

ARP and ICMP Protocols

*Prepared By
Dr. Islam Zakaria*

References

❑ ARP

<https://info.support.huawei.com/info-finder/encyclopedia/en/ARP.html>

❑ ICMP

<https://info.support.huawei.com/info-finder/encyclopedia/en/ICMP.html>

Introduction

- ❑ **Address Resolution Protocol (ARP)** is used to discover the **Layer 2 (MAC)** address of a device on your **local network** when you only know its **Layer 3 (IP) address**.
- ❑ **Internet Control Message Protocol (ICMP)** is used for **sending error** and **control messages between network devices**. It's a fundamental support protocol that **helps routers and hosts communicate about** the **health** and **status** of the network, making it possible to **diagnose problems and ensure efficient operation**.

Comparison: ARP vs ICMP

Feature	ARP	ICMP
Layer	2 / 3	3
Purpose	Map IP → MAC	Control, errors, diagnostics
Works in LAN only?	Yes	No (Internet-wide)
Key message	Request / Reply	Echo, Time Exceeded, Unreachable
Security	Weak	Often blocked by firewalls

ARP

Why Do We Need ARP?

- ❑ **ARP is required to map IP addresses to MAC addresses.**
- ❑ For hosts or other **Layer 3 network devices** to communicate on a **LAN**, the **sender must** know the **destination IP address to which it will send IP packets.**
- ❑ **Sender must first** be **encapsulated** with **MAC addresses** before they can be transmitted over the physical network.
- ❑ It is therefore **necessary** for **hosts or Layer 3 network devices** to maintain an **ARP table** for **storing the mapping information of IP and MAC addresses.**

What Are the Types of ARP?

1. Dynamic ARP

- It **entries** are **automatically** generated and maintained when **ARP packets** are **sent** and **received**.
- **They can be aged, updated, or overwritten by Static ARP entries.**
- **Dynamic ARP applies to complex networks that transmit delay-sensitive services.**

What Are the Types of ARP?

2. Static ARP

- It allows a network administrator to manually create the fixed mappings between **IP** and **MAC** addresses.
- **Static ARP entries cannot be aged or overwritten by dynamic ARP entries, ensuring system security.**
- **In most cases**, devices on a network can use **ARP** to **dynamically** learn **ARP entries** and **age** or **update** the **generated dynamic ARP entries**.
- **However**, when a network **encounters** an **ARP attack**, the **dynamic ARP entries** may be **incorrectly updated** or **aged**.
- **As a result**, the communication between authorized users becomes **abnormal**.

What Are the Types of ARP?

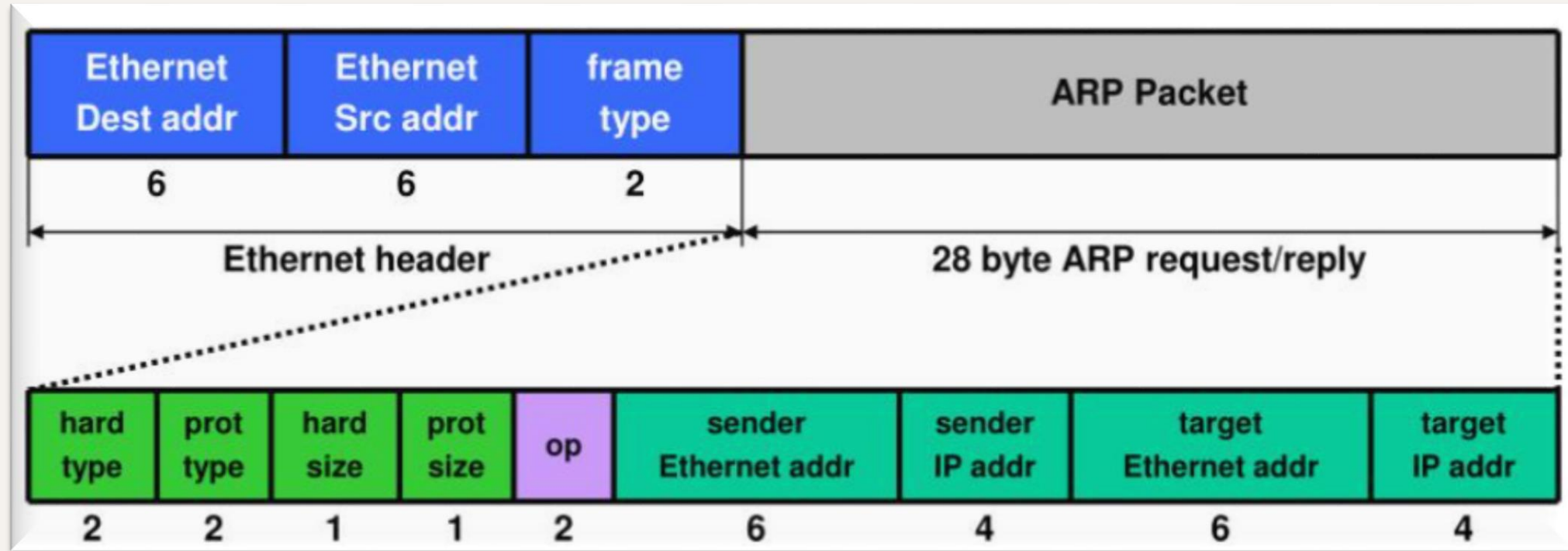
- If a **static ARP** entry is **configured** on a **device**, the **device** can communicate with the **peer device** using **only** the **specified MAC address**.
- **Network attackers cannot modify** the **mapping** between the **IP** and **MAC addresses** using **ARP packets**, **ensuring** communication between the two devices.
- **Static ARP entries are generally configured on gateways.**

What Are the Types of ARP?

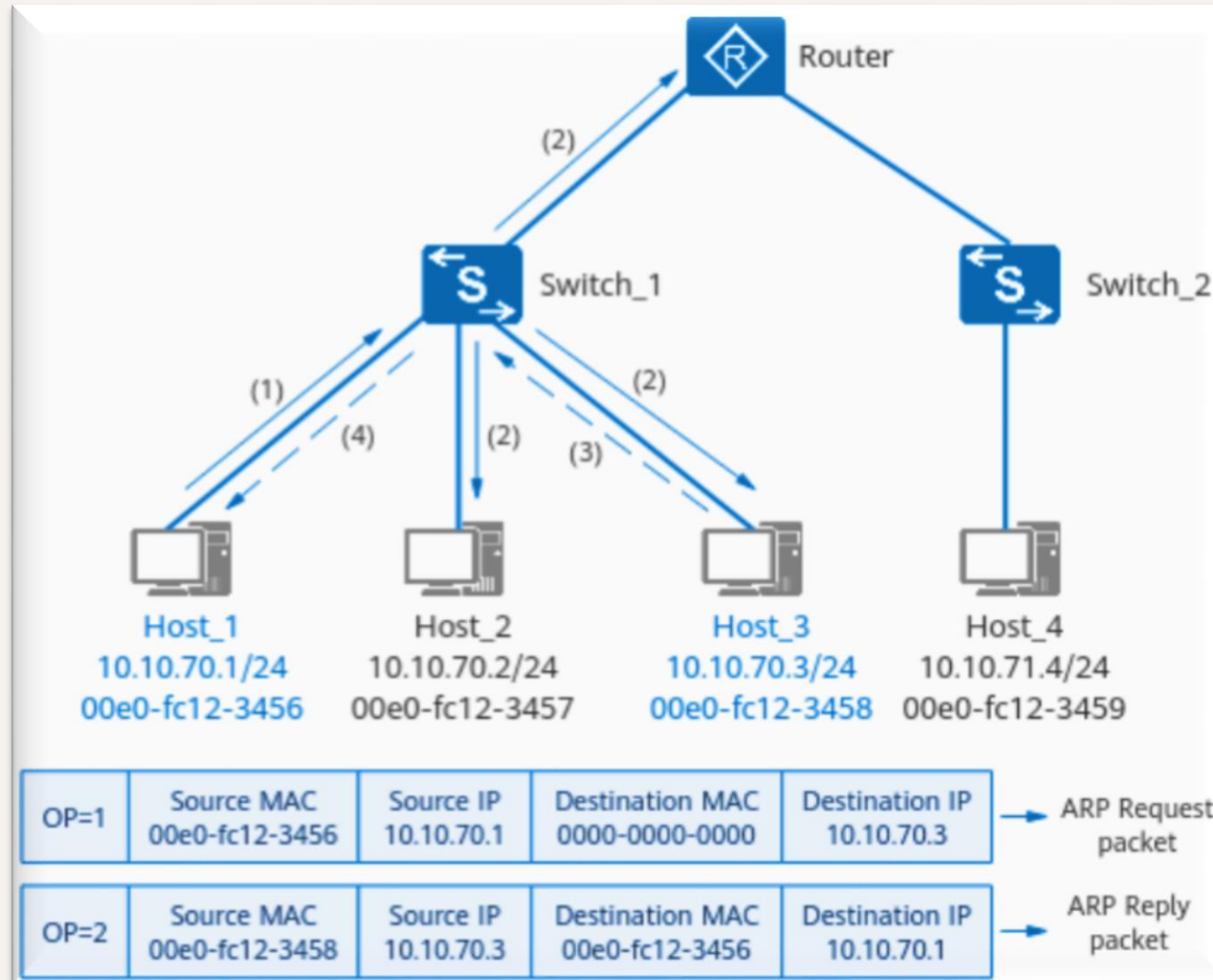
3. Gratuitous ARP

- ❑ It allows a device to send an **ARP Request** packet that **carries** its **own IP address** as the **destination IP address**.
- ❑ **Gratuitous ARP has the following functions:**
 - **Checks for IP address conflicts.**
 - **Advertises a new MAC address.**

ARP Format



How Does ARP Work?



ARP Operation (Example)

- ❑ Assume:

- Host A: **192.168.1.10**
- Host B: **192.168.1.20**
- Host A wants to send packet to Host B.

- ❑ Step 1: ARP Request (**Broadcast**)

- Host A doesn't know B's MAC, so it sends **broadcast frame**:
- Destination MAC: **FF:FF:FF:FF:FF:FF**
- Contents: "Who has **192.168.1.20**?"

- ❑ Step 2: ARP Reply (**Unicast**)

- Host B responds directly to A: **192.168.1.20** is at MAC: **AA:BB:CC:DD:EE:FF**.

ARP Operation (Cont.)

❑ Step 3: ARP Cache Update

➤ **Host A** saves **mapping**:

IP	MAC	Timer
192.168.1.20	AA:BB:CC:DD:EE:FF	~2–20 mins

➤ **This Timer Handling MAC Address Changes (The device using a specific IP address can change, and thus its MAC address will be different)**

❑ Step 4: Communication Begins

➤ Now **Host A** sends actual data to **Host B** using **Layer 2 MAC + Layer 3 IP**.

Problems with ARP

1. Security Problems

- **ARP Spoofing/Poisoning:** Attackers send **fake ARP replies to associate their MAC address with a legitimate IP**, enabling:
 - **Man-in-the-Middle (MitM) attacks for data interception.**
 - **Denial-of-Service (DoS) by redirecting traffic to a non-existent MAC.**
- **MAC Flooding:** Attackers flood a switch with **fake MAC addresses**, causing the switch to **broadcast traffic to all ports (like a hub)**.
- **No Authentication:** ARP has no mechanism to verify that an **ARP reply** is from the **legitimate owner** of an **IP address**. **It is a trusting, stateless protocol.**

Problems with ARP

2. Management & Troubleshooting Problems

- **Lack of Scalability:** In large Layer 2 networks, the **volume of ARP broadcast traffic can become a significant overhead.**
- **No Built-in Loop Prevention:** ARP frames are bridged like any other traffic, so **network loops can cause ARP frames to circulate endlessly, exacerbating storms.**

3. Reliability & Network Problems

- **IP Address Conflicts:** If two devices have the **same IP**, **ARP caches** on other hosts become **unstable, flipping between two MAC addresses and causing broken connectivity.**



ICMP

What Is ICMP?

- ❑ **ICMP** is a **network layer protocol** used to **transmit control messages** between **hosts** and **routers** to **report whether hosts are reachable and routes are available**.
- ❑ It plays an important role in the TCP/IP protocol suite and is typically **used by** the **IP** or **higher layer protocols** (TCP or UDP).
- ❑ Although these **control messages do not transmit user data**.

Why ICMP is Needed

- ❑ ICMP is essential because IP (Internet Protocol) itself is "unreliable" and lacks built-in mechanisms for diagnostics and error reporting. ICMP fills this critical gap.

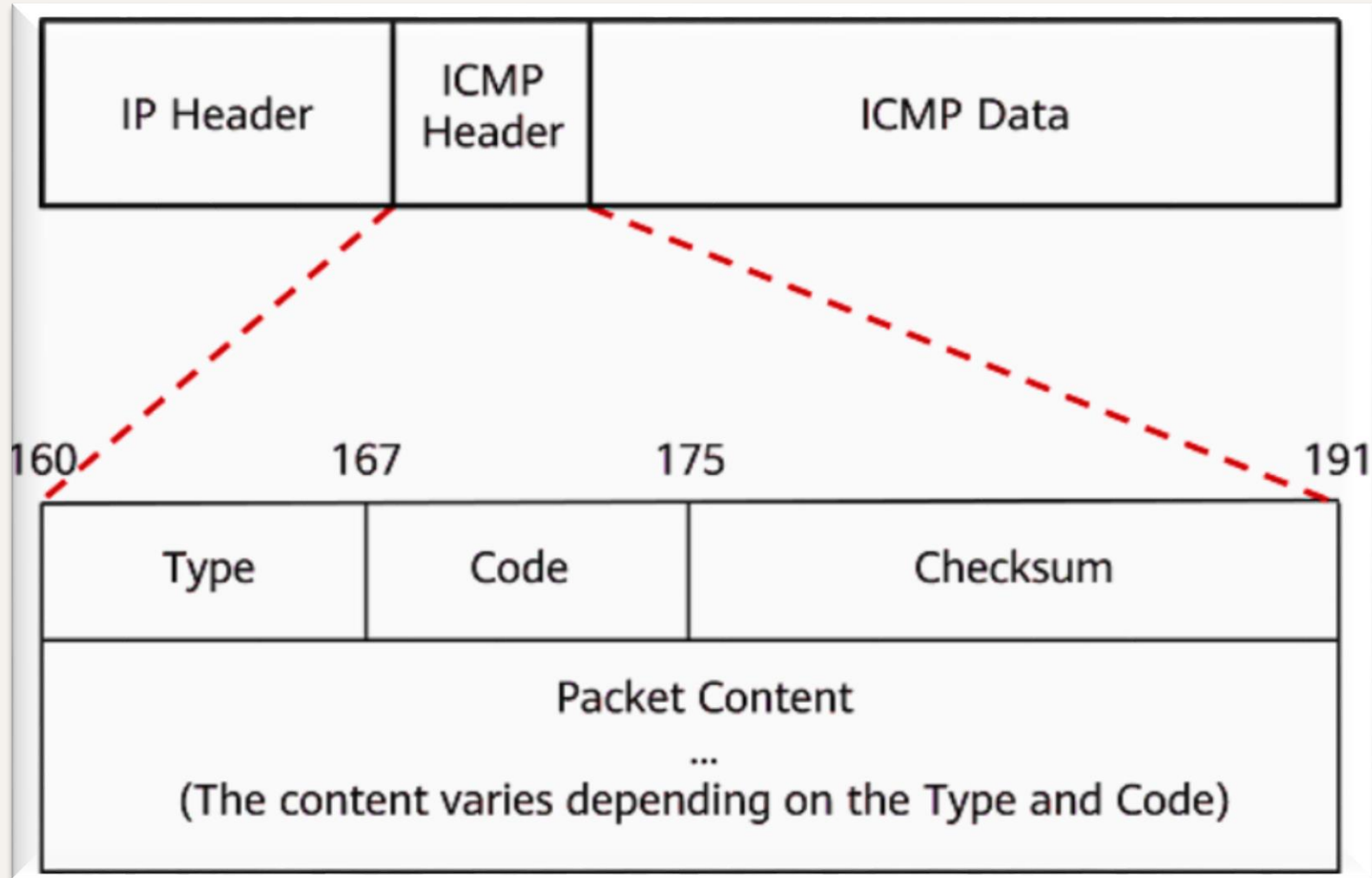
1. For Error Reporting and Signaling.

- **Informs Senders of Delivery Failures.**
- **Prevents Packet Loops:** Sends "**Time Exceeded**" messages when a packet's TTL (Time to Live) reaches zero.

2. For Network Diagnostics and Troubleshooting

- **Connectivity Testing:** The **ping** command uses **ICMP Echo Request** and **Reply** to **verify** if a **remote host** is **online** and **reachable**, and to measure **round-trip latency**.
- **Path Discovery:** The **traceroute** (or **tracert**) **command** uses **ICMP Time Exceeded** and **Destination Unreachable** messages to **map** the **entire network path between source and destination**.

ICMP Message Format



ICMP Message Format (Cont.)

Field	Size (Bytes)	Description
Type	1	Identifies the general category of the ICMP message. <ul style="list-style-type: none">➤ 0 = Echo Reply➤ 8 = Echo Request➤ 3 = Destination Unreachable➤ 11 = Time Exceeded
Code	1	Provides more specific detail within the given Type. e.g., For Type 3 (Destination Unreachable): <ul style="list-style-type: none">➤ 0 = Network unreachable➤ 1 = Host unreachable➤ 3 = Port unreachable
Checksum	2	Error-checking value for the entire ICMP message. Used to detect corruption during transmission.

Common ICMP Messages

1. Echo Request / Echo Reply (ping)

- Used to test: **Host reachability**, **Round-trip time**, and **Packet loss**.
- Ping = ICMP Type 8 (**request**) and Type 0 (**reply**).
- Example:

```
C:\Users\Islam Zakaria>ping www.youtube.com

Pinging youtube-ui.l.google.com [142.250.180.174] with 32 bytes of data:
Reply from 142.250.180.174: bytes=32 time=66ms TTL=111
Reply from 142.250.180.174: bytes=32 time=98ms TTL=111
Reply from 142.250.180.174: bytes=32 time=66ms TTL=111
Reply from 142.250.180.174: bytes=32 time=67ms TTL=111

Ping statistics for 142.250.180.174:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 66ms, Maximum = 98ms, Average = 74ms
```

Fields explained:

bytes → **packet payload**

time → **RTT**

TTL → **remaining hops**

Common ICMP Messages (Cont.)

2. Destination Unreachable (Type 3)

- **Generated when a router or host cannot deliver a packet.**
- **Common codes:**

Code	Meaning
0	Network unreachable
1	Host unreachable
3	Port unreachable
4	Fragmentation needed (MTU issue)

Common ICMP Messages (Cont.)

3. Time Exceeded (Type 11)

- Used by traceroute.
- Occurs when:
 - TTL becomes **zero**, so **packet is dropped**.
 - Router sends **ICMP Time Exceeded** back to sender
- Routers decrement TTL by 1 each hop.

```
C:\Users\Islam Zakaria>tracert www.youtube.com

Tracing route to youtube-ui.l.google.com [142.251.209.46]
over a maximum of 30 hops:

  1  <1 ms    <1 ms    <1 ms    DESKTOP-1LD9KH9 [192.168.1.1]
  2  29 ms    29 ms    30 ms    197.161.132.1
  3  31 ms    28 ms    28 ms    172.24.144.73
  4  28 ms    28 ms    28 ms    172.24.144.53
  5  28 ms    30 ms    28 ms    172.19.1.241
  6  29 ms    29 ms    29 ms    81.10.87.222
  7  70 ms    67 ms    71 ms    93.186.129.182
  8  66 ms    66 ms    65 ms    93.186.129.45
  9  66 ms    66 ms    67 ms    72.14.221.64
 10  66 ms    67 ms    66 ms    192.178.96.161
 11  99 ms    66 ms    66 ms    142.251.235.177
 12  66 ms    66 ms    66 ms    mil04s51-in-f14.1e100.net [142.251.209.46]

Trace complete.
```


ICMP in Real-World Tools

1. ping (Connectivity Test)

- Sends **ICMP Echo Request** (**Type 8**) to target.
- Target replies with **ICMP Echo Reply** (**Type 0**).
- **Measures: Reachability, Round-trip Time (Latency), Packet Loss.**

2. traceroute/tracert (Path Discovery)

- Uses **ICMP Time Exceeded messages** (**Type 11**)
- Sends packets with increasing **TTL** values
- Each router along path sends **ICMP Time Exceeded** when **TTL=0**
- **Maps entire network path to destination**

3. Path MTU Discovery

- Uses **ICMP Fragmentation Needed messages** (**Type 3, Code 4**)
- **Discovers maximum packet size without fragmentation**
- **Automatically adjusts packet size for optimal performance**

ICMP in Real-World Tools (Cont.)

4. Destination Unreachable Diagnostics

- **Helps identify why connections fail**

5. Network Monitoring Systems

- **Use ICMP Echo for continuous availability monitoring**
- **Alert when hosts become unreachable**
- **Track latency and jitter over time**

6. Router Redirect Function

- **Routers inform hosts of better network paths**
- **Optimizes local network routing**

7. Error Reporting in Applications

- **Operating systems use ICMP messages to report connection failures**
- **e.g., "Connection refused" from Port Unreachable messages**
- **"No route to host" from Host/Network Unreachable messages**

ICMP Attacks

1. Reconnaissance Attacks

- **Host Discovery:** Attackers use ping to identify live hosts on a network
- **Network Mapping:** traceroute reveals network topology and firewall locations
- **OS Fingerprinting:** Analyzing ICMP response behavior to identify operating systems.

2. Denial of Service (DoS) Attacks

- **ICMP Flood:** Overwhelm target with massive amounts of ICMP Echo Requests
- **Ping of Death:** Oversized ICMP packets cause buffer overflow and system crashes

3. Redirect Attacks

- **ICMP Redirect:** Attackers send fake redirect messages to poison routing tables

ICMP Security Measures

1. Filtering & Blocking

- Block unnecessary ICMP types at network perimeter
- Use stateful inspection to only allow replies to outbound requests
- Implement rate limiting to prevent flood attacks

2. ICMP Type Management

- **Allow:** Echo Reply (0), Destination Unreachable (3), Time Exceeded (11)
- **Block:** Redirect (5), external Echo Requests (8), Address Mask Requests (17)

3. Monitoring & Detection

- Detect unusual ICMP patterns and volumes
- Inspect payloads for hidden data
- Log suspicious ICMP messages

ICMP Security Measures (Cont.)

4. Host Hardening

- Disable ICMP on critical servers when possible
- Harden OS ICMP stack settings
- Use host-based firewalls for granular control



**Any
Questions**
