Network Security 3

RoadMap

1. Network layer security: IPsec

   网络层安全:IPsec

2. Operational security: firewalls and IDS

   操作安全:防火墙和IDS

What is network-layer confidentiality? 什么是网络层保密性?

- **between two network entities:**

  在两个网络实体之间:

  - sending entity encrypts datagram payload, payload could be:

    发送实体加密数据报有效载荷,有效载荷可能是:

    - TCP or UDP segment, ICMP message, OSPF message ....

      TCP或UDP段,ICMP消息,OSPF消息.....

  - all data sent from one entity to other would be hidden from any third party (that presumably is sniffing the network):

    从一个实体发送到另一个实体的所有数据都将对任何第三方(可能正在嗅探网络)隐藏:

    - web pages, e-mail, P2P file transfers, TCP SYN packets ...

      网页,电子邮件,P2P文档传输,TCP SYN数据包.....

- **“blanket coverage”**

  统括

Virtual Private Networks (VPNs)

motivation: 动机

- **institutions often want private networks for security.**

  机构通常需要专用网络来确保安全。

  - institution could actually deploy a stand-alone physical network that is completely separate from the public Internet.

    机构实际上可以部署一个与公共互联网完全分离的独立物理网络。

  - costly: separate routers, links, DNS infrastructure.

    成本高昂:单独的路由器、链路、DNS 基础设施。

- **VPN: institution’s inter-office traffic is sent over public Internet instead**

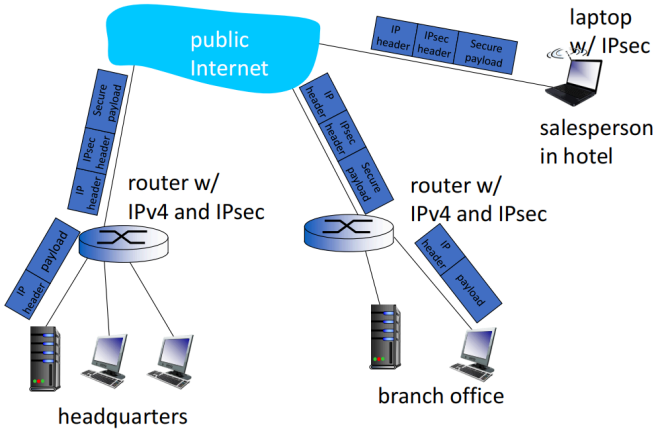
  VPN:机构的办公室间流量通过公共互联网发送

  - encrypted before entering public Internet

    在进入公共互联网之前进行加密

  - logically separate from other traffic

逻辑上与其他流量分开



IPsec

- data integrity

  数据完整性
- origin authentication

  原产地认证
- replay attack prevention

  防止重播攻击
- confidentiality

  保密性
- **two protocols providing different service models:**

  提供不同服务模式的两种协议:
  - **Authentication Header (AH)**

    身份验证标头 (AH)
    - provides source authentication and data integrity but *no* confidentiality

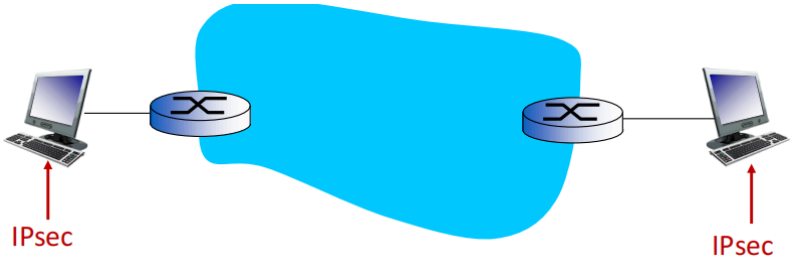
      提供源身份验证和数据完整性,但*没有*保密性
  - **Encapsulation Security Payload (ESP)**

    封装安全有效载荷(ESP)
    - provides source authentication, data integrity, and confidentiality

      提供源身份验证、数据完整性和机密性
    - more widely used than AH

      比 AH 更广泛使用

IPsec transport mode (host mode) IPSec传输模式(主机模式)



- IPsec datagram emitted and received by end-system

  终端系统发送和接收的 IPsec 数据报
- protects upper level protocols

  保护上层协议

IPsec – tunneling mode 隧道模式

• edge routers IPsec-aware • hosts IPsec-aware

Four combinations are possible! 四种组合是可能的!

Host mode with AH	Host mode with ESP
Tunnel mode with AH	Tunnel mode with ESP

most common and most important

Security associations (SAs)

- before sending data, **"security association (SA)"** established from sending to receiving entity

  在发送数据之前,从发送方到接收方实体之间创建 **"安全关联 (SA) "**
  - SAs are simplex: logical connection for only one direction

    SA是单向的:逻辑连接只有一个方向
- ending, receiving entitles maintain state information about SA

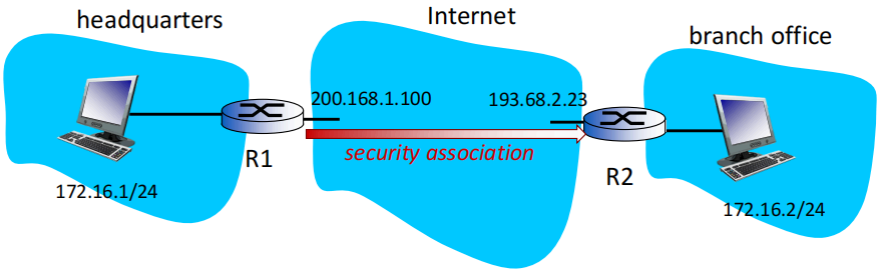
  结束,接收授权维护有关 SA 的状态信息
  - recall: TCP endpoints also maintain state info

    回想一下:TCP 端点也维护状态信息
  - IP is connectionless; IPsec is connection-oriented!

    IP 是无连接的;而 IPsec 是面向连接的!
- how many SAs in VPN w/ one headquarters office, one branch office, and n traveling salesperson?

VPN有多少个SA,一个总部办公室,一个分公司,一个旅行销售员?

Example SA from R1 to R2



R1 stores for SA:

- 32-bit SA identifier: **Security Parameter Index (SPI)**

  32 位 SA 标识符:**安全参数索引 (SPI)**
- origin SA interface (200.168.1.100)

  原点SA接口 (200.168.1.100)
- destination SA interface (193.68.2.23)

  目标 SA 接口 (193.68.2.23)
- type of encryption used (e.g., 3DES with CBC)

  使用的加密类型(例如,使用 CBC 的 3DES)
- encryption key

  加密密钥
- type of integrity check used (e.g., HMAC with MD5)

  使用的完整性检查类型(例如,HMAC与MD5)
- authentication key

  认证密钥

Security Association Database (SAD)

- endpoint holds SA state in **security association database (SAD)**, where it can locate them during processing.

  端点将 SA 状态保存在 **安全关联数据库 (SAD)** 中,可以在处理过程中找到它们。
- with n salespersons, **2 + 2n** SAs in R1's SAD

  n 个销售人员,2 + 2n 个 SAs 在 R1 的 SAD 中
- when sending IPsec datagram, R1 accesses SAD to determine how to process datagram.

  当发送 IPsec 数据报时,R1 访问 SAD 以确定如何处理数据报。
- when IPsec datagram arrives to R2, R2 examines **SPI** in IPsec datagram, indexes SAD with SPI, and processes datagram accordingly

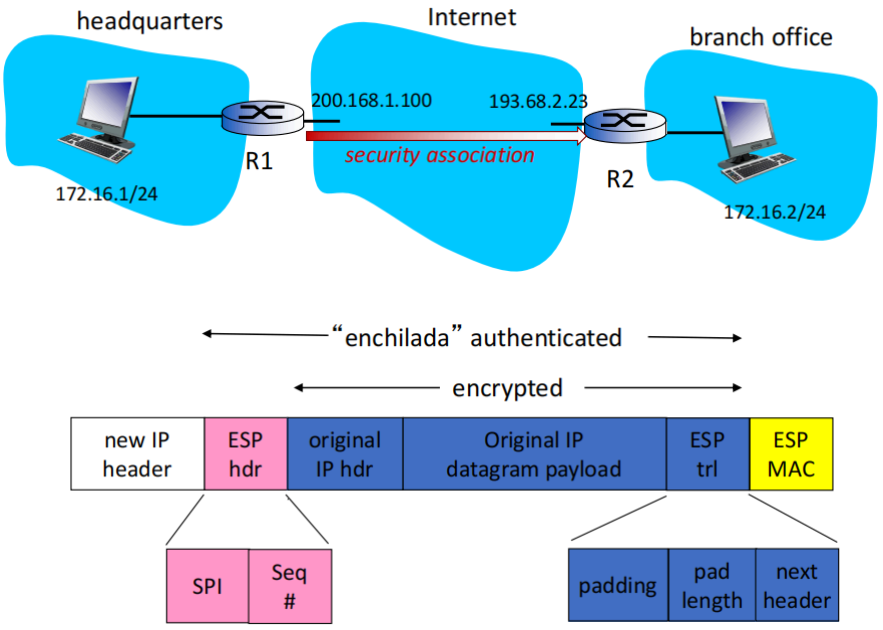
  当 IPsec 数据报到达 R2 时,R2 检查 IPsec 数据报中的 SPI,用 SPI 索引 SAD,并相应地处理数据报

IPsec datagram IPsec 数据报

focus for now on tunnel mode with ESP

现在专注于**ESP的隧道模式**

加密过程: R1: convert original datagram to IPsec datagram



- appends to back of original datagram (that includes original header fields!) an “ESP trailer” field.

  在原始数据报(包括原始报头字段!)后面附加一个"ESP trailer"字段。
- encrypts result using algorithm & key specified by SA.

  使用 SA 指定的算法和密钥加密结果。
- appends to front of this encrypted quantity the “ESP header, creating “enchilada”.

  将"ESP 标头"附加到该加密数量的前面,创建"enchilada"。
- creates authentication MAC over the whole enchilada, using algorithm and key specified in SA.

  使用 SA 中指定的算法和密钥,在整个 enchilada 上创建认证 MAC。
- appends MAC to back of enchilada, forming payload.

  将 MAC 连接到 Enchilada 的背面,形成有效载荷。
- creates brand new IP header, with all the classic IPv4 header fields, which it appends before payload.

  创建全新的 IP 标头,包含所有经典的 IPv4 标头字段,并将其附加在有效载荷之前。

Inside the enchilada:

- **ESP trailer: Padding for block ciphers**
- **ESP header:**
  - SPI, so receiving entity knows what to do
  - Sequence number, to thwart replay attacks
- **MAC in ESP auth field is created with shared secret key**

IPsec sequence numbers IPsec 串行号

- **for new SA, sender initializes seq. # to 0**

  对于新的 SA,发送方将 seq. # 初始化为 0

- **each time datagram is sent on SA:**

  每次在 SA 上发送数据报时:

  - sender increments seq # counter

    s 增加 s 串行号 计数器

  - places value in seq # field

    在 seq # 字段中放置值

- **goal:**

  - prevent attacker from sniffing and replaying a packet

    防止攻击者嗅探和重播数据包

  - receipt of duplicate, authenticated IP packets may disrupt service

    收到重复的、经过身份验证的 IP 数据包可能会中断服务

- **method:**

  - destination checks for duplicates

    目的地检查重复项

  - doesn't keep track of *all* received packets; instead uses a window

    不会跟踪 *所有* 接收的数据包;而是使用一个窗口

Security Policy Database (SPD) 安全策略数据库

- policy: For a given datagram, sending entity needs to know if it should use IPsec or vanilla IP

  策略:对于给定的数据报,发送实体需要知道它应该使用 IPsec 还是 vanilla IP

- needs also to know which SA to use

  还需要知道使用哪个SA

- may use: source and destination IP address; protocol number

  可能使用:源和目标 IP 地址;协议号

- info in SPD indicates "what" to do with arriving datagram

  SPD 中的 info 指示如何处理到达的数据报文

- info in SAD indicates "how" to do it

  SAD 中的信息指出了"如何"做到这一点

Summary: IPsec services IPsec服务总结

suppose Trudy sits somewhere between R1 and R2. she doesn't know the keys.

假设特鲁迪坐在R1和R2之间,她不知道按键。

- will Trudy be able to see original contents of datagram? How about source, dest IP address, transport protocol, application port?

  Trudy 能看到数据报的原始内容吗?源地址、目标 IP 地址、传输协议、应用进程端口等信息呢?

- flip bits without detection?

  在没有检测的情况下翻转比特?
- masquerade as R1 using R1's IP address?

  使用 R1 的 IP 地址伪装成 R1 吗?
- replay a datagram?

  重播数据报?

IKE: Internet Key Exchange 互联网密钥交换

- **previous examples:** manual establishment of IPsec SAs in IPsec endpoints:

  以前的示例:在 IPsec 端点中手动创建 IPsec SA:

  Example SA

  SPI: 12345

  Source IP: 200.168.1.100

  Dest IP: 193.68.2.23

  Protocol: ESP

  Encryption algorithm: 3DES-cbc

  HMAC algorithm: MD5

  Encryption key: 0x7aeaca…

  HMAC key:0xc0291f…
- manual keying is impractical for VPN with 100s of endpoints

  对于具有 100 个端点的 VPN,手动键入是不切实际的
- instead use **IPsec IKE (Internet Key Exchange**) protocol, specified in RFC 5996.

  改为使用 RFC 5996 中规定的 IPSec IKE(互联网密钥交换)协议。

IPsec summary IPSec概述

- IKE message exchange for algorithms, secret keys, SPI numbers

  IKE 消息交换算法、密钥、SPI 数字
- either AH or ESP protocol (or both)

  AH 或 ESP 协议(或两者)
  - AH provides integrity, source authentication

    AH提供完整性,源身份验证
  - ESP protocol (with AH) additionally provides encryption

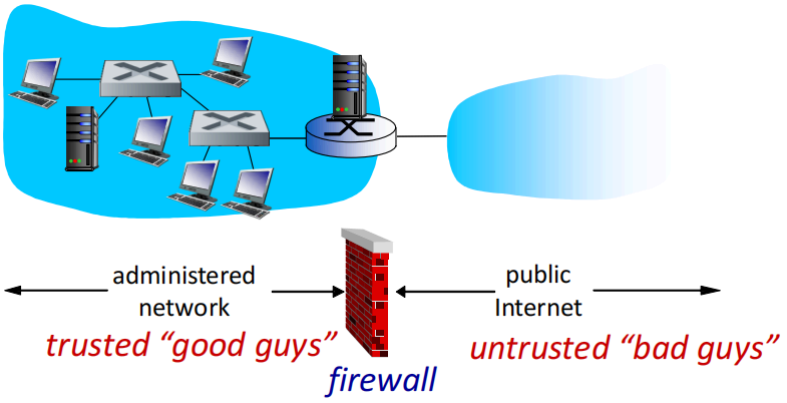
    ESP 协议(带 AH)另外提供加密
- IPsec peers can be two end systems, two routers/firewalls, or a router/firewall and an end system

  IPsec 对等体可以是两个终端系统、两个路由器/防火墙,或者一个路由器/防火墙和一个终端系统

Operational Security: firewall and IDS 操作安全性:防火墙和IDS

Firewall: isolates organization's internal net from larger Internet, allowing some packets to pass, blocking others

防火墙:将组织的内部网络与更大的互联网隔离,允许一些数据包通过,阻止其他数据包



为什么要有防火墙

prevent denial of service attacks:

防止拒绝服务攻击:

- SYN flooding: attacker establishes many bogus TCP connections, no resources left for "real" connections

  SYN 泛滥:攻击者创建了许多伪造的 TCP 连接,没有资源用于"真实"连接

prevent illegal modification/access of internal data

防止非法修改/访问内部数据

- e.g., attacker replaces CIA's homepage with something else

  例如,攻击者用别的东西替换了 CIA 的主页

allow only authorized access to inside network

只允许授权访问内部网络

- set of authenticated users/hosts

  一组经过身份验证的用户/主机

three types of firewalls:

三种类型的防火墙:

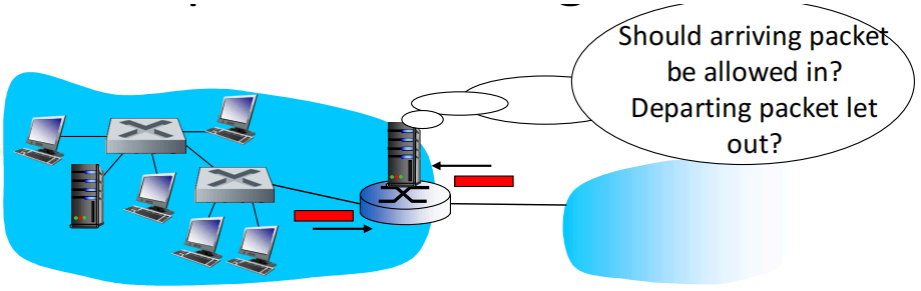
- stateless packet filters

  无状态数据包过滤器
- stateful packet filters

  状态包过滤器
- application gateways

  应用网关 (Application Gateways)

Stateless packet filtering 无状态数据包过滤



无状态：防火墙不维持内外网的状态

- internal network connected to Internet via **router firewall**

  内部网络通过**路由器防火墙**连接到互联网

- router f**ilters packet-by-packet**, decision to forward/drop packet based on:

  路由器逐包过滤,决定转发/丢弃数据包基于:

  - source IP address, destination IP address

    源 IP 地址、目标 IP 地址

  - TCP/UDP source and destination port numbers

    TCP/UDP 源端口和目的端口号

  - ICMP message type

    ICMP 消息类型

  - TCP SYN and ACK bits

    TCP SYN 和 ACK 位

Example:

- **example 1**: block incoming and outgoing datagrams with IP protocol field = 17 and with either source or dest port = 23

  示例 1:阻止 IP 协议字段 = 17 和源端口或目标端口 = 23 的传入和传出数据报

  - **result**: all incoming, outgoing UDP flows and telnet connections are blocked

    结果:所有传入、传出的 UDP 流和 Telnet 连接都被阻塞

- **example 2**: block inbound TCP segments with ACK=0.

  示例2:阻止ACK=0的入站TCP段。

  - **result**: prevents external clients from making TCP connections with internal clients, but allows internal clients to connect to outside.

    result:阻止外部客户端与内部客户端创建 TCP 连接,但允许内部客户端连接到外部。

More examples:

Policy	Firewall Setting
No outside Web access.	Drop all outgoing packets to any IP address, port 80
No incoming TCP connections, except those for institution's public Web server only.	Drop all incoming TCP SYN packets to any IP except 130.207.244.203, port 80

Policy	Firewall Setting
Prevent Web-radios from eating up the available bandwidth.	Drop all incoming UDP packets - except DNS and router broadcasts.
Prevent your network from being used for a smurf DoS attack.	Drop all ICMP packets going to a “broadcast” address (e.g. 130.207.255.255).
Prevent your network from being tracerouted	Drop all outgoing ICMP TTL expired traffic

Access Control Lists

ACL: table of rules, applied top to bottom to incoming packets: (action, condition) pairs: looks like OpenFlow forwarding table!

ACL:规则表,从上到下应用于传入数据包:(动作,条件)对:看起来像OpenFlow转发表!

action	source address	dest address	protocol	source port	dest port	flag bit
allow	222.22/16	outside of 222.22/16	TCP	> 1023	80	any
allow	outside of 222.22/16	222.22/16	TCP	80	> 1023	ACK
allow	222.22/16	outside of 222.22/16	UDP	> 1023	53	---
allow	outside of 222.22/16	222.22/16	UDP	53	> 1023	----
deny	all	all	all	all	all	all

Stateful packet filtering 有状态分组过滤

- **stateless packet filter**: heavy handed tool

  无状态数据包过滤器:重型工具

  - It may admit packets that “make no sense,” e.g., dest port = 80, ACK bit set, even though no TCP connection established:

    它可能会接受"没有意义"的数据包,例如,dest port = 80,ACK位设置,即使没有创建TCP连接:

action	source address	dest address	protocol	source port	dest port	flag bit
allow	outside of 222.22/16	222.22/16	TCP	80	> 1023	ACK

- **stateful packet filter**: track status of every TCP connection

  状态数据包过滤器:跟踪每个 TCP 连接的状态

  - track connection setup (SYN), teardown (FIN): determine whether incoming, outgoing packets “makes sense”

    跟踪连接设置(SYN),拆解(FIN):确定传入,传出数据包是否"有意义"

  - timeout inactive connections at firewall: no longer admit packets

    防火墙超时非活动连接:不再接受数据包

ACL augmented to indicate need to check connection state table before admitting packet

ACL 增强,以指示在接受数据包之前需要检查连接状态表 （需要连接建立起来才能发送流量）

action	source address	dest address	proto	source port	dest port	flag bit	check conxion
allow	222.22/16	outside of 222.22/16	TCP	> 1023	80	any	
allow	outside of 222.22/16	222.22/16	TCP	80	> 1023	ACK	X
allow	222.22/16	outside of 222.22/16	UDP	> 1023	53	---	
allow	outside of 222.22/16	222.22/16	UDP	53	> 1023	----	X
deny	all	all	all	all	all	all	

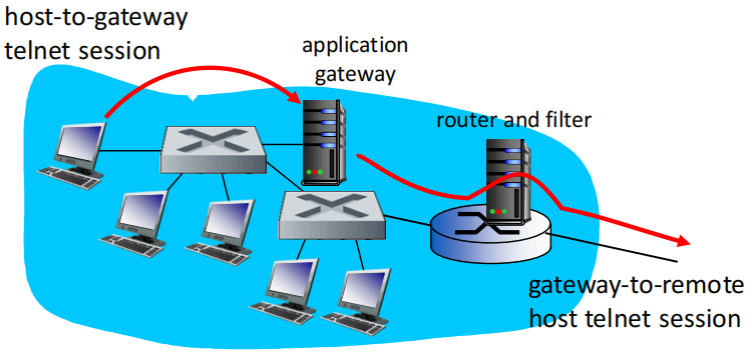
Application gateways 应用进程网关

- filter packets on application data as well as on IP/TCP/UDP fields.

  过滤应用进程数据包以及 IP/TCP/UDP 字段。 (在应用层做深入的应用数据流的剖析)

- **example**: allow select internal users to telnet outside

  示例:允许选定的内部用户在外部进行telnet



router and filter部分：设置内部除了application gateway，都不能和外界建立talenet session。 （要想建立，只能通过application gateway）

1. . require all telnet users to telnet through gateway.

   要求所有telnet用户通过网关进行telnet。

2. for authorized users, gateway sets up telnet connection to dest host. Gateway relays data between 2 connections.

   对于认证的用户而言，网关建立和目标主机的telnet connection ， 网关在2个连接上进行中继

3. router filter blocks all telnet connections not originating from gateway.

   路由器过滤器对所有不是来自网关的telnet的分组全部过滤掉

Limitations of firewalls, gateways 防火墙和应用程序网关的局限性

- **IP spoofing**: router can't know if data "really" comes from claimed source

  IP欺骗:路由器无法知道数据是否"真正"来自声称的来源
- if multiple app's. need special treatment, each has own application gateway

  如果多个应用进程需要特殊处理,则每个应用进程都有自己的应用进程网关
- client software must know how to contact gateway.

  客户端软件必须知道如何联系网关。
  - e.g., must set IP address of proxy in Web browser

    例如,必须在 Web 浏览器中设置代理的 IP 地址
- filters often use all or nothing policy for UDP

  过滤器通常使用 UDP 的全有或全无策略
- tradeoff: degree of communication with outside world, level of security

  权衡:与外部世界的沟通程度,安全水平
- many highly protected sites still suffer from attacks

  许多高度保护的网站仍然遭受攻击

Intrusion detection systems IDS：入侵检测系统

- **packet filtering:**

  数据包过滤:
  - operates on TCP/IP headers only

    仅在 TCP/IP 标头上运行
  - no correlation check among sessions

    没有会话之间的相关性检查
- **IDS: intrusion detection system**

  IDS:入侵检测系统
  - *deep packet inspection:* look at packet contents (e.g., check character strings in packet against database of known virus, attack strings)

    深度数据包检查:查看数据包内容(例如,检查数据包中的字符串与已知病毒数据库,攻击字符串)
  - examine correlation among multiple packets

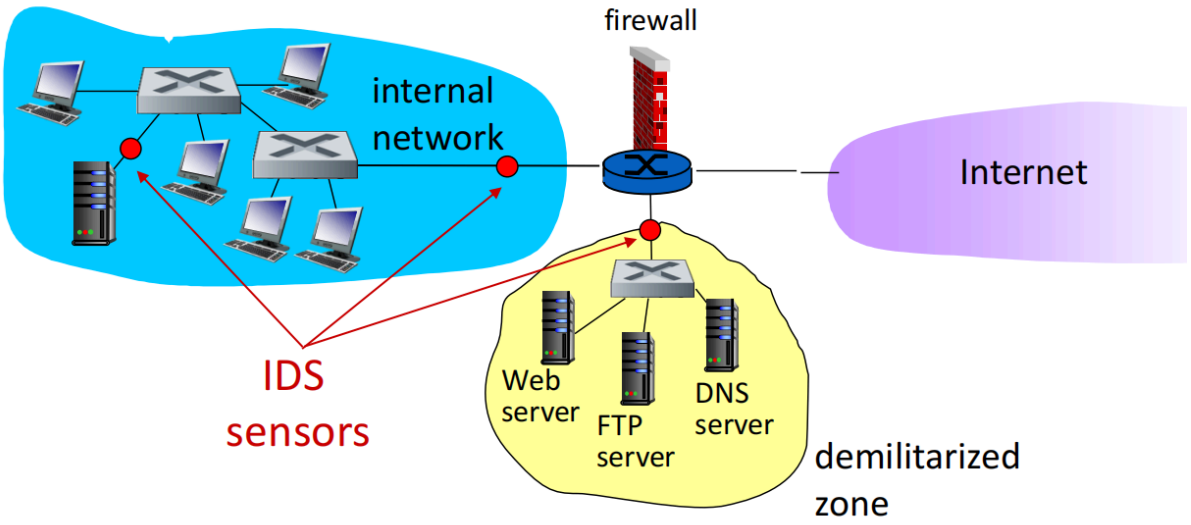
    检查多个数据包之间的相关性
    - port scanning

      端口扫描
    - network mapping

      网络映射(Network Mapping)
    - DoS attack

      DoS攻击

multiple IDSs: different types of checking at different locations



Network Security Summary

basic techniques.....

- cryptography (symmetric and public)
- message integrity
- end-point authentication

.... used in many different security scenarios

- secure email
- secure transport (SSL)
- IP sec
- 802.11

operational security: firewalls and IDS