DSS – preparation for the oral exam

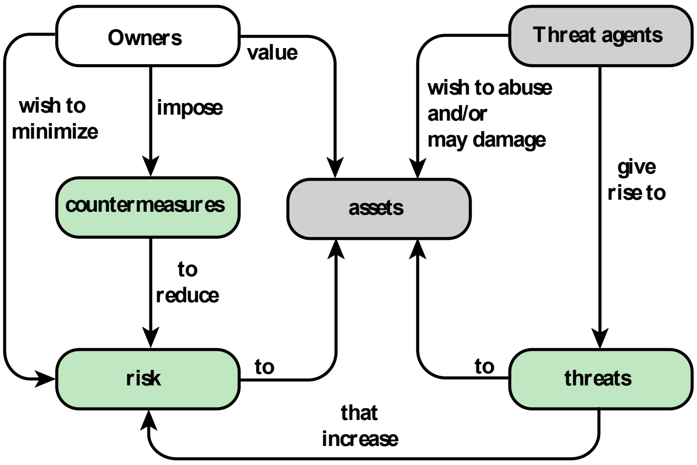
I may start the oral exam by asking you to comment/explain one of the following schemas or by asking you to answer to one of the following questions.

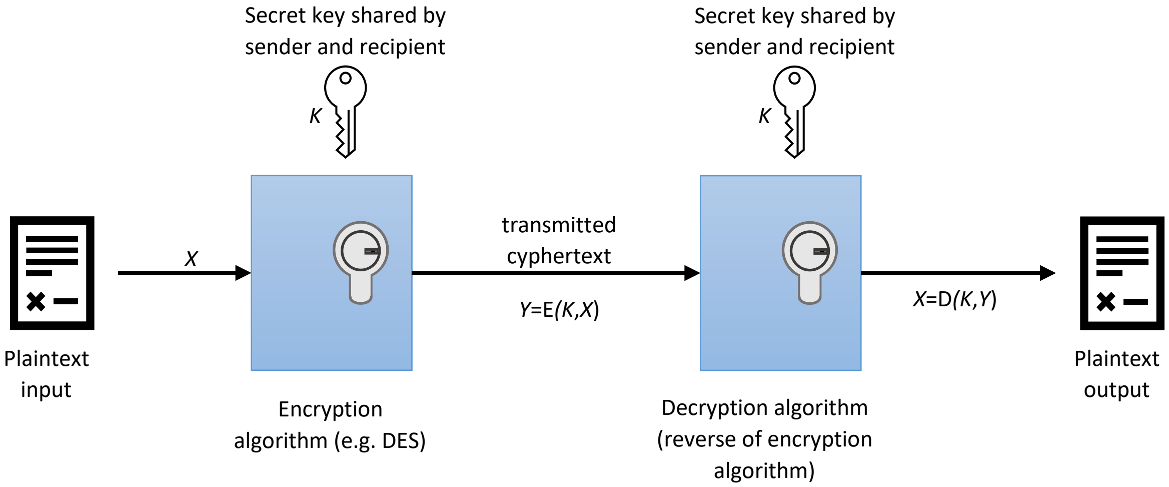
Hands-on

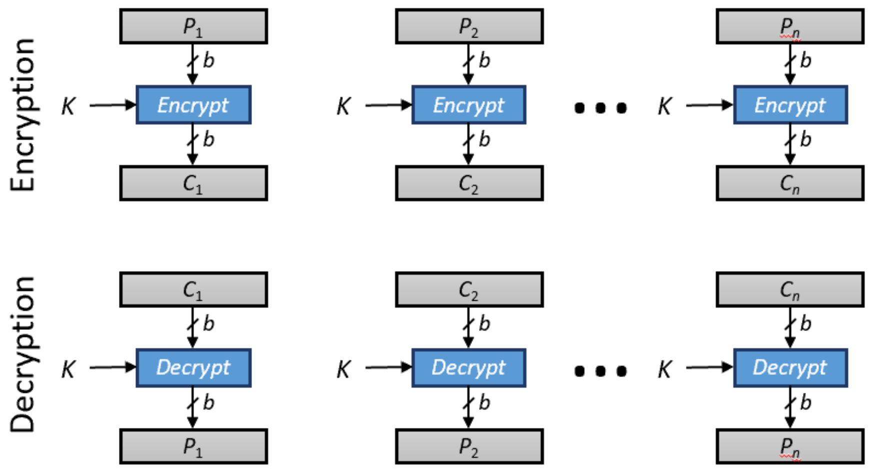
- Discuss the hands-on class on brute force attack and present your solution
- Discuss the hands-on class on Buffer overflow and present your solution
- Discuss the hands-on class on Keylogger and present your solution
- Discuss the hands-on class on Proof of Work and present your solution
- Discuss the hands-on class on Fat32 inspection and present your solution

Part 1

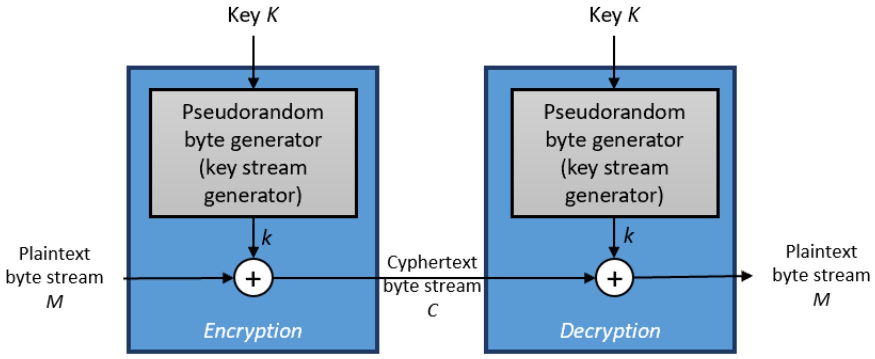
- What is the CIA? Explain its key security concepts.
- Define threats, attacks and assets; define the concepts of attack surface and defense in depth and provide relevant examples.
- Present and explain the properties of one-way hash functions
- Explain the meaning of “multifactor authentication” and provide relevant examples
- Discuss the methodologies of password cracking, explain the concepts of dictionary attack and of rainbow table attack and explain the role of the salt in the Unix password file.
- Discuss the policies to strength the password management and how they can be enforced (proactive password checking, complex password policy, etc.)
- Discuss the different methods for biometric authentication
- Discuss the token-based authentication
- Explain the challenge-response protocol for remote user authentication
- Define Discretionary access control, Role-based accesso control, Attribute-based access control and give relevant examples
- Explain the differences between access control matrix, lists of capabilities and access control lists
- Explain the basic model of Unix for access control
- Discuss advantages and disadvantages of RBAC and ABAC
- Discuss methods to implement complex passwords policy and proactive password checking
- Explain how does RBAC can be implemented
- Discuss the Unix model for access control


Owners
value
wish to minimize
impose
Threat agents
wish to abuse and/or may damage
give rise to
countermeasures
assets
to reduce
risk
to
to
threats
that increase

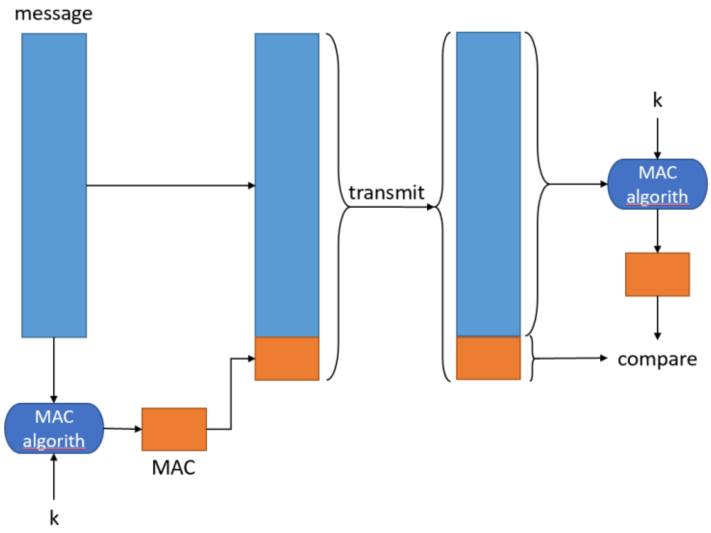

Secret key shared by sender and recipient
K
Secret key shared by sender and recipient
K
X
transmitted cyphertext
Y=E(K,X)
X=D(K,Y)
Plaintext input
Encryption algorithm (e.g. DES)
Decryption algorithm (reverse of encryption algorithm)
Plaintext output

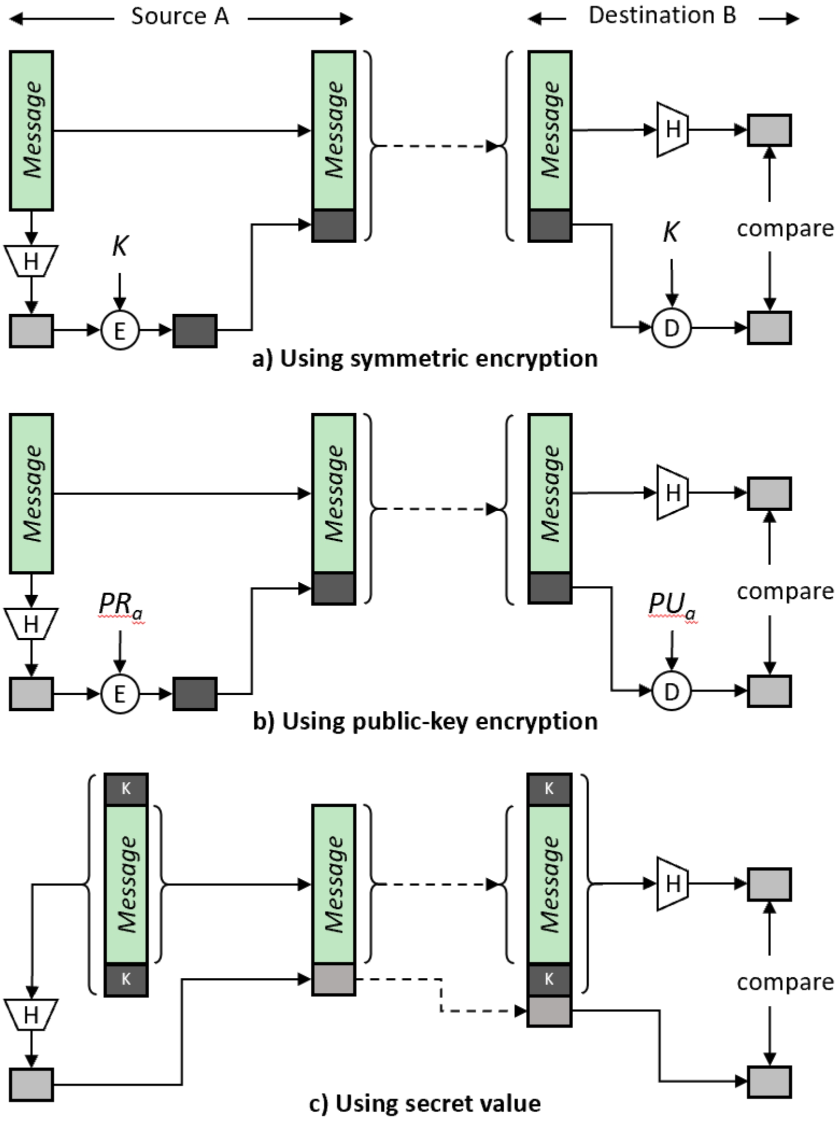


Block cipher encryption (electronic codebook mode)



Stream encryption

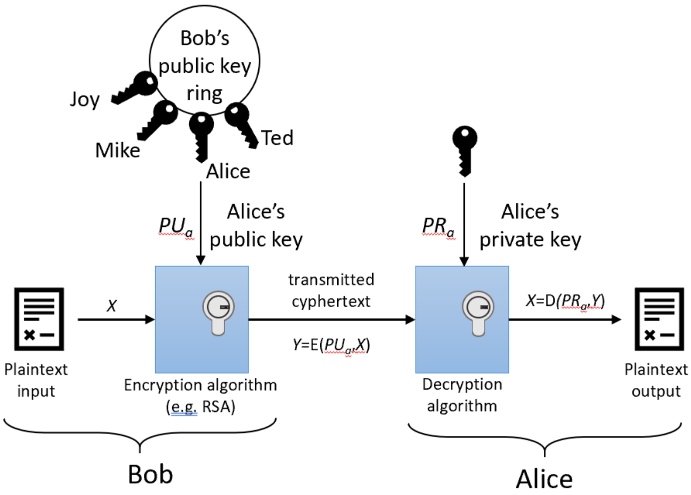




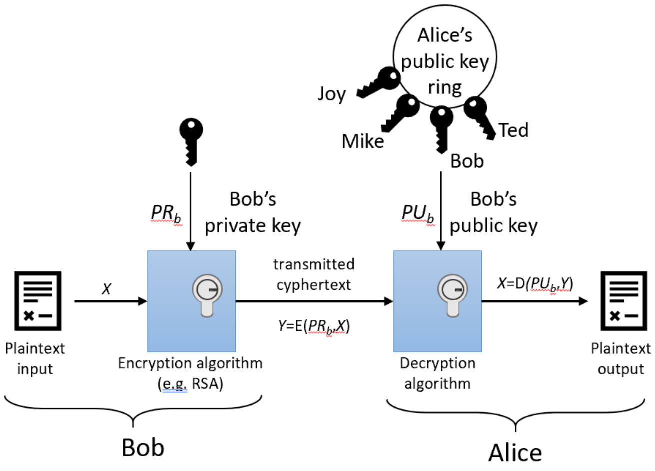
a) Using symmetric encryption

b) Using public-key encryption

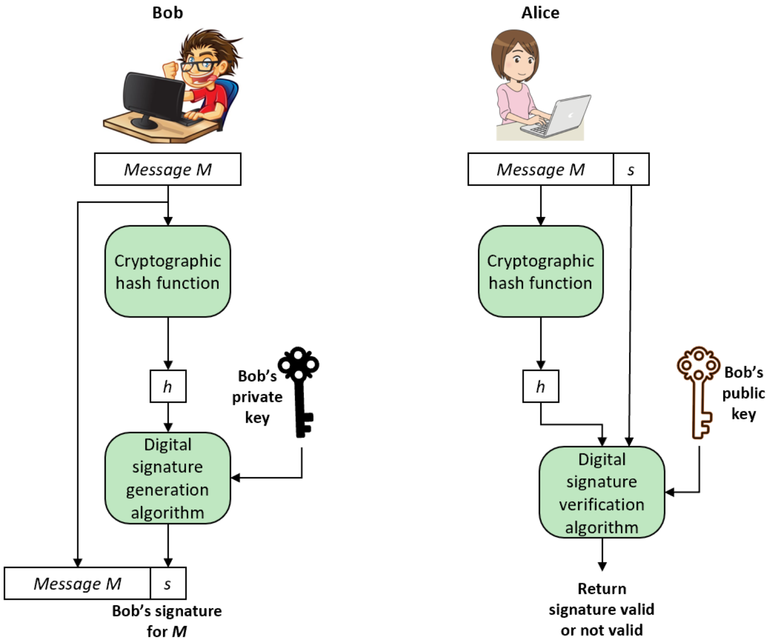
c) Using secret value



Encryption with public key

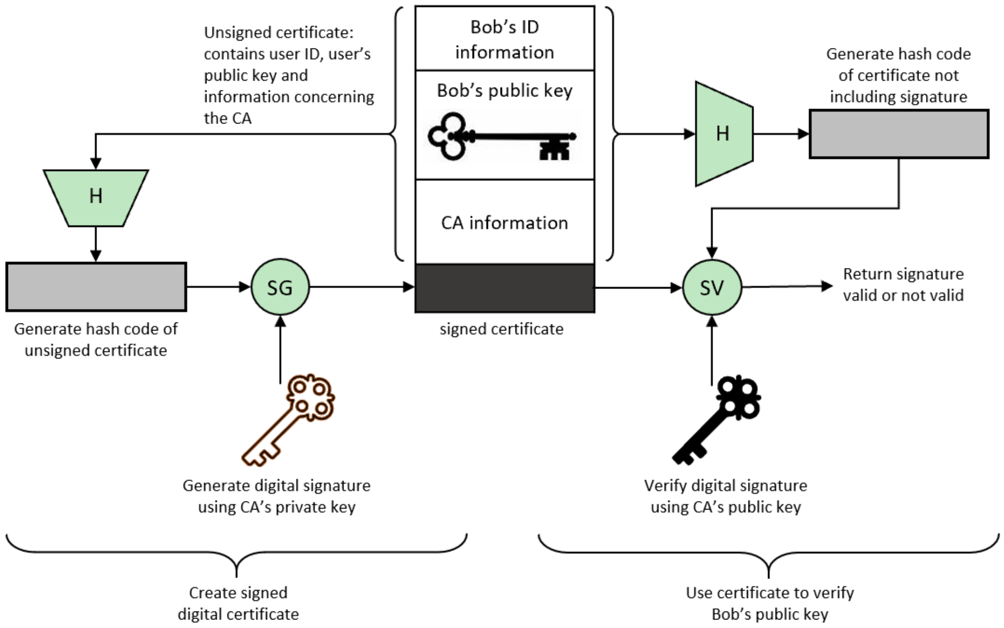


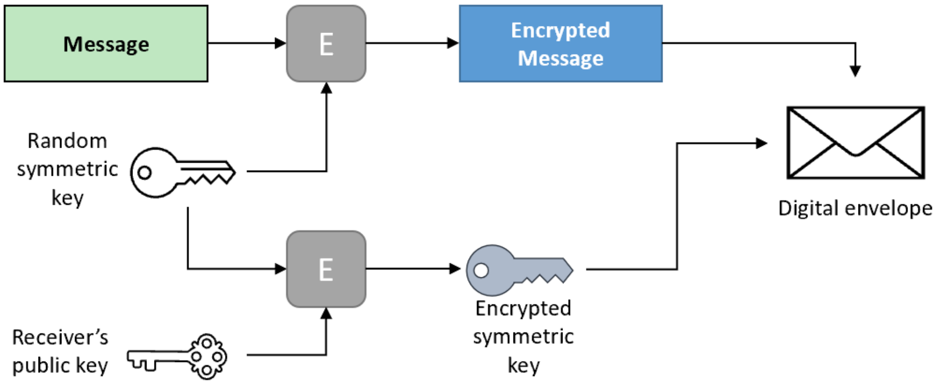
Encryption with private key


Bob
Message M
Cryptographic hash function
h
Bob's private key
Digital signature generation algorithm
Message M
s
Bob's signature for M
Alice
Message M
s
Cryptographic hash function
h
Bob's public key
Digital signature verification algorithm
Return signature valid or not valid

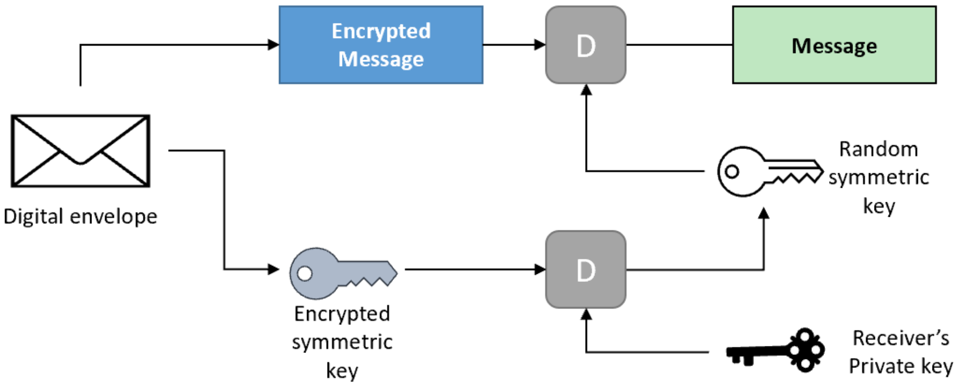
a) Bob signs a message

b) Alice verifies the signature

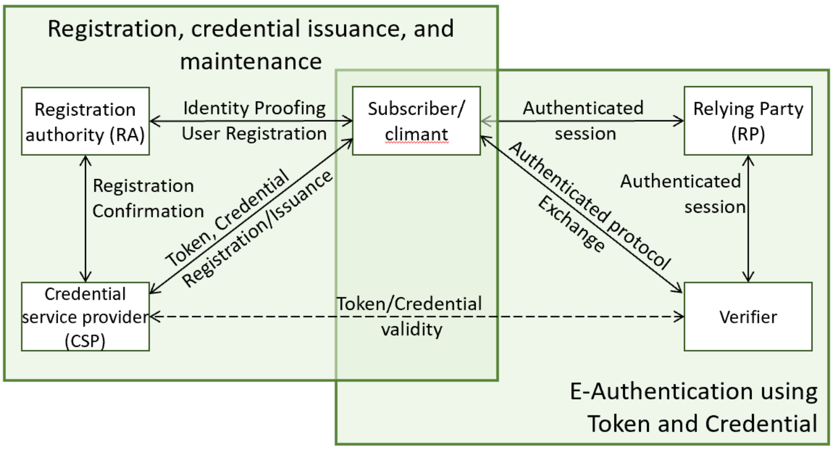

Unsigned certificate: contains user ID, user's public key and information concerning the CA
Bob's ID information
Bob's public key
CA information
H
Generate hash code of unsigned certificate
SG
signed certificate
Generate digital signature using CA's private key
Create signed digital certificate
H
Generate hash code of certificate not including signature
SV
Return signature valid or not valid
Verify digital signature using CA's public key
Use certificate to verify Bob's public key



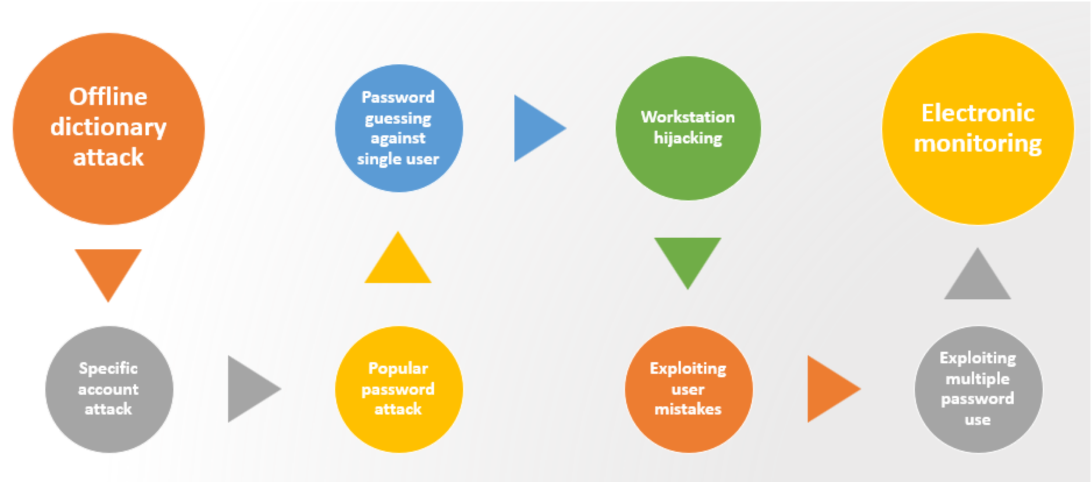
a) Creation of a digital envelope

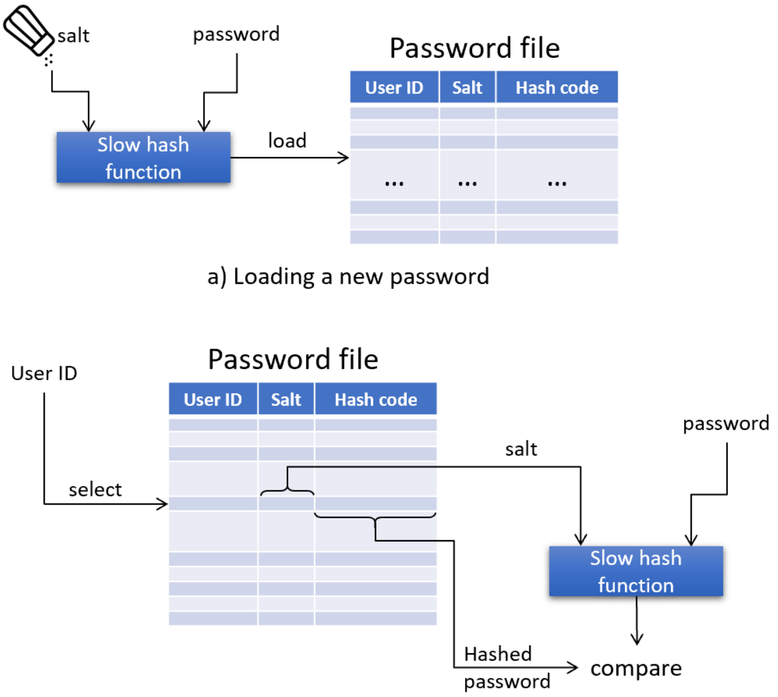


b) Opening a digital envelope


Registration, credential issuance, and maintenance
Registration authority (RA)
Identity Proofing
User Registration
Subscriber/ climant
Authenticated session
Relying Party (RP)
Registration Confirmation
Token, Credential
Registration/Issuance
Authenticated protocol
Exchange
Authenticated session
Credential service provider (CSP)
Token/Credential validity
Verifier
E-Authentication using Token and Credential

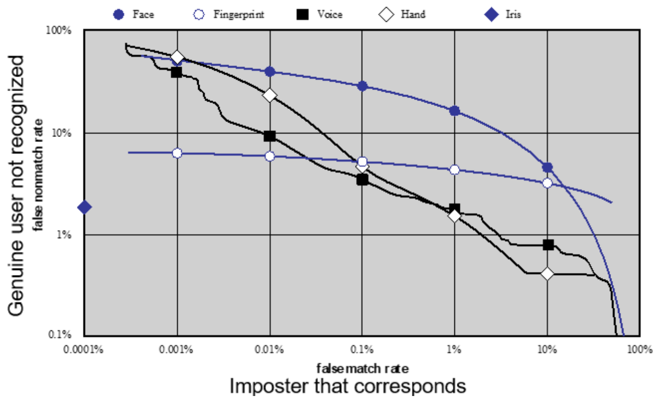
The NIST SP 800-63-3 E-authentication architectural model

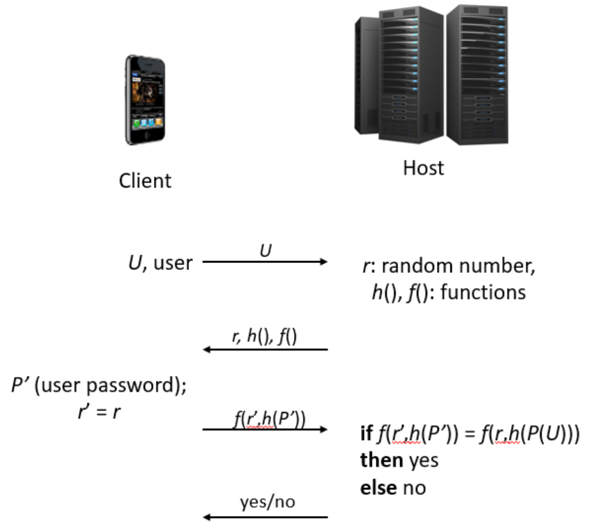




a) Loading a new password

b) Verifying a password





Client

Host

U, user $\xrightarrow{U}$

r: random number,
$h()$, $f()$: functions

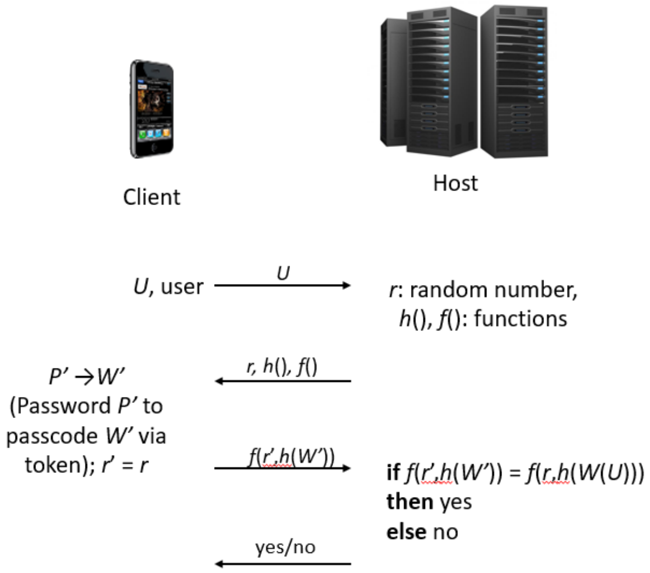
$\xleftarrow{r,\ h(),\ f()}$

P' (user password);
$r' = r$

$\xrightarrow{f(r', h(P'))}$

if $f(r', h(P')) = f(r, h(P(U)))$
then yes
else no

$\xleftarrow{\text{yes/no}}$



Client

Host

U, user $\xrightarrow{U}$

r: random number,
$h()$, $f()$: functions

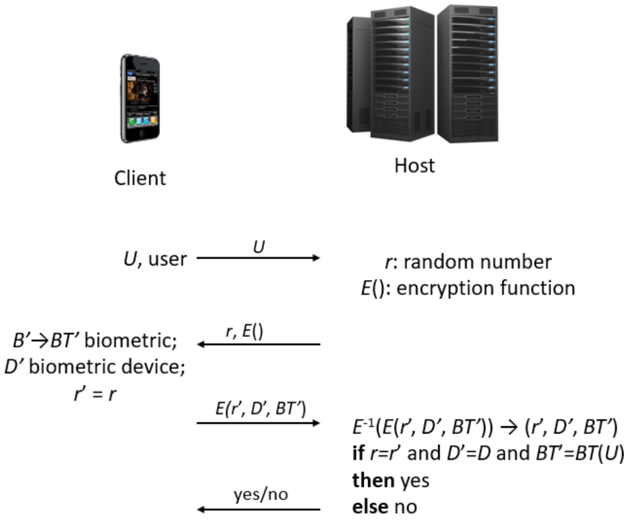
$P' \rightarrow W'$
(Password P' to passcode W' via token); $r' = r$

$\xleftarrow{r,\ h(),\ f()}$

$\xrightarrow{f(r', h(W'))}$

if $f(r', h(W')) = f(r, h(W(U)))$
then yes
else no

$\xleftarrow{\text{yes/no}}$



Client

Host

U, user $\xrightarrow{U}$

r: random number
$E()$: encryption function

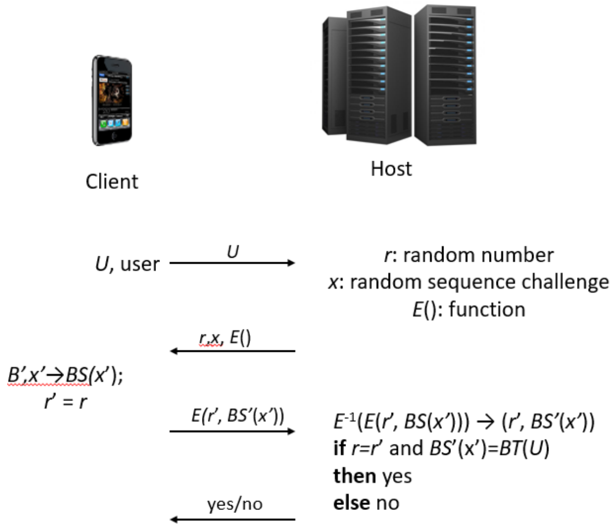
$B' \rightarrow BT'$ biometric;
D' biometric device;
$r' = r$

$\xleftarrow{r,\ E()}$

$\xrightarrow{E(r', D', BT')}$

$E^{-1}(E(r', D', BT')) \rightarrow (r', D', BT')$
if $r = r'$ and $D' = D$ and $BT' = BT(U)$
then yes
else no

$\xleftarrow{\text{yes/no}}$



Client

Host

U, user $\xrightarrow{U}$

r: random number
x: random sequence challenge
$E()$: function

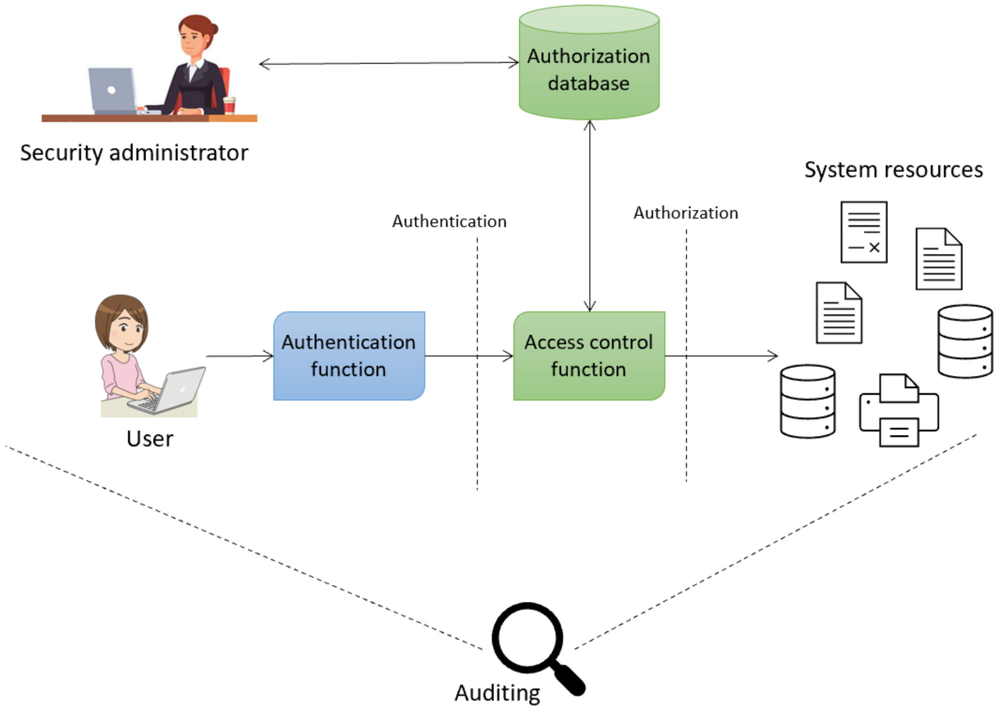
$\xleftarrow{r, x,\ E()}$

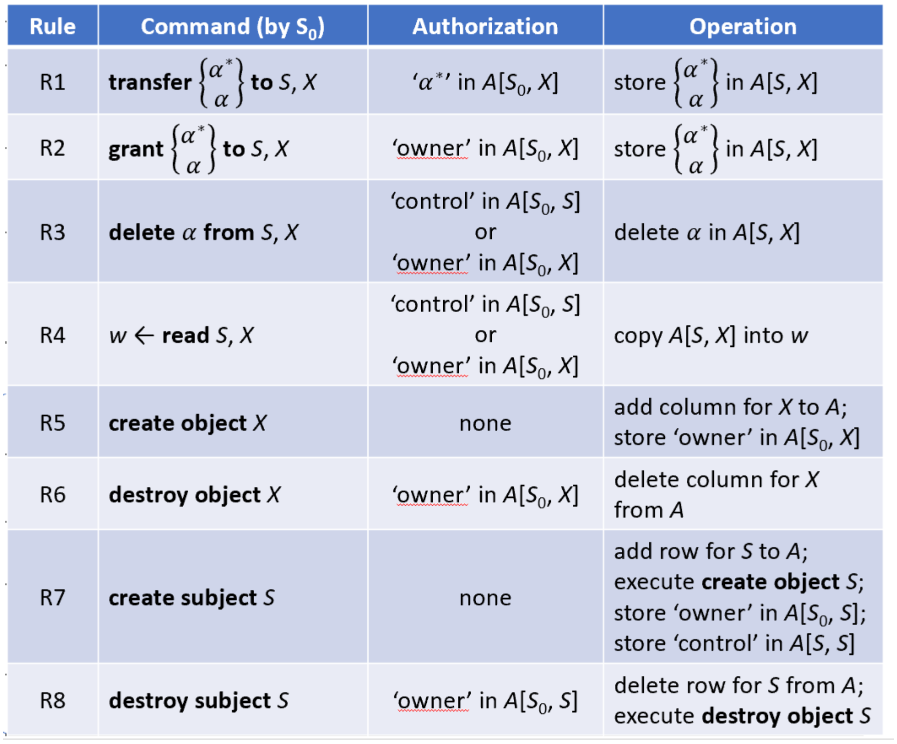
$B', x' \rightarrow BS(x')$;
$r' = r$

$\xrightarrow{E(r', BS'(x'))}$

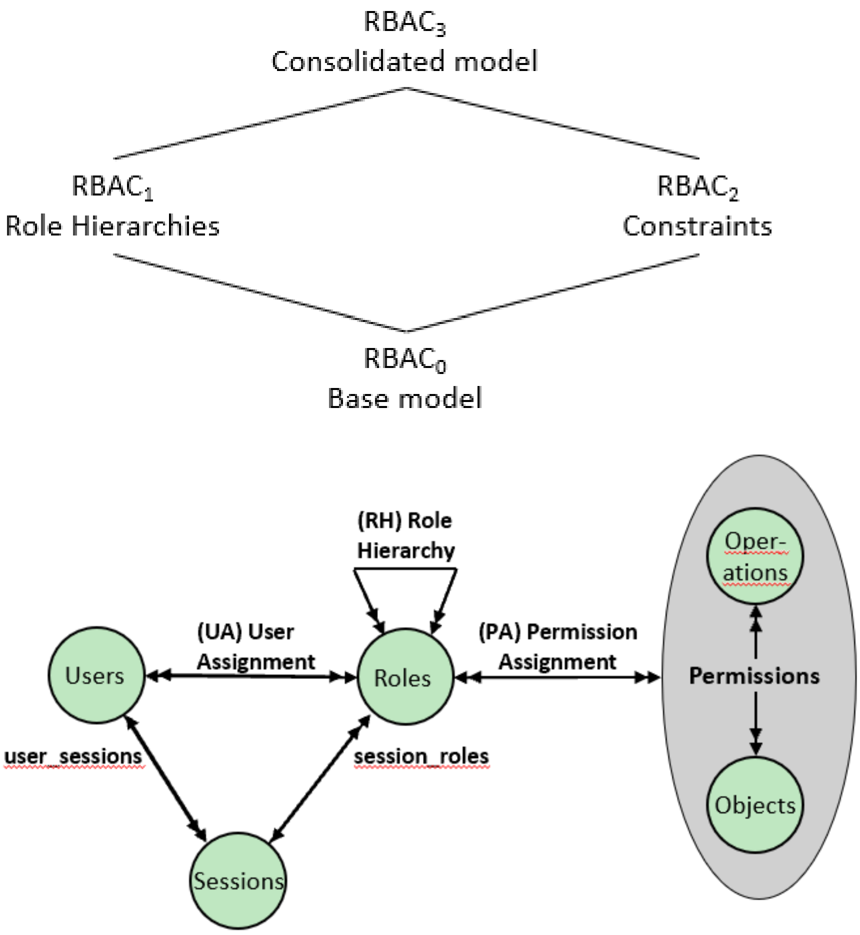
$E^{-1}(E(r', BS(x'))) \rightarrow (r', BS'(x'))$
if $r = r'$ and $BS'(x') = BT(U)$
then yes
else no

$\xleftarrow{\text{yes/no}}$



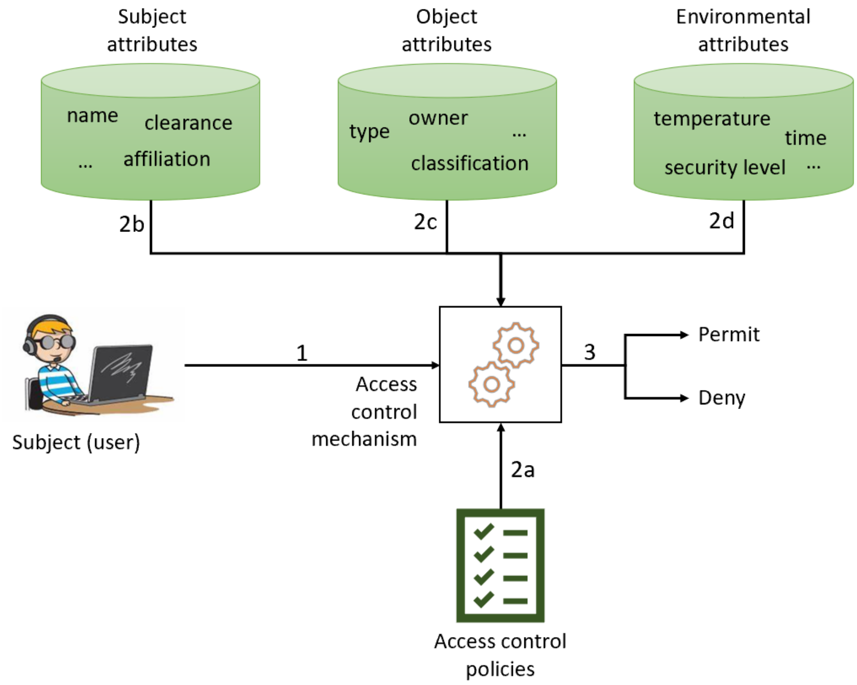


Rule	Command (by S_0)	Authorization	Operation
R1	**transfer** $\begin{Bmatrix}\alpha^*\\ \alpha\end{Bmatrix}$ **to** *S*, *X*	'α^*' in $A[S_0, X]$	store $\begin{Bmatrix}\alpha^*\\ \alpha\end{Bmatrix}$ in $A[S, X]$
R2	**grant** $\begin{Bmatrix}\alpha^*\\ \alpha\end{Bmatrix}$ **to** *S*, *X*	'owner' in $A[S_0, X]$	store $\begin{Bmatrix}\alpha^*\\ \alpha\end{Bmatrix}$ in $A[S, X]$
R3	**delete** α **from** *S*, *X*	'control' in $A[S_0, S]$ or 'owner' in $A[S_0, X]$	delete α in $A[S, X]$
R4	$w \leftarrow$ **read** *S*, *X*	'control' in $A[S_0, S]$ or 'owner' in $A[S_0, X]$	copy $A[S, X]$ into *w*
R5	**create object** *X*	none	add column for *X* to *A*; store 'owner' in $A[S_0, X]$
R6	**destroy object** *X*	'owner' in $A[S_0, X]$	delete column for *X* from *A*
R7	**create subject** *S*	none	add row for *S* to *A*; execute **create object** *S*; store 'owner' in $A[S_0, S]$; store 'control' in $A[S, S]$
R8	**destroy subject** *S*	'owner' in $A[S_0, S]$	delete row for *S* from *A*; execute **destroy object** *S*

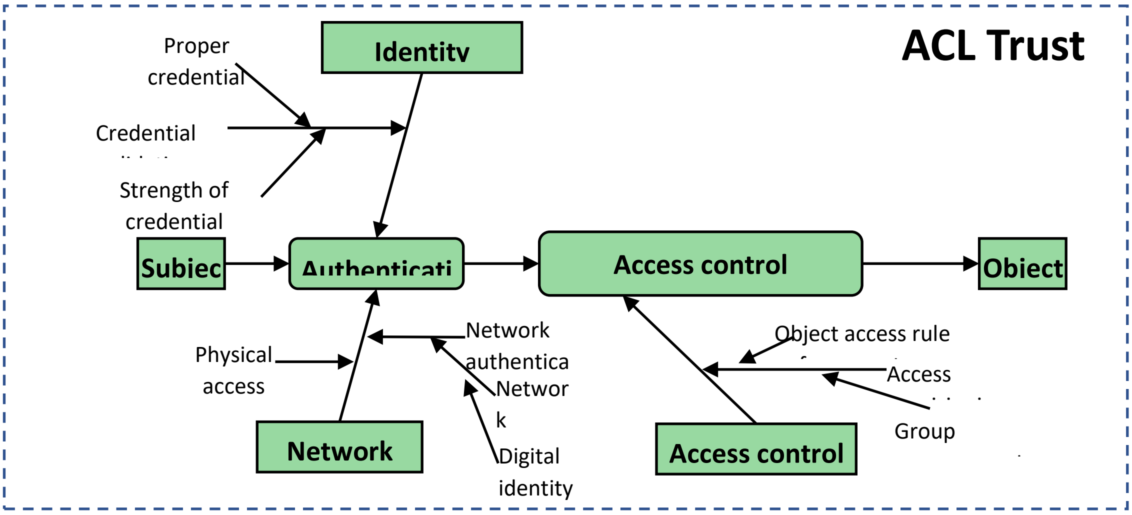


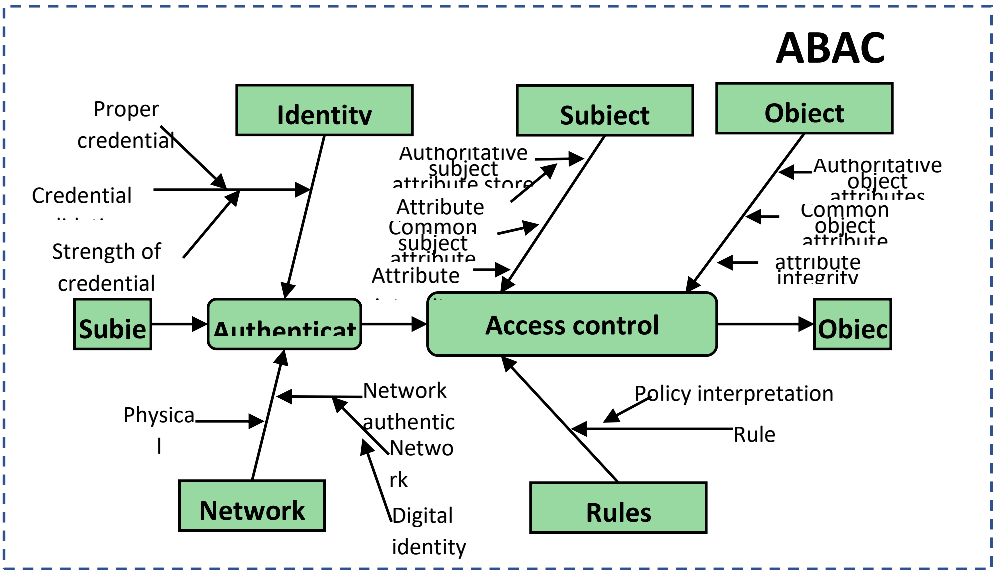
RBAC$_3$
Consolidated model
RBAC$_1$
Role Hierarchies
RBAC$_2$
Constraints
RBAC$_0$
Base model
(RH) Role Hierarchy
(UA) User Assignment
(PA) Permission Assignment
Users
Roles
Oper-ations
Permissions
Objects
user_sessions
session_roles
Sessions

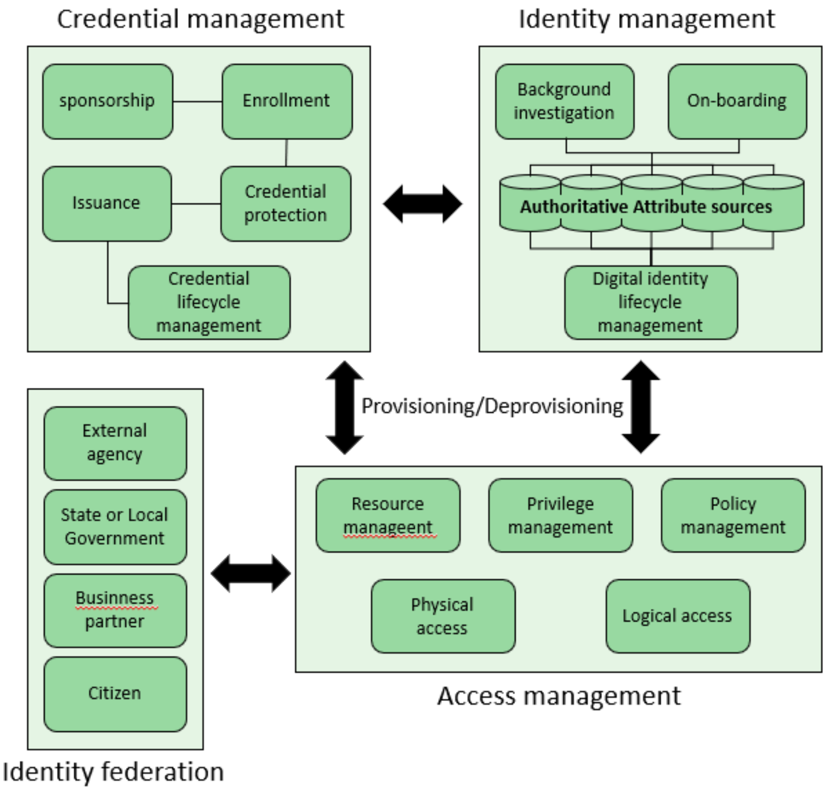
RBAC models



Subject attributes
name
clearance
...
affiliation
Object attributes
type
owner
...
classification
Environmental attributes
temperature
time
security level
...
2b
2c
2d
1
Access control mechanism
3
Permit
Deny
Subject (user)
2a
Access control policies


ACL Trust
Identitv
Proper credential
Credential
Strength of credential
Subiec
Authenticati
Access control
Obiect
Physical access
Network authentica
Networ k
Digital identity
Network
Object access rule
Access
Group
Access control


ABAC
Identity
Subject
Object
Proper credential
Credential
Strength of credential
Authoritative subject attribute store
Attribute
Common subject attribute
Attribute
Authoritative object attributes
Common object attribute
attribute integrity
Subie
Authenticat
Access control
Obiec
Physical
Network
authentic
Network
Digital identity
Policy interpretation
Rule
Network
Rules


Credential management
sponsorship
Enrollment
Issuance
Credential protection
Credential lifecycle management
Identity management
Background investigation
On-boarding
Authoritative Attribute sources
Digital identity lifecycle management
Provisioning/Deprovisioning
External agency
State or Local Government
Businness partner
Citizen
Identity federation
Resource manageent
Privilege management
Policy management
Physical access
Logical access
Access management

Part 2

- Explain the need for security in databases
- Explain what is an SQL-injection attack and what are its “avenues”. Provide an example of an SQL-injection attack
- Discuss advanced persistent threats
- Define a virus and a worm and discuss their differences.
- Explain the purpose and the methodologies for intrusion detection

Figure 5.1

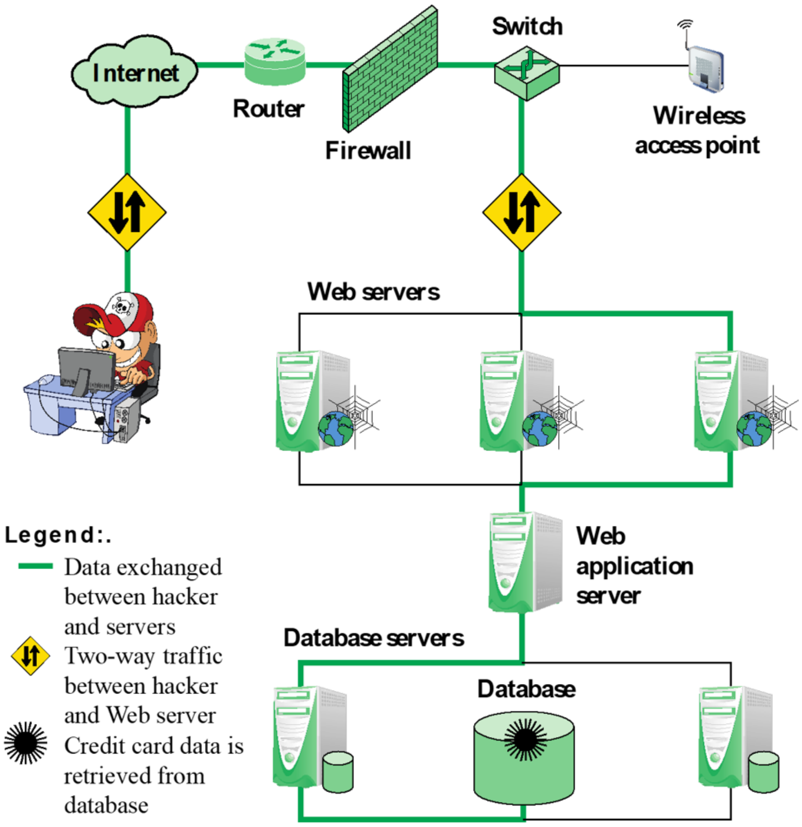

Internet
Router
Firewall
Switch
Wireless access point
Web servers
Web application server
Database servers
Database
Legend:.
Data exchanged between hacker and servers
Two-way traffic between hacker and Web server
Credit card data is retrieved from database

Figure 5.2

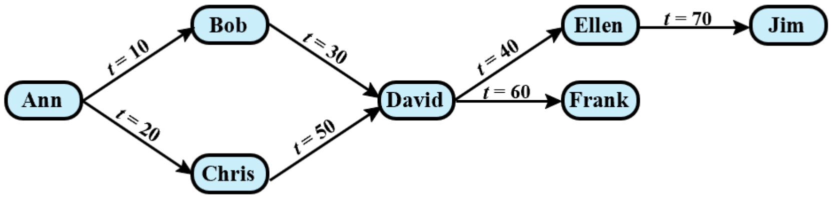


Figure 5.3

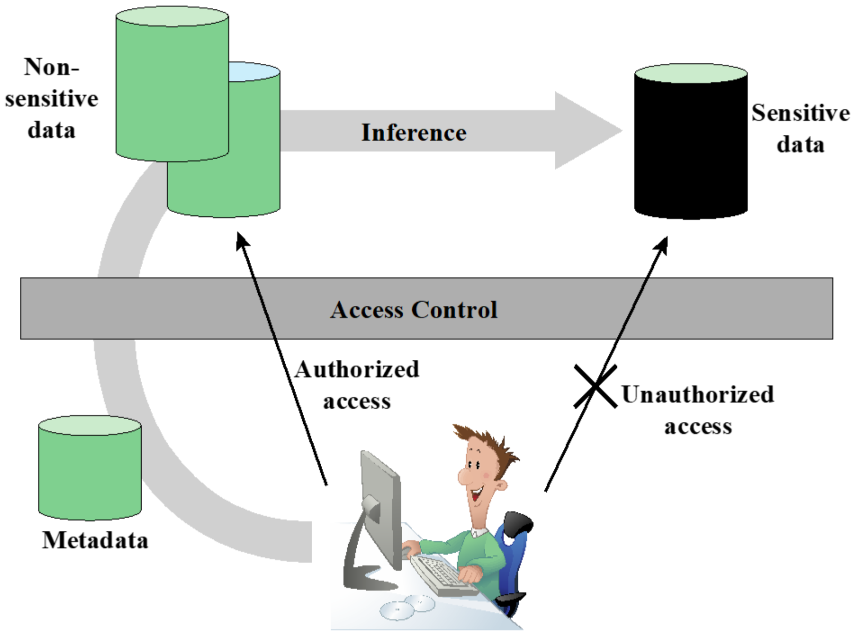
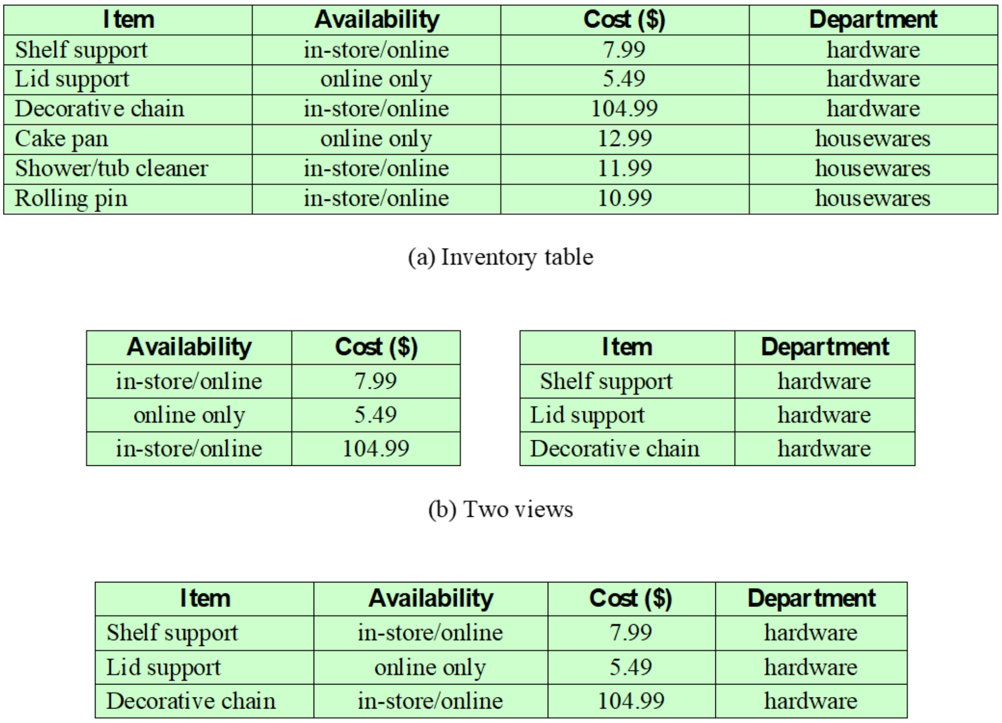


Figure 5.4 – inference example



Item	Availability	Cost ($)	Department
Shelf support	in-store/online	7.99	hardware
Lid support	online only	5.49	hardware
Decorative chain	in-store/online	104.99	hardware
Cake pan	online only	12.99	housewares
Shower/tub cleaner	in-store/online	11.99	housewares
Rolling pin	in-store/online	10.99	housewares

(a) Inventory table

Availability	Cost ($)
in-store/online	7.99
online only	5.49
in-store/online	104.99

Item	Department
Shelf support	hardware
Lid support	hardware
Decorative chain	hardware

(b) Two views

Item	Availability	Cost ($)	Department
Shelf support	in-store/online	7.99	hardware
Lid support	online only	5.49	hardware
Decorative chain	in-store/online	104.99	hardware

(c) Table derived from combining query answers

Figure 5.5

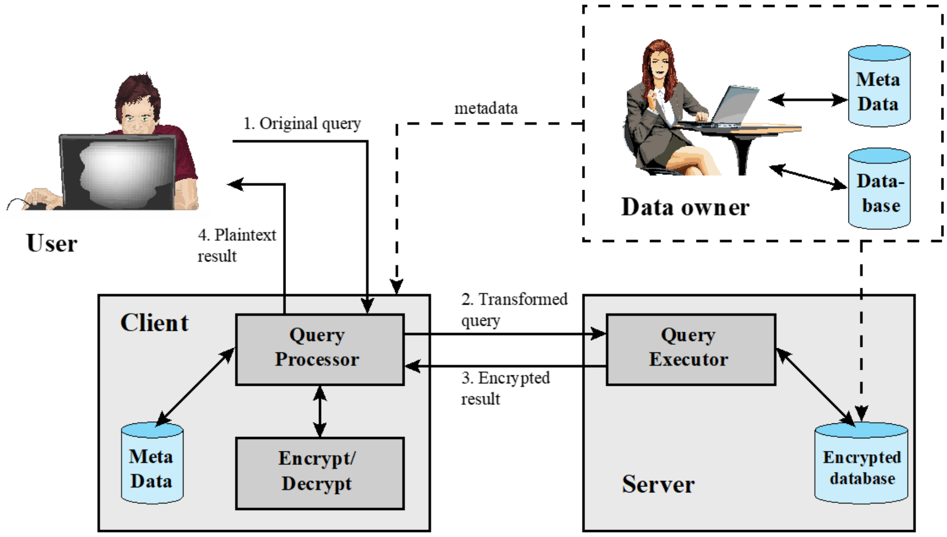
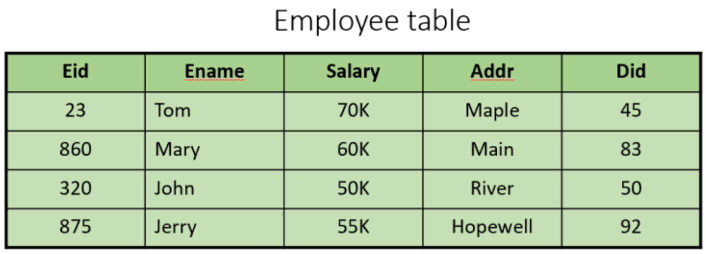
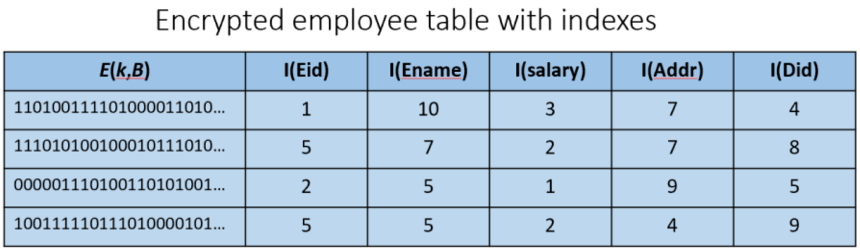


Figure 5.6 - range queries in encrypted DB



Employee table

Eid	Ename	Salary	Addr	Did
23	Tom	70K	Maple	45
860	Mary	60K	Main	83
320	John	50K	River	50
875	Jerry	55K	Hopewell	92

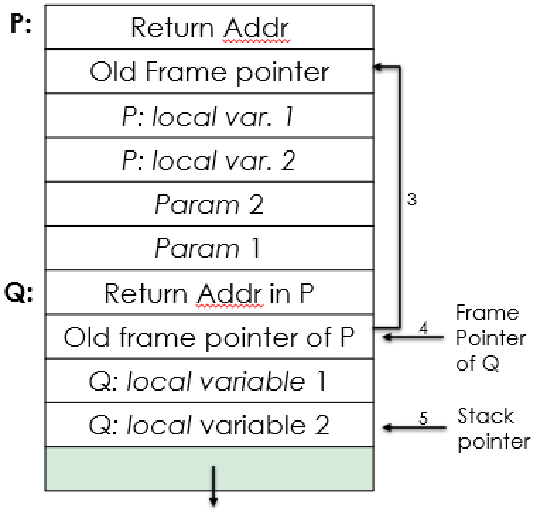


Encrypted employee table with indexes

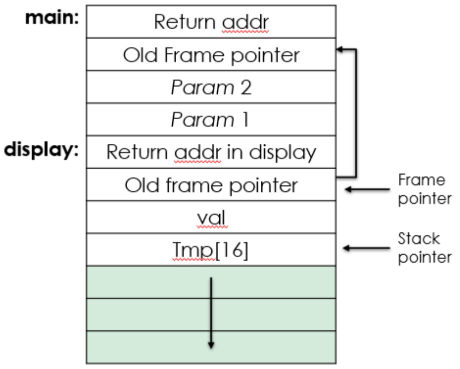
***E*(*k*,*B*)**	I(Eid)	I(Ename)	I(salary)	I(Addr)	I(Did)
1101001111101000011010…	1	10	3	7	4
1110101001000101111010…	5	7	2	7	8
000001110100110101001…	2	5	1	9	5
1001111110111010000101…	5	5	2	4	9

Part 3

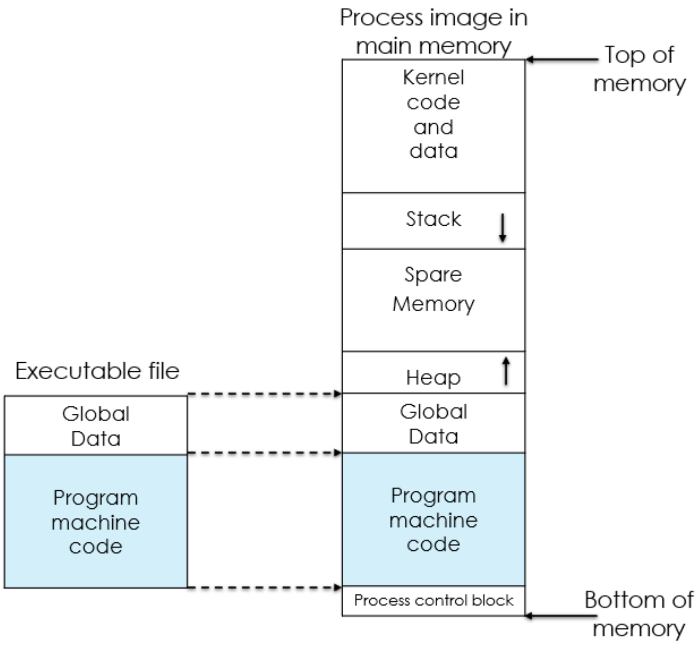
- Explain the purpose of the shellcode in a buffer overflow attack and explain its main functionalities.
- Discuss the following defenses against stack overflow: random canary, Stackshield and Return Address Defender, stack space randomization, guard pages, executable address space protection
- Explain the relationship between software security, quality and reliability
- Discuss the best practices for defense programming
- Explain the concept of operating system hardening and its main steps
- Explain the following protection methods: system call filtering, sandbox, code signing, compile-based/language-based protection.
- Discuss the security concerns about virtualization.
- Discuss the different types of malware and classify them according to propagation method and payload

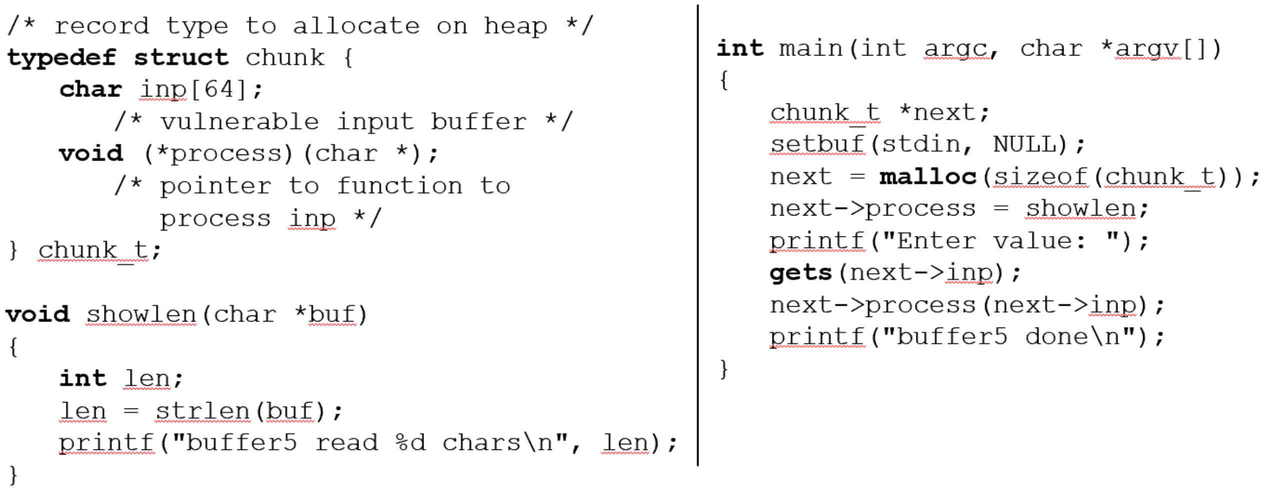


Example



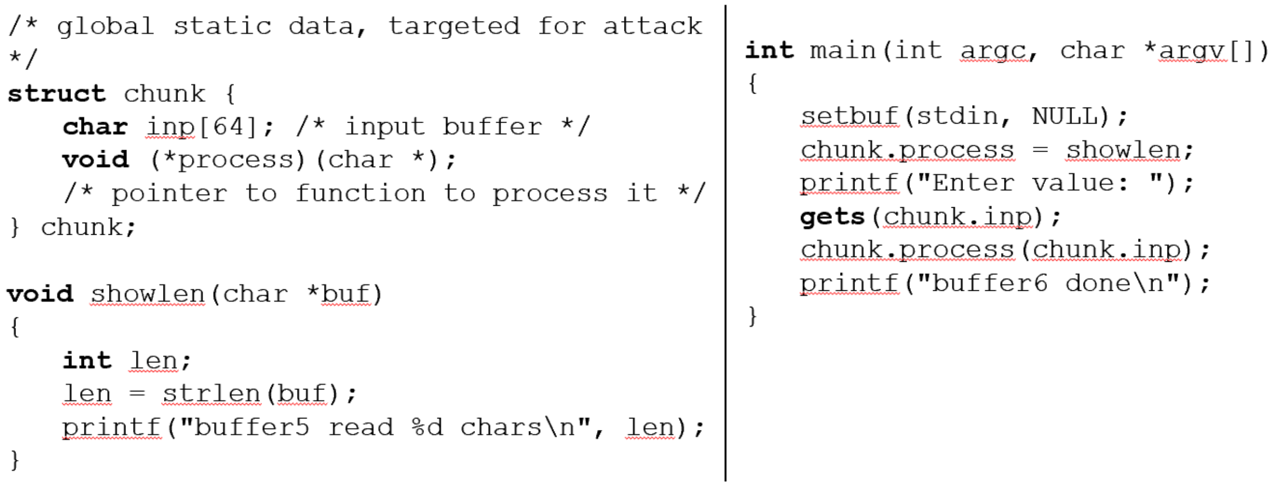
```
void getinp(char *inp, int siz)
{
 puts("Input value: ");
 fgets(inp, siz, stdin);
 printf("buffer3 getinp read %s\n", inp);
}
void display(char *val)
{
 char tmp[16];
 sprintf(tmp, "read : %s\n", val);
 puts(tmp);
}
int main(int argc, char *argv[])
{
 char buf[16];
 getinp (buf, sizeof(buf));
 display(buf);
 printf("buffer3 done\n");
}
```





```
/* record type to allocate on heap */
typedef struct chunk {
    char inp[64];
        /* vulnerable input buffer */
    void (*process)(char *);
        /* pointer to function to
           process inp */
} chunk_t;

void showlen(char *buf)
{
    int len;
    len = strlen(buf);
    printf("buffer5 read %d chars\n", len);
}
```

```
int main(int argc, char *argv[])
{
    chunk_t *next;
    setbuf(stdin, NULL);
    next = malloc(sizeof(chunk_t));
    next->process = showlen;
    printf("Enter value: ");
    gets(next->inp);
    next->process(next->inp);
    printf("buffer5 done\n");
}
```



```
/* global static data, targeted for attack
*/
struct chunk {
    char inp[64]; /* input buffer */
    void (*process)(char *);
    /* pointer to function to process it */
} chunk;

void showlen(char *buf)
{
    int len;
    len = strlen(buf);
    printf("buffer5 read %d chars\n", len);
}
```

```
int main(int argc, char *argv[])
{
    setbuf(stdin, NULL);
    chunk.process = showlen;
    printf("Enter value: ");
    gets(chunk.inp);
    chunk.process(chunk.inp);
    printf("buffer6 done\n");
}
```

```
int main(int argc, char *argv[]) {
  int valid = FALSE;
  char str1[8];
  char str2[8];

  next_tag(str1);   // puts a valid string in str1, say "START"
  gets(str2);       // reads str2 from stdin
  if (strncmp(str1, str2, 8) == 0)
    valid = TRUE;
  printf("buffer1: str1(%s), str2(%s), valid(%d)\n",
                            str1, str2, valid);
}
```

Basic buffer overflow C code

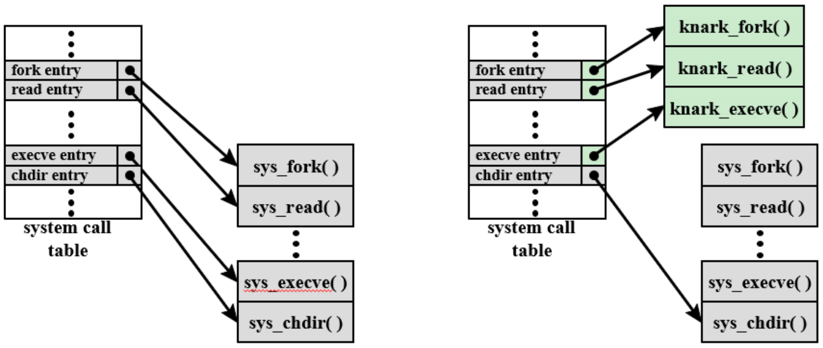
```
$ cc -g -o buffer1 buffer1.c
$ ./buffer1
START
buffer1: str1(START), str2(START), valid(1)
$ ./buffer1
EVILINPUTVALUE
buffer1: str1(TVALUE), str2(EVILINPUTVALUE), valid(0)
$ ./buffer1
BADINPUTBADINPUT
buffer1: str1(BADINPUT), str2(BADINPUTBADINPUT), valid(1)
```

Basic buffer overflow example runs

Memory Address	Before gets(str2)	After gets(str2)	Contains Value of
. . . .	. . . .	. . . .	
bffffbf4	34fcffbf 4 . . .	34fcffbf 3 . . .	argv
bffffbf0	01000000	01000000	argc
bffffbec	c6bd0340 . . . @	c6bd0340 . . . @	return addr
bffffbe8	08fcffbf	08fcffbf	old base ptr
bffffbe4	00000000	01000000	valid
bffffbe0	80640140 . d . @	00640140 . d . @	
bffffbdc	54001540 T . . @	4e505554 N P U T	str1[4-7]
bffffbd8	53544152 S T A R	42414449 B A D I	str1[0-3]
bffffbd4	00850408	4e505554 N P U T	str2[4-7]
bffffbd0	30561540 0 V . @	42414449 B A D I	str2[0-3]
. . . .	. . . .	. . . .	

Stack grows in this way

Figure 6.6



(a) Normal kernel memory layout

(b) After knark install

System Call table modification by rootkit

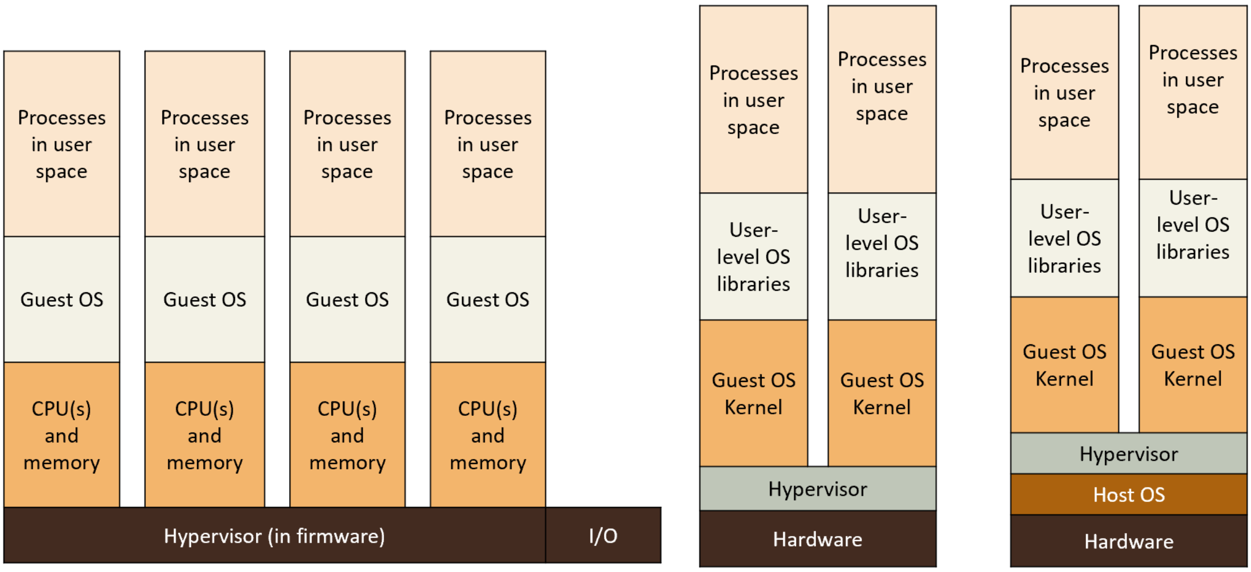


Figure10.2

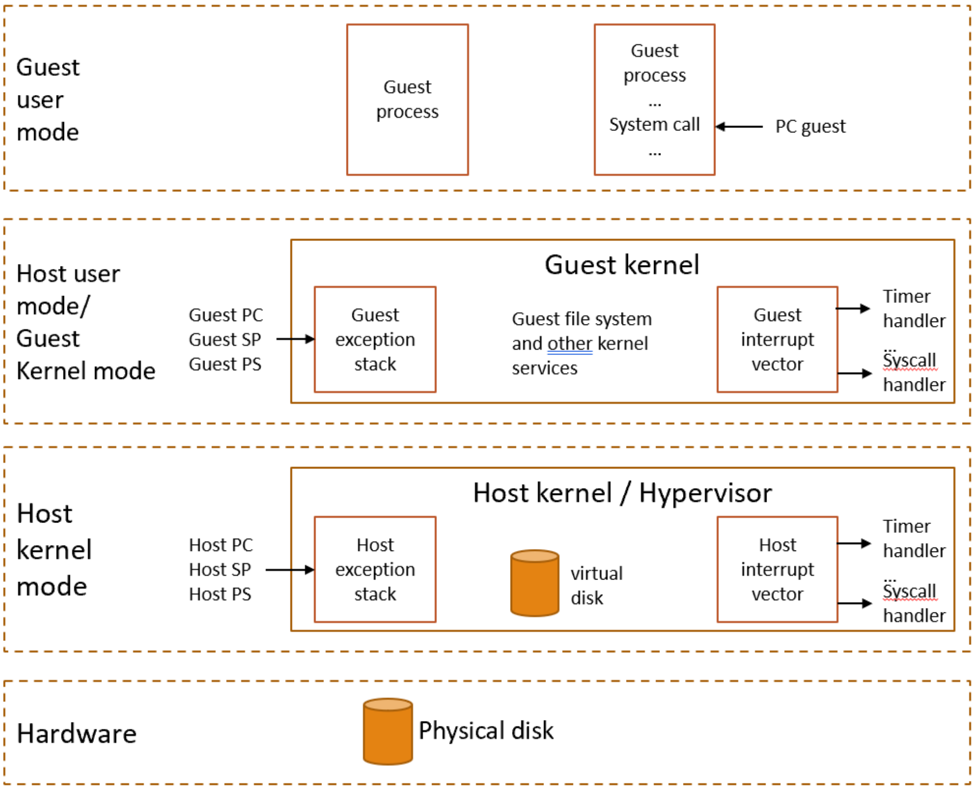


Figure 10.3

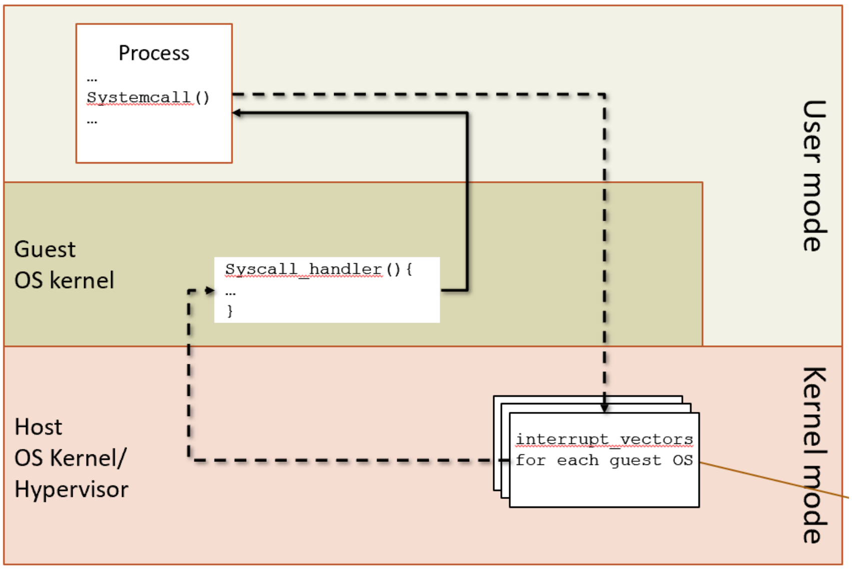


Figure 10.4

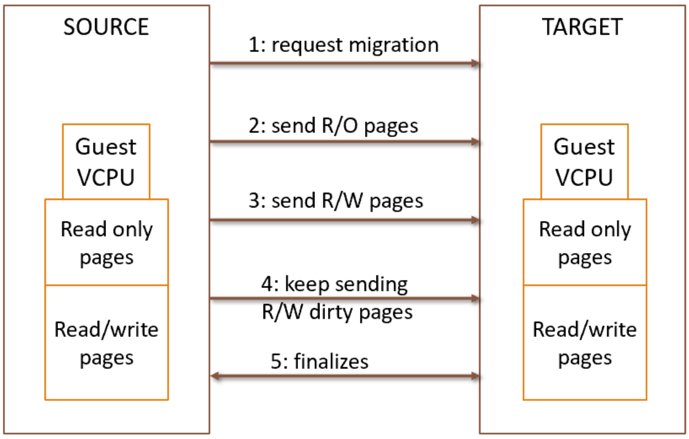
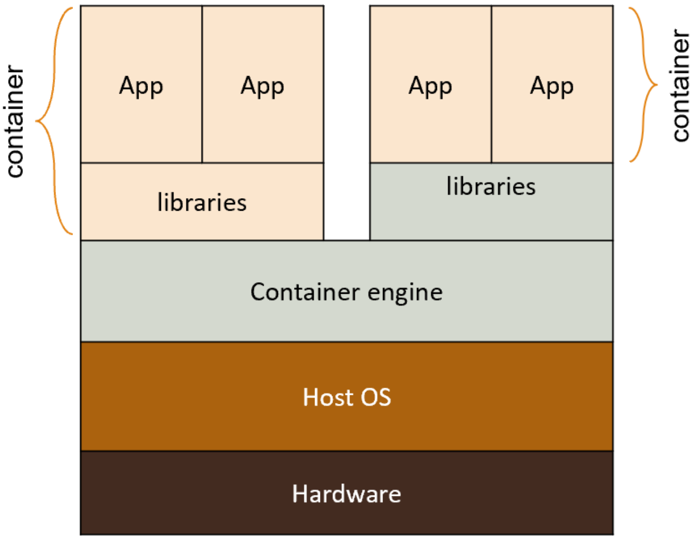
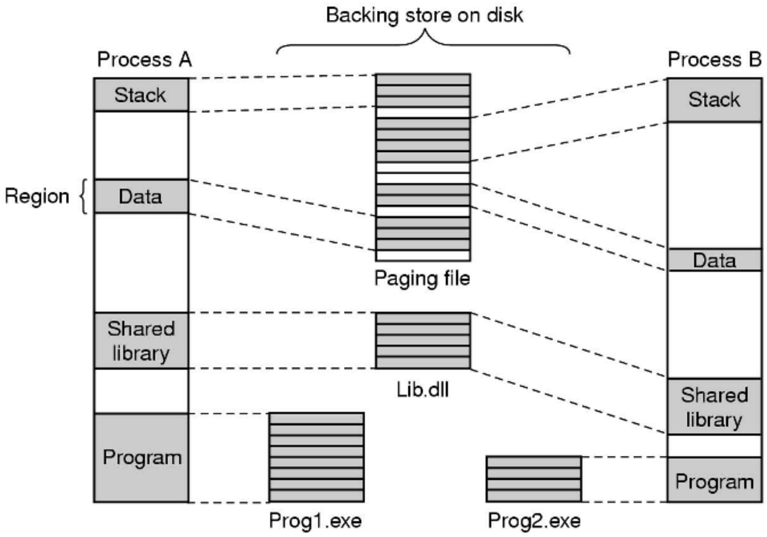

SOURCE
TARGET
1: request migration
2: send R/O pages
3: send R/W pages
4: keep sending
R/W dirty pages
5: finalizes
Guest
VCPU
Read only
pages
Read/write
pages
Guest
VCPU
Read only
pages
Read/write
pages

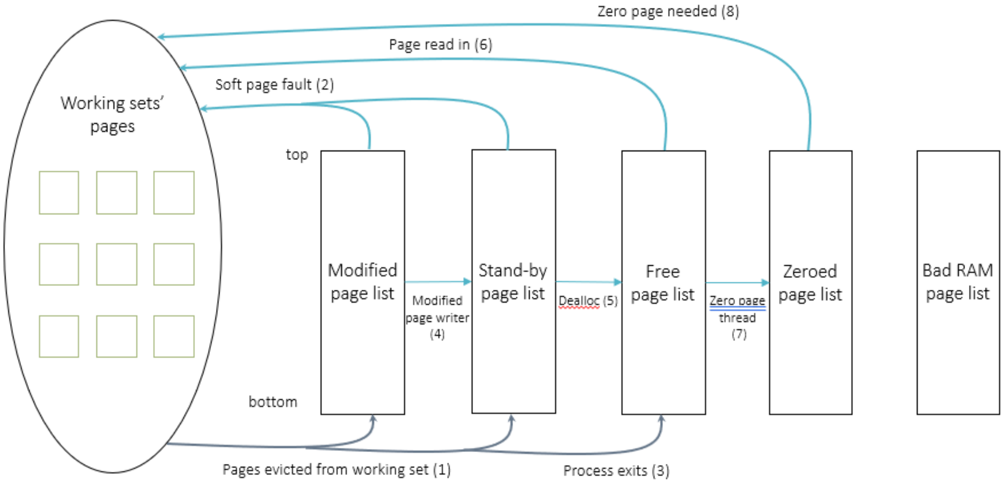
Figure 10.5


container
App
App
App
App
container
libraries
libraries
Container engine
Host OS
Hardware

Part 4

- Explain the security model of Windows. Discuss its discretionary access control its mandatory access control
- In Windows discuss the purpose of these components: Security reference monitor, Local security authority, Security account manager, Active directory
- Discuss how journaling works in Windows NTFS
- Discuss the NTFS security features
- Present the Windows defences
- Discuss the purpose of integrity levels in Windows
- Discuss the Byzantine Generals Problem
- Discuss the vulnerabilities of, and attacks against blockchains





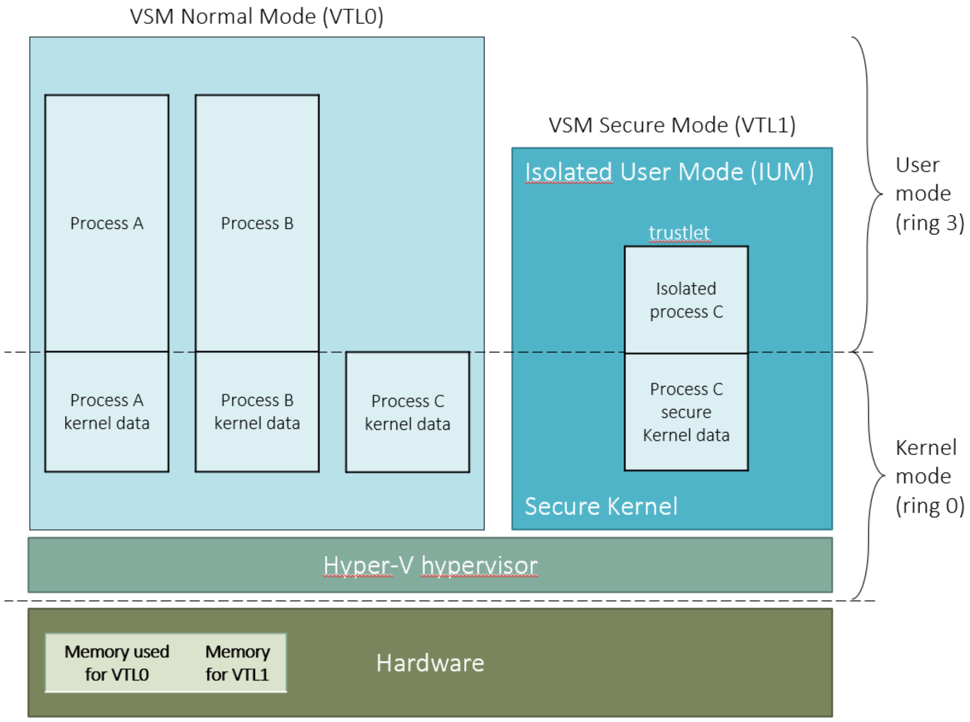
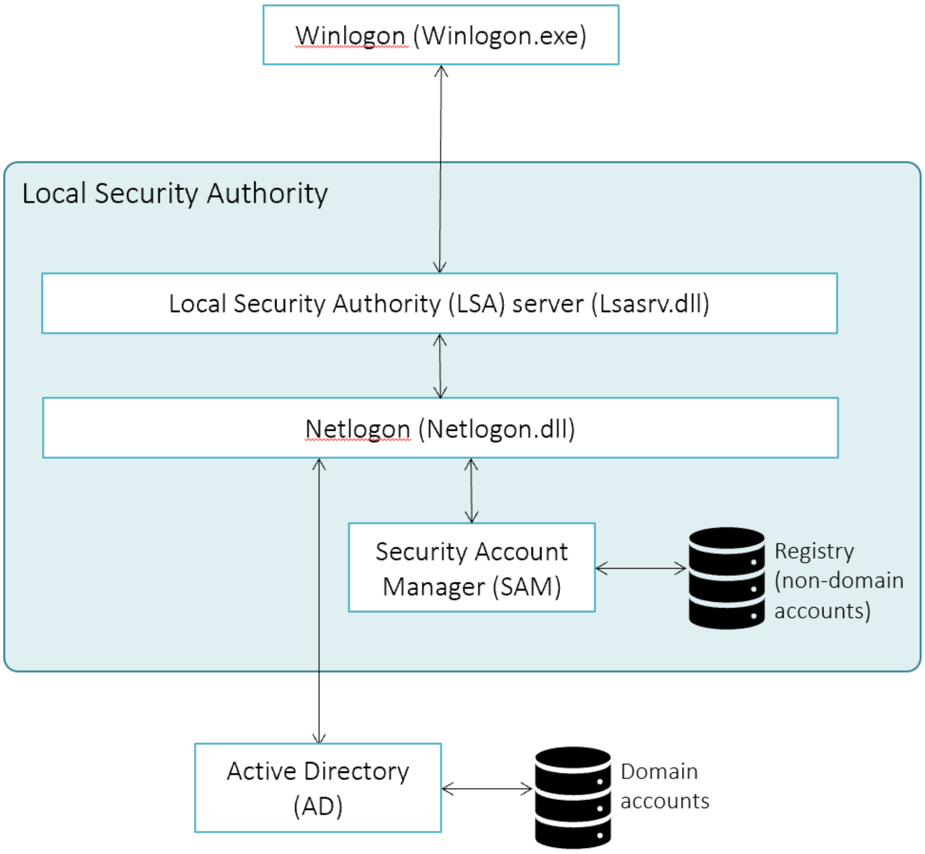
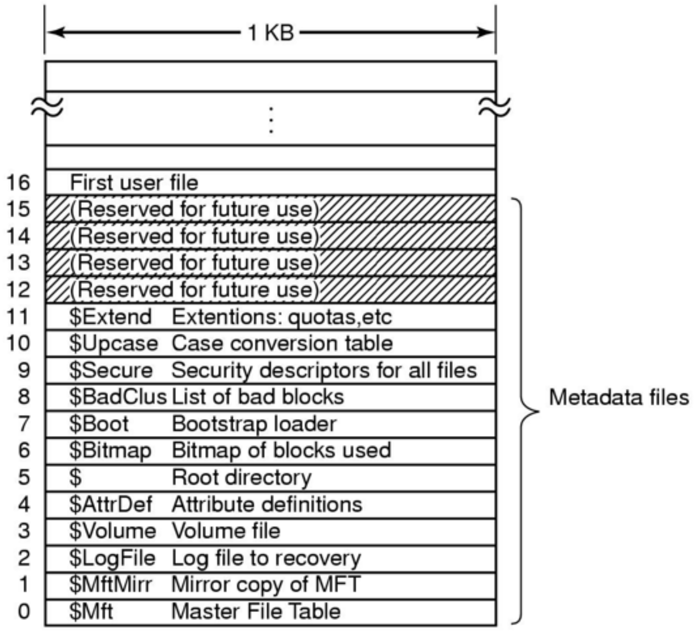

VSM Normal Mode (VTL0)
Process A
Process B
Process A kernel data
Process B kernel data
Process C kernel data
VSM Secure Mode (VTL1)
Isolated User Mode (IUM)
trustlet
Isolated process C
Process C secure Kernel data
Secure Kernel
User mode (ring 3)
Kernel mode (ring 0)
Hyper-V hypervisor
Memory used for VTL0
Memory for VTL1
Hardware

Figure 13.2


Winlogon (Winlogon.exe)
Local Security Authority
Local Security Authority (LSA) server (Lsasrv.dll)
Netlogon (Netlogon.dll)
Security Account Manager (SAM)
Registry (non-domain accounts)
Active Directory (AD)
Domain accounts


1 KB
16 First user file
15 (Reserved for future use)
14 (Reserved for future use)
13 (Reserved for future use)
12 (Reserved for future use)
11 $Extend Extentions: quotas,etc
10 $Upcase Case conversion table
9 $Secure Security descriptors for all files
8 $BadClus List of bad blocks
7 $Boot Bootstrap loader
6 $Bitmap Bitmap of blocks used
5 $ Root directory
4 $AttrDef Attribute definitions
3 $Volume Volume file
2 $LogFile Log file to recovery
1 $MftMirr Mirror copy of MFT
0 $Mft Master File Table
Metadata files

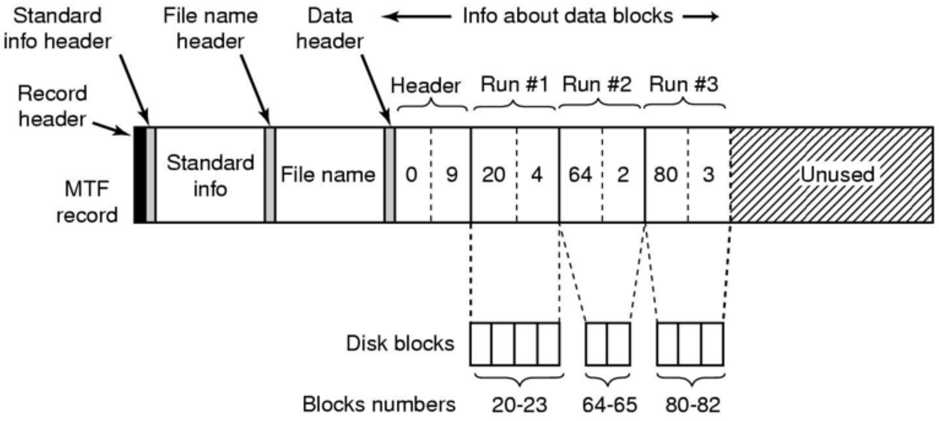
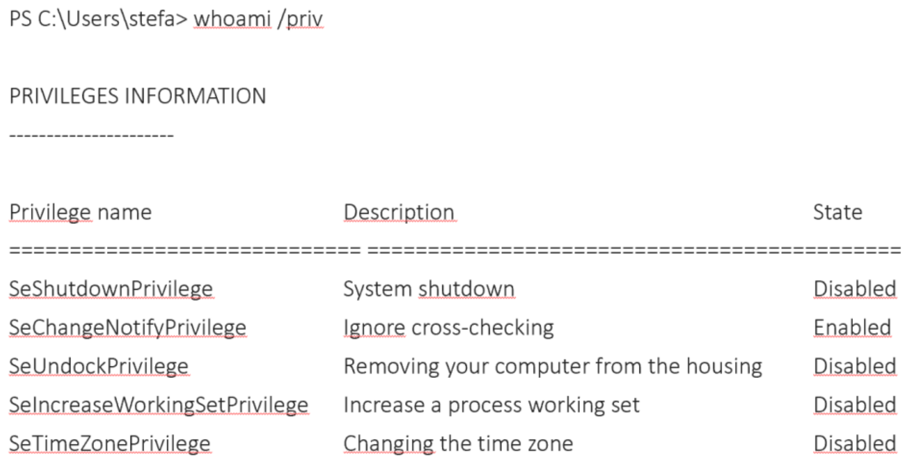
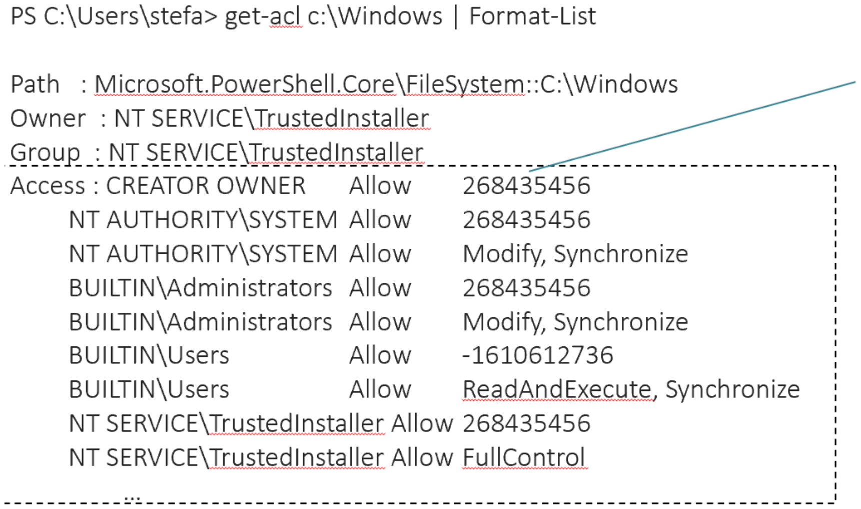


Figure 13.3 - Explain the concept of “privilege” in Windows and present some privileges that concern the file system

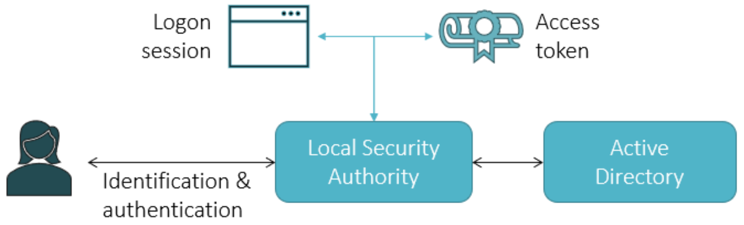


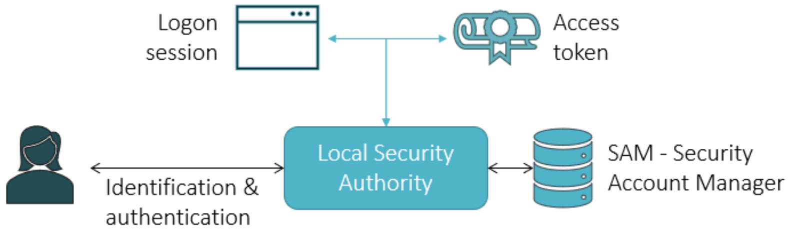
```
PS C:\Users\stefa> whoami /priv

PRIVILEGES INFORMATION
----------------------

Privilege name                Description                              State
============================= ============================================
SeShutdownPrivilege           System shutdown                          Disabled
SeChangeNotifyPrivilege       Ignore cross-checking                    Enabled
SeUndockPrivilege             Removing your computer from the housing  Disabled
SeIncreaseWorkingSetPrivilege Increase a process working set           Disabled
SeTimeZonePrivilege           Changing the time zone                   Disabled
```

Figure 13.4 – explain the structure and purpose of a security descriptor. Discuss some examples of access rights concerning the file system



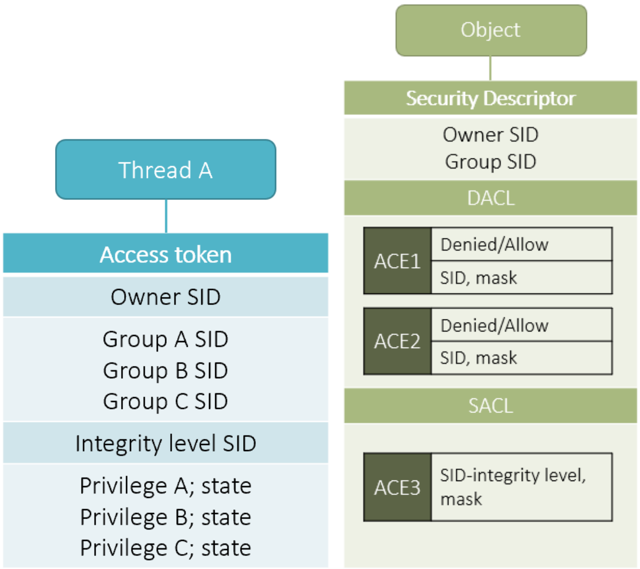
```
PS C:\Users\stefa> get-acl c:\Windows | Format-List

Path   : Microsoft.PowerShell.Core\FileSystem::C:\Windows
Owner  : NT SERVICE\TrustedInstaller
Group  : NT SERVICE\TrustedInstaller
Access : CREATOR OWNER         Allow      268435456
         NT AUTHORITY\SYSTEM   Allow      268435456
         NT AUTHORITY\SYSTEM   Allow      Modify, Synchronize
         BUILTIN\Administrators  Allow    268435456
         BUILTIN\Administrators  Allow    Modify, Synchronize
         BUILTIN\Users         Allow      -1610612736
         BUILTIN\Users         Allow      ReadAndExecute, Synchronize
         NT SERVICE\TrustedInstaller Allow 268435456
         NT SERVICE\TrustedInstaller Allow FullControl
     ...
```

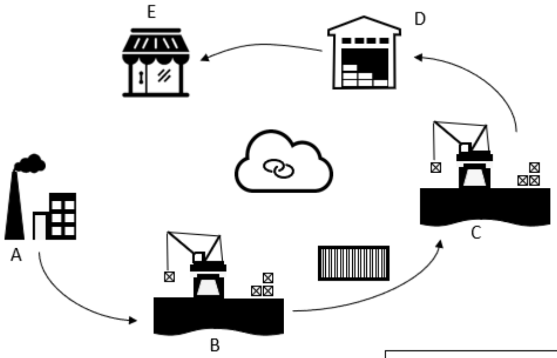




Logon session
Access token
Identification & authentication
Local Security Authority
SAM - Security Account Manager

Figure 13.5 – access token





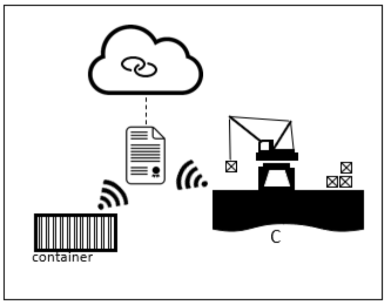
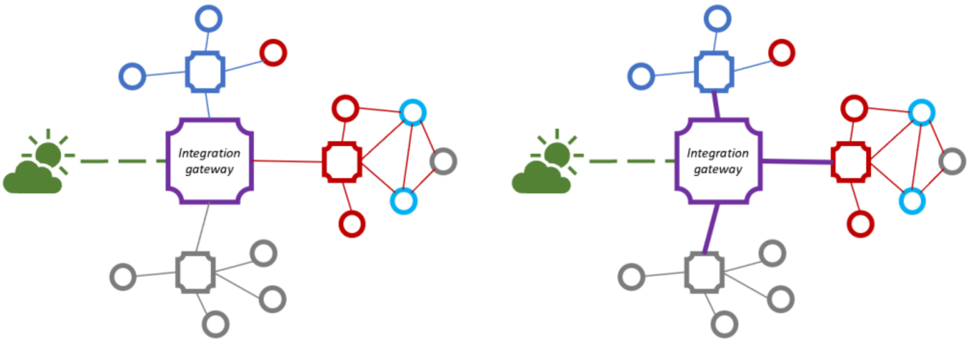


Figure 14.1



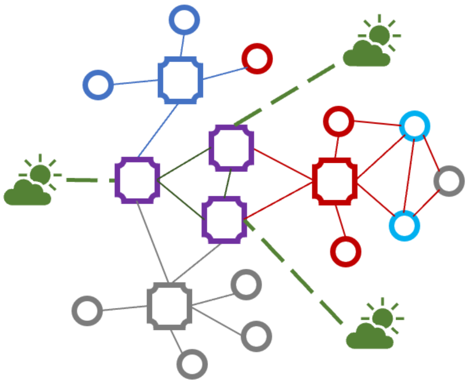


Figure 14.2

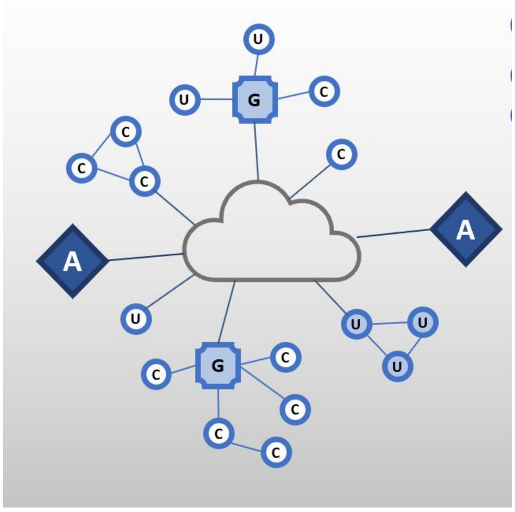
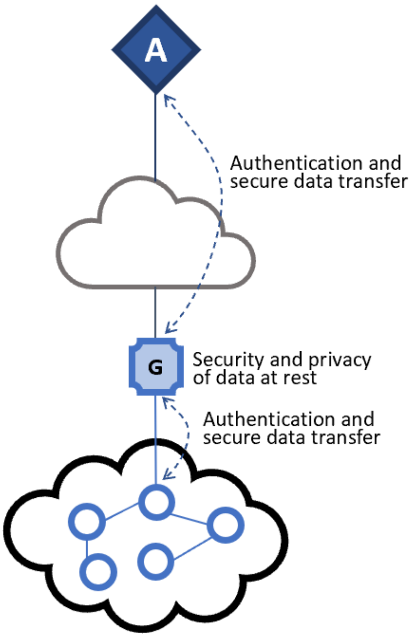


Figure 14.3


A
Authentication and
secure data transfer
G
Security and privacy
of data at rest
Authentication and
secure data transfer

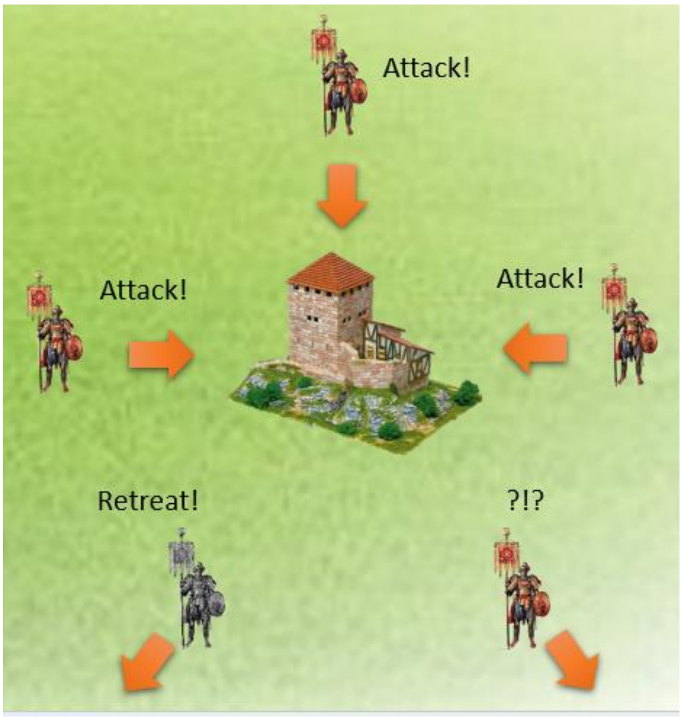
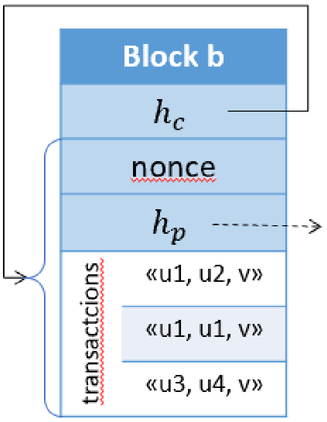

Attack!
Attack!
Attack!
Retreat!
?!?

Figure 15.1

```
function create_block() {
     // executed by miner $m_i$ when the
     // transaction pool is full, to
     // propose the append of a new block

// let $B_i$ be the blockchain at miner $m_i$
b = new block;
b.transactions = get_transactions(pool);
while true do
   nounce=local-random-coin()
   b.pow=nounce;
   b.parent=last_block($B_i$);
   if solve_cryptopuzzle(b) {
        broadcast(b);      //included itself
        break;
   }
}

function update(b) {
    // executed by miner $M_i$ upon
    // reception of block b to append

  // let $B_i$ be the blockchain at miner $M_i$
  if !check_validity(b) { reject b; return; }
  $B_i$ = $B_i$ ∪ b;
}
```

Figure 15.2



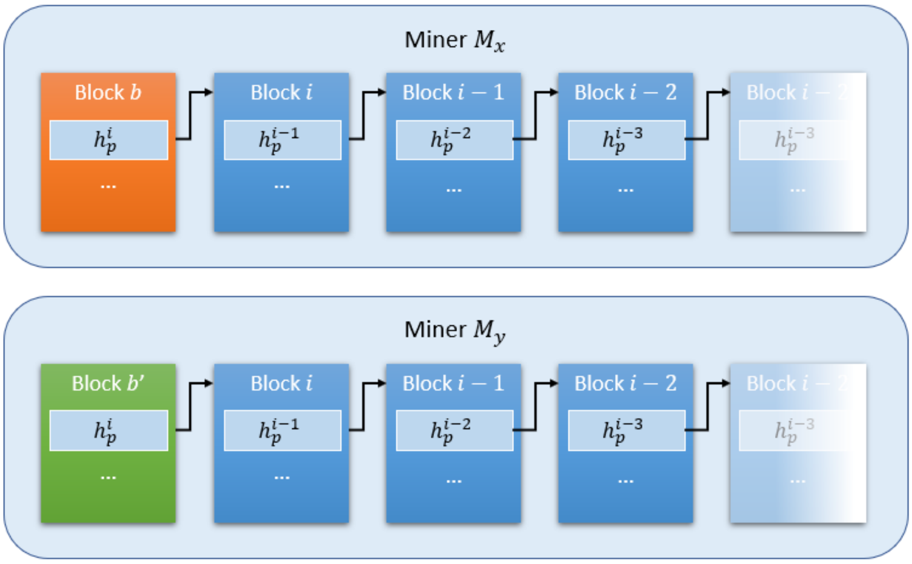


Figure 15.3 - Discuss the problem of forks in the blockchain

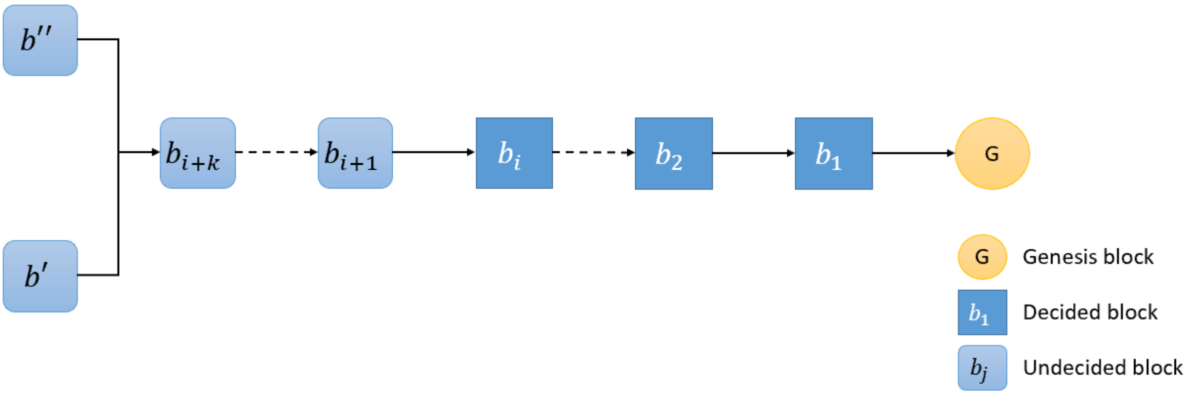
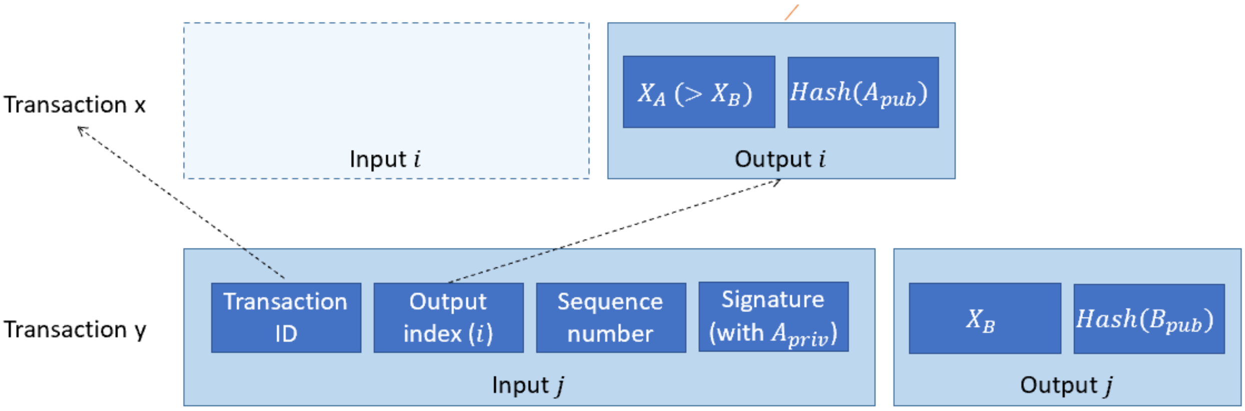


Figure 15.4


Transaction x
Input i
$X_A\ (> X_B)$
$Hash(A_{pub})$
Output i
Transaction y
Transaction ID
Output index (i)
Sequence number
Signature (with A_{priv})
Input j
X_B
$Hash(B_{pub})$
Output j