Aalto University
School of Electrical Engineering

Basic Principles in Networking

IPsec

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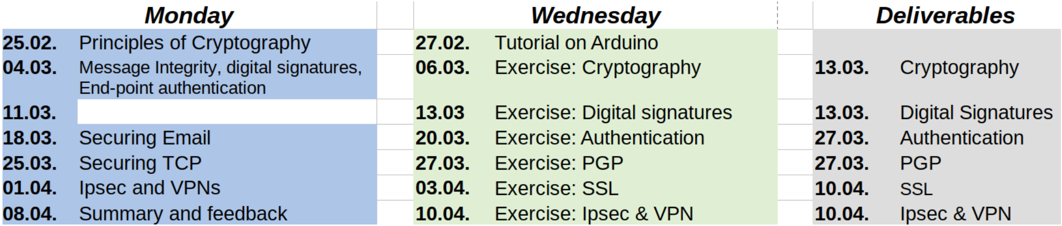
Lecture overview



Monday		***Wednesday***		***Deliverables***	
25.02.	Principles of Cryptography	**27.02.**	Tutorial on Arduino		
04.03.	Message Integrity, digital signatures, End-point authentication	**06.03.**	Exercise: Cryptography	**13.03.**	Cryptography
11.03.		**13.03**	Exercise: Digital signatures	**13.03.**	Digital Signatures
18.03.	Securing Email	**20.03.**	Exercise: Authentication	**27.03.**	Authentication
25.03.	Securing TCP	**27.03.**	Exercise: PGP	**27.03.**	PGP
01.04.	Ipsec and VPNs	**03.04.**	Exercise: SSL	**10.04.**	SSL
08.04.	Summary and feedback	**10.04.**	Exercise: Ipsec & VPN	**10.04.**	Ipsec & VPN

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Engineering

Motivation (5 min)

Sha-1 collision (Defcon 2017)

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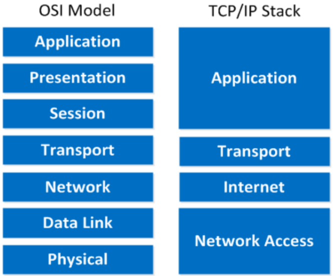
Part I (20 min)

IPsec

IPSec



OSI Model

Application

Presentation

Session

Transport

Network

Data Link

Physical

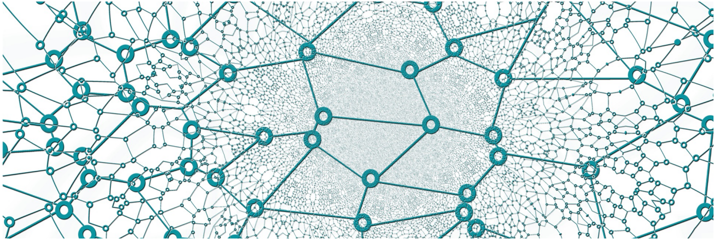
TCP/IP Stack

Application

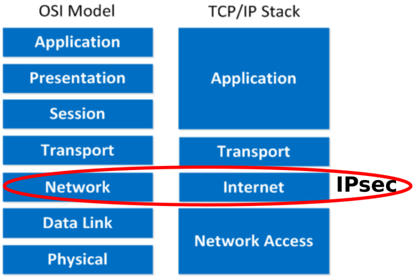
Transport

Internet

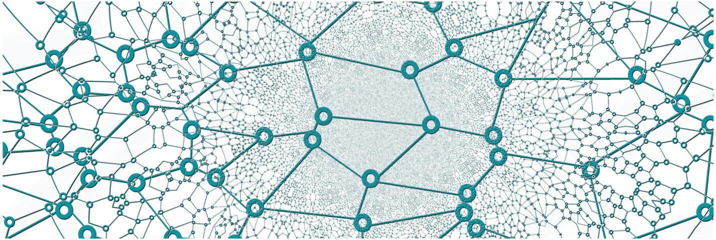
Network Access



IPSec



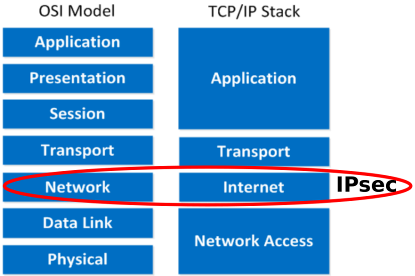
OSI Model	TCP/IP Stack	
Application	Application	
Presentation		
Session		
Transport	Transport	
Network	Internet	IPsec
Data Link	Network Access	
Physical		



IPSec

With confidentiality at network layer ...

...all protocol and type information hidden (e.g. TCP, UDP, ICMP, SMTP, ...)



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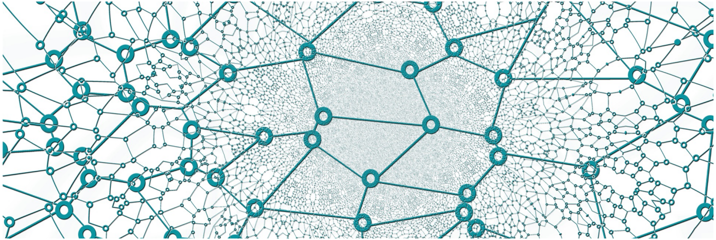
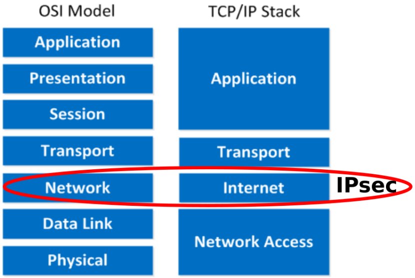
IPsec



IPSec



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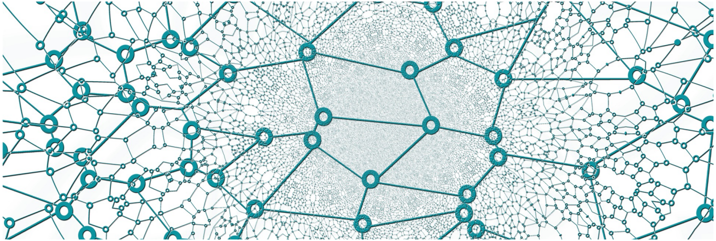
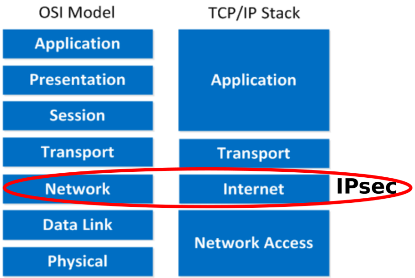


IPSec Services

1. confidentiality
2. authentication
3. data integrity
4. replay-attack prevention

IPSec



OSI Model	TCP/IP Stack
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IPsec

IPSec Services

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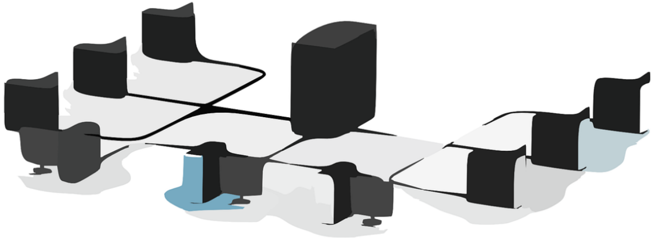
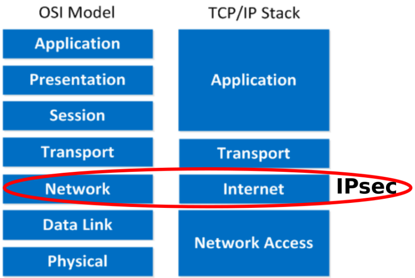
VPNs

Stand-alone physical network including routers, links and DNS infrastructure

Separated from the public internet



IPSec

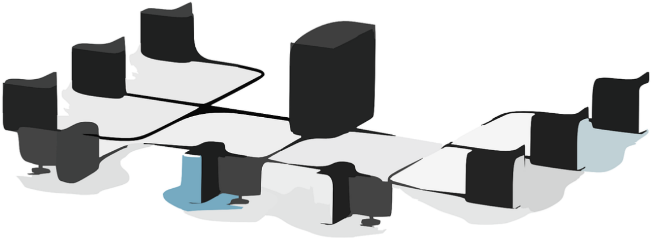


VPNs

Stand-alone physical network including routers, links and DNS infrastructure

Separated from the public internet

High maintenance cost



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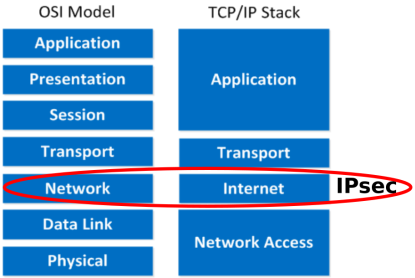

OSI Model

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TCP/IP Stack

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IPsec

VPNs

institution’s inter-office traffic is sent over the public internet rather than over a prhysical independent network.

IPSec Services

1. confidentiality
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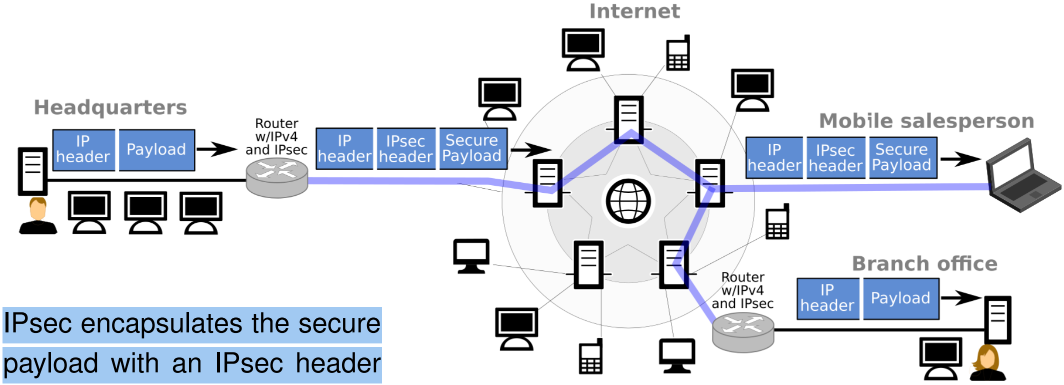
4. replay-attack prevention

IPsec

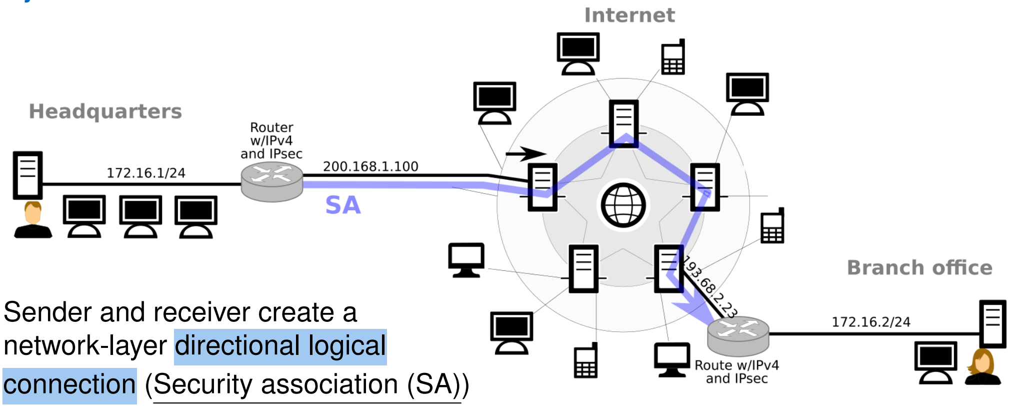
IPsec and VPNs



IPsec encapsulates the secure payload with an IPsec header in a standard IP packet

IPsec

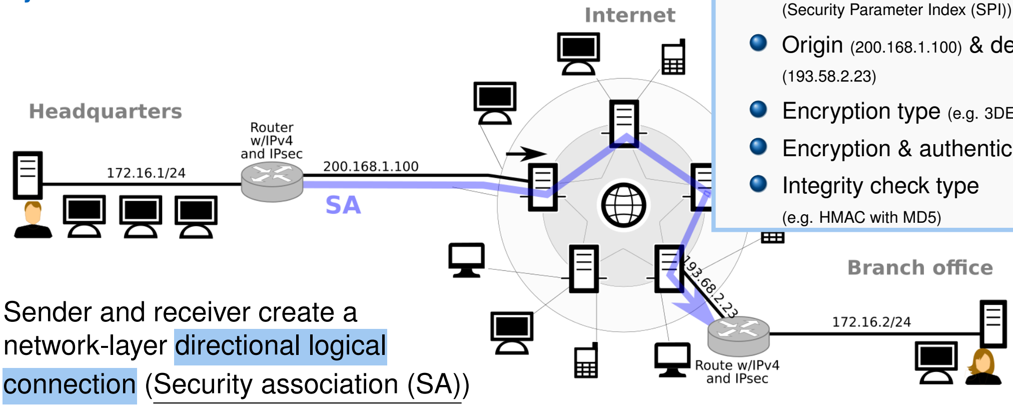
Security associations



Init: Sender and receiver create a network-layer directional logical connection (Security association (SA))

IPsec

Security associations



Security Association

- 32-bit identifier for SA (Security Parameter Index (SPI))
- Origin (200.168.1.100) & destination (193.58.2.23)
- Encryption type (e.g. 3DES with CBC)
- Encryption & authentication keys
- Integrity check type (e.g. HMAC with MD5)

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IPsec

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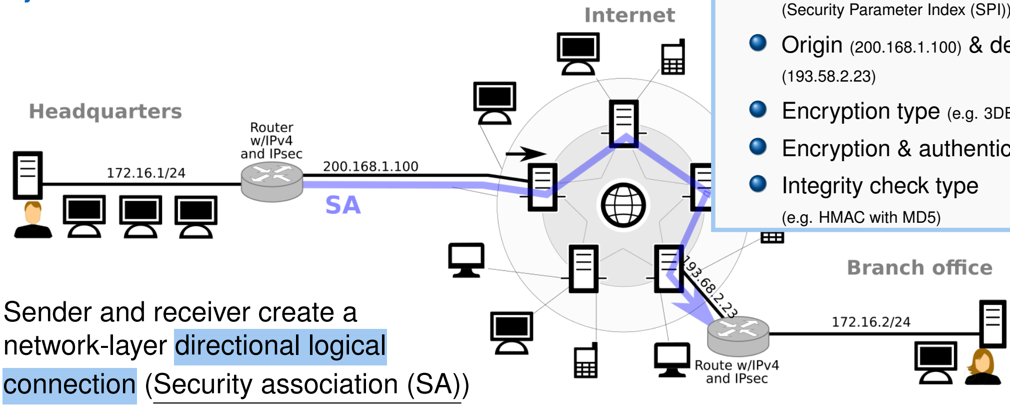


Init: Sender and receiver create a network-layer directional logical connection (Security association (SA))

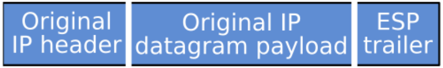
SA state maintained at origin and destination for session management

IPsec

IPsec datagram

Construct IPsec datagram

1. Original IPv4 datagram attached with ’Esp trailer’



IPsec

IPsec datagram

Construct IPsec datagram

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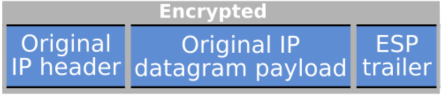
2. Encrypt using the algorithm and key specified by SA

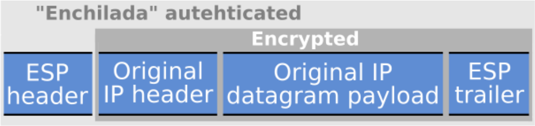


IPsec

IPsec datagram

Construct IPsec datagram

1. Original IPv4 datagram attached with ’Esp trailer’
2. Encrypt using the algorithm and key specified by SA
3. Append ESP header and create MAC over whole enchilada using algorithm and key specified in SA



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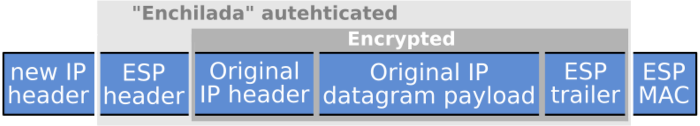

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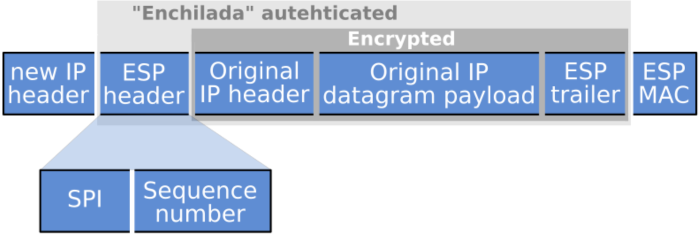

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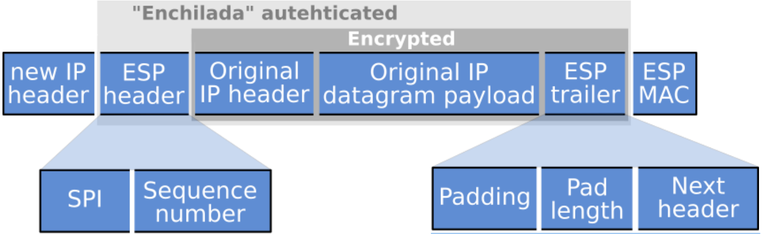
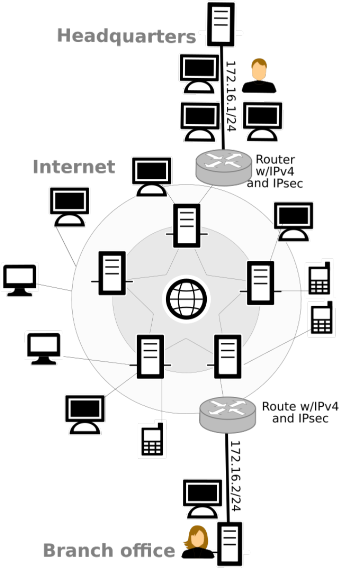


Padding of	blockcipher
Pad length	of padding
Next header:	type of data in payload

IPsec

Key management in IPsec

IPsec uses Internet Key Exchange (IKE)

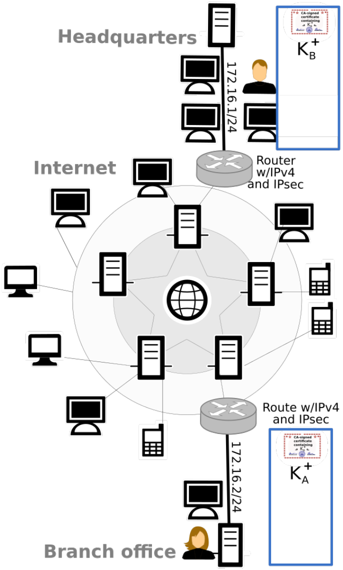


IPsec

Key management in IPsec

IPsec uses Internet Key Exchange (IKE)

init: Each IPsec entity has certificate & public key



IPsec

Key management in IPsec

IPsec uses Internet Key Exchange (IKE)

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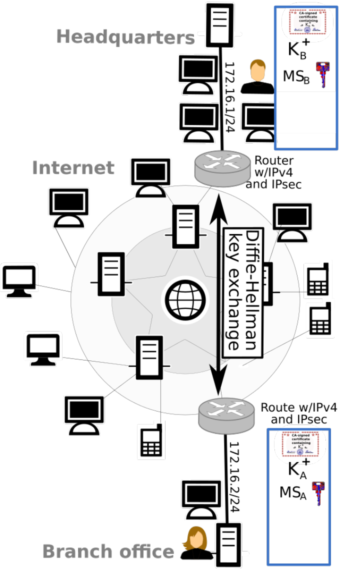
First: Bi-directional IKE SA between entities via Diffie-Hellman (no authentication)

- Establish master key



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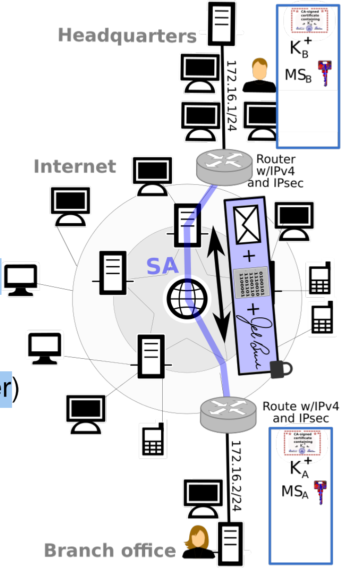
Encrypted: Sign messages to authenticate (invisible to eavesdropper)



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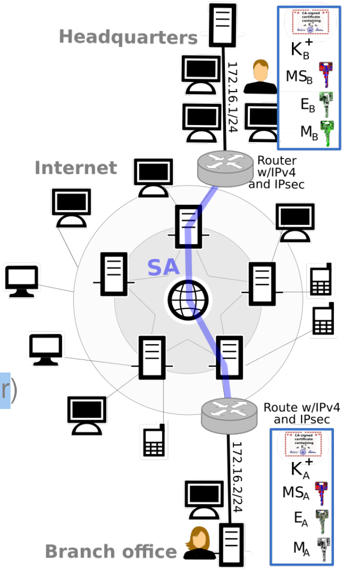
Compute: IPsec SA keys from master secret



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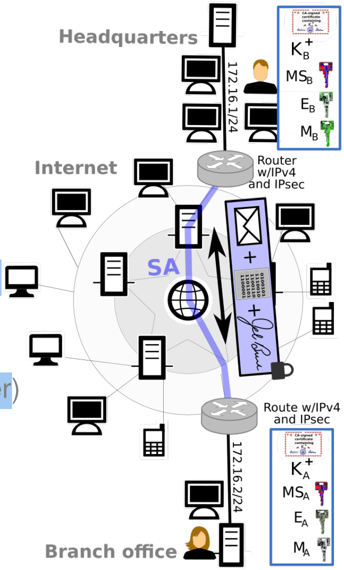
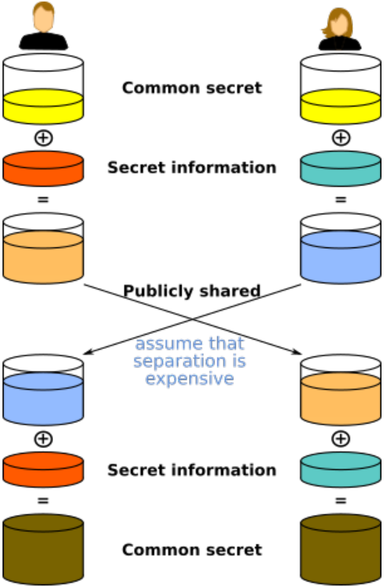
Compute: IPsec SA keys from master secret

Negotiate: IPsec encryption and authentication algorithms



IPsec

Diffie-Hellman Key Exchange



IPsec

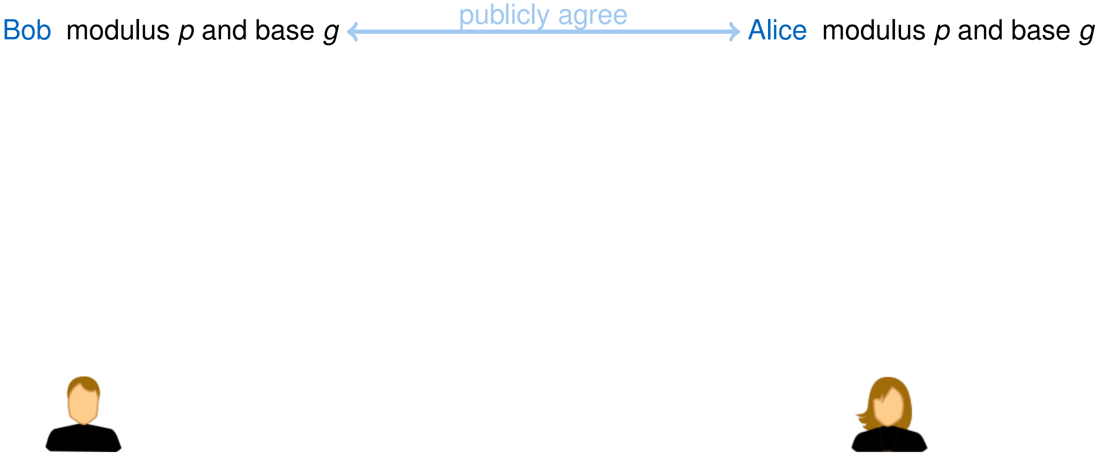
Diffie-Hellman Key Exchange

Bob modulus p and base g

Alice modulus p and base g

IPsec

Diffie-Hellman Key Exchange



Bob modulus p and base g ⟷ publicly agree ⟷ Alice modulus p and base g

IPsec

Diffie-Hellman Key Exchange

publicly agree

Bob modulus p and base g ↔ Alice modulus p and base g

Bob choose secret b

Alice

IPsec

Diffie-Hellman Key Exchange

Bob modulus p and base g ← publicly agree → Alice modulus p and base g

Bob choose secret b → Send $B = g^b \mod p$ → Alice

IPsec

Diffie-Hellman Key Exchange

Bob modulus p and base g ← publicly agree → Alice modulus p and base g

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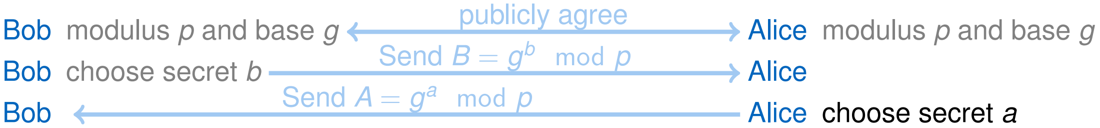
Bob

Alice choose secret a

IPsec

Diffie-Hellman Key Exchange



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Bob ← Send $A = g^a \mod p$ — Alice choose secret a

IPsec

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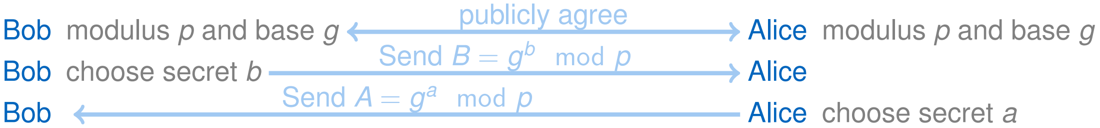

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Bob compute:

$$\begin{aligned} s &= A^b \mod p \\ &= g^{ab} \mod p \end{aligned}$$

Alice compute:

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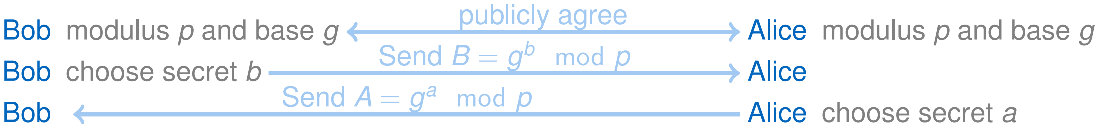
IPsec

Diffie-Hellman Key Exchange



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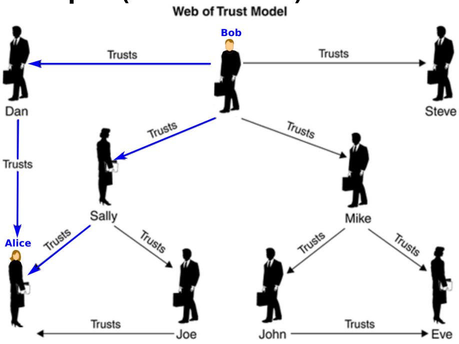
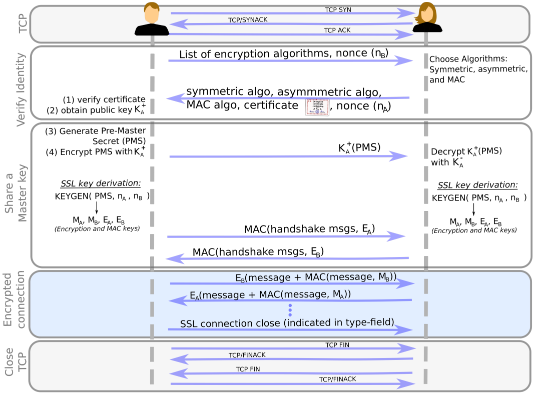
Recap-slam (15 min)

Recap-Slam

Group A (Web of Trust):



Group B (SSL handshake):



TCP
TCP SYN
TCP/SYNACK
TCP ACK
Verify identity
List of encryption algorithms, nonce (n_B)
Choose Algorithms: Symmetric, asymmetric, and MAC
(1) verify certificate
(2) obtain public key K_A^+
symmetric algo, asymmmetric algo, MAC algo, certificate , nonce (n_A)
Share a Master key
(3) Generate Pre-Master Secret (PMS)
(4) Encrypt PMS with K_A^+
K_A^+(PMS)
Decrypt K_A^+(PMS) with K_A^-
SSL key derivation:
KEYGEN(PMS, n_A , n_B)
M_A, M_B, E_A, E_B
(Encryption and MAC keys)
SSL key derivation:
KEYGEN(PMS, n_A , n_B)
M_A, M_B, E_A, E_B
(Encryption and MAC keys)
MAC(handshake msgs, E_A)
MAC(handshake msgs, E_B)
Encrypted connection
E_B(message + MAC(message, M_B))
E_A(message + MAC(message, M_A))
SSL connection close (indicated in type-field)
Close TCP
TCP FIN
TCP/FINACK
TCP FIN
TCP/FINACK

Preparation 5 minutes

Presentation Group A/B 5+5 minutes

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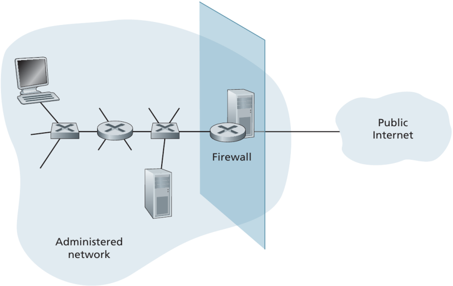
Part II (20 min)

Firewalls and Intrusion Detection Systems

Firewalls

Isolates local network from the Internet

- all traffic passes through the firewall
- all non-authorized traffic is dropped
- firewall shall be immune to penetration



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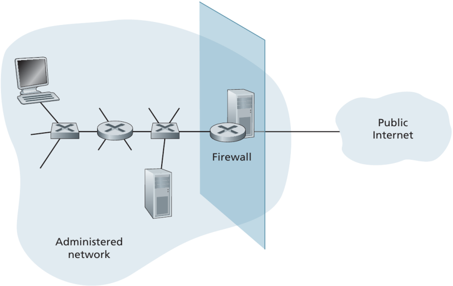


Three categories of firewalls:

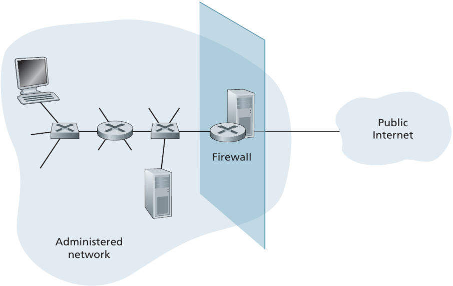
1. Packet filters
2. Stateful filters
3. Application gateways

Firewalls

Packet filters

Gateway router

- examines each datagram in isolations
- administrator-specific rules for pass or drop



Firewalls

Packet filters

Gateway router

- examines each datagram in isolations
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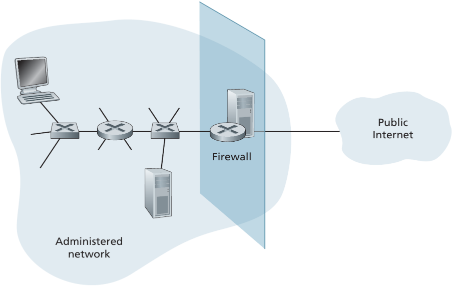
Filtering decisions based on (e.g.):

1. IP source or destination address
2. Protocol type in IP datagram field (TCP, UDP, ICMP, OSPF, ...)
3. TCP/UDP source and destination port
4. TCP flag bits: SYN, ACK, ...
5. ICMP message type



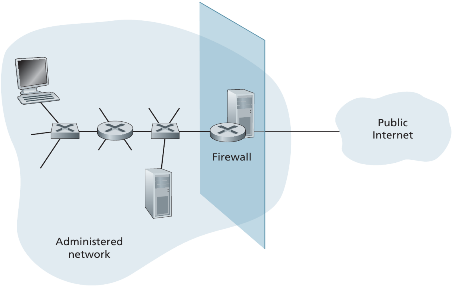
Firewalls

Packet filters

Gateway router

- examines each datagram in isolations
- administrator-specific rules for pass or drop

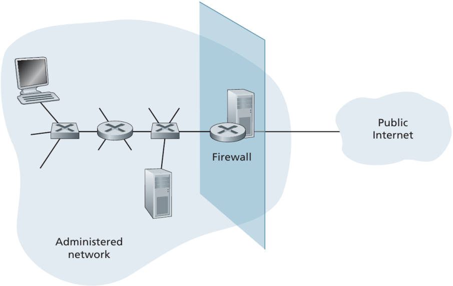
Policy	firewall setting
No outside web address	Drop outgoing packets to any IP adr, port 80
No incoming TCP	Drop TCP SYN packets
Resilience against smurf DoS attack	Drop ICMP ping pkts to broadcast adr (e.g. 130.207.255.255)
Prevent network traceroute	Drop all outgoing ICMP TTL expired traffic



Firewalls

Stateful filters

- Track all ongoing TCP traffic in a connection table



Firewalls

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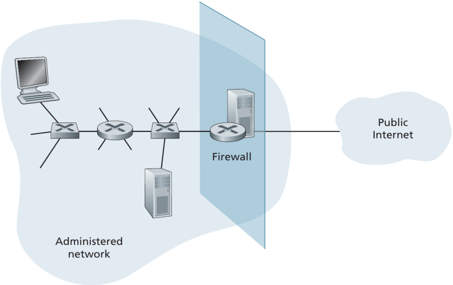
Prevent network traceroute	Drop all outgoing ICMP TTL expired traffic

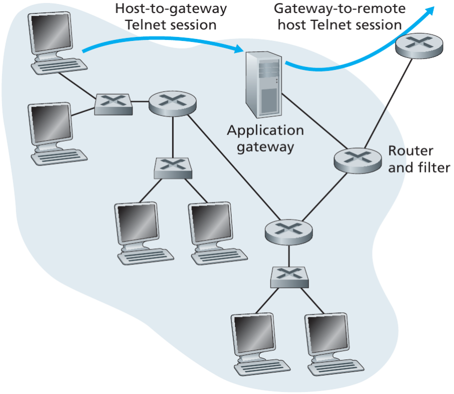


In stateless filter example, packets with ACK=1 and source port 80 get through the filter and could be used to crash local systems with malformed ACK packets

Firewalls

Application gateways

- allow application specific rules for selected users



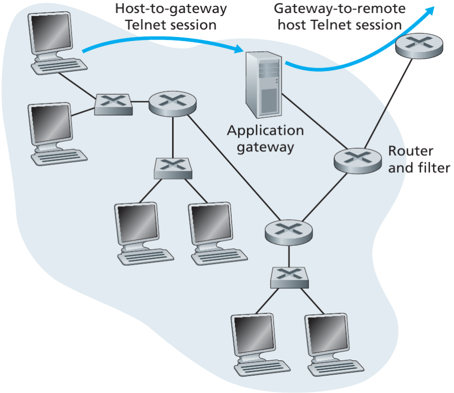
Firewalls

Application gateways

- allow application specific rules for selected users

An application gateway...

1. make policy ecitions based on application data
2. take decisions beyond IP/TCP/UDP headers
3. is an application-specific server through which all application data must pass
4. performs user authorization


Host-to-gateway Telnet session
Gateway-to-remote host Telnet session
Application gateway
Router and filter

Firewalls

Application gateways

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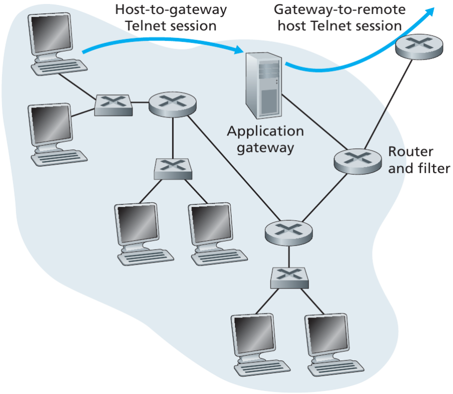


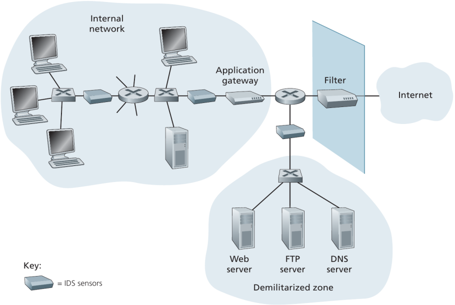
Host-to-gateway Telnet session
Gateway-to-remote host Telnet session
Application gateway
Router and filter

performance penalty since all traffic passes through application gateway

Intrusion detection systems

For many attack types, deep packet inspection is needed

→ Look beyond header fields and into actual application data carried by packets



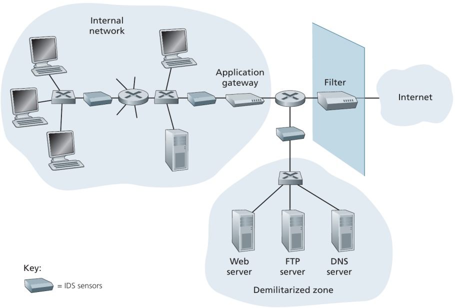
Intrusion detection systems

For many attack types, deep packet inspection is needed

→ Look beyond header fields and into actual application data carried by packets

IDSs detect wide range of attacks

- network mapping
- port scans
- TCP stack scans
- DoS bandwidth-flooding attacks
- Worms and viruses
- OS/application vulnerability attacks



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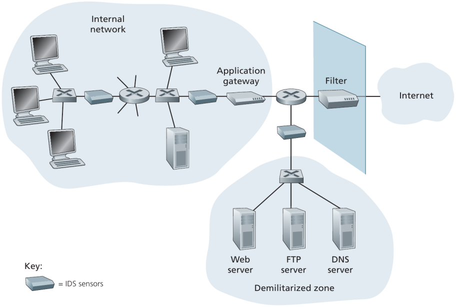
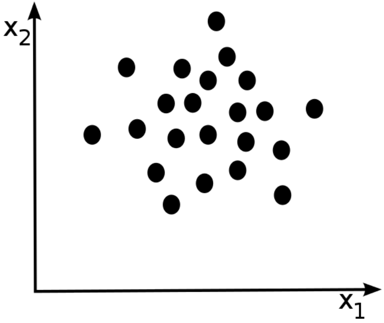


IDS systems are either signature-based or anomaly-based

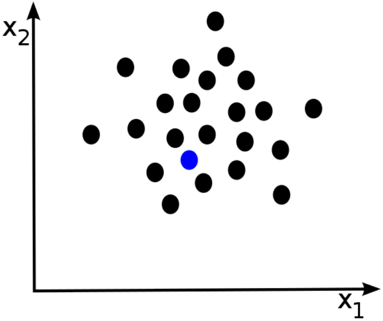
Anomaly detection

Problem statement



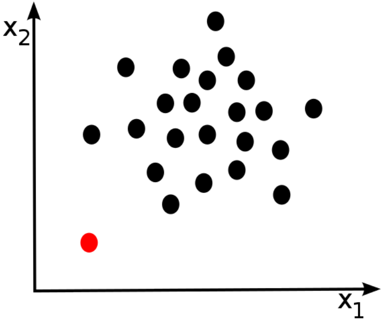
Anomaly detection

Problem statement



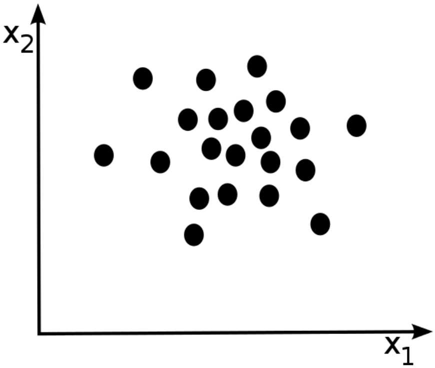
Anomaly detection

Problem statement



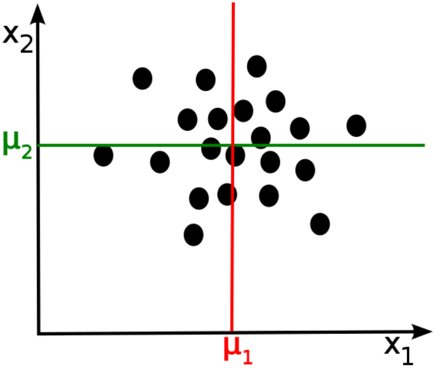
Anomaly detection

Example



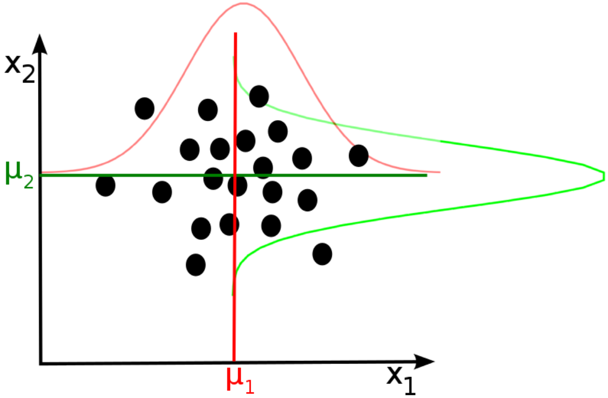
Anomaly detection

Example



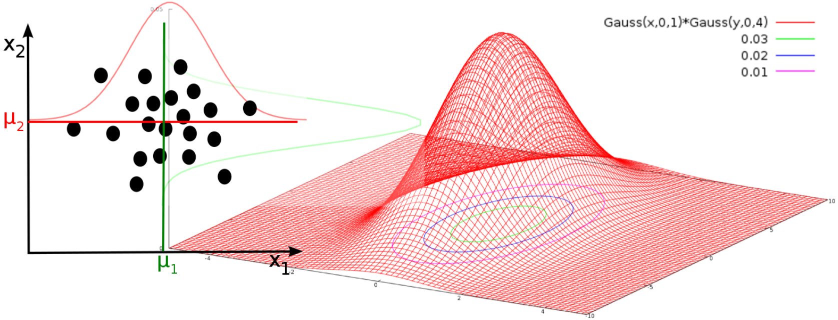
Anomaly detection

Example



Anomaly detection

Example



Anomaly detection

Problem statement

Choice of good values for ε

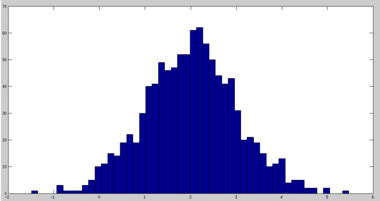
Using crossvalidation and testing sets, calculate

- Precision/Recall
- F_1-score
- ...

Anomaly detection

Non-Gaussian features

In anomaly detection, we have so far assumed Gaussian distributed features.

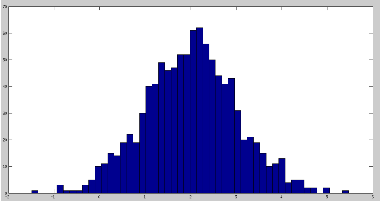


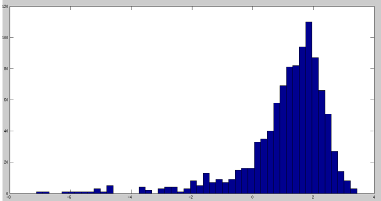
Anomaly detection

Non-Gaussian features

In anomaly detection, we have so far assumed Gaussian distributed features.

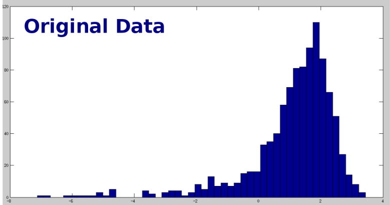
→ What if the feature distribution is not Gaussian ?

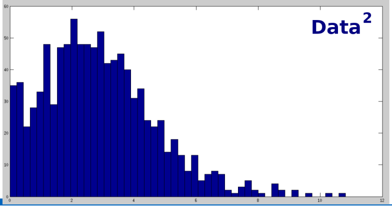


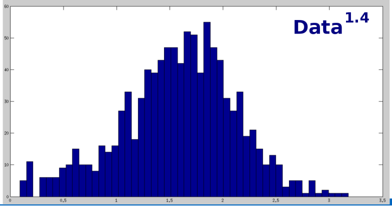


Anomaly detection

Generate new features with a more Gaussian-like distribution







Anomaly detection

Non-Gaussian features

Possible operations on features

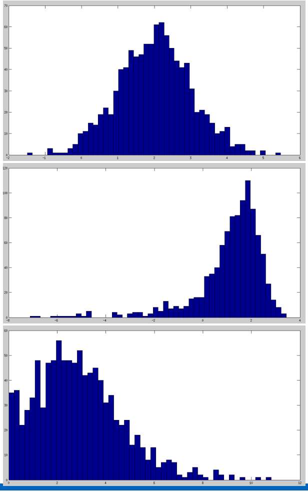
$$x_{\text{new}} = \log(x)$$

$$x_{\text{new}} = \sqrt{x}$$

$$x_{\text{new}} = x^{\frac{1}{3}}$$

$$x_{\text{new}} = \log(x + k)$$

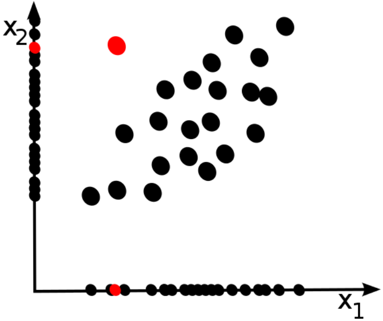
$$\vdots$$



Anomaly detection

Multivariate Gaussian Distribution

- Note that there are cases in which the anomaly looks perfectly normal when considering each dimension separately

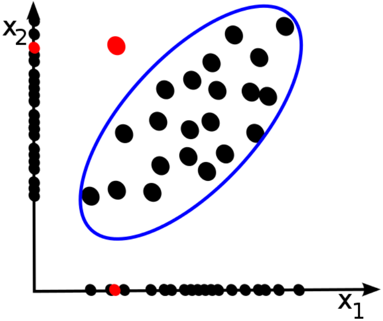


Anomaly detection

Multivariate Gaussian Distribution

- Note that there are cases in which the anomaly looks perfectly normal when considering each dimension separately

→ The consideration of multivariate Gaussian distributions might help to to detect such anomalies.



Aalto University
School of Electrical Engineering

Video: Future perspectives (5 min)

R. Rivest, W. Diffie, A. Shamir, M. Marlinspike

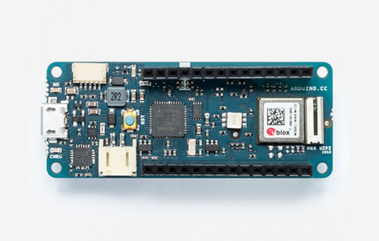
Aalto University
School of Electrical Engineering

Hands-on group work (10 min)

Exercises, feedback and Q&A

Hands-on group work

- Additional pracical guidance
- Some hints on the exercises
- Q&A



Questions?

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Literature

- J.F. Kurose,K.W. Ross: Computer Networking: A Top-Down approach (7th edition), Pearson, 2016.
- J.F. Kurose,K.W. Ross: Computer Networking: A Top-Down approach (6th edition), Addison-Wesley, 2012.