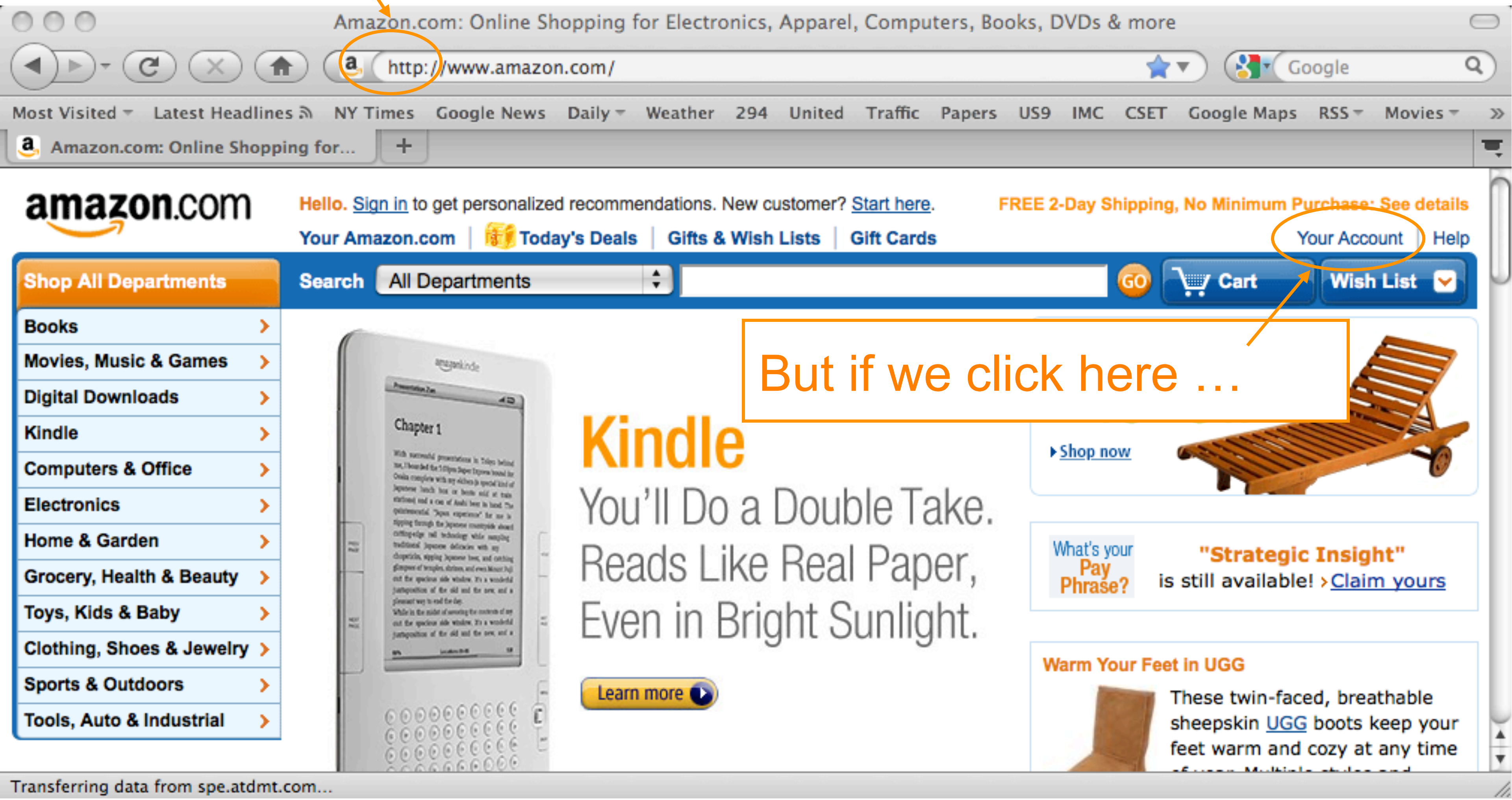
SSL/TLS In Network Layering



Building A Secure End-to-End Channel: SSL/TLS

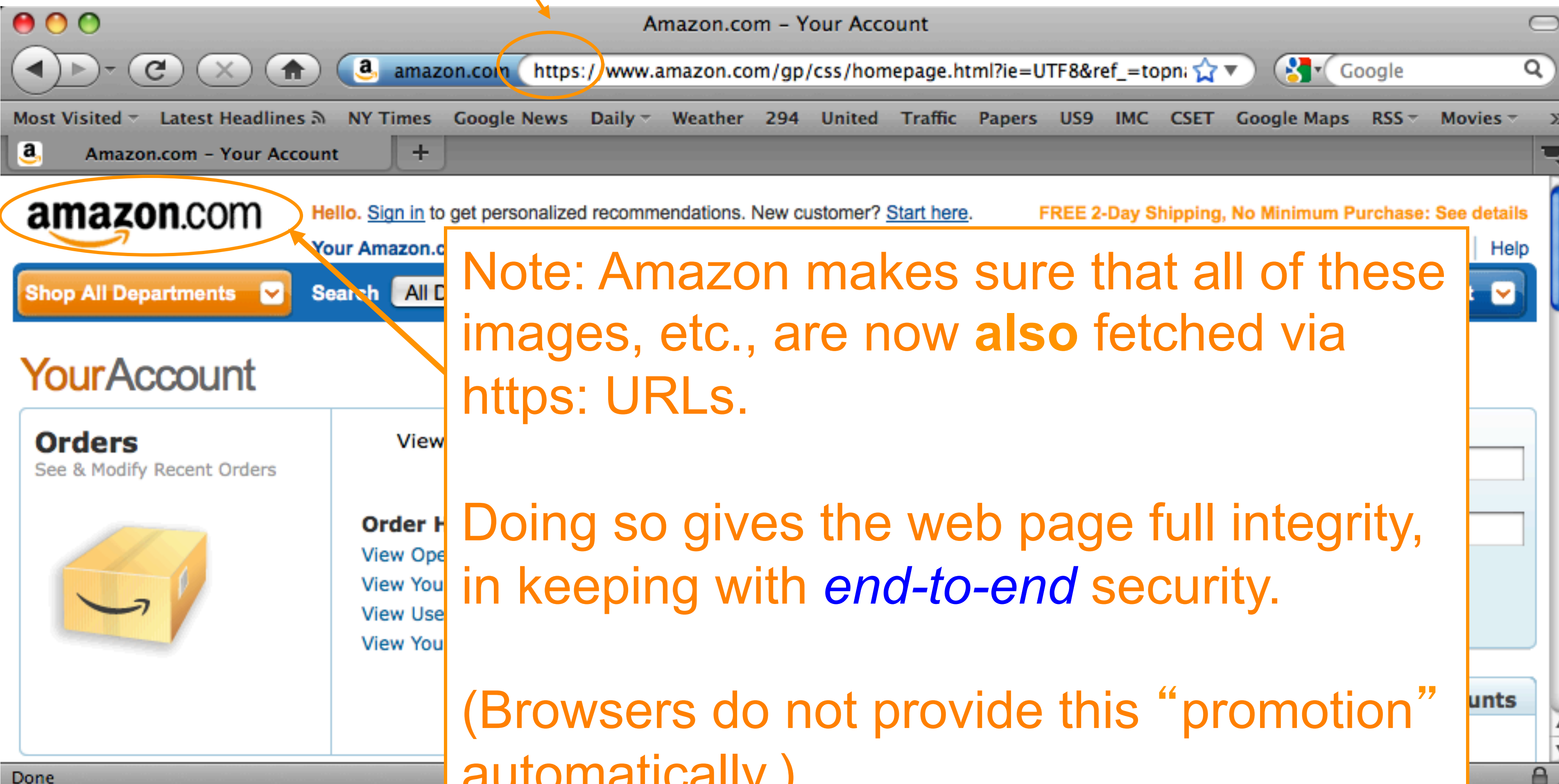
- SSL = *Secure Sockets Layer* (predecessor)
- TLS = *Transport Layer Security* (standard)
  - Both terms used interchangeably
- Notion: provide means to secure *any* application that uses TCP
  - Secure = encryption/confidentiality + integrity + authentication (of server, but *not* of client)
  - E.g., puts the ‘s’ in “https”

Regular web surfing - http: URL



But if we click here …

Web surfing with TLS/SSL - https: URL



Note: Amazon makes sure that all of these images, etc., are now **also** fetched via https: URLs.

Doing so gives the web page full integrity, in keeping with *end-to-end* security.

(Browsers do not provide this "promotion" automatically.)

Basic idea

- Browser (client) picks some symmetric keys for encryption + authentication
- Client sends them to server, encrypted using RSA public-key encryption
- Both sides send MACs
- Now they use these keys to encrypt and authenticate all subsequent messages, using symmetric-key crypto