CMSC388N:

Build It, Break It, Fix It: Competing to Secure Software

Lecture 2 - Networking and Other Stuff

Prof. Daniel Votipka

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(some slides courtesy of Micah Sherr and Michael Hicks)

COMPUTER SCIENCE
UNIVERSITY OF MARYLAND

The Plan

- Administrivia
- Project specification updates
- Networking
- Scanning and Parsing
- Project submission (and git) demo
- In-class build time! (maybe)

Administrivia

- Each team should all have…
  - …access to umdcmsc388n.slack.com with a channel per team
  - …a team repo on gitlab.cs.umd.edu
- Daily status reports start today: ter.ps/388Nreport

Project Specification Updates

Problem Spec Update

- Passwords
- Access control
- Assume network is secure

Passwords

```
as principal admin password "admin" do
   create principal bob “B0BPWxxd"
   change password admin “BetterPassword”
   set rule too_hot if temperature >= 80 then set air_conditioning = 2
   activate rule too_hot
   set delegation air_conditioning admin read -> bob
   return temperature.0
***
```

Access Control - Grammar

<prim_cmd> ::=

create principal *p s*

| **change password** *p s*

| **set** *x* **=** <expr>

| **local set** *x* **=** <expr>

| **if** <cond> **then** <prim_cmd>

| **set delegation** <tgt> *q* <right> **->** *p*

| **delete delegation** <tgt> *q* <right> **->** *p*

| **default delegator** *p*

| **print** <expr>

| **set rule** *x* = **if** <cond> **then** <prim_cmd>

| **activate rule** x

| **deactivate rule** x

<tgt> ::= **all** | *x*

<right> ::= **read** | **write** | **delegate** | **toggle**

Access Control - Language Description

set *x* **=** <expr>

Sets *x*'s value to the result of evaluating <expr>, where *x* is a variable. If *x* does not exist this command creates it. If *x* is created by this command, and the current principal is not admin, then the current principal is delegated **read**, **write**, and **delegate** rights from the admin on *x* (equivalent to executing **set delegation** *x* admin **read** **->** *p* and **set delegation** *x* admin **write** **->** *p*, etc. where *p* is the current principal).

Failure conditions:

Fails or exhibits security violation if evaluating <expr> does

Fails if *x* is already set to a rule

Security violation x exists and the current principal does not have **write** permission on *x*. (DENIED_WRITE)

Successful status code: SET

Access Control - Enforcement

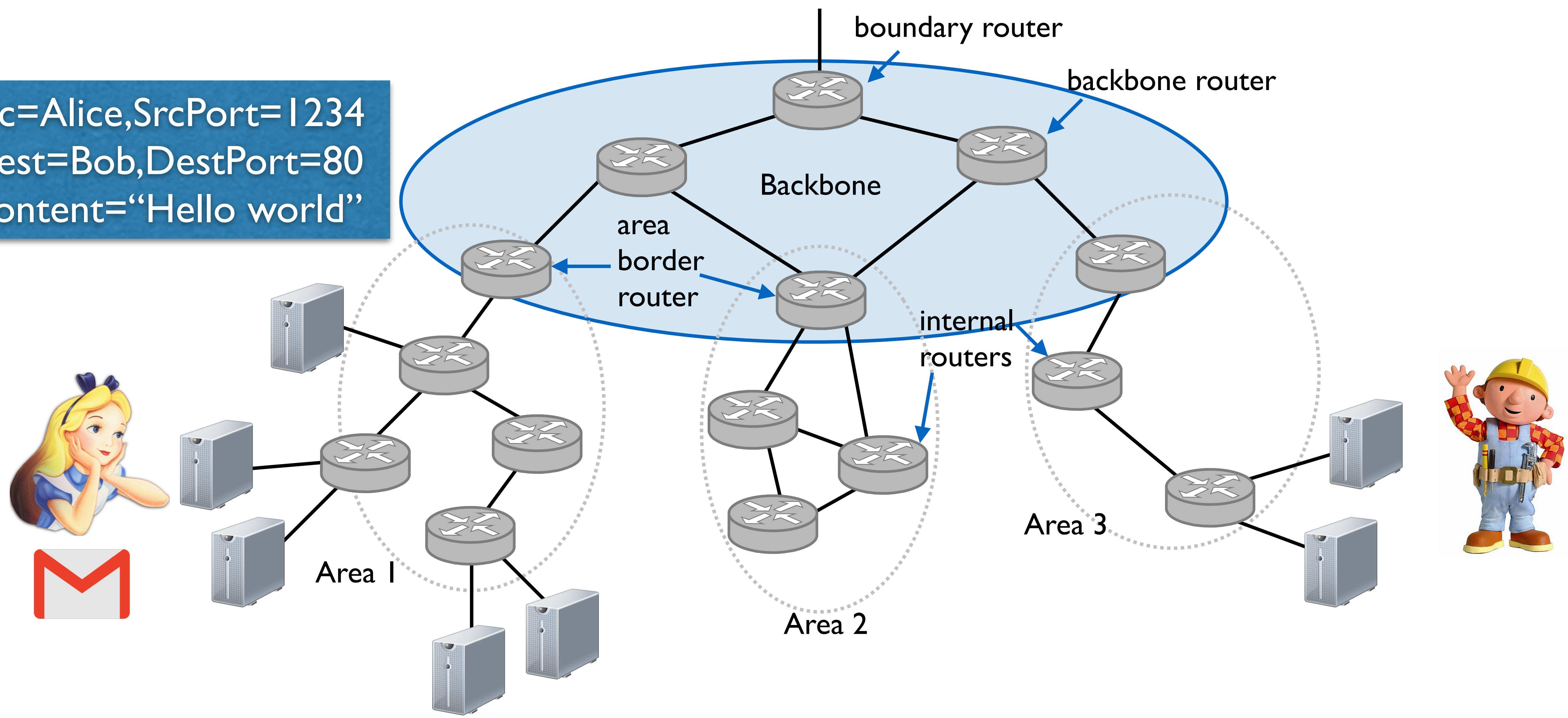
1. *Admin* has <right> on *x* (for all rights <right> on variables *x**)
2. A principal *p* has <right> on *x* if principal *anyone* has <right> on *x*.
3. A principal *p* has <right>on *x* if there exists some *q* that has <right> on *x* and $\mathbf{S_d}$ includes a delegation assertion *q x <right> -> p*.

Networking
(Abbreviated)

What is the Internet?

A collection of independently operated *autonomous systems (ASes)*

Src=Alice,SrcPort=1234
Dest=Bob,DestPort=80
Content="Hello world"



Network Programming

(aka Sockets)

- The operating system provides an *interface* for sending/receiving network packets
- A ***socket*** is a descriptor for network communication
- As a client, you ***connect*** your socket to a remote host, and read/write to that socket as you would a file
- As a server, you ***listen*** and ***accept*** incoming connections, and read/write to that socket as you would a file
- read()/recv() is a blocking operation; to wait for input from multiple sources, use ***select***

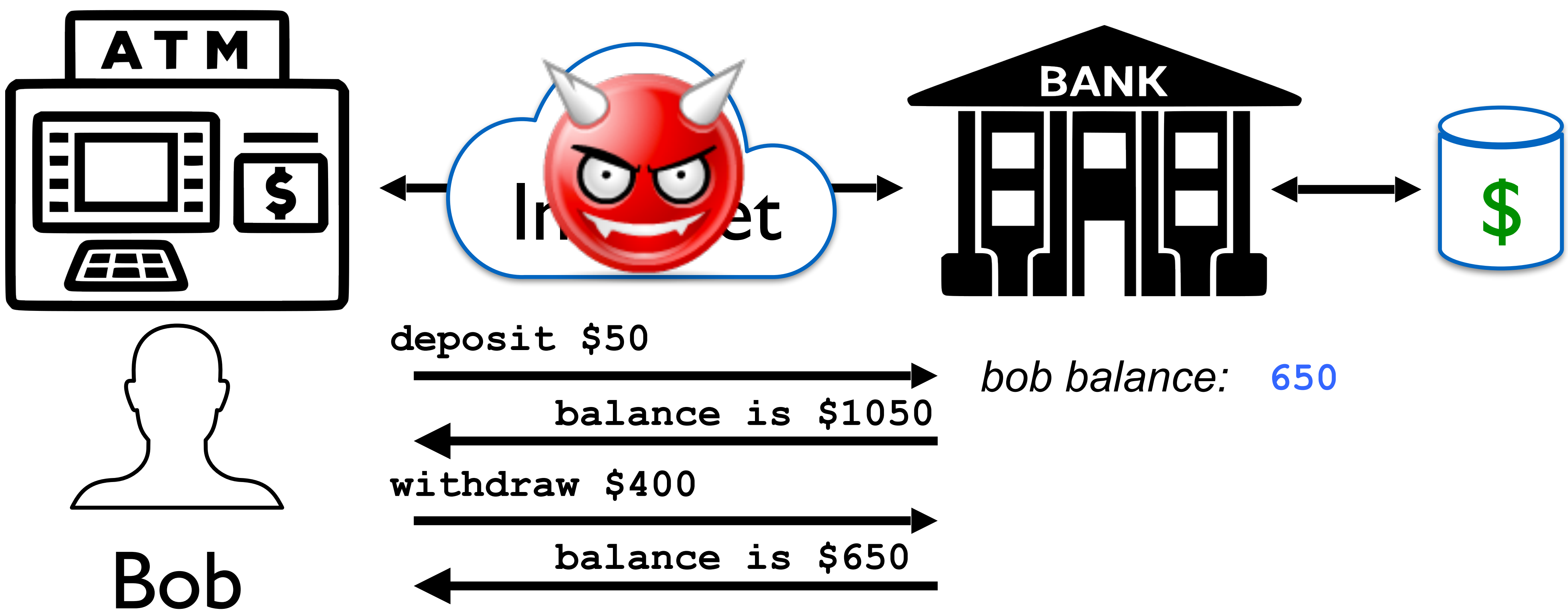
Select example

myselect.py

```python
import socket,select

listen_socket = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
listen_socket.bind(('', 9998))
listen_socket.listen(10)
client_sockets = []                         # an empty list

while True:
    read_list = [listen_socket] + client_sockets
    (ready_read,_,_) = select.select(read_list,[],[])

    for sock in ready_read:
        if sock is listen_socket:
            new_conn, addr = sock.accept()  # accept the connection
            client_sockets.append(new_conn)
        else:
            data = sock.recv(1024)          # read up to 1K of data
            if data != "":                  # the connection is open
                sock.send("Go away.\n")     #   I'm not very nice
            else:                           # the connection is closed
                client_sockets.remove(sock)
                sock.close()
```

U:--- myselect.py All (7,0) (Py Outl)

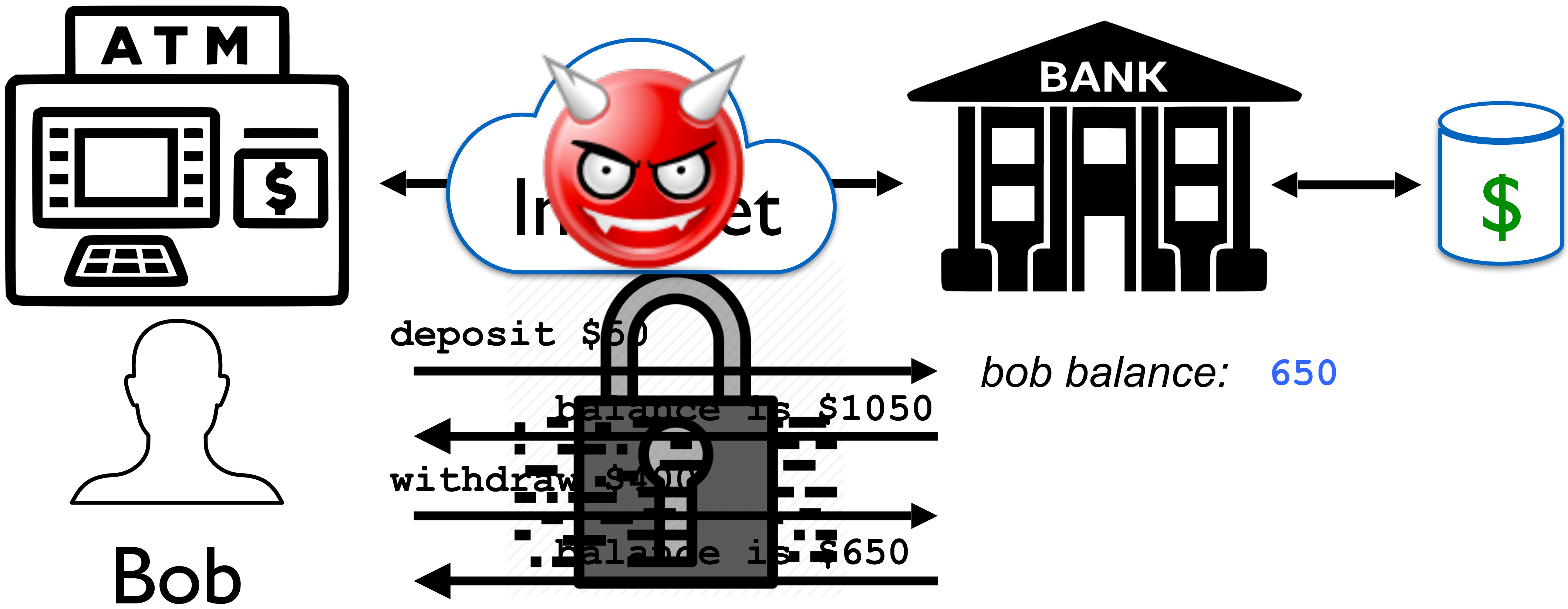
What can go wrong?



Man-in-the Middle can…

- …listen in
- …change data
- …replay

What should we do?



Man-in-the Middle can…

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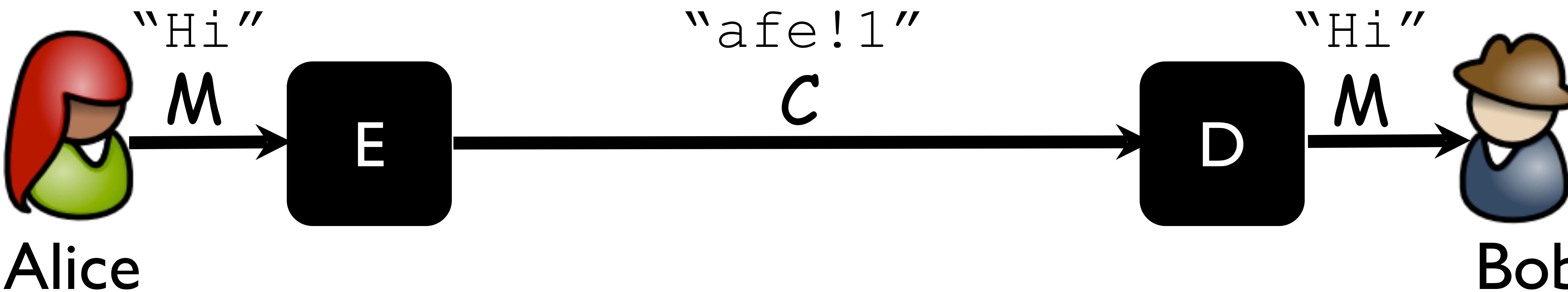
Encryption and Decryption

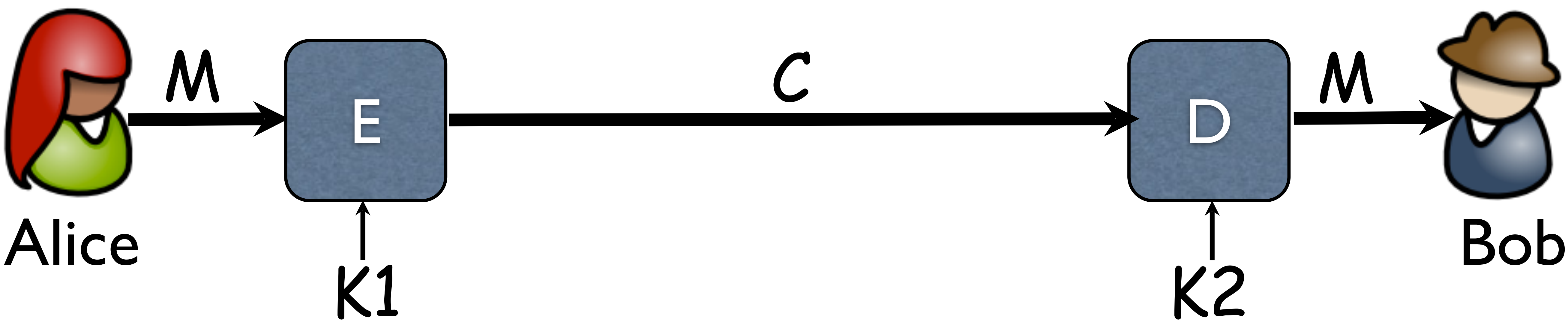


C=E(M)
M=D(C)
i.e.,
M=D(E(M))

where

M = plaintext
C = ciphertext
E(x) = encryption function
D(y) = decryption function

Symmetric and Asymmetric Crypto



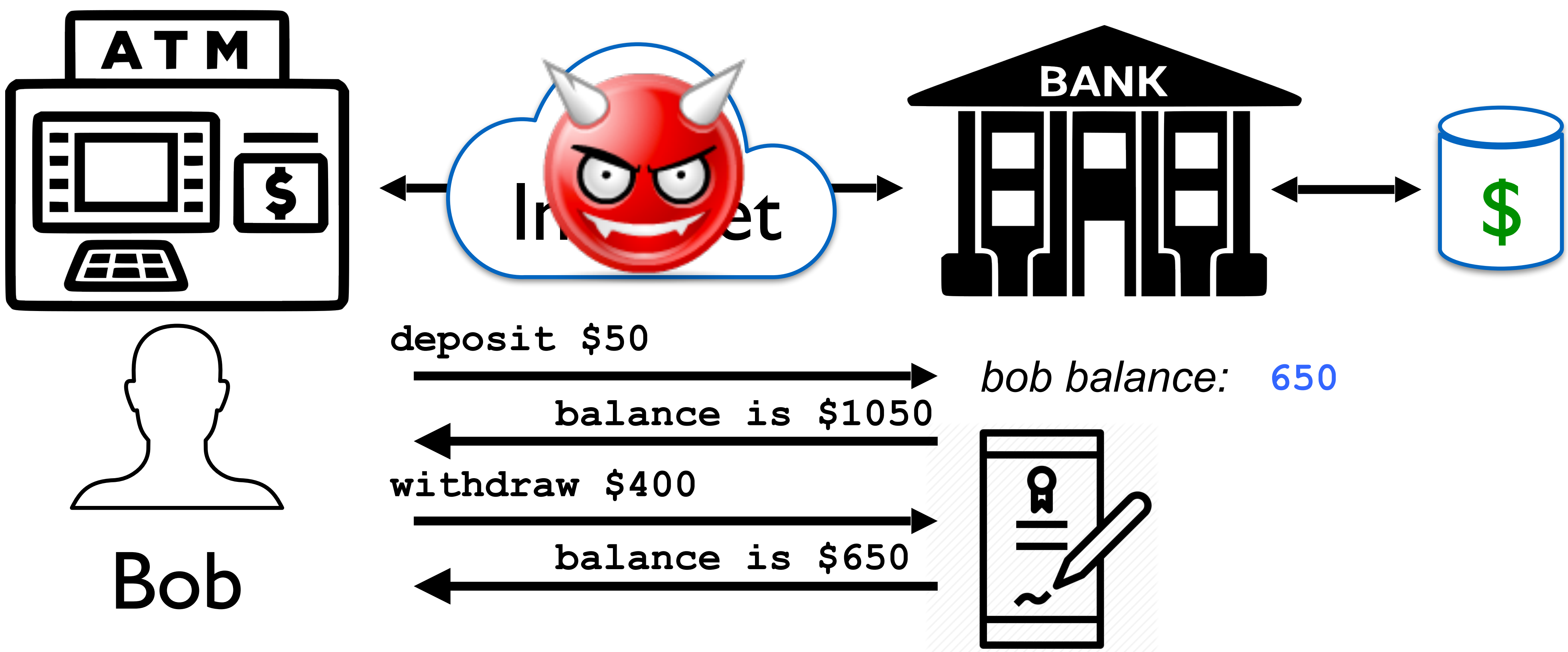
- **Symmetric crypto:** (also called **private key crypto**)
  - Alice and Bob share the same key (K=K1=K2)
  - K used for both encrypting and decrypting
  - Doesn't imply that encrypting and decrypting are the same algorithm
  - Also called **private key** or **secret key** cryptography, since knowledge of … t
- **Asymmetric crypto:** (also called **public key crypto**)
  - Alice and Bob have different keys
  - Alice encrypts with K1 and Bob decrypts with K2
  - Also called **public key** cryptography, since Alice and Bob can publicly post their *public* keys

AES, Triple DES

NIST Approved

RSA, ECDSA

What should we do?



Man-in-the Middle can…

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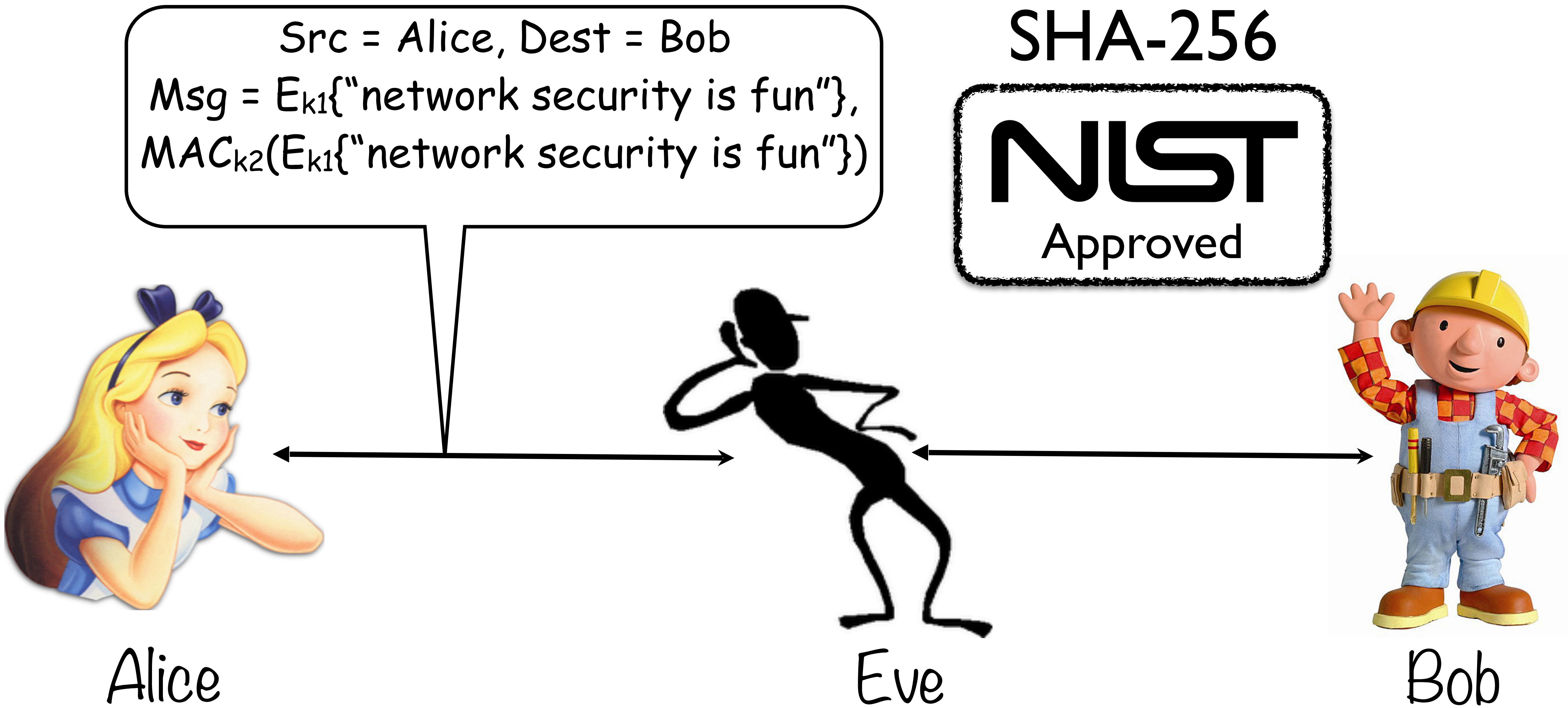
Message Authentication Code

RSA Digital Signature

Message Authentication Codes (MACs)

- MACs provide message **integrity** and **authenticity**
- $MAC_K(M)$ – use symmetric encryption to produce short sequence of bits that depends on both the message (M) and the key (K)
- MACs should be resistant to **existential forgery**: Eve should not be able to produce a valid MAC for a message M' without knowing K
- To provide confidentiality, authenticity, and integrity of a message, Alice sends
  - $E_K(M, MAC_K(M))$ where $E_K(X)$ is the encryption of X using key K; or
  - $E_K(M), MAC_K(E_K(M))$
  - Proves that M was encrypted (confidentiality) by someone who knew K (authenticity) and hasn't been changed (integrity)

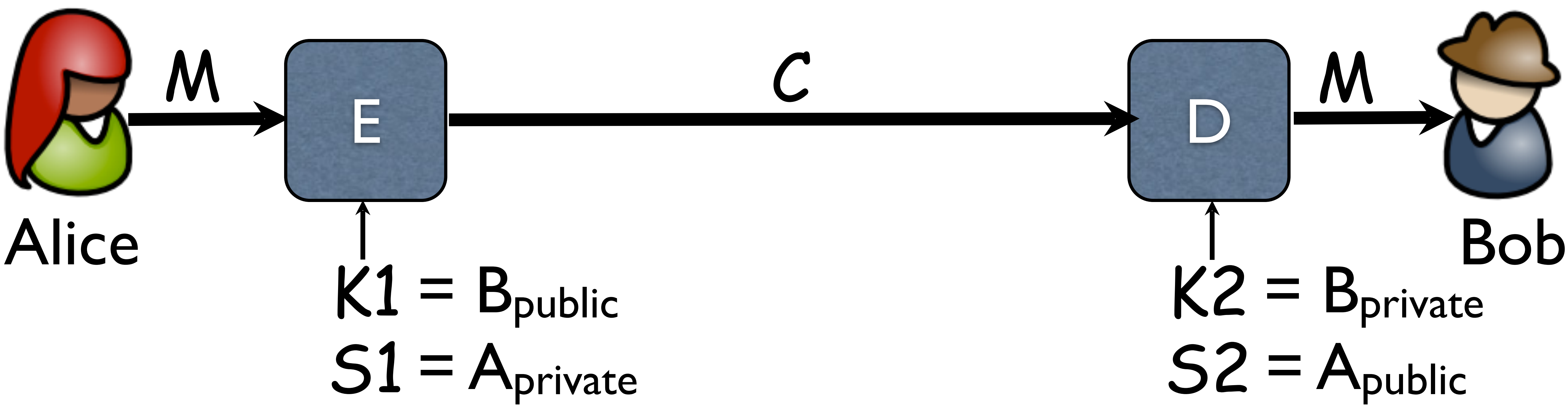
Encryption and Message Authenticity



Without knowing *k1*,
Eve can't read Alice's message.

Without knowing *k2*, Eve can't compute a valid MAC for her forged message!

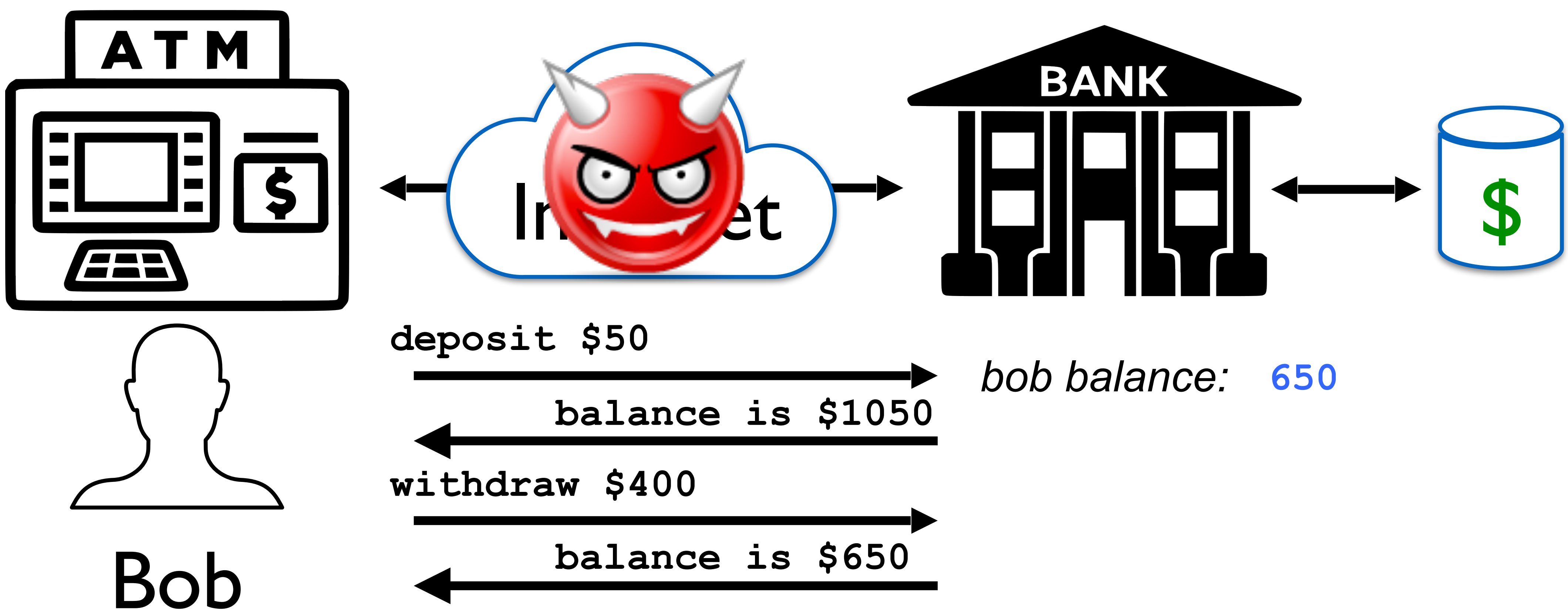
Asymmetric Crypto



RSA, ECDSA

NIST Approved

What should we do?



Man-in-the Middle can…

- …listen in
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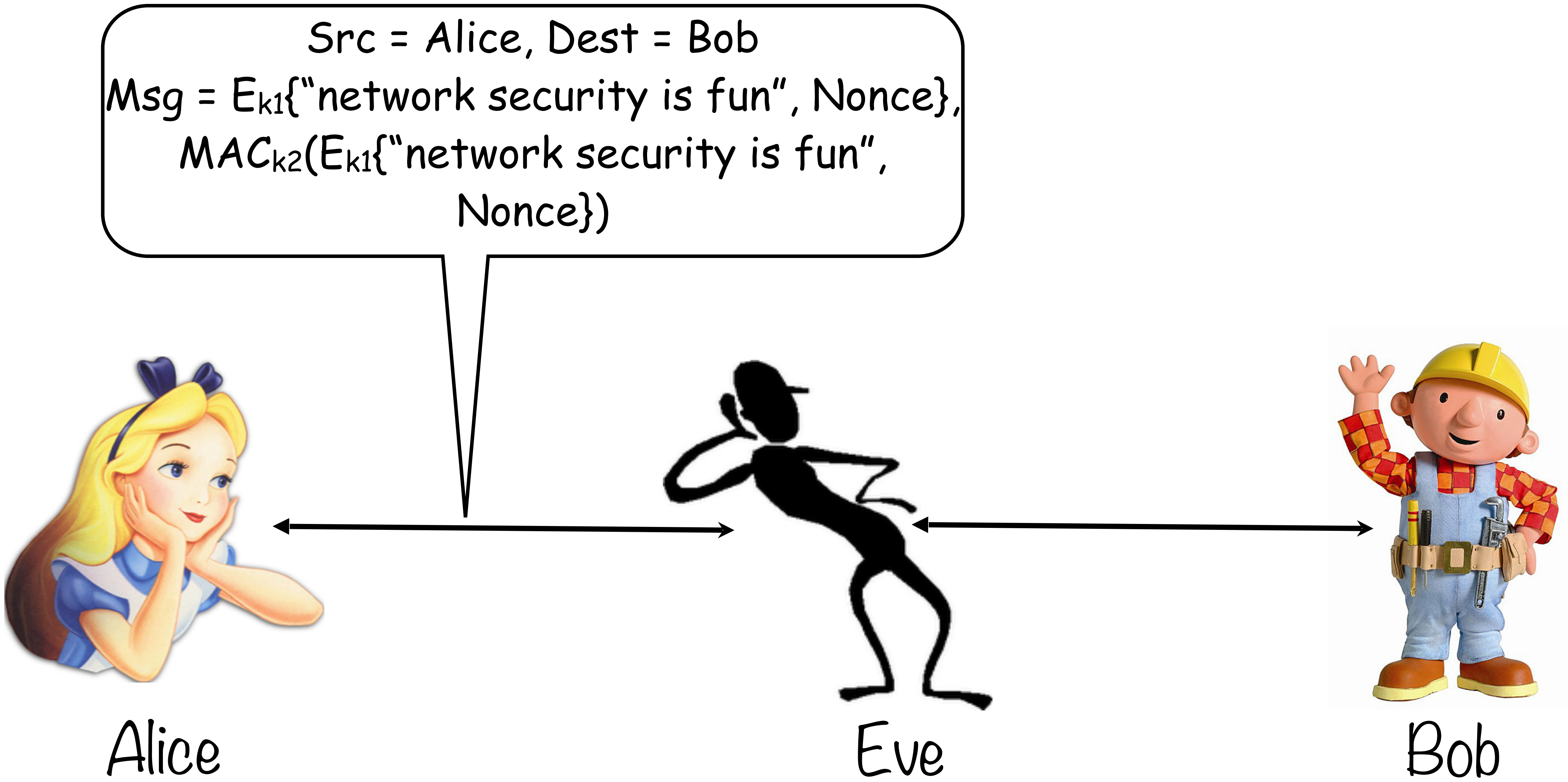
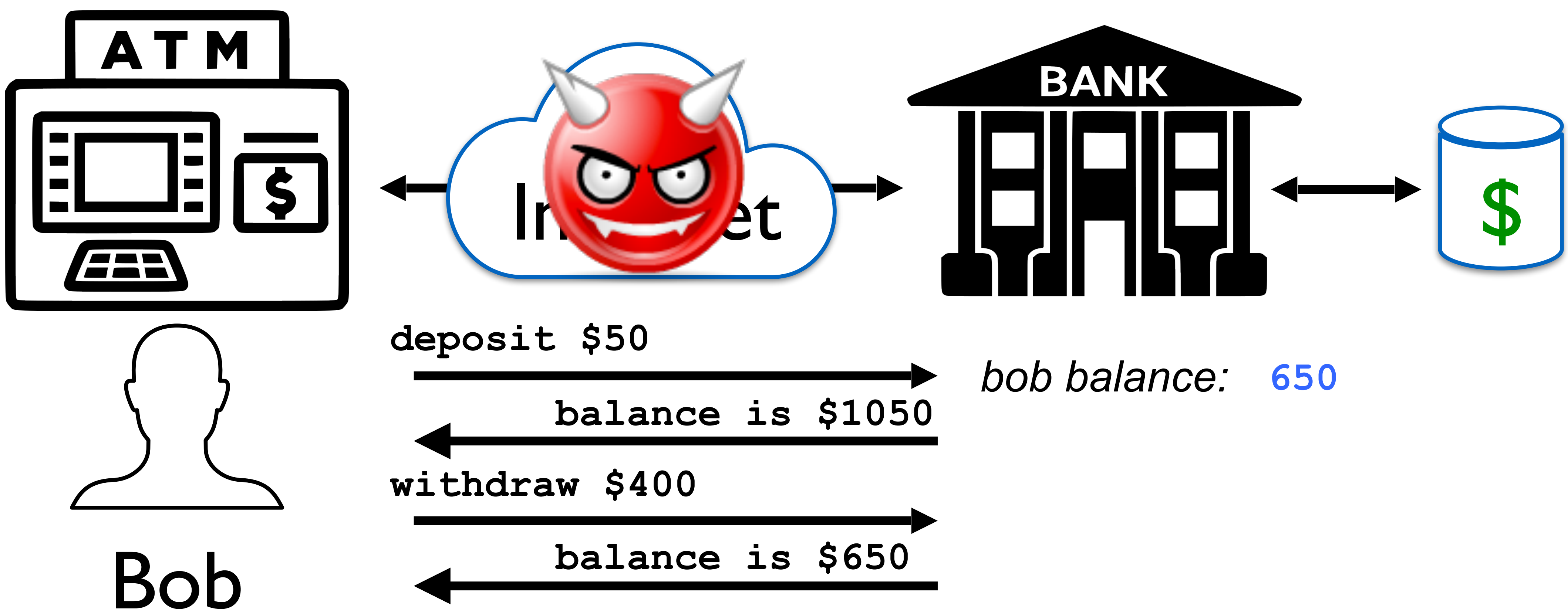
- …replay

Nonces!

Nonces


Src = Alice, Dest = Bob
Msg = E_{k1}{“network security is fun”, Nonce},
MAC_{k2}(E_{k1}{“network security is fun”,
Nonce})
Alice
Eve
Bob

What should we do?



Man-in-the Middle can…

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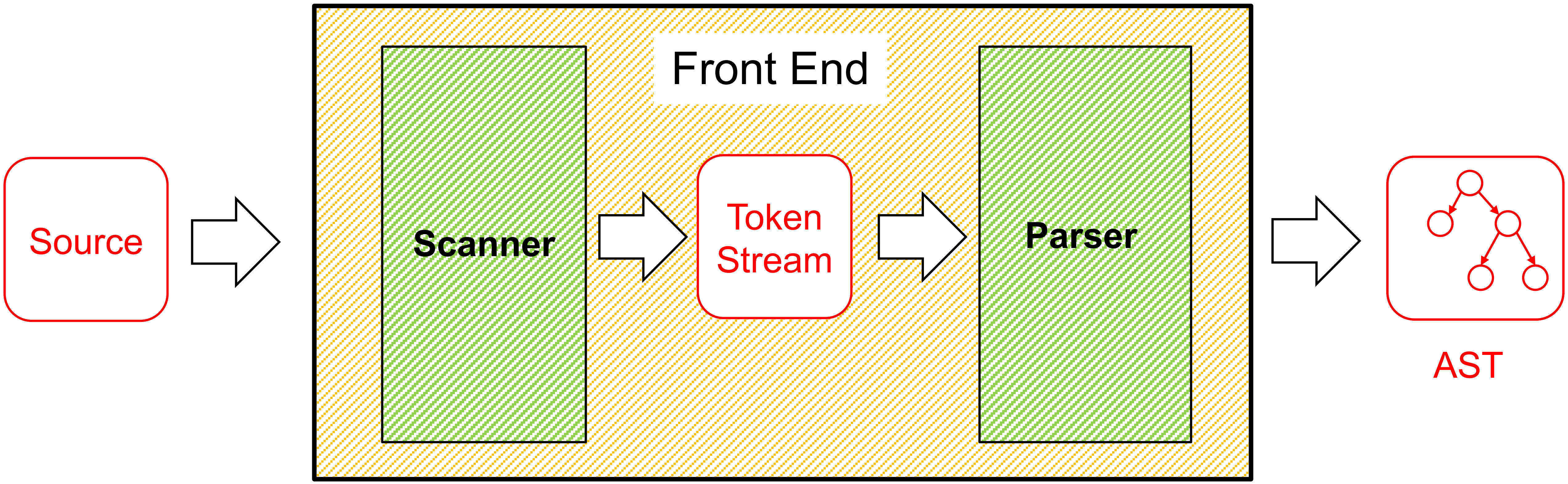
TLS and PKI

Scanning and Parsing

(Abbreviated)

Scanner and Parser



- Scanner / lexer / tokenizer converts program source into tokens (keywords, variable names, operators, numbers, etc.) with regular expressions
- Parser converts tokens into an AST (abstract syntax tree) based on a context free grammar (CFG)

Scanning (“tokenizing”)

Converts textual input into a stream of tokens

- These are the terminals in the parser’s CFG
- Example tokens are keywords, identifiers, numbers, punctuation, etc.

Tokens determined with regular expressions

- Identifiers match regexp [a-zA-Z_][a-zA-Z0-9_]*
- Non-negative integers match [0-9]+
- Etc.

Scanner typically ignores/eliminates whitespace

Implementing Parsers

Many efficient techniques for parsing

- LL(k), SLR(k), LR(k), LALR(k)…
- Take CMSC 430 for more details

One simple technique: recursive descent parsing

- This is a top-down parsing algorithm

Other algorithms are bottom-up

Recursive Descent - Intuition

Non-terminal

Terminal

$E \rightarrow$ id = n | { L }
$L \rightarrow$ E ; L | ε

(Assume: id is variable name, n is integer)

Show parse tree for
{ x = 3 ; { y = 4 ; } ; }

lookahead

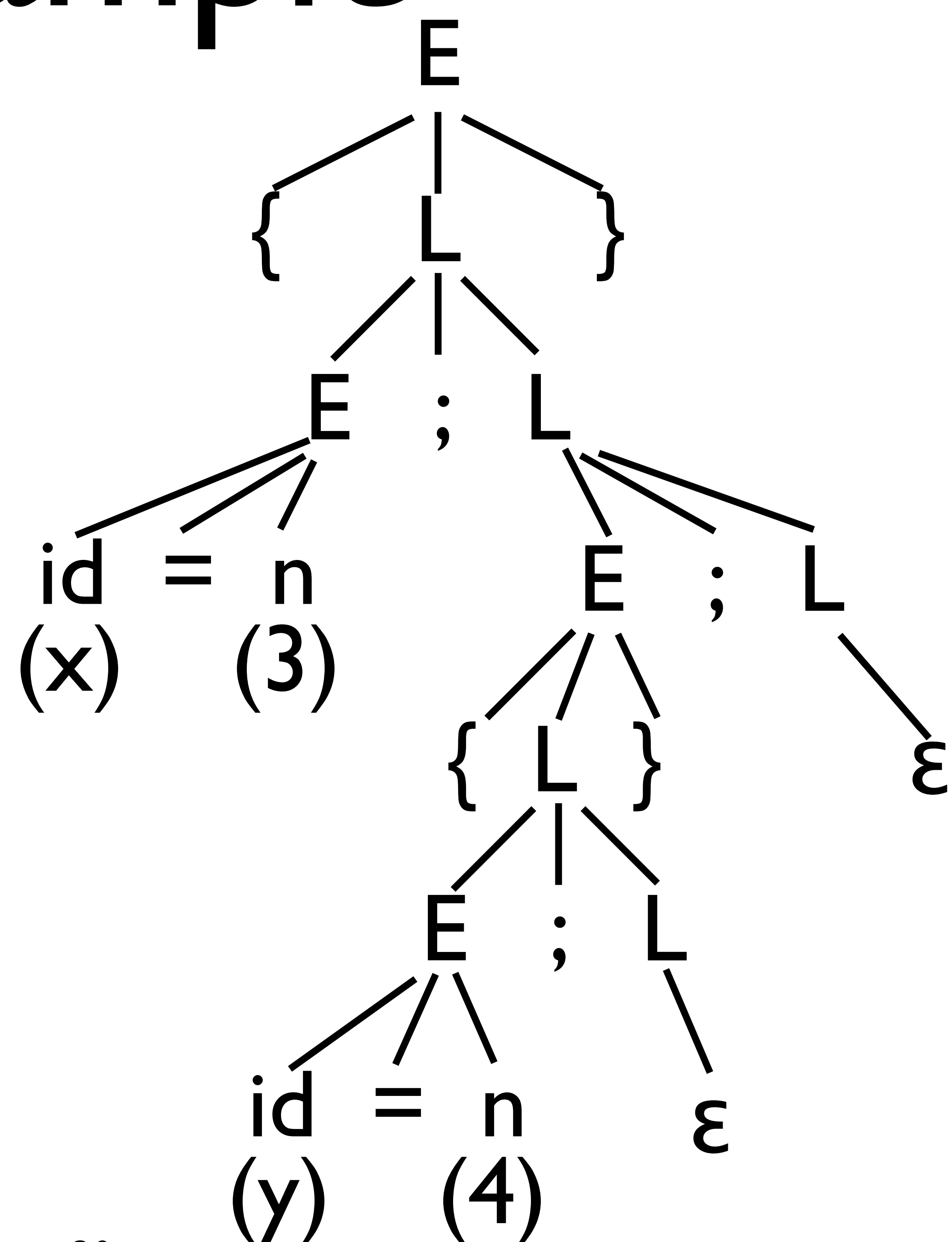
Start at the top, try productions in order

Recursive Descent - Example

$E \rightarrow id = n \mid \{ L \}$
$L \rightarrow E \; ; \; L \mid \varepsilon$

(Assume: id is variable name, n is integer)

Show parse tree for
{ x = 3 ; { y = 4 ; } ; }



Recursive Descent

At each step, we'll keep track of two facts

- What grammar element are we trying to match/expand?
- What is the lookahead (next token of the input string)?

At each step, apply one of three possible cases

- If we're trying to match a terminal
  - If the lookahead is that token, then succeed, advance the lookahead, and continue
- If we're trying to match a nonterminal
  - Pick which production to apply based on the lookahead
- Otherwise fail with a parsing error

Additional Material

- Video series by Alex Aiken
  - https://www.youtube.com/playlist?list=PLDcmCgguL9rxPoVn2ykUFc8TOpLyDU5gx
  - 6.3 - Recursive Descent Overview
  - 6.4 - Recursive Descent Implementation
  - Other parsing algorithms
- Parsing slides by Michael Hicks (CMSC 330)
  - http://www.cs.umd.edu/class/spring2019/cmsc330/lectures/04-parsing.pdf

Project Submission Demo

Summary

- Project Specification Updates
  - Passwords
  - Access Control
  - Network is secure!
- Networking basics
  - Socket programming tutorials on website
- Scanning and Parsing basics
  - Additional materials on website
- Project submission demo
- Daily status reports start today: ter.ps/388Nreport

JSON, git, and Socket tutorials on course website

In-class Build Time!

- Divide up into teams and spread out
  - You can leave this room, but stay on this floor
  - Send us a message in Slack with where you go
- Some possible-todos:
  - Merge design documents
  - Discuss logistics
    - Ex: language, libraries, divide-and-conquer vs. pair programming
  - Start writing code!
- Instructors will come around to talk