Security, privacy and data integrity

A-Level Computer Science

Security, privacy and integrity —three different ideas

These sound alike but mean different things:

- **security** 安全—protecting data from **unauthorised** 未授权 access, change or destruction.
- **privacy** 隐私—an individual's right to **control who sees their personal data**, with consent and a clear purpose.
- **integrity** 完整性—the data being **accurate and complete** —not corrupted or accidentally changed.

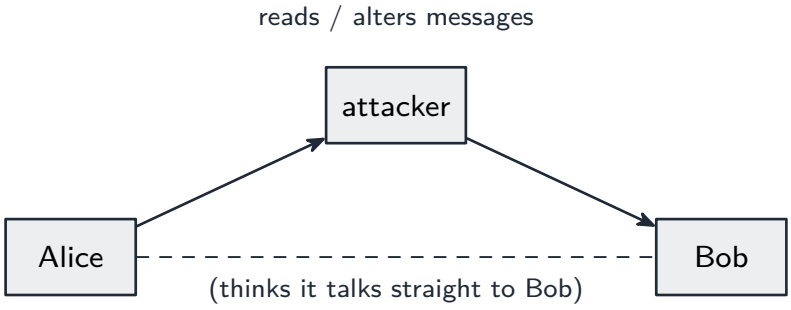
A file can be secure (only the right people can open it) but lack integrity (a typo corrupted it); or accurate but not private (anyone can read it). All three are needed.

Why security matters

Two things to protect: the **data** itself (keep it confidential, intact and available) and the **computer system** (a compromised system can attack others, steal credentials, or be held to ransom).

Threats from networks and the internet

Threats fall into three groups.



A man-in-the-middle attacker sits between the two parties

1. **Malware** 恶意软件 (malicious software) —harmful programs:

- **virus** 病毒—self-copying code that attaches to other programs and spreads when they run.
- **worm** 蠕虫—self-copying code that spreads over **networks** 网络 with no user action.
- **Trojan horse** 木马—looks useful but hides malicious code.

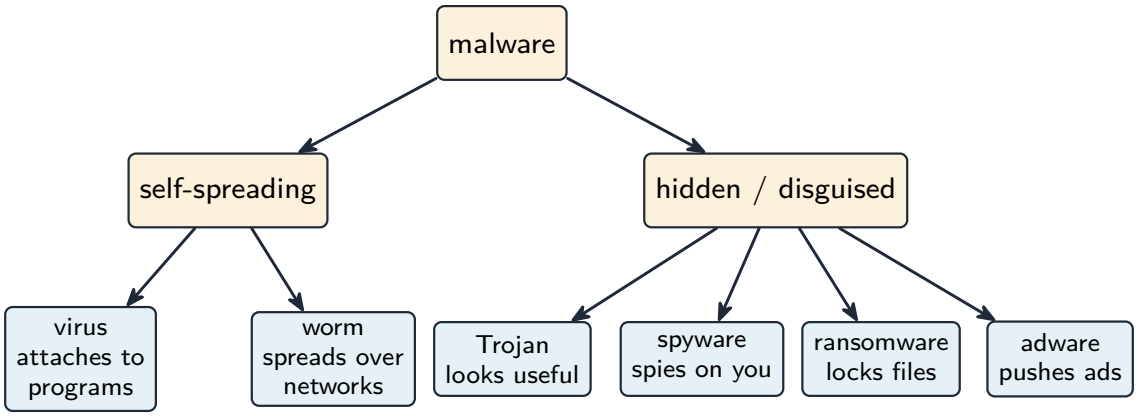
- **spyware** 间谍软件—secretly collects information (keystrokes, passwords).
- **ransomware** 勒索软件—encrypts your files and demands payment.
- **adware** 广告软件—pushes unwanted adverts.

2. **Tricking people** (social attacks):

- **phishing** 网络钓鱼—fake emails/sites that trick users into giving credentials.
- **pharming** 域名欺骗—redirects a user to a fake site even when they type the correct address.
- **social engineering** 社会工程—tricking people into giving up information.

3. **Attacks on the network:**

- **hacking** 黑客入侵 by **hackers** 黑客—unauthorised access, often via weak passwords or software flaws.
- **denial of service** 拒绝服务 (DoS/DDoS) —floods a server so real users cannot reach it.
- **eavesdropping** 窃听—capturing data in transit (a risk on open Wi-Fi).
- **man-in-the-middle** 中间人攻击—an attacker secretly relays or alters messages between two parties.



Malware by behaviour: self-spreading (virus, worm) versus hidden/disguised (Trojan, spyware, ransomware, adware)

Security measures

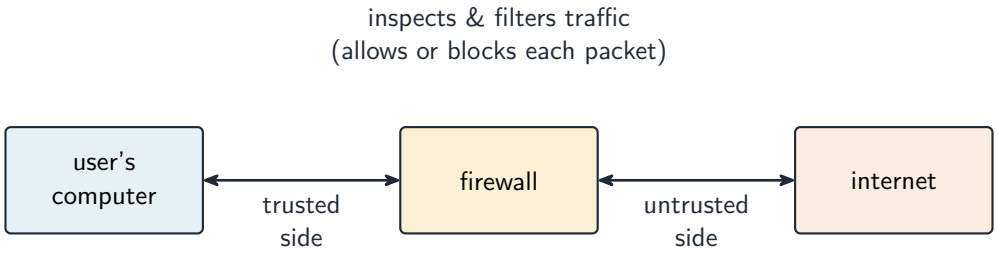
Measures protect both the **security of data** (against loss, theft or corruption) and the **security of the computer system** (its hardware, software and network).

A standalone PC

- a strong password; **antivirus** kept up to date; prompt **software updates**; **backup** 备份 to separate media; full-disk **encryption** 加密; a locked screen.

A networked PC

All the above, plus a **firewall** 防火墙, per-user **permissions** (admin rights only for admins), central management of **user accounts** 用户账户, and **audit logs** 审计日志 (who logged in, what they touched).



A firewall sits between the user's computer and the internet

Across the internet

- **VPN** 虚拟专用网—encrypts traffic between the user and the corporate gateway.
- **HTTPS / TLS** —encrypt web traffic.
- **digital signatures** 数字签名—prove who sent a message and that it was not altered in transit.
- intrusion detection —watches traffic for known attack patterns.

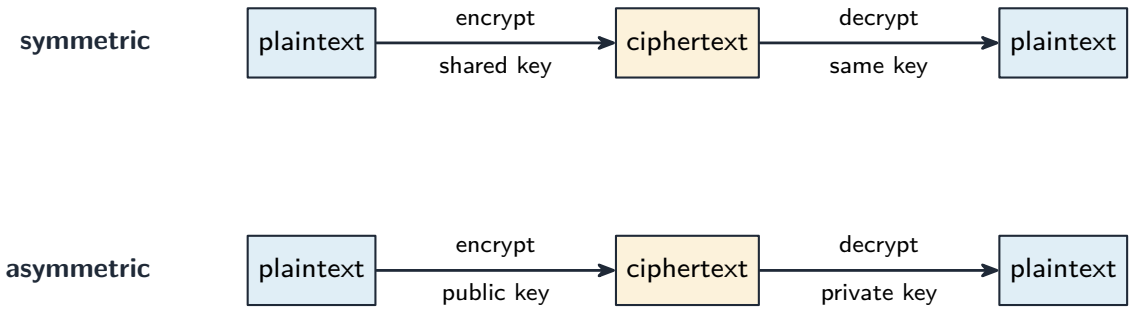
Matching measures to threats

- **interception in transit** → **encrypt** the data (HTTPS, VPN). Intercepted ciphertext is useless without the key.
- **unauthorised access** → strong **authentication** 身份验证 (long passwords; **two-factor authentication** 双因素认证 with a phone code or key); user **authorisation** 授权; lock-out after failed logins.
- **malware** → **anti-virus software** and **anti-spyware** 反间谍软件 with real-time scanning; patching; avoid untrusted downloads.
- **phishing** → user training; email filtering; check the URL before entering credentials.
- **internal threats** → the **least-privilege** 最小权限 principle (give each user only what they need); auditing.
- **DDoS** → rate limiting and traffic filtering.

Protecting the data itself

- **encryption** —turn **plaintext** 明文 into **ciphertext** 密文 with a key. **Symmetric encryption** 对称加密 (AES) uses one shared key; **asymmetric encryption** 非对称加密 (RSA) uses a **public key** 公钥 and a **private key** 私钥. Protects data at rest and in transit.

- **access control** 访问控制—file permissions (read/write/execute) and **access rights** 访问权限, enforced by the OS.
- **authentication** —**authentication techniques** verify the user: something you know (password), have (token, phone), or are (**biometrics** 生物识别—fingerprint, face, iris); strongest combined.
- **backups** —keep copies (some **off-site**) so loss or corruption is recoverable.
- **physical security** —locked server rooms, cable locks.



Symmetric uses one shared key; asymmetric uses a public key to encrypt and a private key to decrypt

A security token shows a changing code for two-factor authentication ("something you have")

Image: RSA Security, Product image (www.tokenguard.com)

A fingerprint reader checks "something you are" —a feature of the person, not a password

Image: HID DigitalPersona, Product image (store.fulcrumbiometrics.com)

Data integrity

Data has integrity when it is accurate and complete. Two techniques: **data validation** (catch bad data before storing) and **data verification** (confirm data was entered or transferred correctly).

Validation —does the data make sense?

Validation 验证 checks data against sensible rules, automatically:

- **range check** —within limits (a month is 1–12).
- **limit check** —on the correct side of a single limit (e.g. age 18).
- **existence check** —the referenced item exists (e.g. a product code is in the table).
- **length check** —the right number of characters.
- **type / character check** —the right kind of data (a phone field allows only digits).
- **format check** —matches a pattern (an email must contain `@`).
- **presence check** —required fields are not empty.
- **check digit** 校验位—an extra digit computed from the others (ISBN, card numbers) that spots transcription errors.
- **lookup check** and **consistency check** (e.g. delivery date order date).

Validation catches data that is wrongly **formatted**, but not data that is the right format yet factually wrong ("Bob" for "Bib").

Verification —was the data entered or transferred correctly?

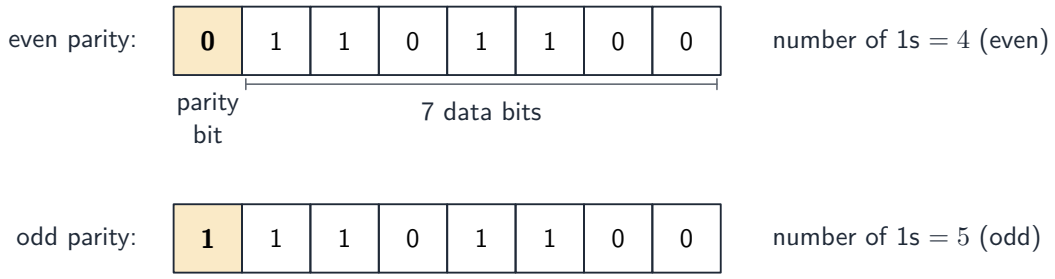
Verification 核对 checks the data was not changed in moving from one place to another.

During entry: **double entry** (type it twice and compare, as for a new password) or **visual** check.

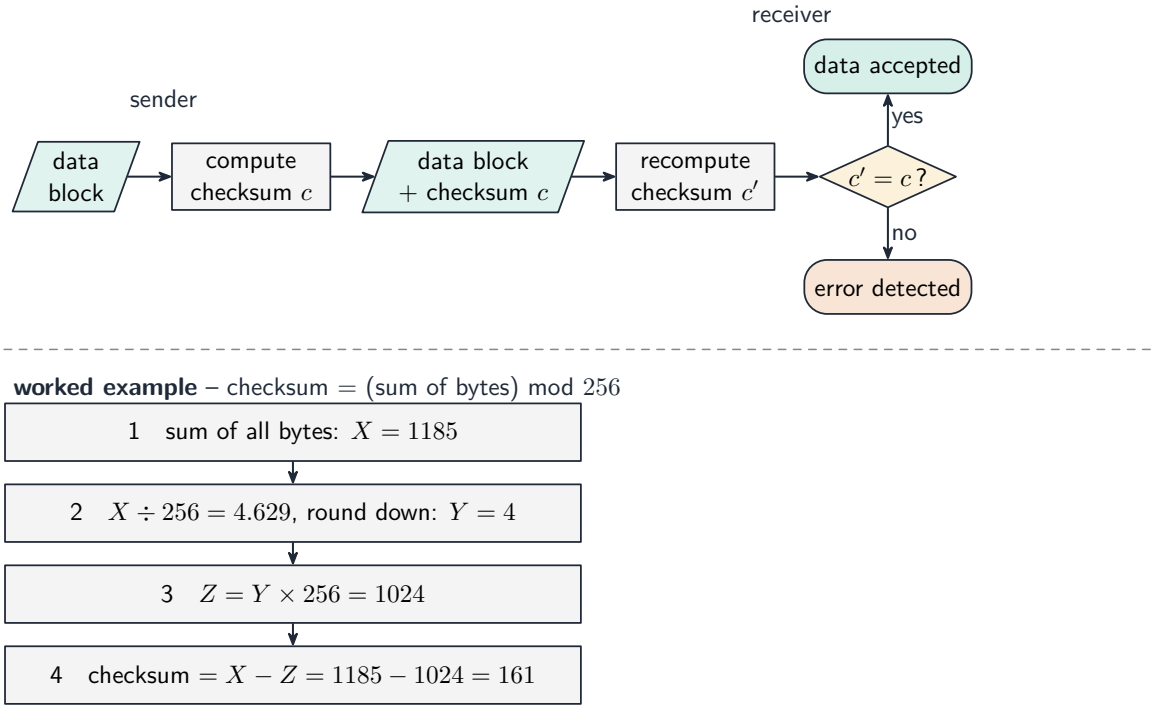
During transfer (bits can flip):

- **parity check** 奇偶校验—an extra bit makes the number of 1s even (even parity) or odd. The receiver re-counts. Catches single-bit errors.
- **checksum** 校验和—the sender sends a summary value of the data; the receiver re-computes it and compares.
- **cyclic redundancy check** 循环冗余校验 (CRC) —a stronger checksum using polynomial division, catching many more error types.

A **parity block check** 奇偶块校验 goes further and *locates* the error. Arrange the bytes in a grid: give each byte a **row** parity bit, then compute one extra **parity byte** whose bits are the **column** parity of the bytes above. A single flipped bit now fails **one row and one column** –their intersection pinpoints exactly which bit changed, so it can even be corrected.

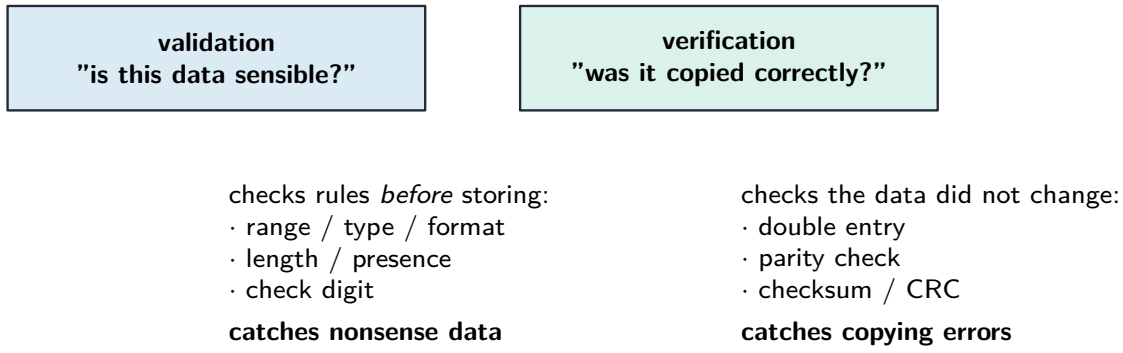


The parity bit is set to make the number of 1s even or odd



Working out a checksum for a block of data

Verification only proves what arrived matches what was sent —not that the data is correct, and not against deliberate tampering. **Validation** asks "is this sensible?"; **verification** asks "was this copied correctly?" —use both.



Validation checks the data makes sense; verification checks it was copied without change

Worked example. A user types their date of birth as `31/02/2009`, and types their email address twice. Which check catches which error, and what is the difference? **Validation** asks "is this data **sensible**?" - the computer tests it against a rule, and a format or range check rejects `31/02/2009` because February never has 31 days. **Verification** asks "was this data **entered correctly**?" - typing the email twice is **double entry**, and comparing the two copies catches a typing slip. The limit is what makes this a favourite question: validation can never tell you the data is **right**, only that it is **possible** - `01/02/2009` passes every validation rule even if the user was actually born on a different day. Say what each check **can** and **cannot** catch.

Exam tips

- Keep the three ideas separate: **security** (keeping data safe), **privacy** (who may see it), **integrity** (keeping it correct).
- Match each **threat** (malware, hacking, phishing, interception) to a **measure** (firewall, encryption, authentication, access rights).
- Encryption protects **confidentiality, not integrity** —use a checksum, parity or check digit for integrity.
- Distinguish a **virus, worm and Trojan** and how each spreads.