

Link layer security

CS642:

Computer Security



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Announcements

- Reminder: homework 1 due Thursday at midnight
 - If you can't get an exploit working, give a nice write-up about the vulnerability and your exploit attempt for partial credit
- Projects:
 - 1 page (or less!) proposal for project
 - Due November 1st
 - Undergrads can do for extra credit

Announcements

- Projects:
 - 1 page (or less!) proposal for project
 - Due November 1st
 - Undergrads can do for extra credit
- Proposal should be a short abstract
 - Use latex, turn in a PDF
 - Come up with a title for your project (bonus points if it is clever)
 - 1 paragraph introducing topic area
 - 1 paragraph on what you're going to do

Getting started on network security



Internet protocol stack

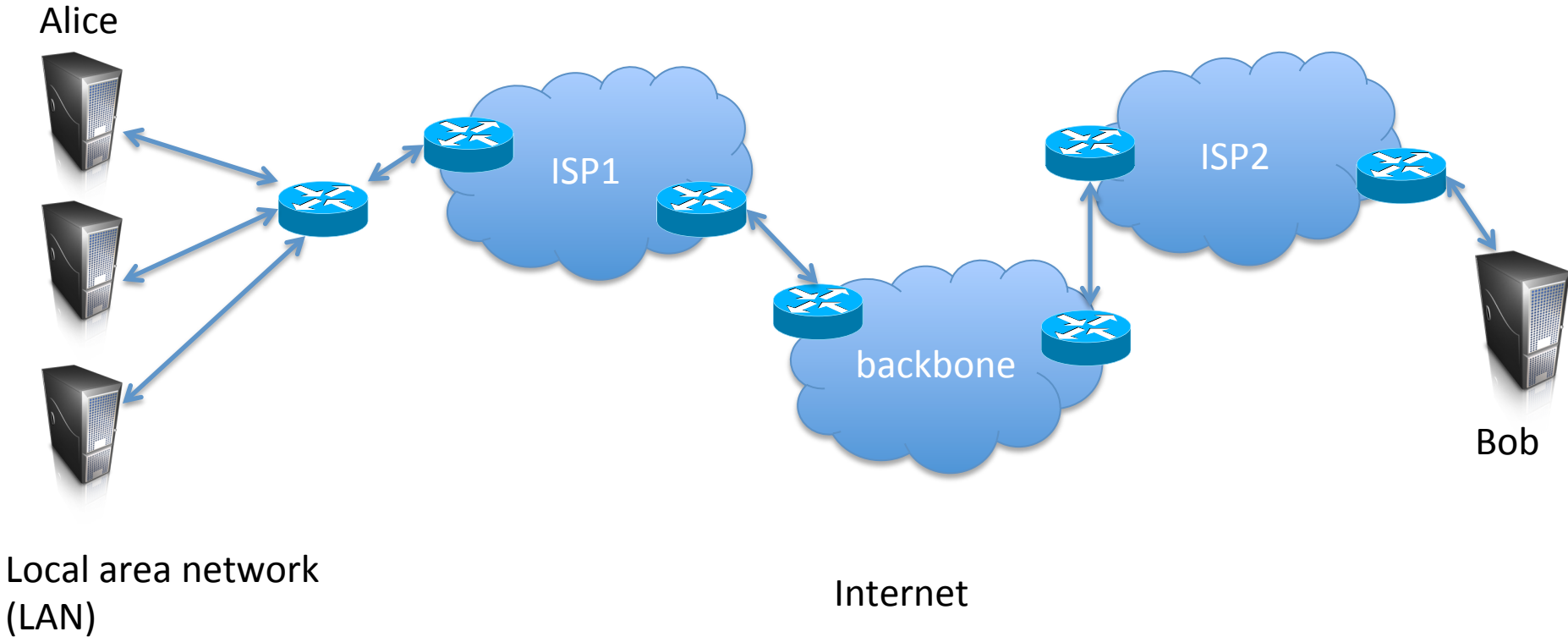
Man-in-the-middle

Address resolution protocol and
ARP spoofing

802.11

Jamming and MITM prevention

Internet



Ethernet

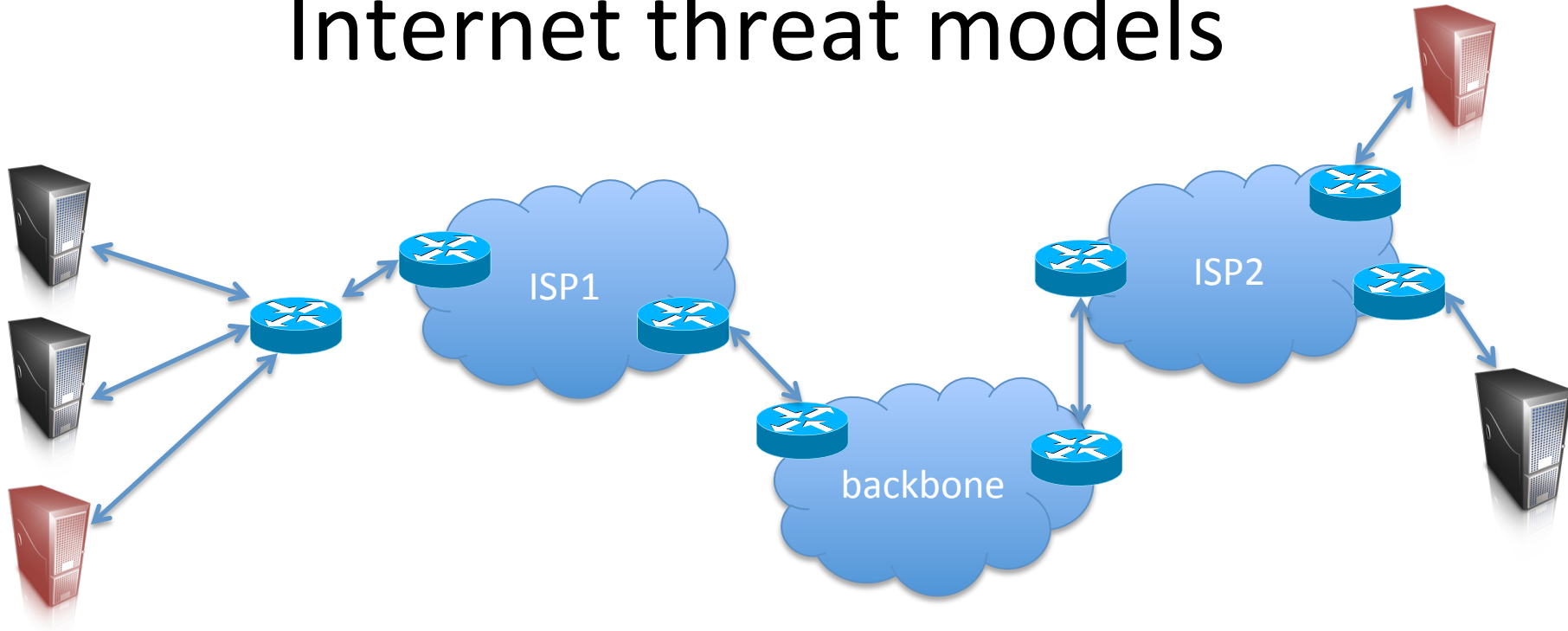
802.11

TCP/IP

BGP (border gateway protocol)

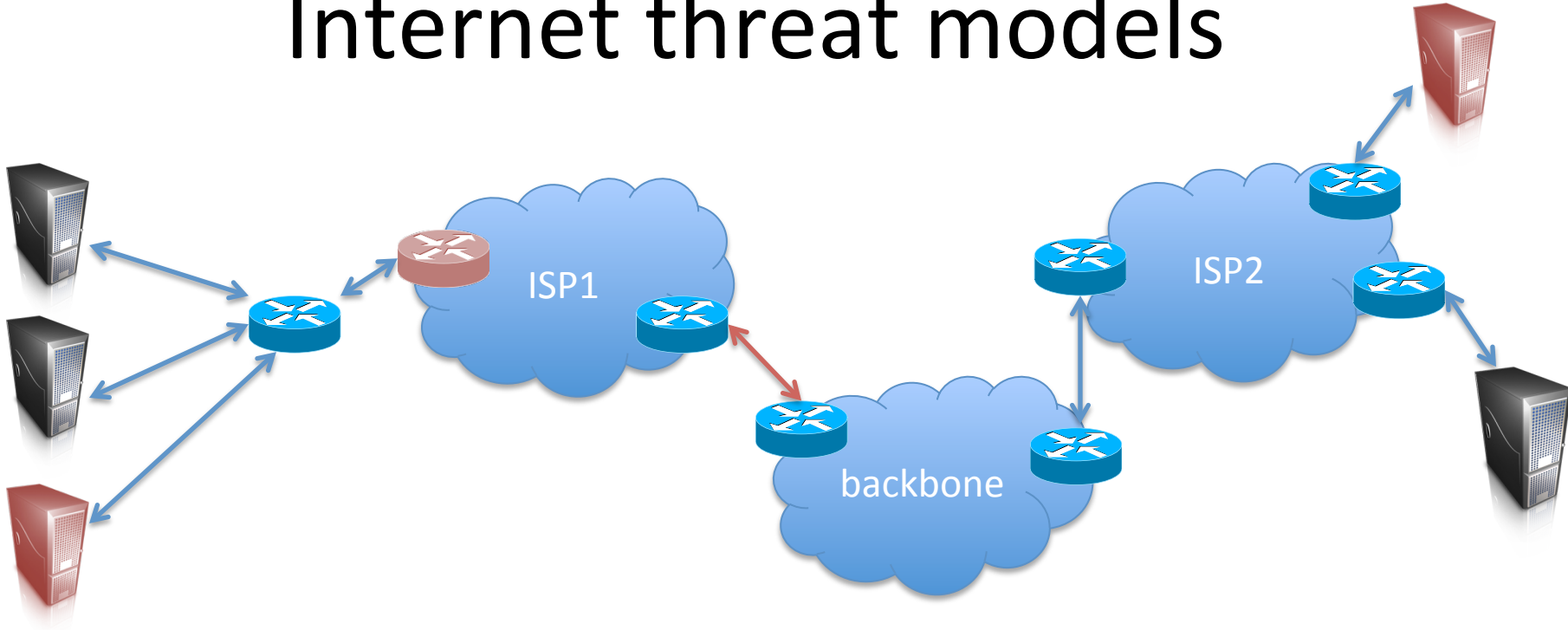
DNS (domain name system)

Internet threat models



(1) Malicious hosts

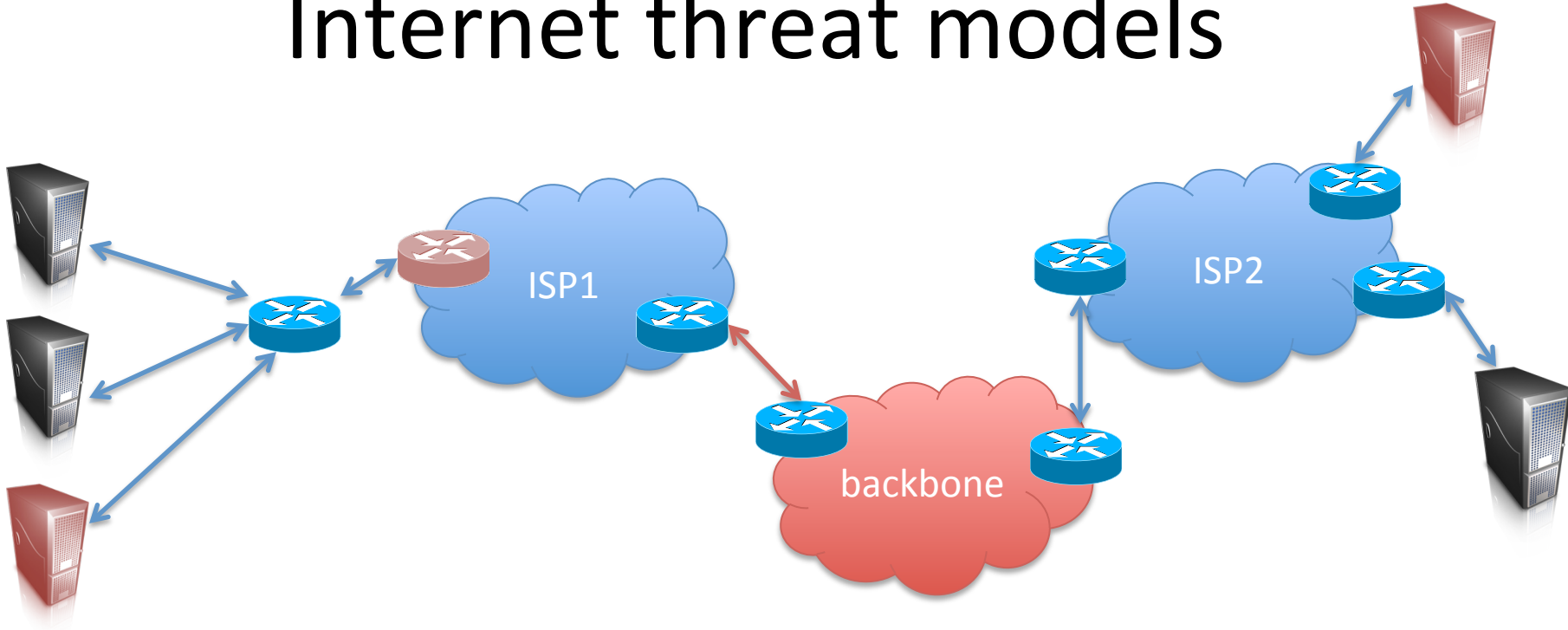
Internet threat models



(1) Malicious hosts

(2) Subverted routers or links

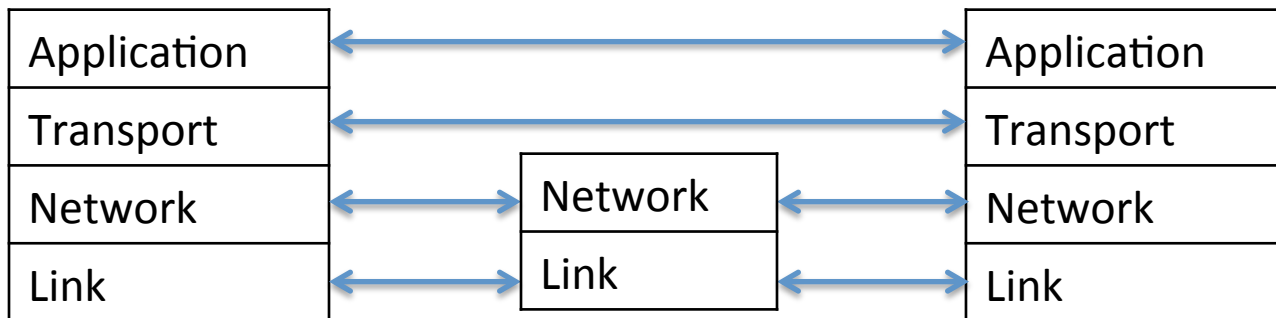
Internet threat models



- (1) Malicious hosts
- (2) Subverted routers or links
- (3) Malicious ISPs or backbone

Internet protocol stack

Application	HTTP, FTP, SMTP, SSH, etc.
Transport	TCP, UDP
Network	IP, ICMP, IGMP
Link	802x (802.11, Ethernet)

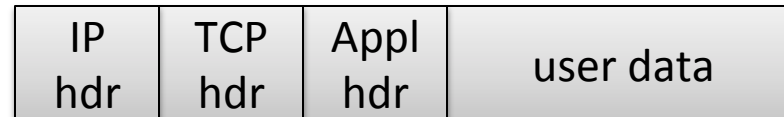


Internet protocol stack

Application
TCP
IP
Ethernet



TCP segment



IP datagram



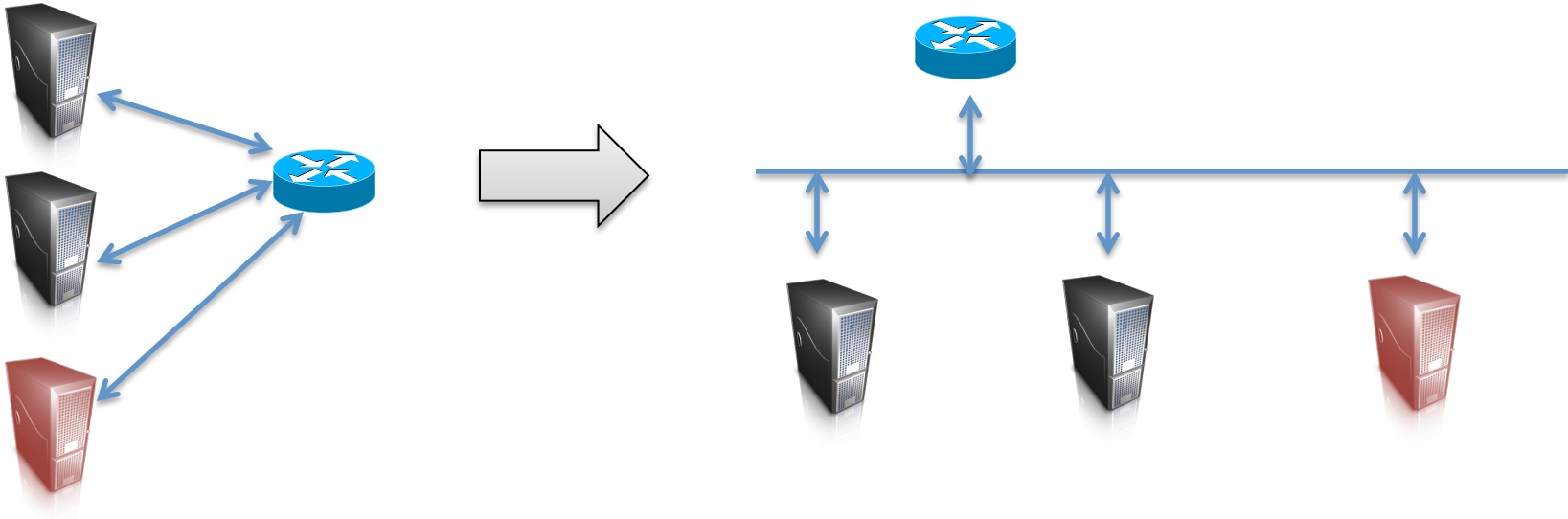
Ethernet frame

14 20 20



46 to 1500 bytes

Ethernet



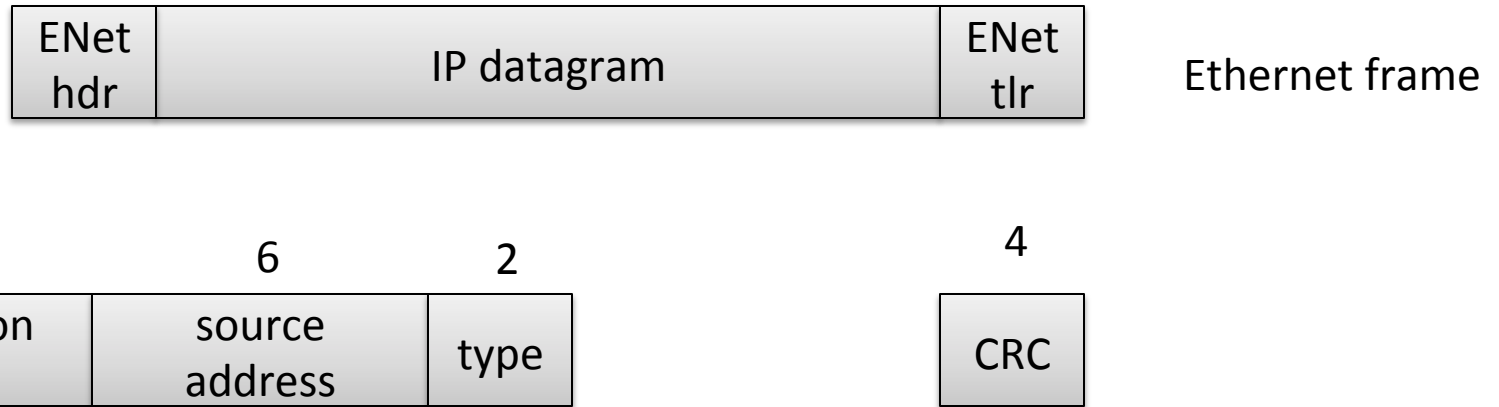
Carrier Sense, Multiple Access with Collision Detection (CSMA/CD)

Take turns using broadcast channel (the wire)

Detect collisions, jam, and random backoff

Security issues?

Ethernet



Media access control (MAC) addresses 48 bits

Type = what is data payload (0x0800 = IPv4, 0x0806 = ARP, 0x86DD = IPv6)

32 bit Cyclic Redundancy Check (CRC) checksum

802.2 LLC frame format slightly different, but similar ideas

MAC addresses

- Two types: universally or locally administered



- 2 LSBs of first byte are control bits:
 - 1st LSB: multicast/unicast
 - 2nd LSB: universal/local flag
- Hardware (ethernet card/WiFi card) initialized with MAC address
- But:
 - Most ethernet cards allow one to change address

MAC spoofing

- Many LANs, WiFis use MAC-based access controls

Changing Your MAC Address/Mac OS X

[< Changing Your MAC Address](#)

Under Mac OS X, the MAC address can be altered in a fashion similar to the [Linux](#) and [FreeBSD](#) methods:

```
ifconfig en0 lladdr 02:01:02:03:04:05
```

or

```
ifconfig en0 ether 02:01:02:03:04:05
```

This must be done as the superuser and only works for the computer's ethernet card. Instructions on spoofing

Courtesy of wikibooks

http://en.wikibooks.org/wiki/Changing_Your_MAC_Address/Mac_OS_X

MAC spoofing

Aaron Swartz, a fellow at Harvard University's Center for Ethics and an open source programmer involved with creating the RSS 1.0 specification and more generally in the open culture movement, has been arrested and charged with **wire fraud, computer fraud, unlawfully obtaining information from a protected computer, and recklessly damaging a protected computer** after he entered a computer lab at MIT in Cambridge, Massachusetts and downloaded two-thirds of the material on JSTOR, an academic journal repository.



http://en.wikinews.org/wiki/Aaron_Swartz_arrested_and_charged_for_downloading_JSTOR_articles

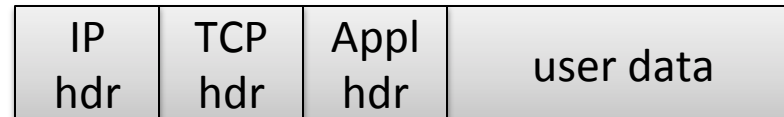
Supposedly used MAC spoofing to get onto MIT network

Internet protocol stack

Application
TCP
IP
Ethernet



TCP segment



IP datagram



Ethernet frame

14

20

20



46 to 1500 bytes

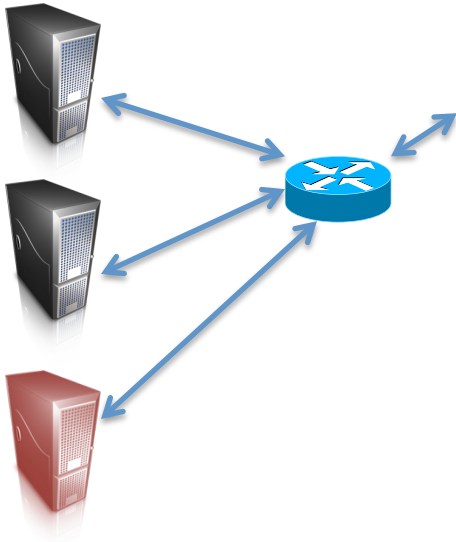
IPv4



Ethernet frame
containing
IP datagram

4-bit version	4-bit hdr len	8-bit type of service	16-bit total length (in bytes)	
16-bit identification			3-bit flags	13-bit fragmentation offset
8-bit time to live (TTL)		8-bit protocol	16-bit header checksum	
32-bit source IP address				
32-bit destination IP address				
options (optional)				

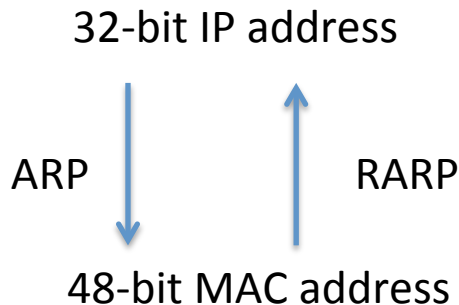
Address resolution protocol



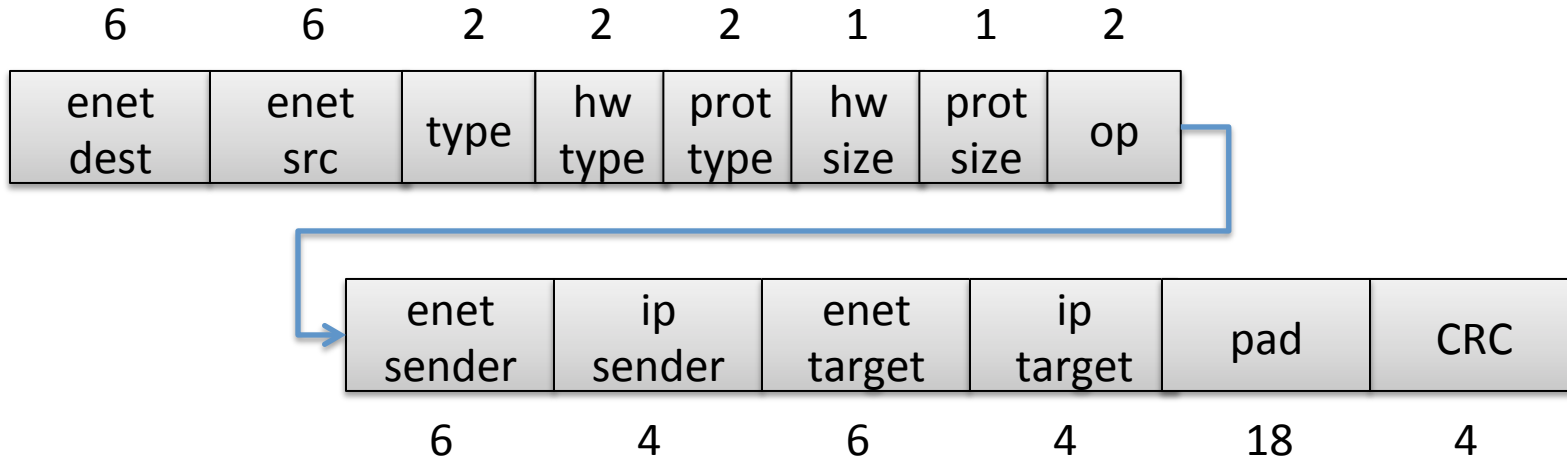
IP routing:
Figure out where to send
an IP packet based on destination
address.

Link layer and IP must cooperate to get
things sent

ARP/RARP enables this cooperation by
mapping IPs to MACs



Address resolution protocol



frame type = 0x0806 (ARP) or 0x8035 (RARP)

enet dest is all 1's, 0xFFFFFFFF for broadcast

hw type, prot(ocol) type specify what types of addresses we're looking up

op specifies whether this is an ARP request, ARP reply, RARP request, RARP reply

ARP caches

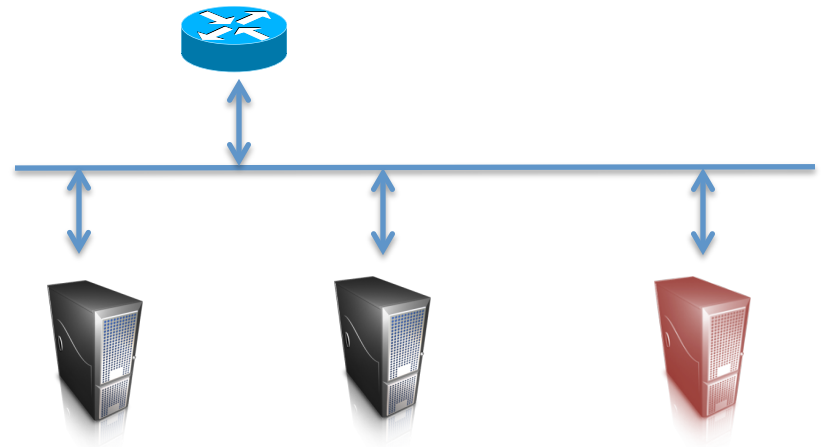
- Hosts maintain cache of ARP data
 - just a table mapping between IPs and MACs

```
rist@wifi-212:~/work/teaching/642-fall-2011/slides$ arp
usage: arp [-n] [-i interface] hostname
        arp [-n] [-i interface] -a
        arp -d hostname [pub] [ifscope interface]
        arp -d [-i interface] -a
        arp -s hostname ether_addr [temp] [reject] [blackhole] [pub [only]] [ifsc
ope interface]
        arp -S hostname ether_addr [temp] [reject] [blackhole] [pub [only]] [ifsc
ope interface]
        arp -f filename
rist@wifi-212:~/work/teaching/642-fall-2011/slides$ arp -a
? (172.16.219.1) at 0:50:56:c0:0:1 on vmnet1 ifscope permanent [ethernet]
? (172.16.219.255) at (incomplete) on vmnet1 ifscope [ethernet]
? (192.168.1.1) at 98:fc:11:91:73:92 on en1 ifscope [ethernet]
? (192.168.1.255) at (incomplete) on en1 ifscope [ethernet]
? (192.168.38.255) at (incomplete) on vmnet8 ifscope [ethernet]
rist@wifi-212:~/work/teaching/642-fall-2011/slides$
```

ARP has no authentication

- Easy to sniff packets on (non-switched) ethernet
- What else can we do?

Easy Denial of Service (DoS):
Send ARP reply associating
gateway 192.168.1.1 with a
non-used MAC address



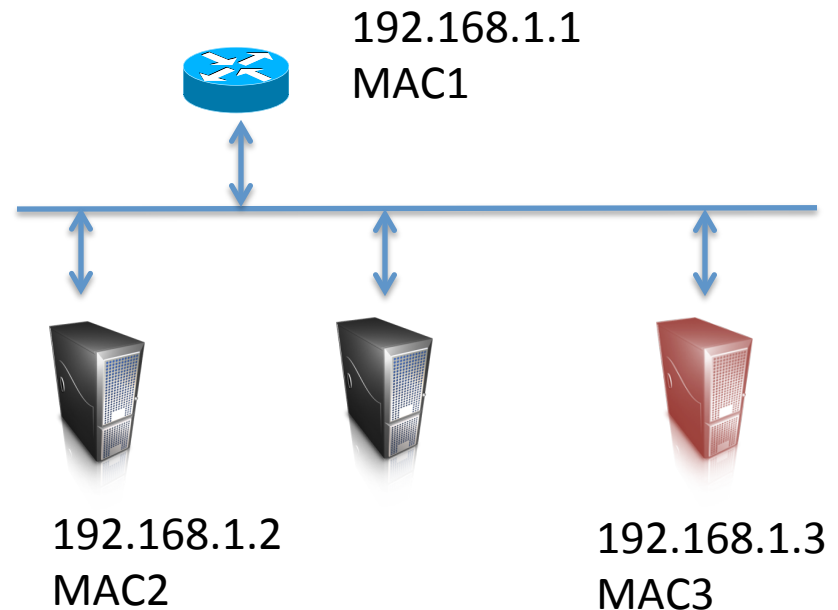
ARP has no authentication

- Easy to sniff packets on (non-switched) ethernet
- What else can we do?

Active Man-in-the-Middle:

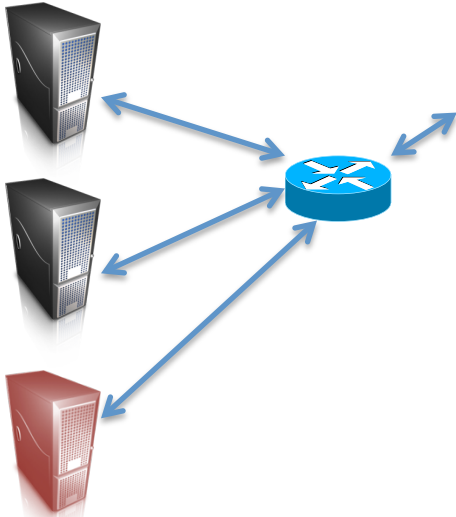
ARP reply to MAC2
192.168.1.1 -> MAC3

ARP reply to MAC1
192.168.1.2 -> MAC3



Now traffic “routed” through malicious box

ARP and switched networks

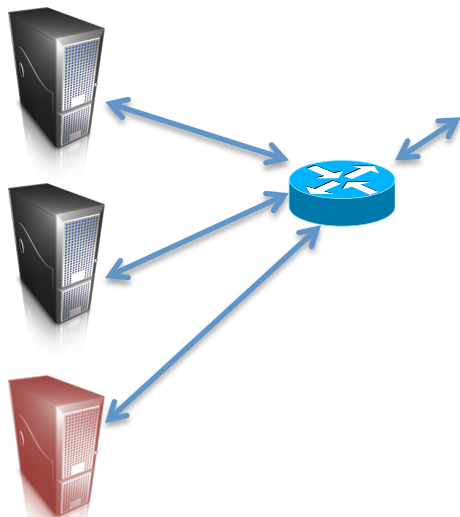


Switches do not broadcast, but transfer traffic through appropriate ports

Inhibits traffic sniffing

ARP poisoning MitM inhibited (one MAC address per port)

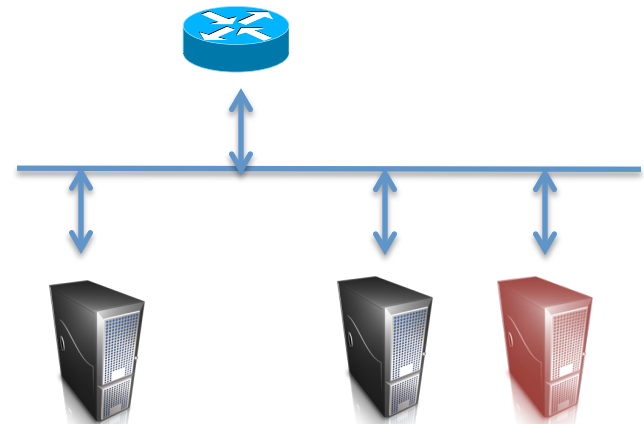
Some switches allow MAC flooding attacks



Flood ARP replies to switch



Switch can't store all values, fails to broadcast



Detection and prevention

- ARPWATCH
 - logs ARP mapping changes
 - emails admin if something suspicious comes up
- Switched networks with real authentication

David Parter will give guest lectures in two weeks. Ask him what the CSL does ...

802.11

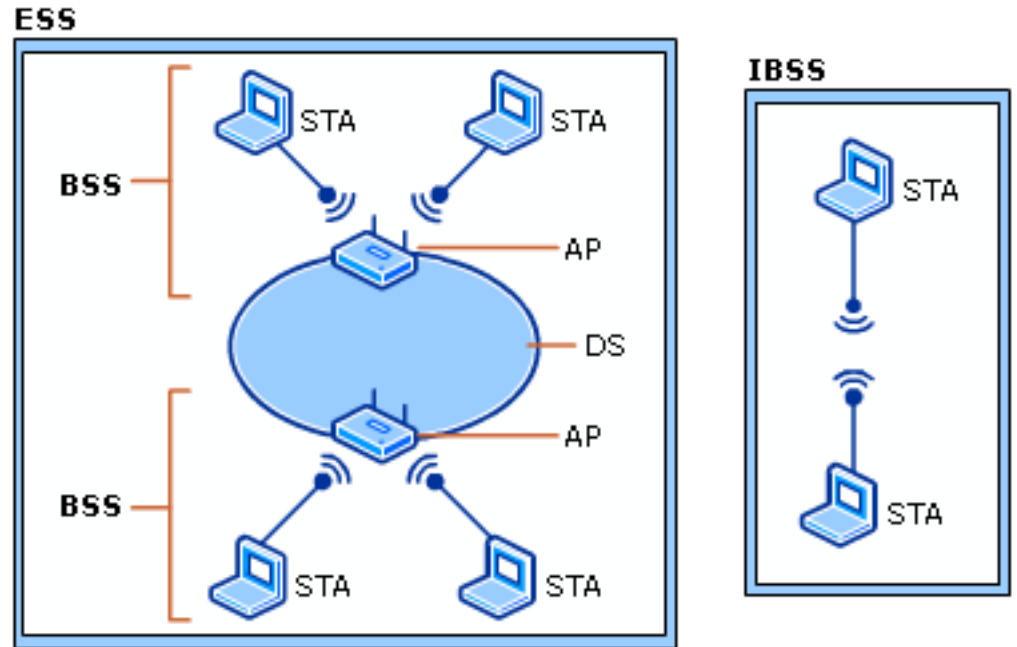
STA = station

BSS = basic service set

DS = distribution service

ESS = extended service set

SSID (service set identifier)
identifies the 802.11 network

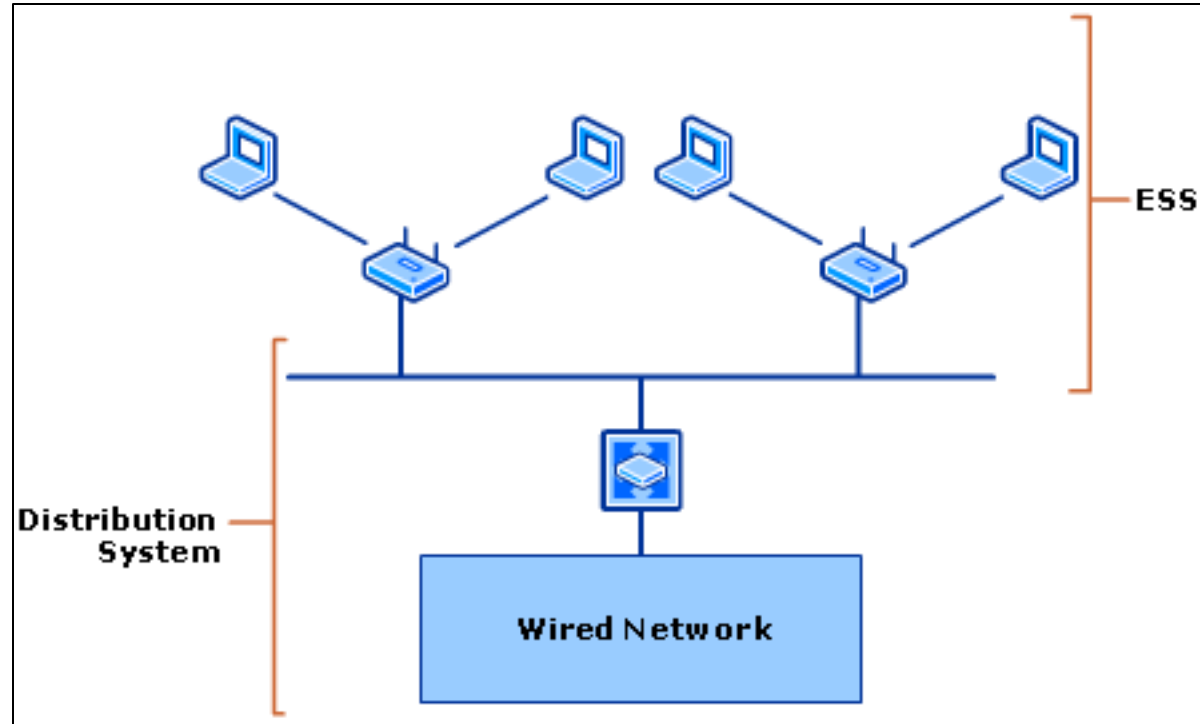


[http://technet.microsoft.com/en-us/library/cc757419\(WS.10\).aspx](http://technet.microsoft.com/en-us/library/cc757419(WS.10).aspx)

802.11

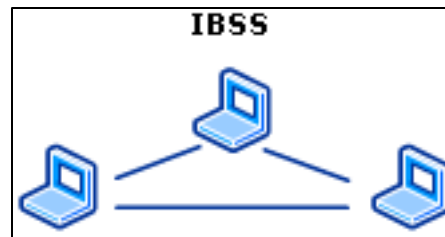
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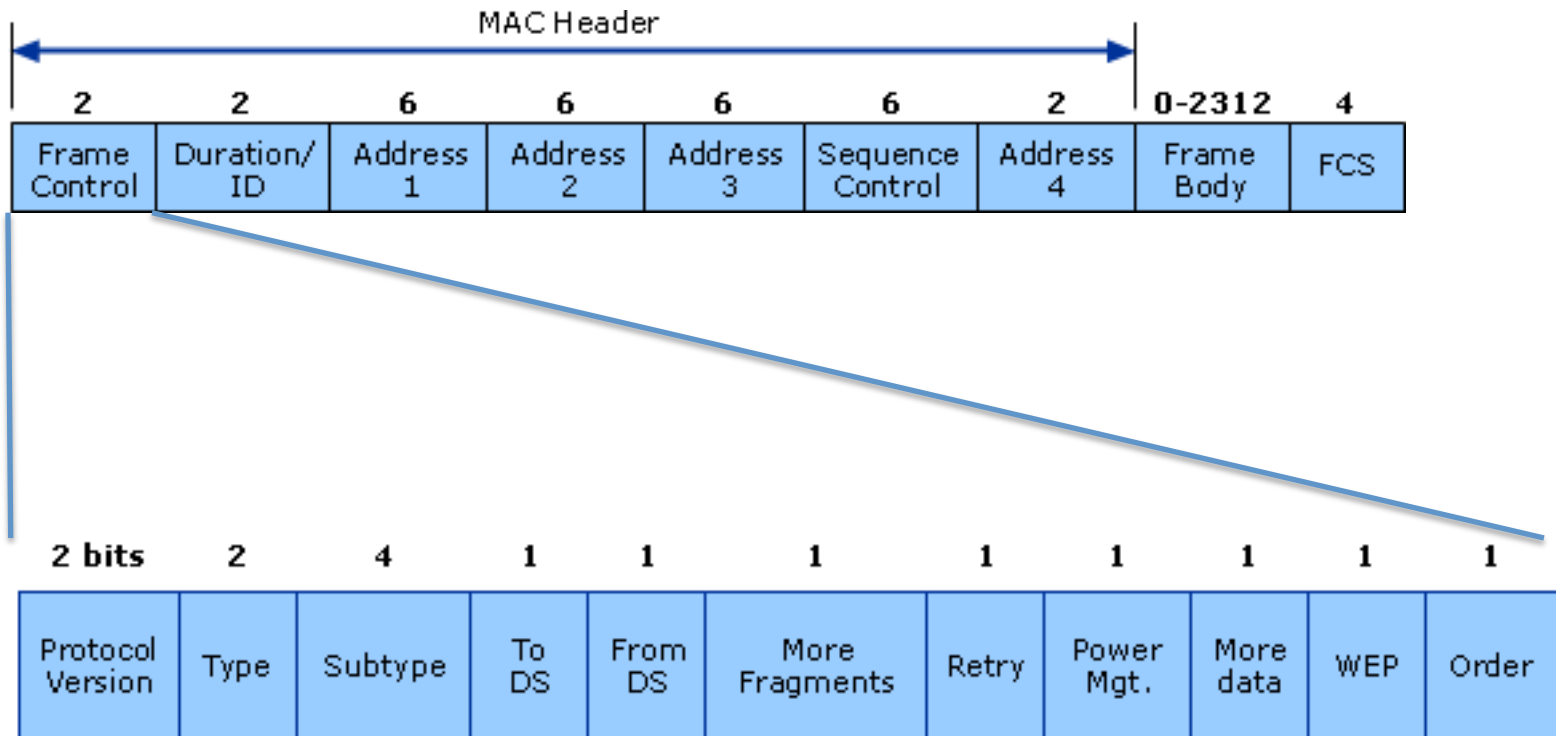


[http://technet.microsoft.com/en-us/library/cc757419\(WS.10\).aspx](http://technet.microsoft.com/en-us/library/cc757419(WS.10).aspx)

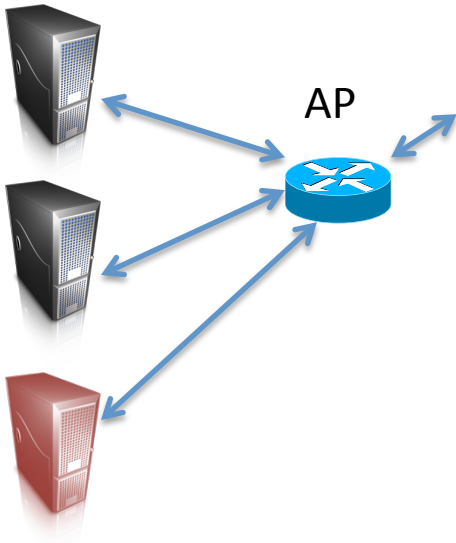
Infrastructure mode (top)
versus
Ad-hoc (bottom)



802.11



802.11 security issues

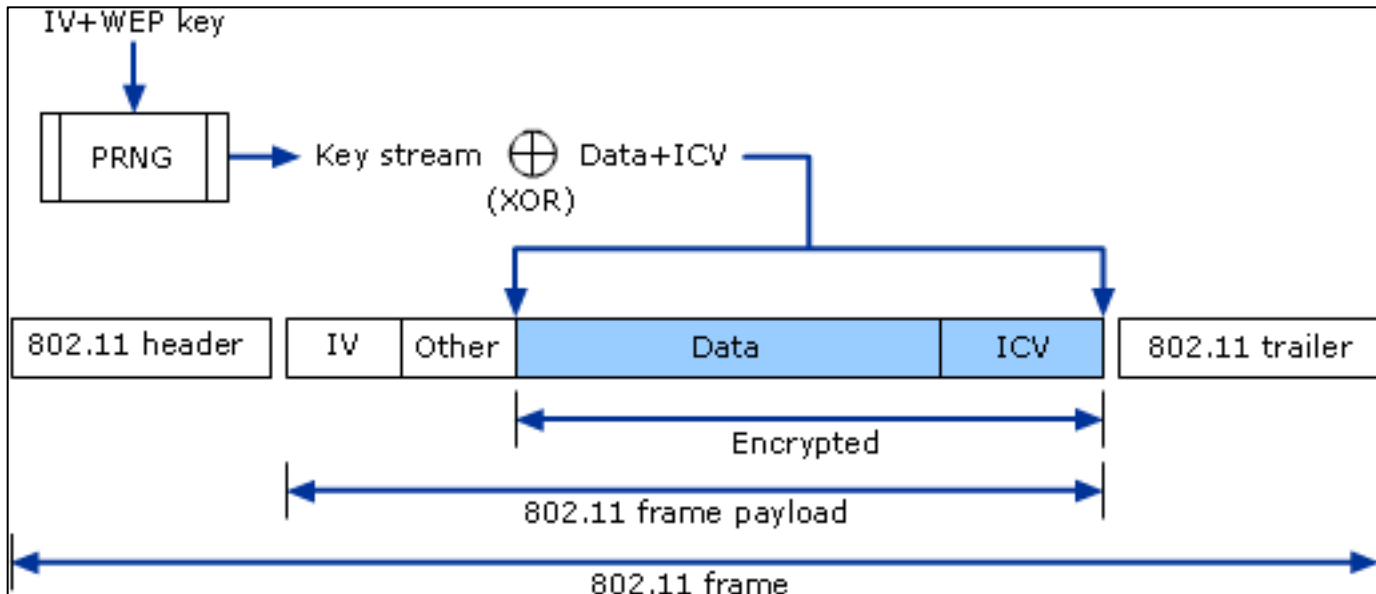


Wired versus wireless

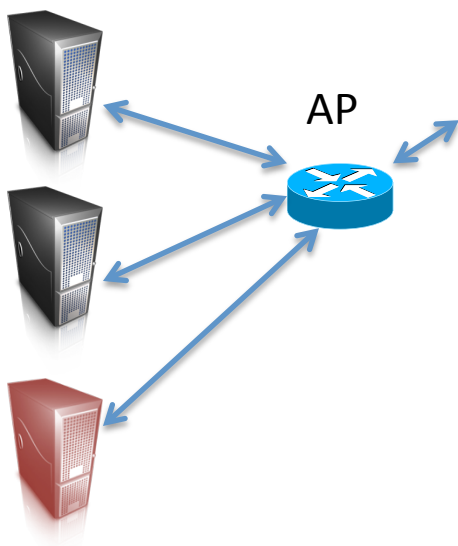
Wireless can (try to) compensate via cryptography

- WEP = epic failure
- WPA = better but not great
- WPA2 = better yet

We'll see more on this in crypto section



802.11 security issues



WPA-personal

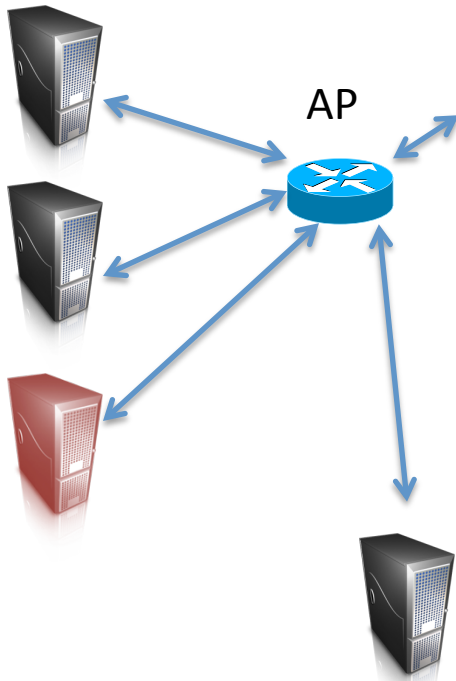
- Pre-shared key mode
- User types in a password to gain access

Default settings

- IP address: 192.168.1.1 (WRT54G-TM and WRT54G-RG: 192.168.0.1)
- Web interface username: "admin" for most routers, no user name or "root" on some
- Password: "admin"

http://en.wikipedia.org/wiki/Linksys_WRT54G_series

802.11 security issues



WPA-personal

- Pre-shared key mode
- User types in a password to gain access

WPA-enterprise

- Extended Authentication Protocol (EAP)
- Centralized Authentication, Authorization, and Accounting (AAA)

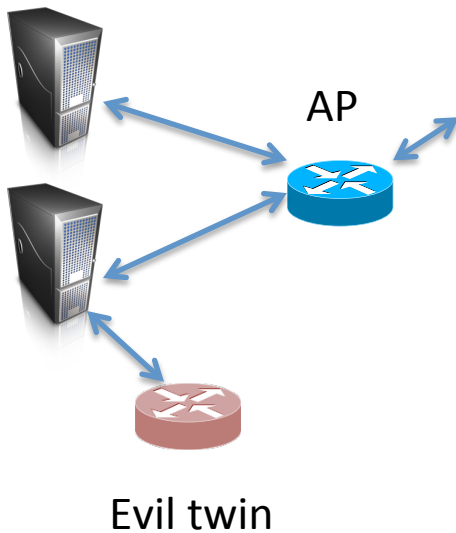
RADIUS (Remote Authentication Dial In User Service) authentication server

Client-server protocol over UDP

- 1) Authenticate users/devices before granting access to network
- 2) Authorize users/devices to access certain network services
- 3) Account for usage of services

Many security issues identified

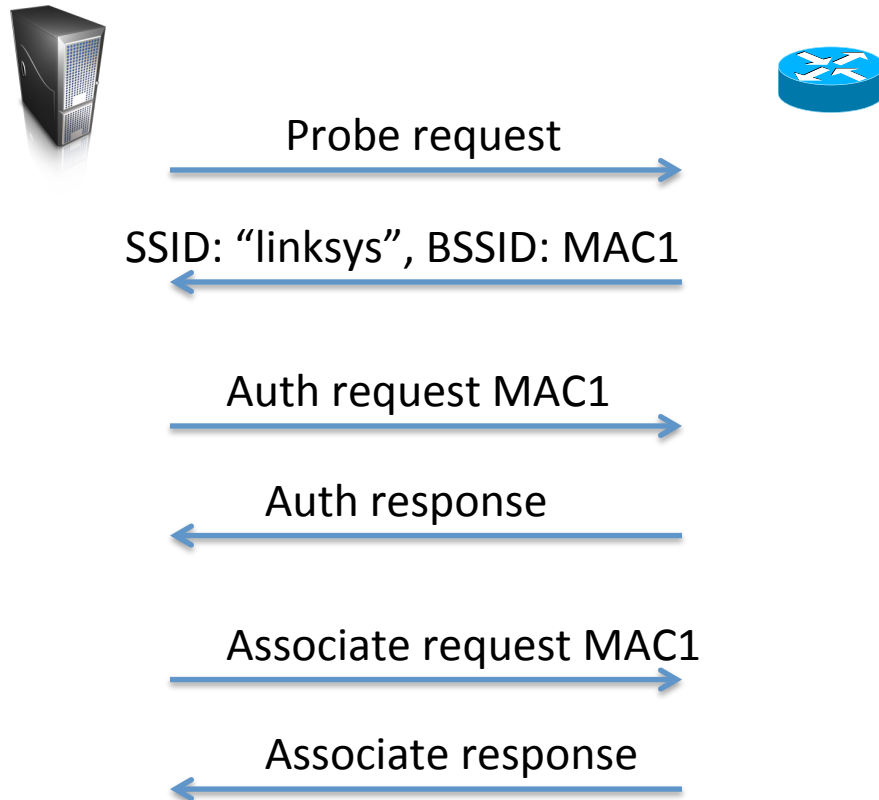
802.11 evil twins



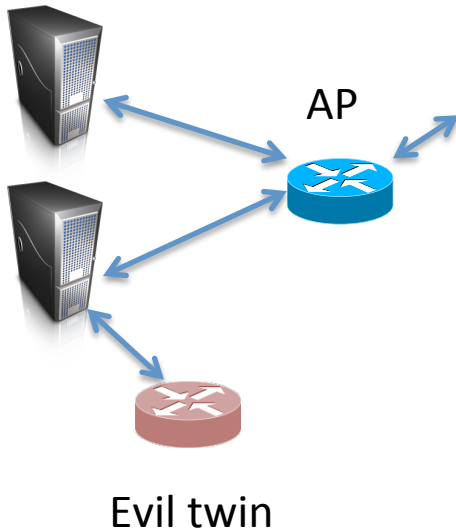
Basic idea:

- Attacker pretends to be an AP to intercept traffic or collect data

802.11 association



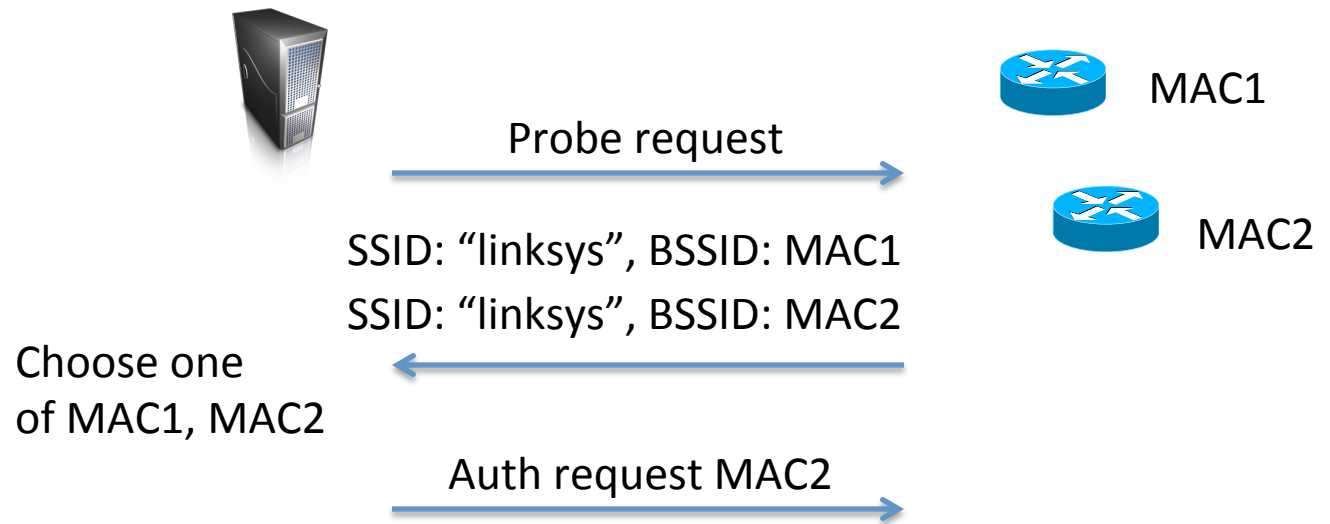
802.11 evil twins



Basic idea:

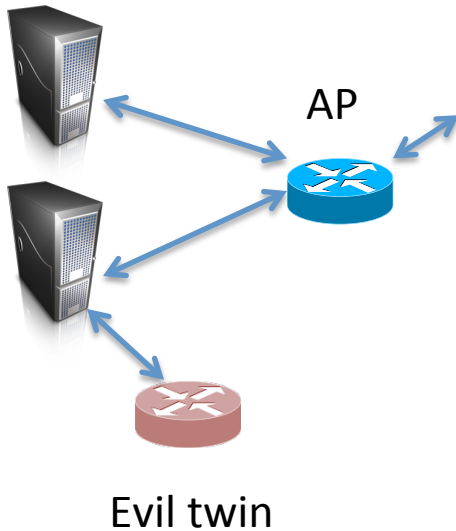
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Two APs for same network



...

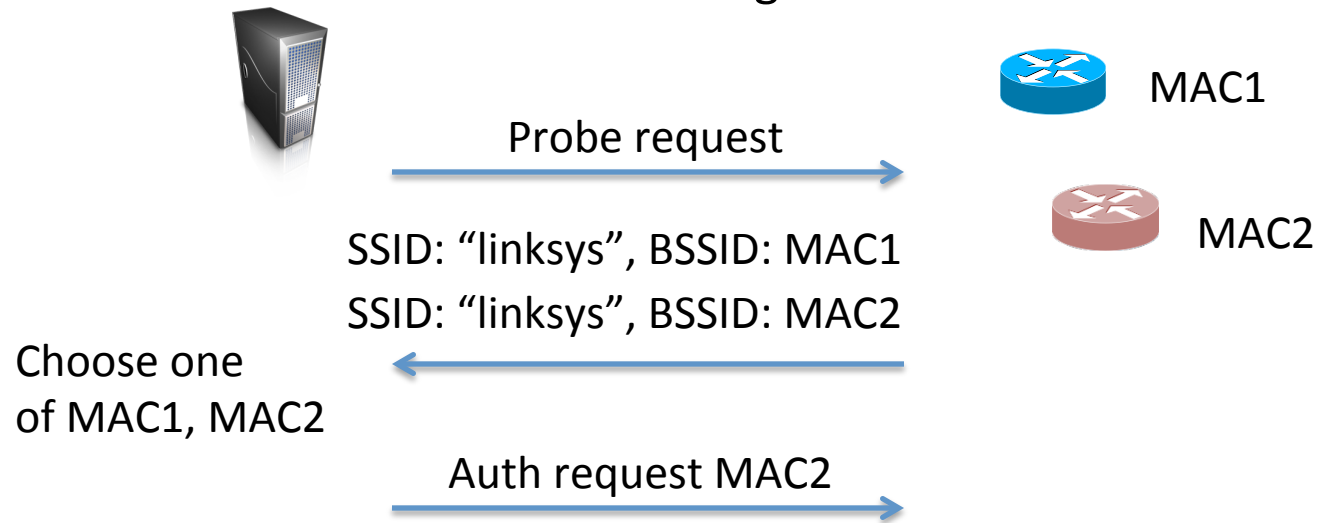
802.11 evil twins



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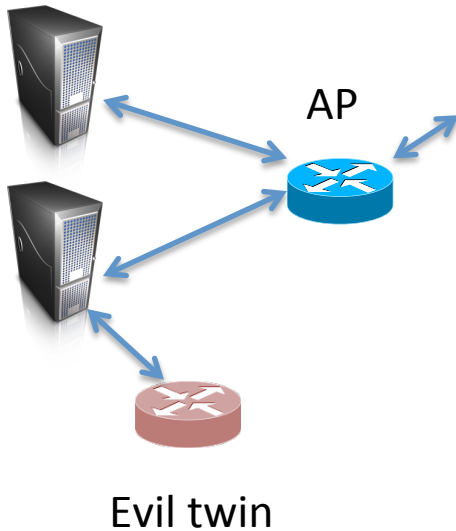
- Attacker pretends to be an AP to intercept traffic or collect data

Basic attack: rogue AP



...

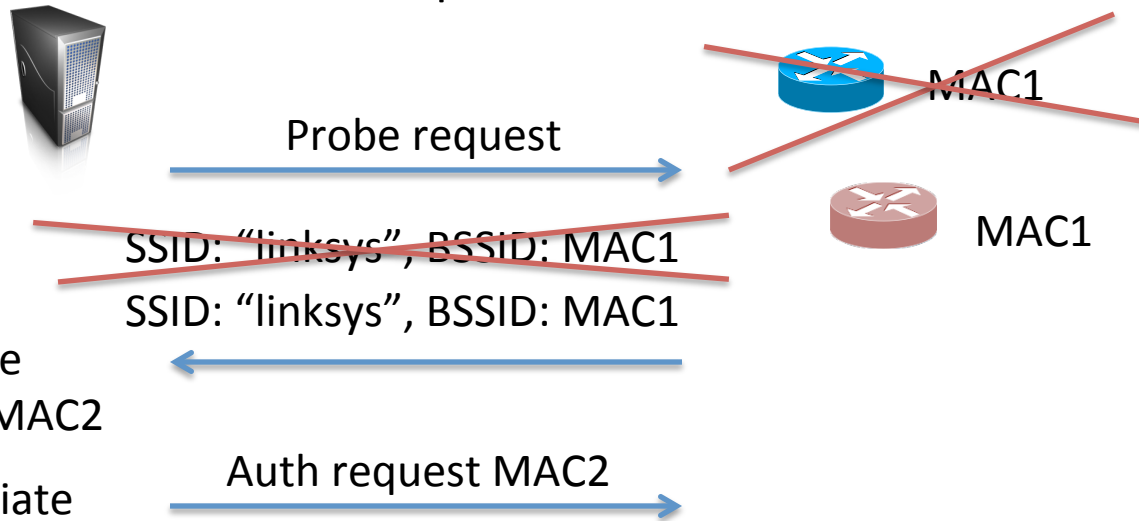
802.11 evil twins



Basic idea:

- Attacker pretends to be an AP to intercept traffic or collect data

Evil twin: spoof MAC1



Choose one of MAC1, MAC2

Attacker can send forged disassociate message to victim to get it to look for new connection

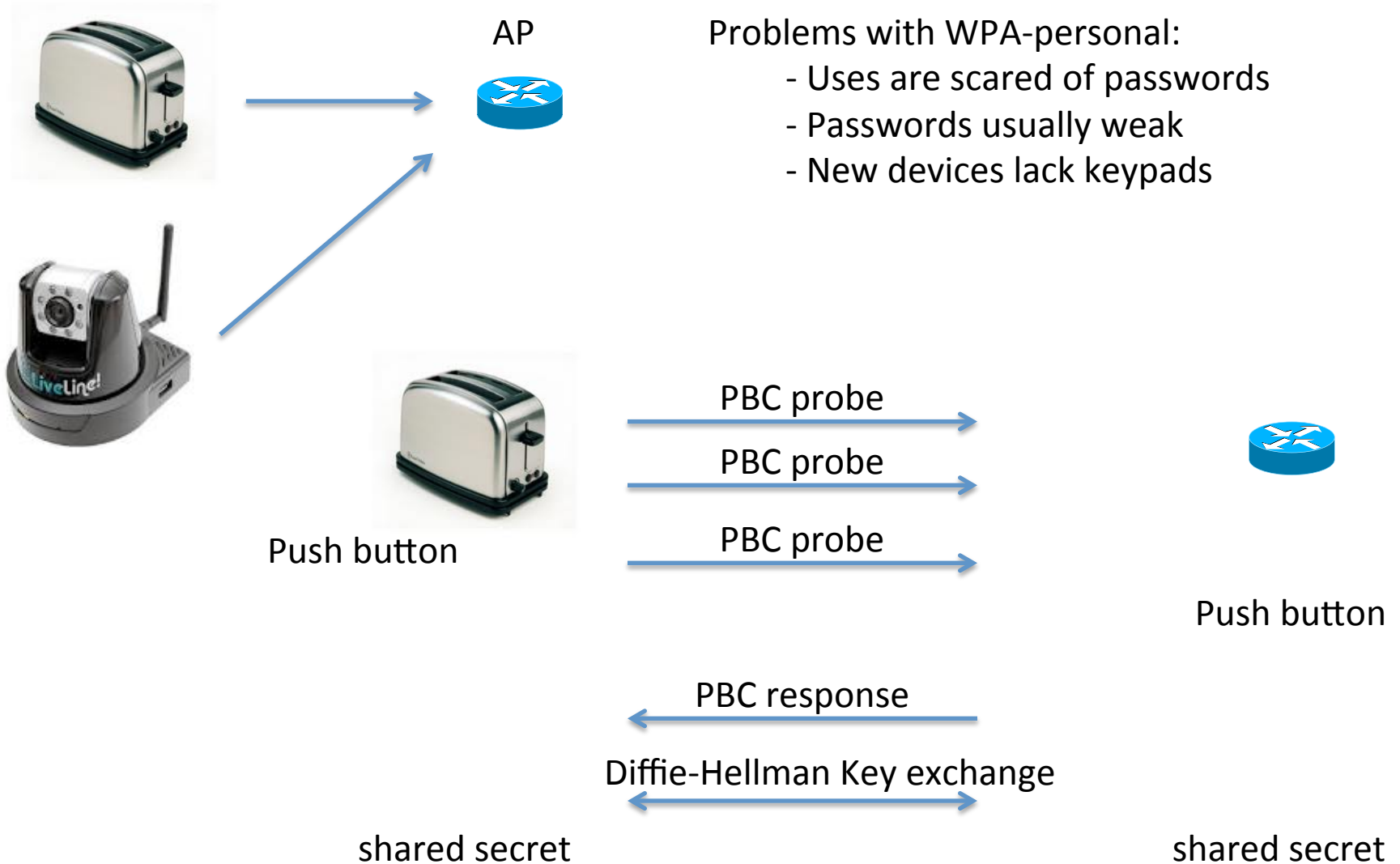
Victim might send out probe requests for particular SSIDs, giving attacker info

...

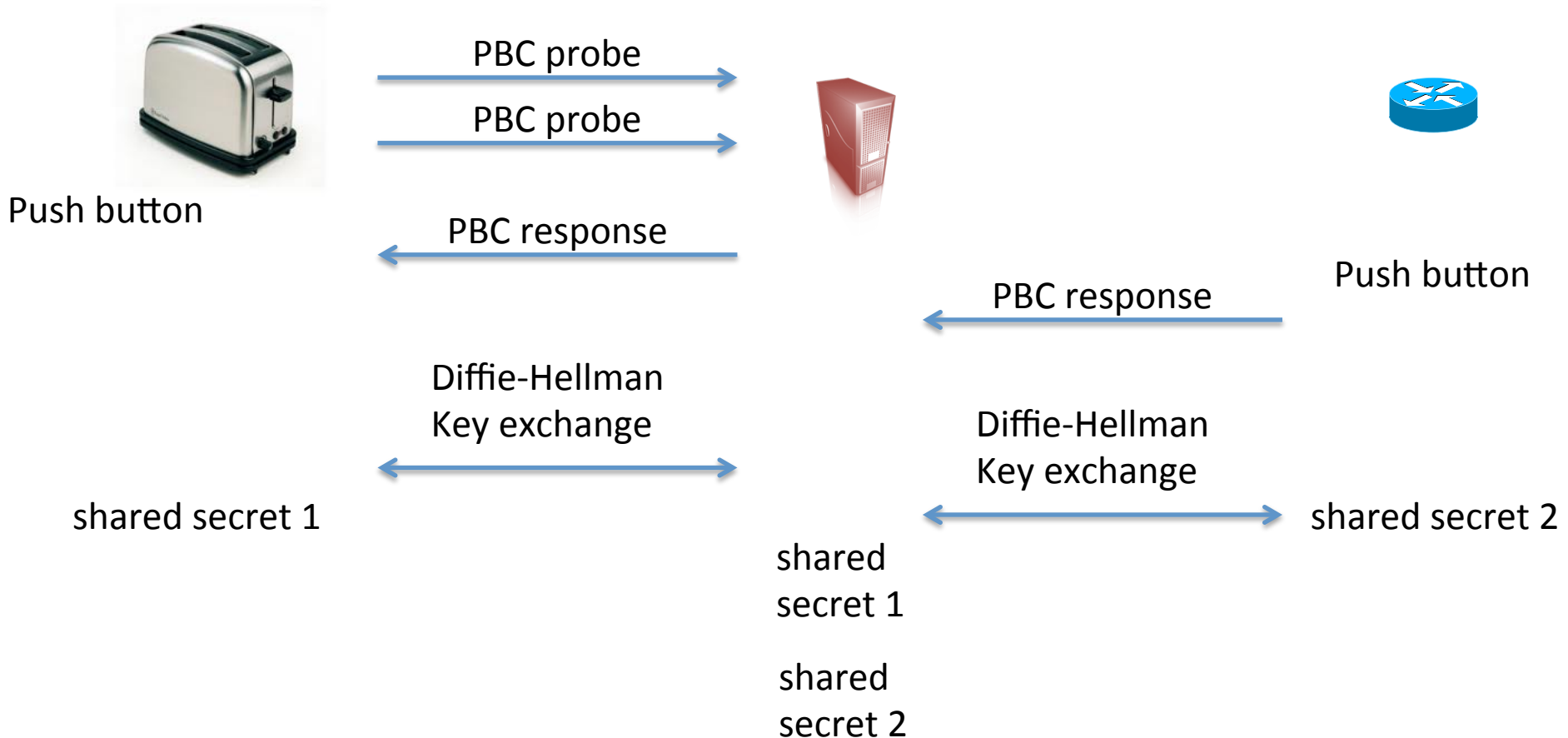
Conceptually similar to ARP poisoning

Push-button configuration (PBC)

- Problems with WPA-personal:
- Users are scared of passwords
 - Passwords usually weak
 - New devices lack keypads



Push-button configuration (PBC)



But this is on wireless, so all messages are seen by all parties

Attacker can jam messages, overpower legitimate messages

Can we prevent MitM?

Gollakata et al., Secure In-Band Wireless Pairing, Security 2011

Basic observations:

- Assume all parties in range of each other (all honest broadcasts seen)
- Jamming can be made detectable

Can we prevent MitM?

Gollakata et al., Secure In-Band Wireless Pairing, Security 2011

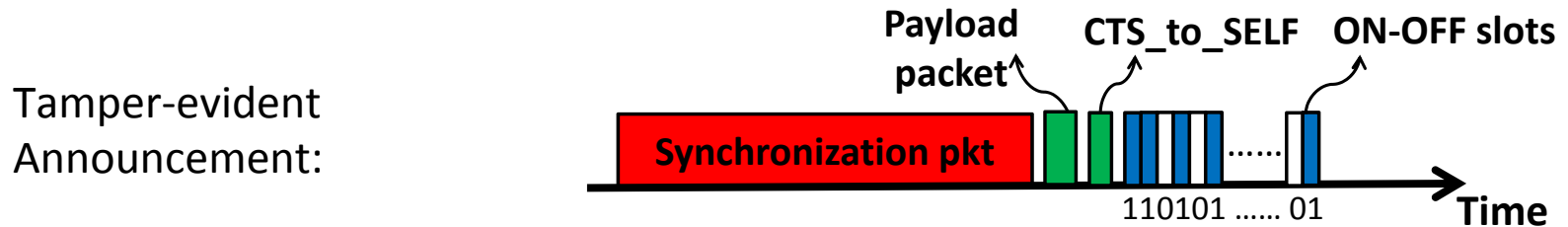


Figure 1: The format of a tamper-evident announcement (TEA).

Synchronization: long random data to make overpowering detectable

Payload: key exchange data (public key, etc.)

On-Off slots:

Encode cryptographic hash of payload in a manipulation-detectable way

Can we prevent MitM?

Gollakata et al., Secure In-Band Wireless Pairing, Security 2011

On-Off slots:

Encode cryptographic hash of payload in a manipulation-detectable way

b1 b2 h1 h2 ... h128

1 0 1 1 ... 0

1 0 10 10 ... 01

Encode in a way that balances number of 0's and 1's

Attacker can only turn 0's to 1's



Transmitting a 1:
send packet with random data

Transmitting a 0:
send nothing

Receiver detects if channel in use, concludes a 1

Otherwise concludes a 0

Checks that # of 1's = # of 0's

Checks hash of payload

To change payload, attacker must change hash value, but can't

Discussion

- What attacks aren't prevented?
- PBC relies on what physical assumptions?
- How easy are such jamming based attacks?

