Enhancing ICMP/ICMPv6 Error Message Authentication Using Challenge-Confirm Mechanism

Presenter: Ao Wang, Yuxiang Yang

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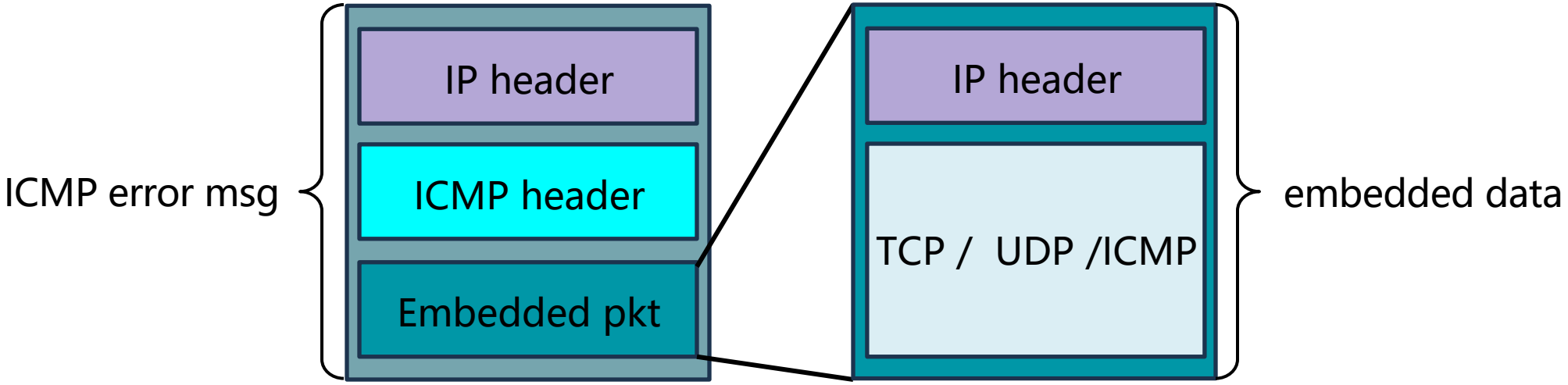
Problem Statement

ICMP Error Message

- ICMP error message
  - ICMP error messages, defined in RFC 792 / 4443, are used to **report network errors**, aiding in network diagnostics and troubleshooting.
- Verification of ICMP error message
  - Verification of ICMP error messages involves verifying the integrity and accuracy of these messages to accurately reflect network issues.



Specifications on ICMP Error Message

- RFC 792 / 1122 specifies:
  - Every ICMP error message **includes the Internet header and at least the first 8 data octets of the datagram** that triggered the error; more than 8 octets MAY be sent; this **header and data MUST be unchanged** from the received datagram.

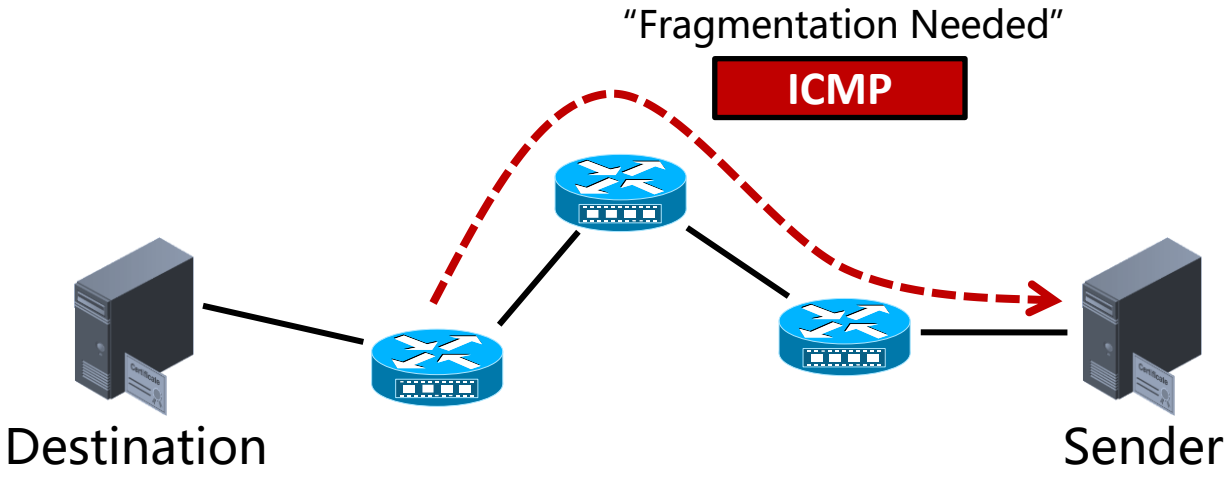
- RFC 1812 specifies:
  - The ICMP datagram **SHOULD contain as much of the original datagram as possible** without the length of the ICMP datagram exceeding 576 bytes.

- RFC 4443 specifies:
  - Every ICMPv6 error message (type < 128) **MUST include as much of the IPv6 offending (invoking) packet (the packet that caused the error) as possible** without making the error message packet exceed the minimum IPv6 MTU.

Problem

Current ICMP/ICMPv6 specifications have inherent limitations that allow off-path attackers to forge ICMP error messages.

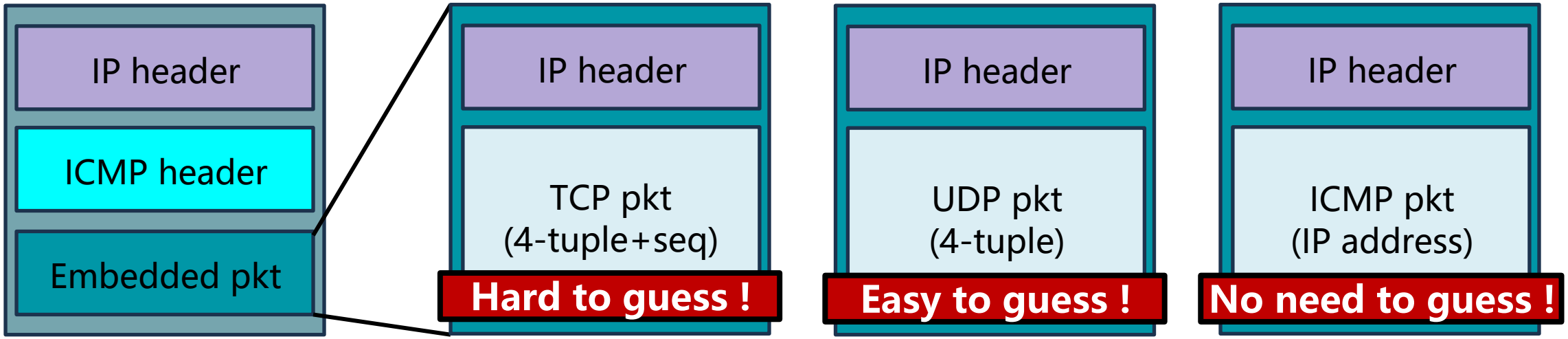
- Lack of Source IP Address-Based Verification
  - Certain ICMP/ICMPv6 error messages can originate from **any intermediate router** along the packet path.



Problem

Current ICMP/ICMPv6 specifications have inherent limitations that allow off-path attackers to forge ICMP error messages.

- Check on Embedded Packet is Bypassable
  - For stateful embedded packets (e.g., TCP), **hard to bypass**.
  - For stateless embedded packets (e.g., UDP, ICMP), **easy to bypass**.



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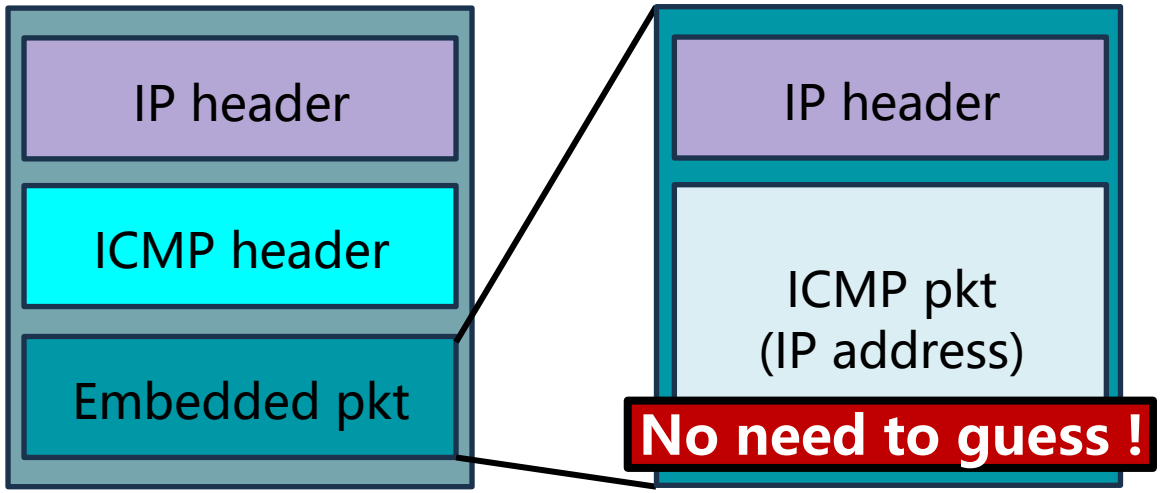
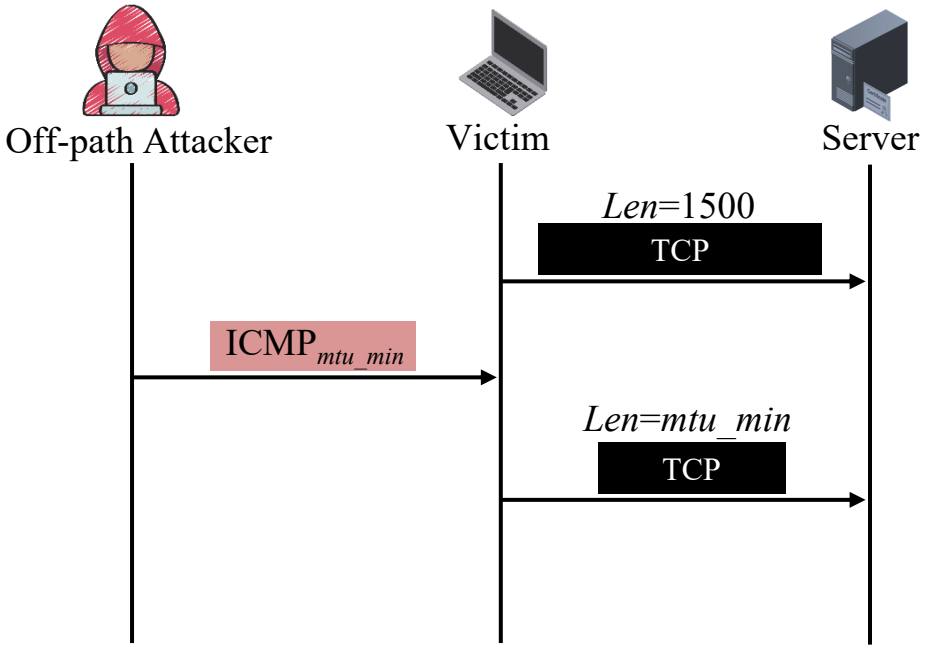


Can impact all upper-layer protocols !

Attack Cases

ICMP Fragmentation Attack

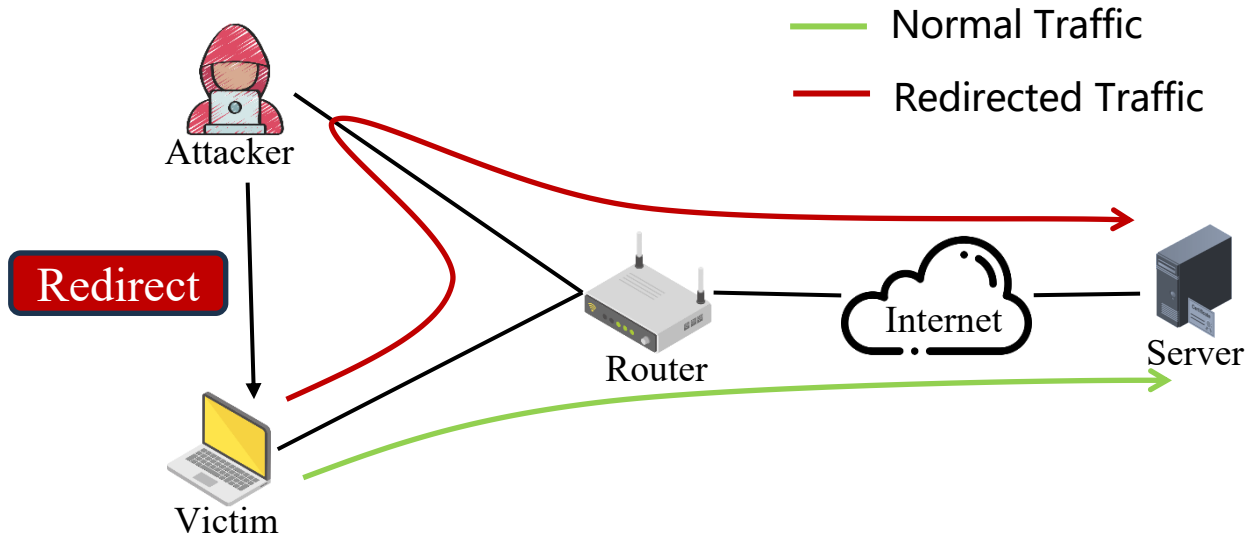
◆Forge ICMP "Fragmentation Needed" messages to lower hosts Path MTU.



[1] Feng, X., Li, Q., Sun, K., Fu, C., and K. Xu, "Off-path TCP hijacking attacks via the side channel of downgraded IPID"

ICMP Redirect Attack

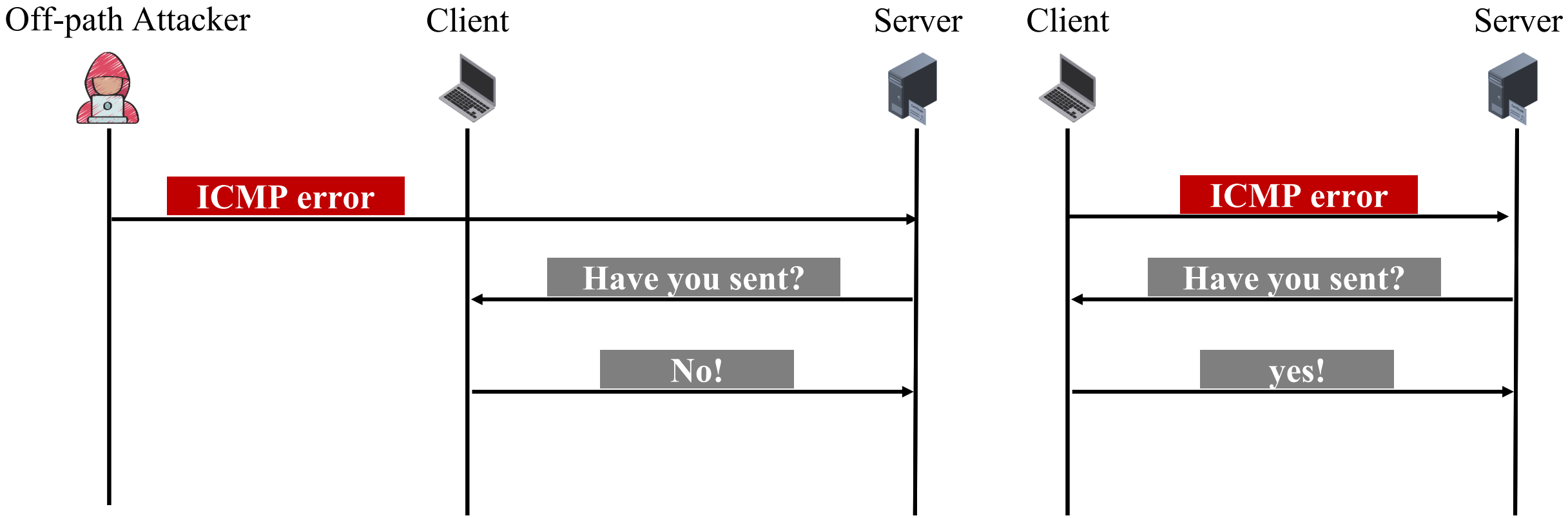
◆Forge ICMP Redirect messages to tamper with a victim's gateway, enabling Man-in-the-Middle (MitM) attack.



[2] Feng, X., Li, Q., Sun, K., Yang, Y., and K. Xu, "Man-in-the-middle attacks without rogue AP: When WPAs meet ICMP redirects"

Proposed Solution

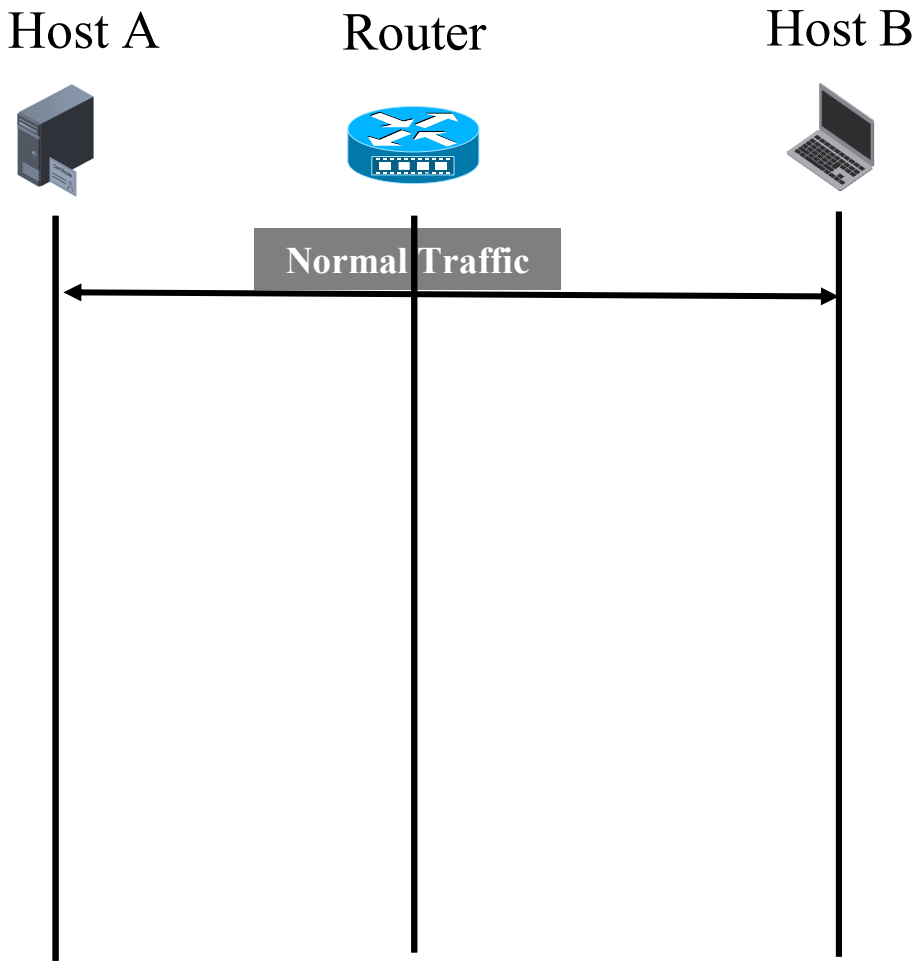
Basic Idea: Double Check



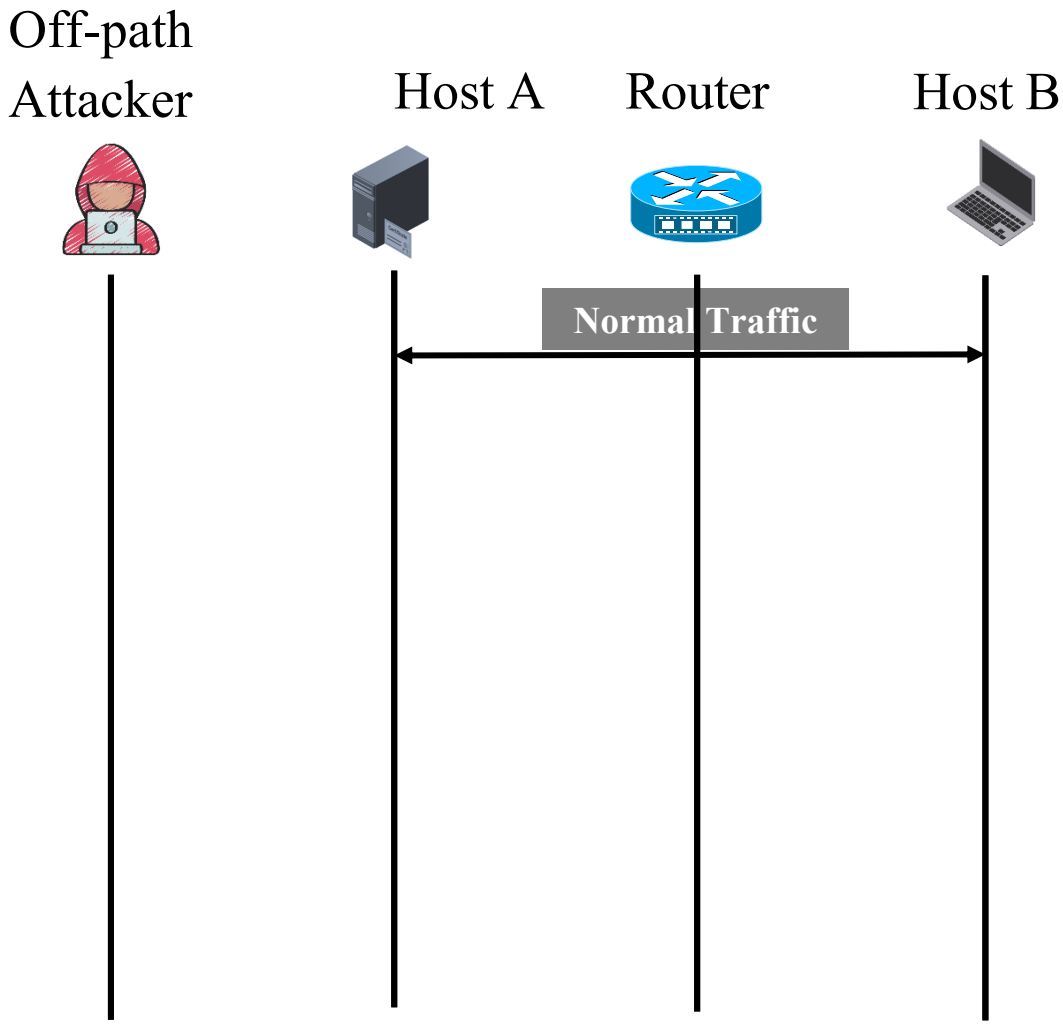
Can we design a mechanism by double-checking ICMP error messages to enhance the security of ICMP protocol?

The ICMP Challenge-Confirm Mechanism

Real ICMP Error Messages



Forged ICMP Error Messages



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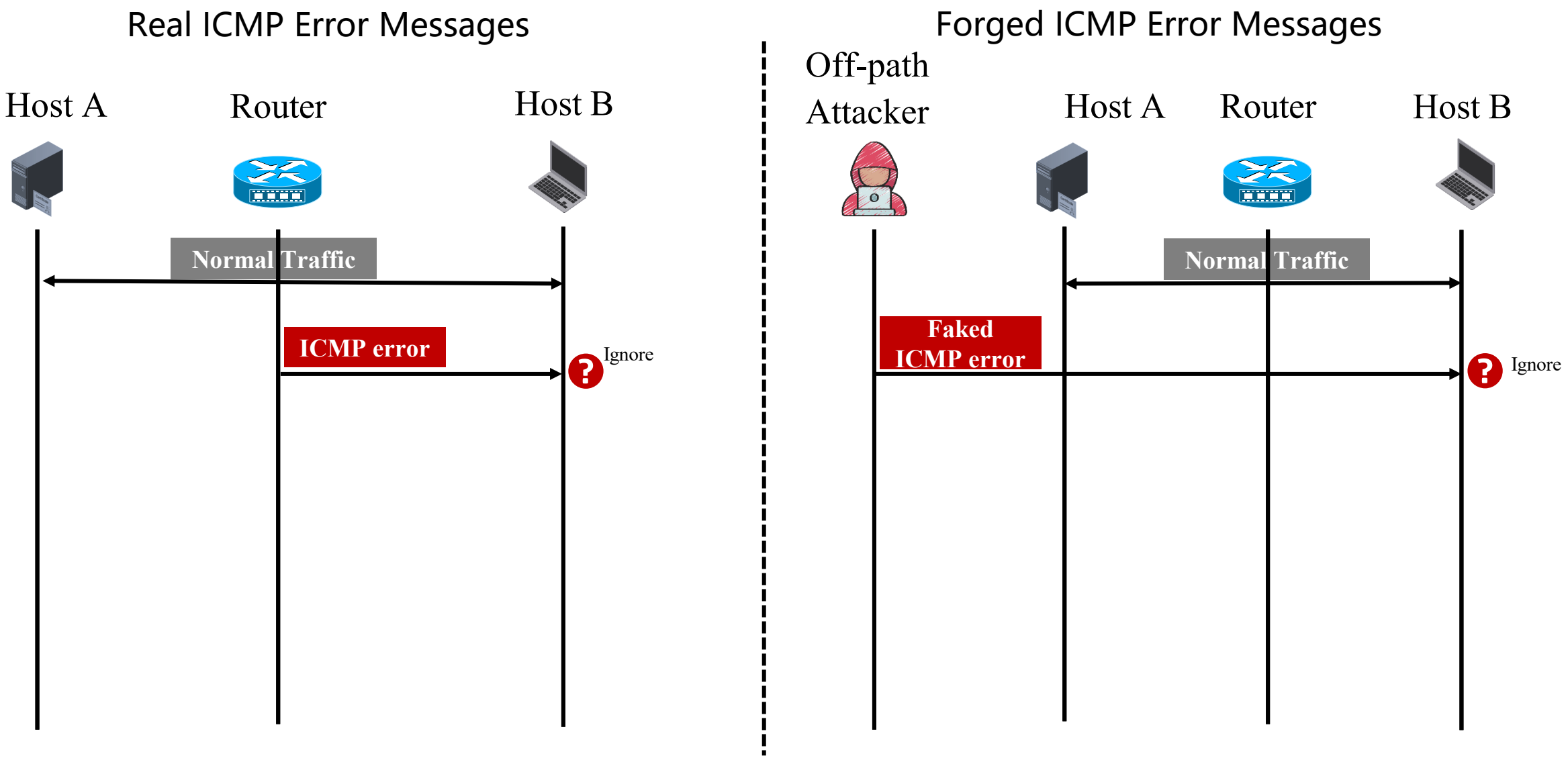

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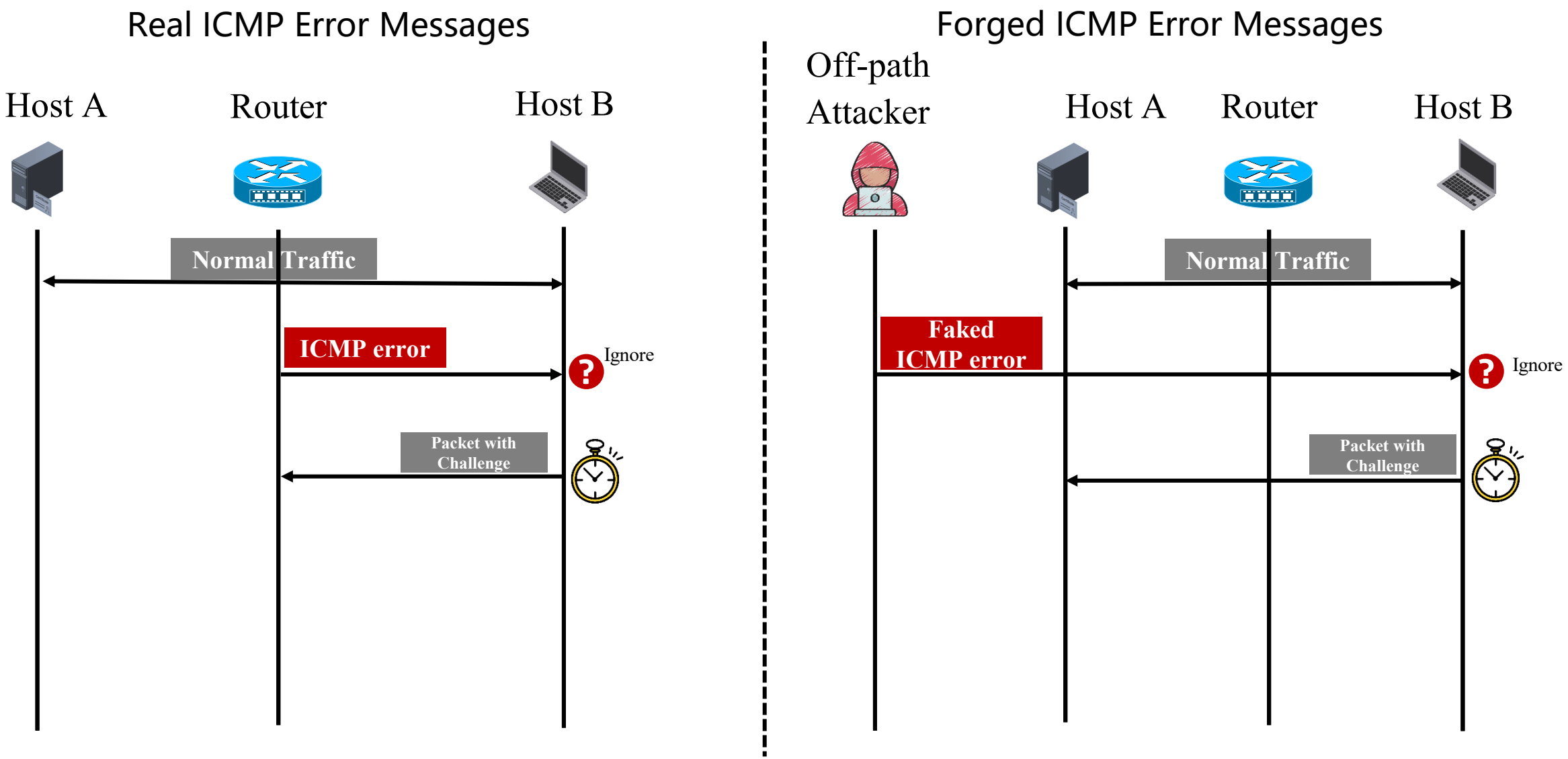

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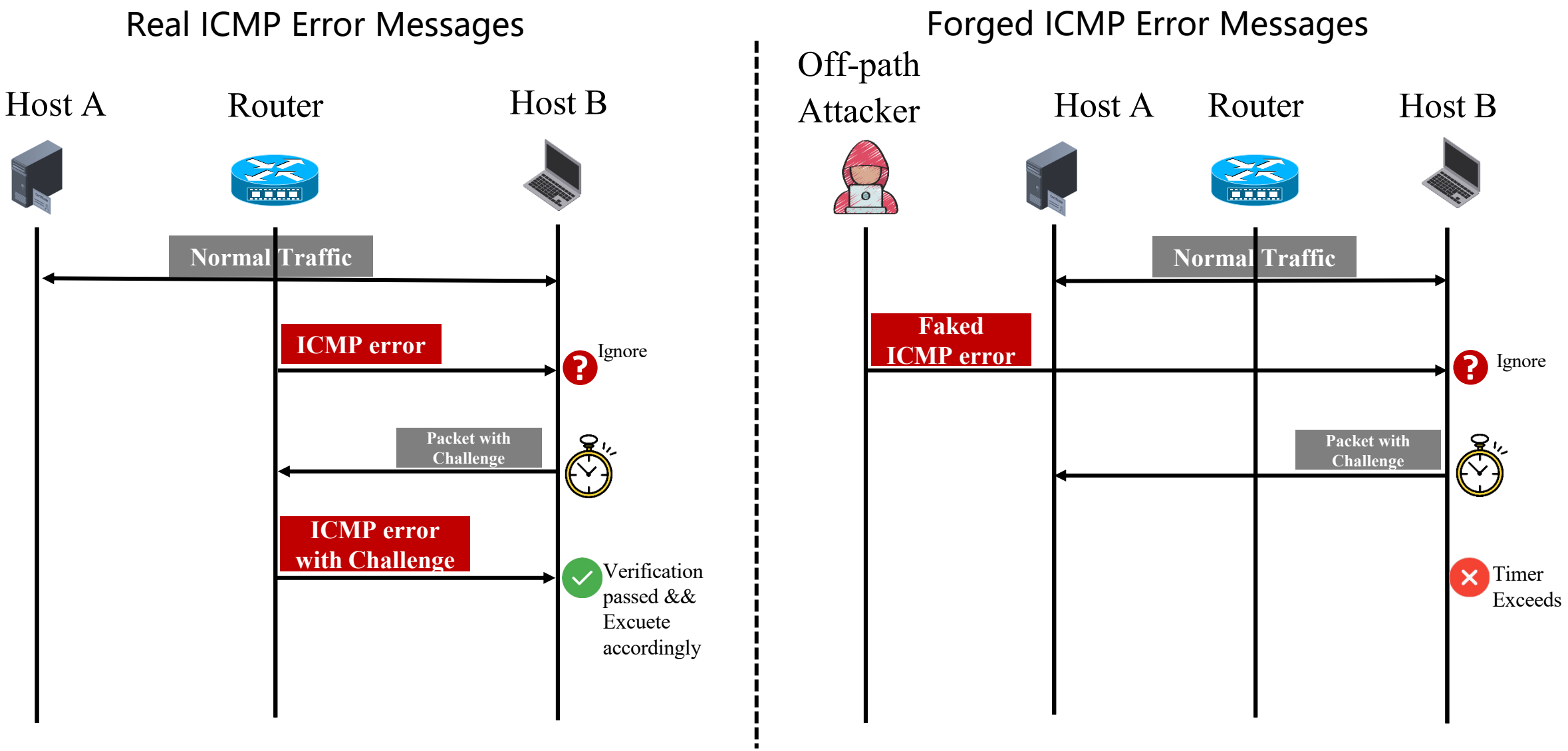
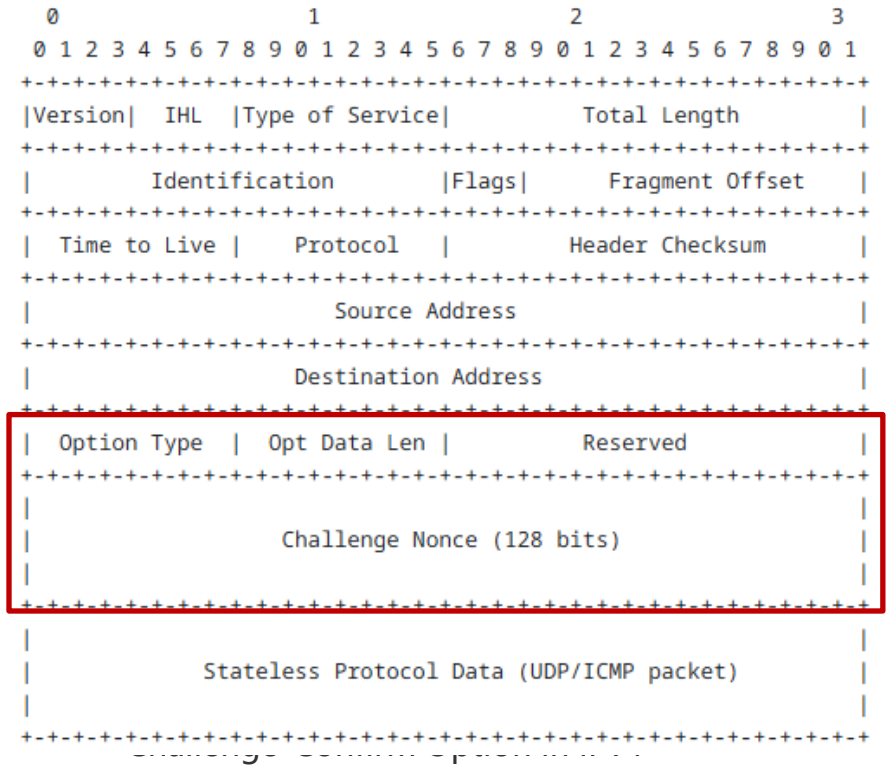
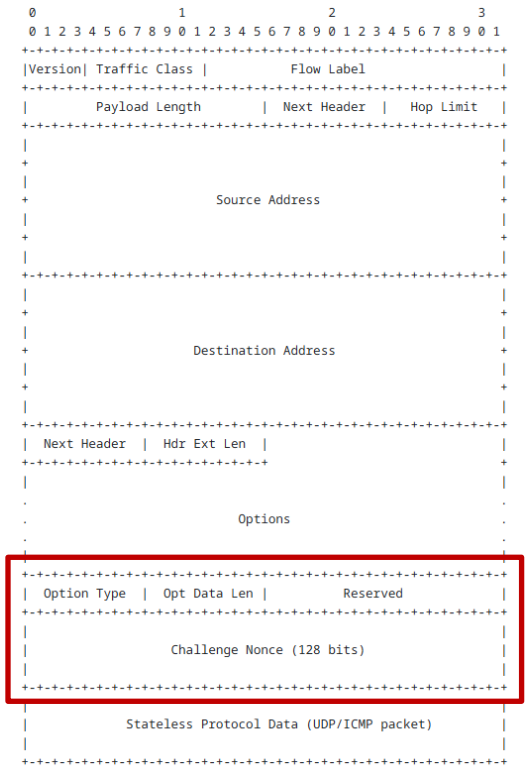


Updated Packet Formats

- The challenge will be carried in IP option as a random number.
  - ◆The middle routers and peers do not have to perform any additional processing on the option.



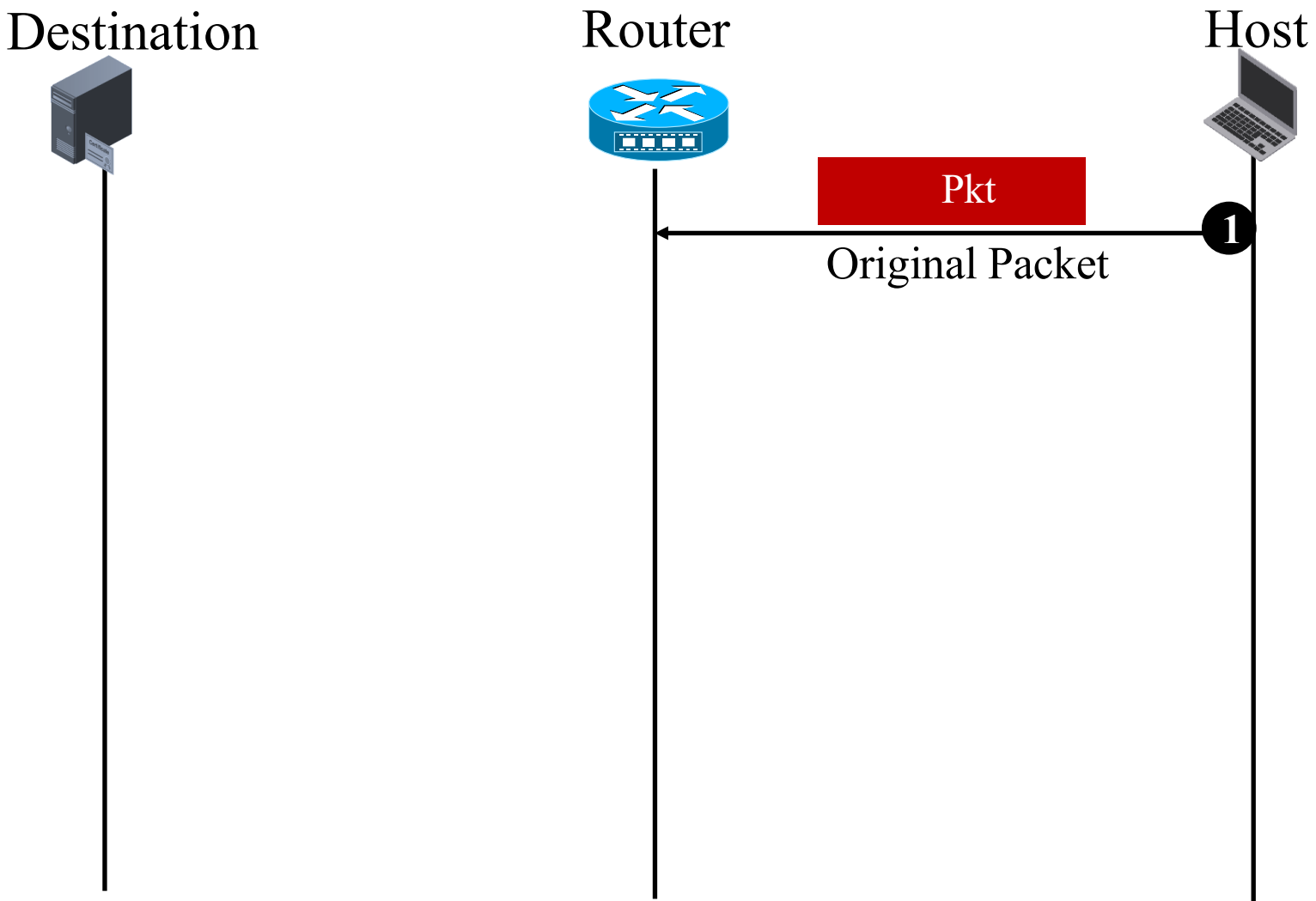


Challenge-Confirm Option in IPv6

Case Study

Case Study

- The mechanism when dealing with ICMP Fragmentation Needed messages



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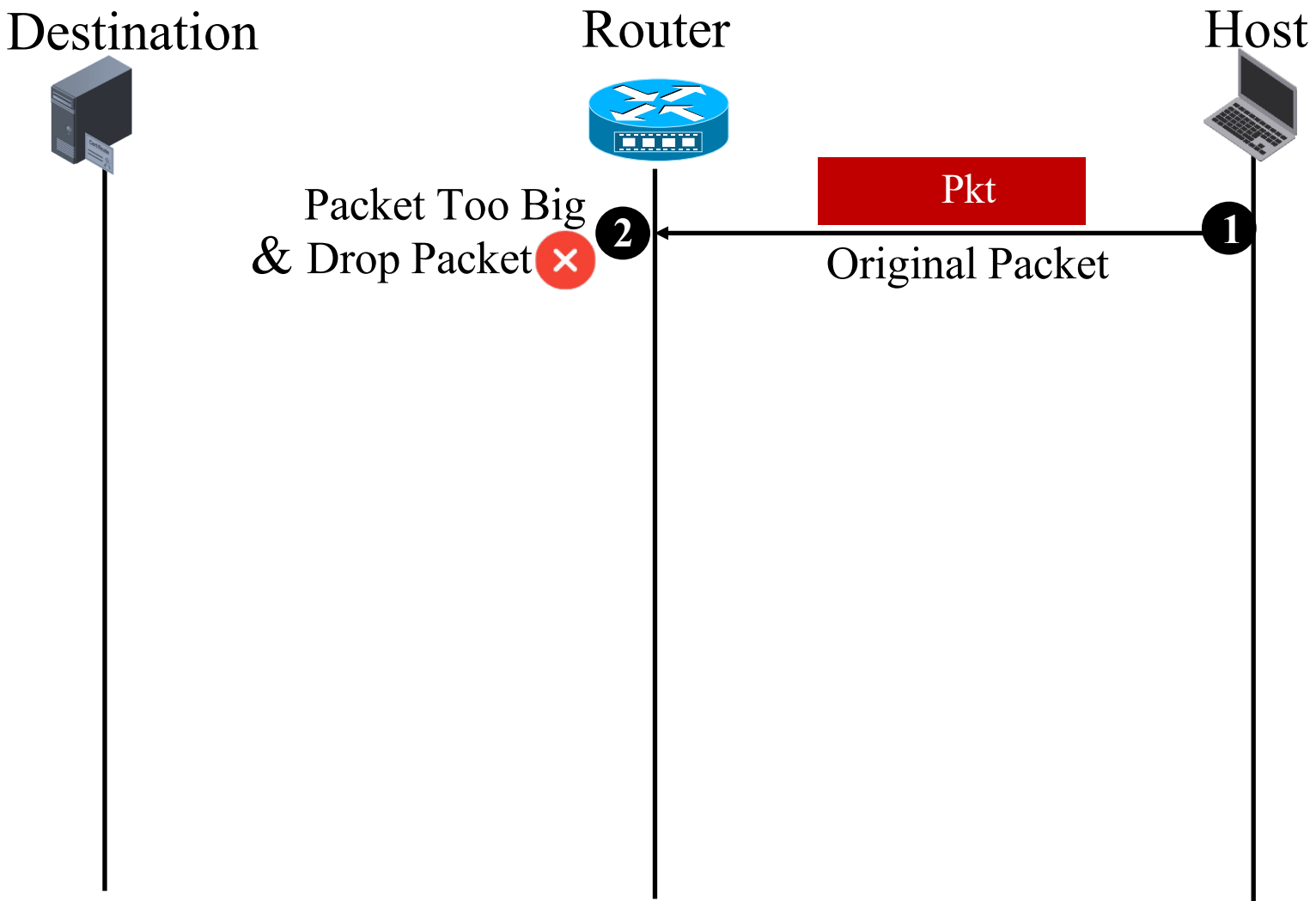

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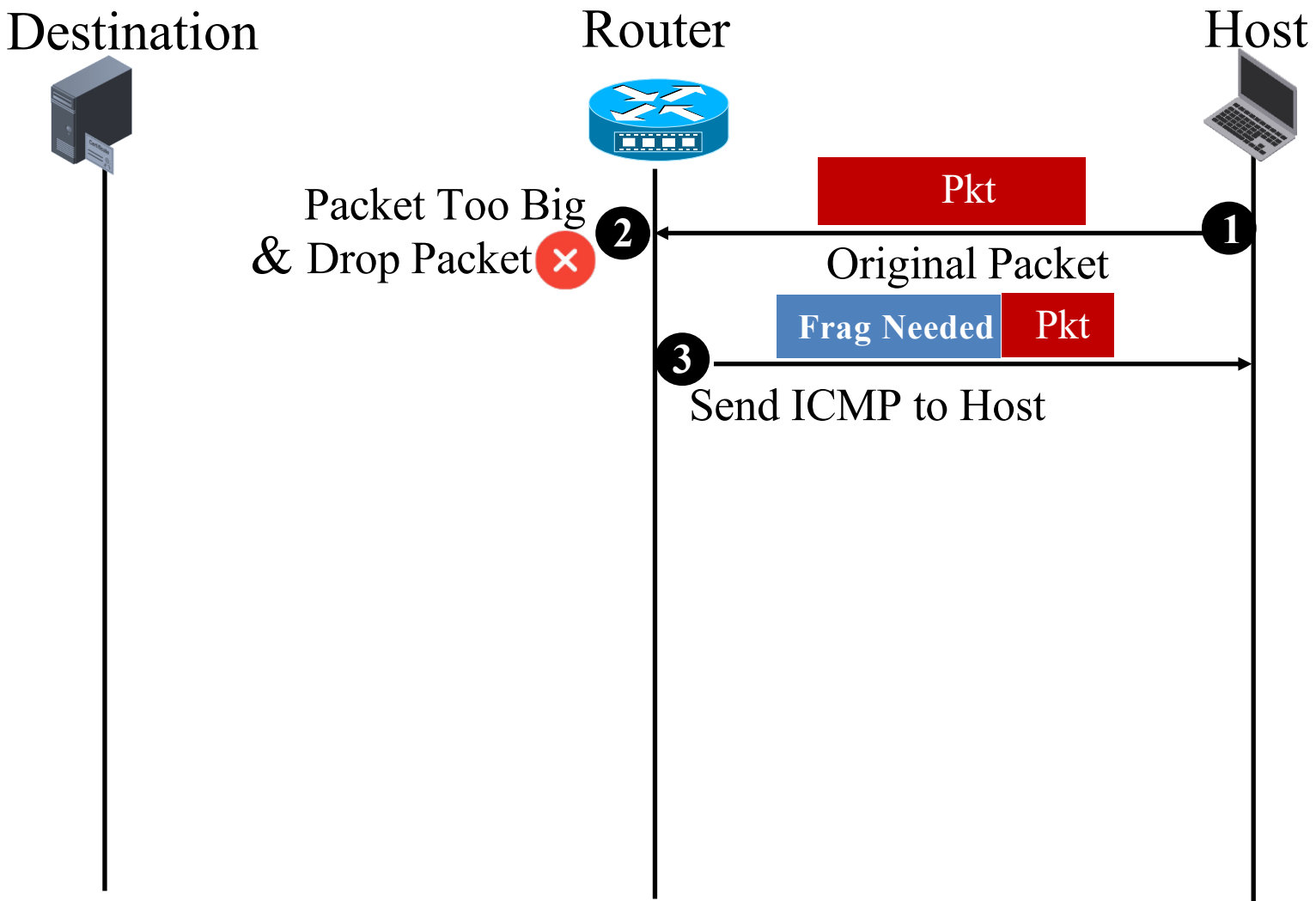

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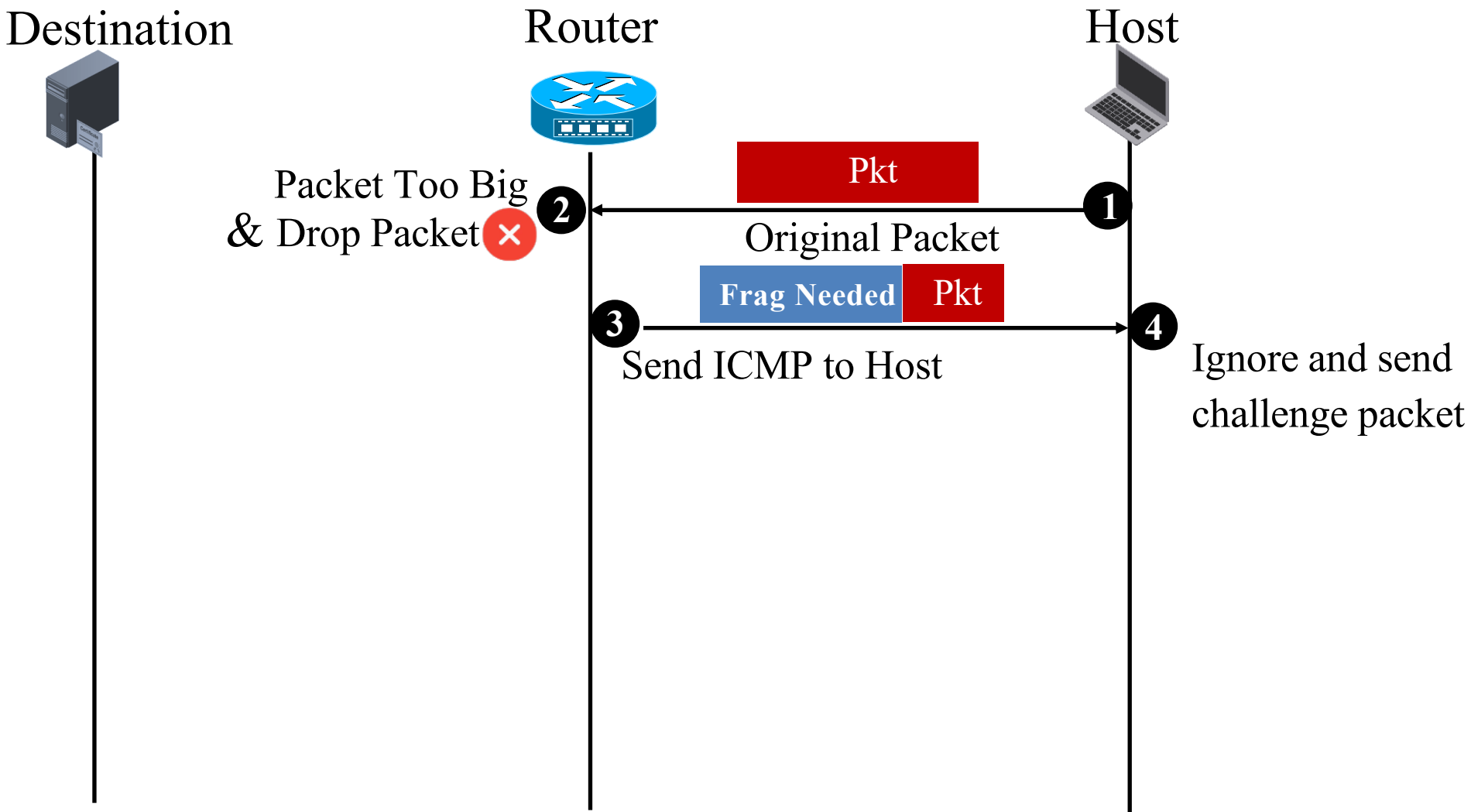

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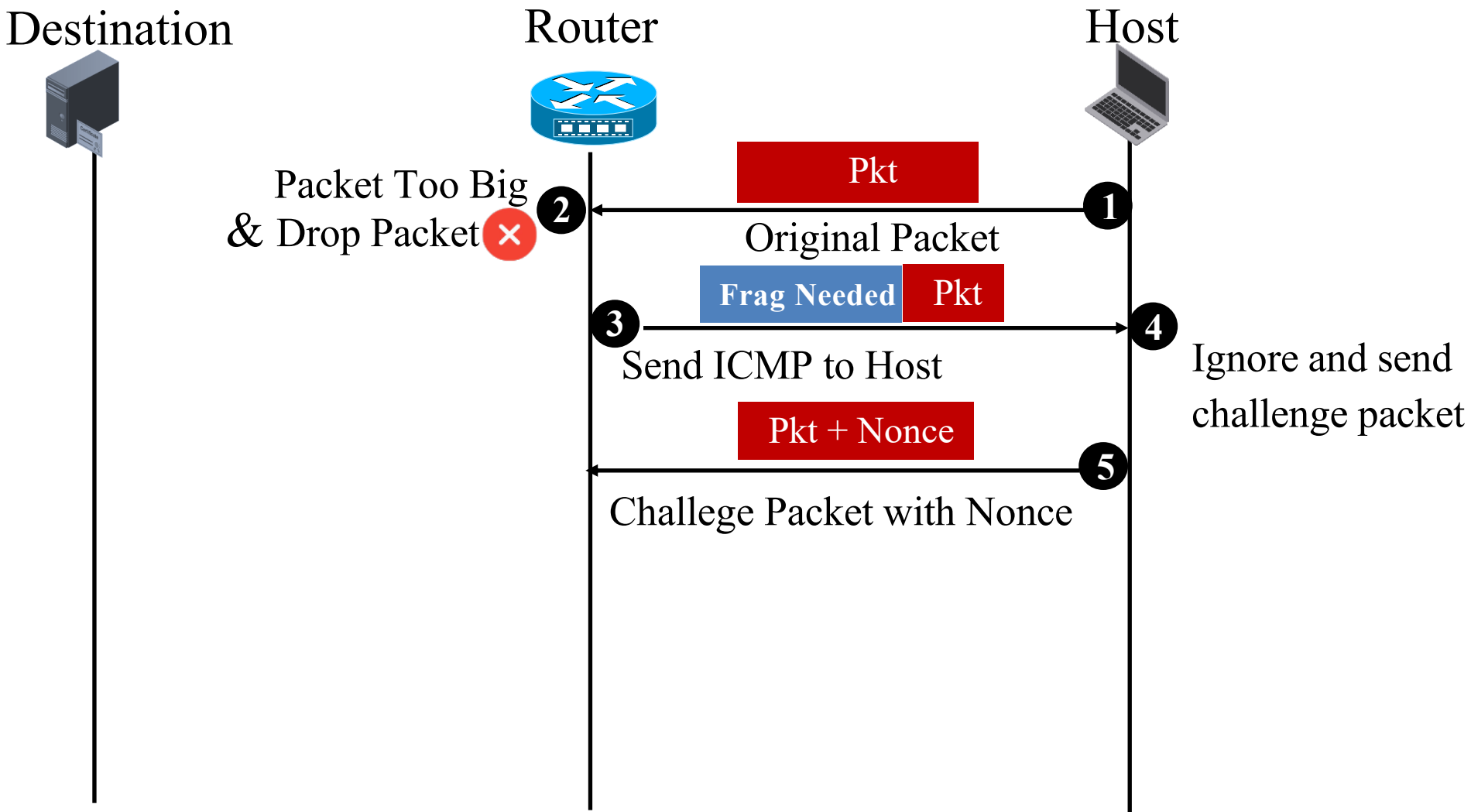

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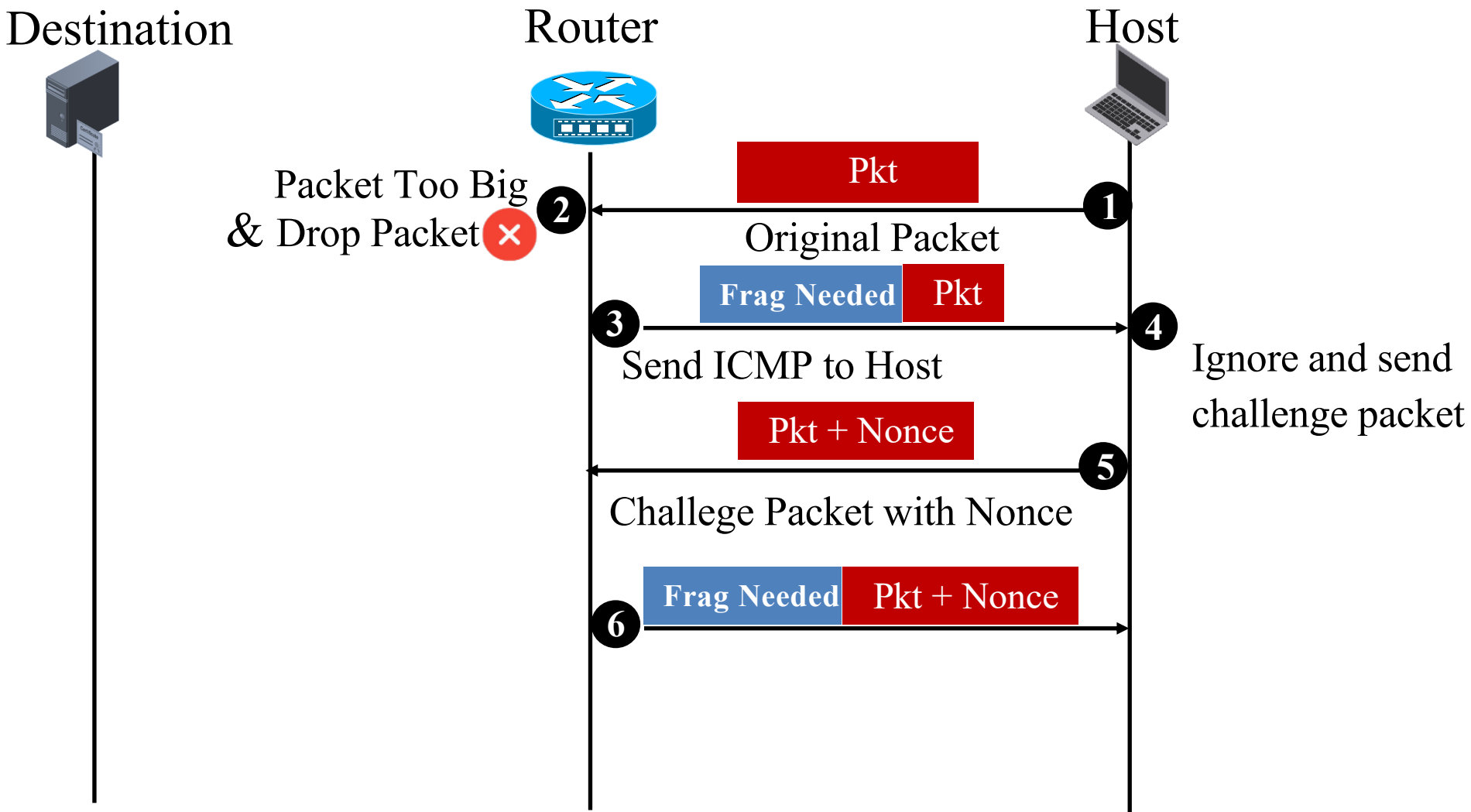

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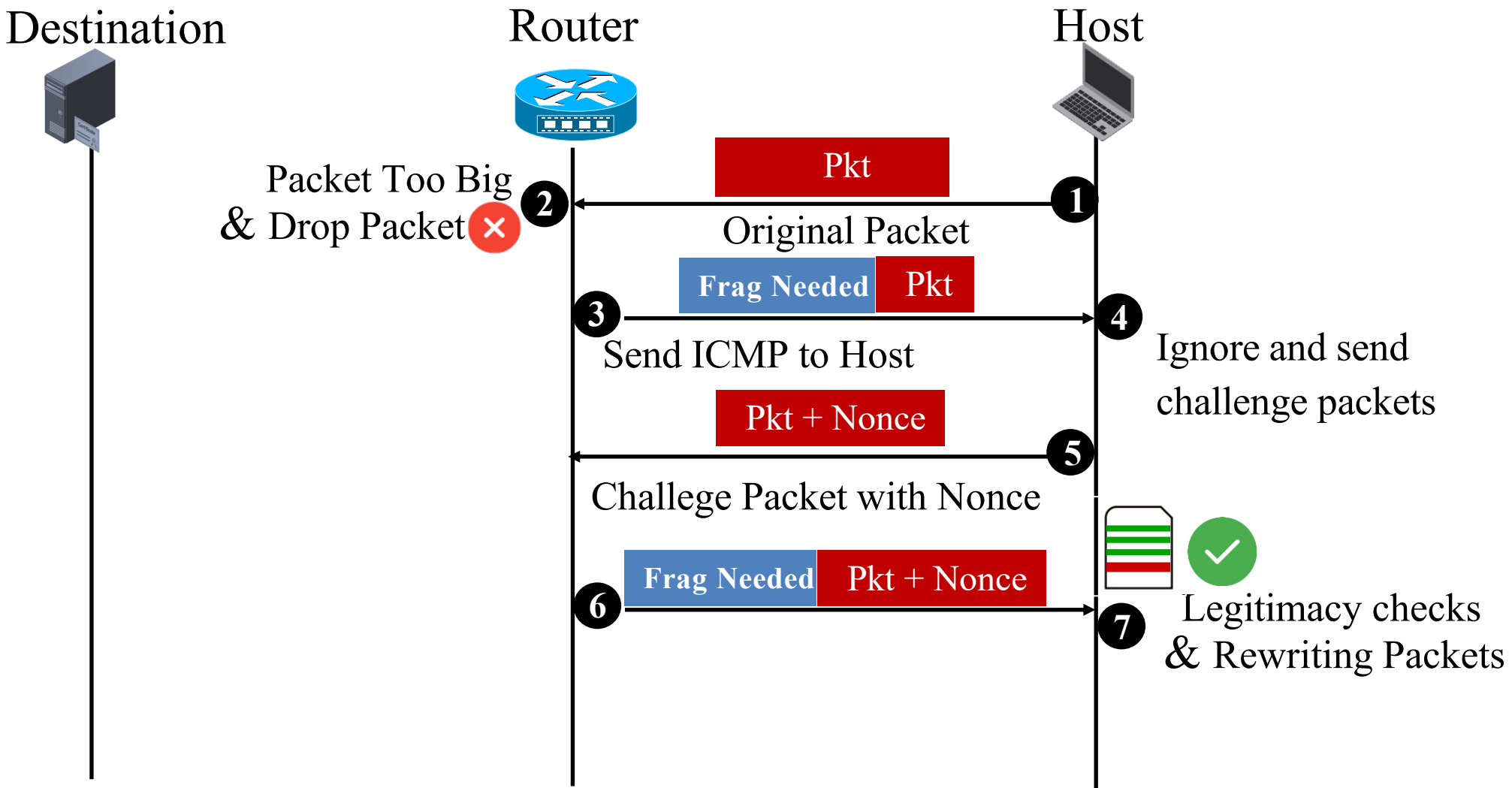

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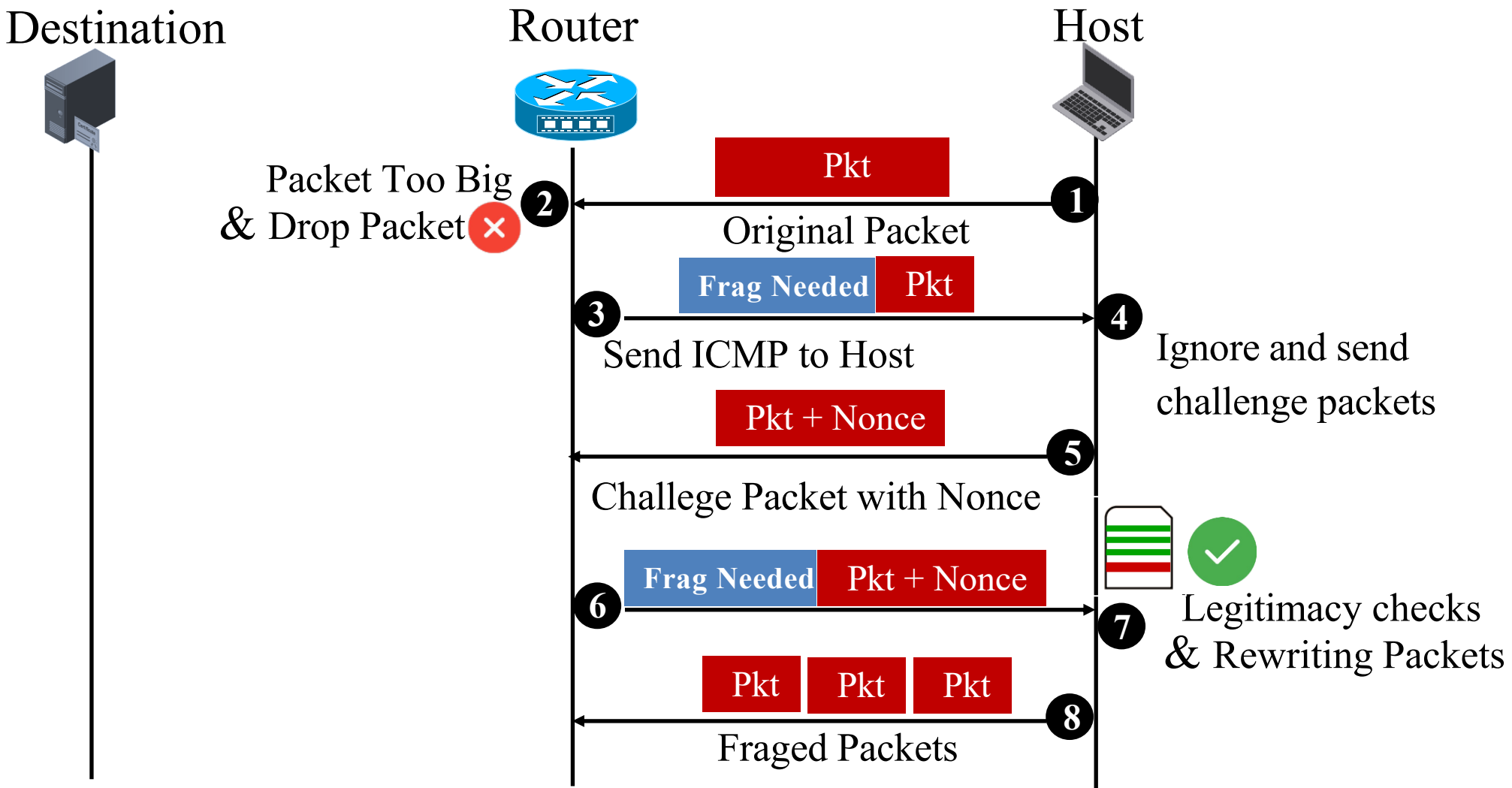

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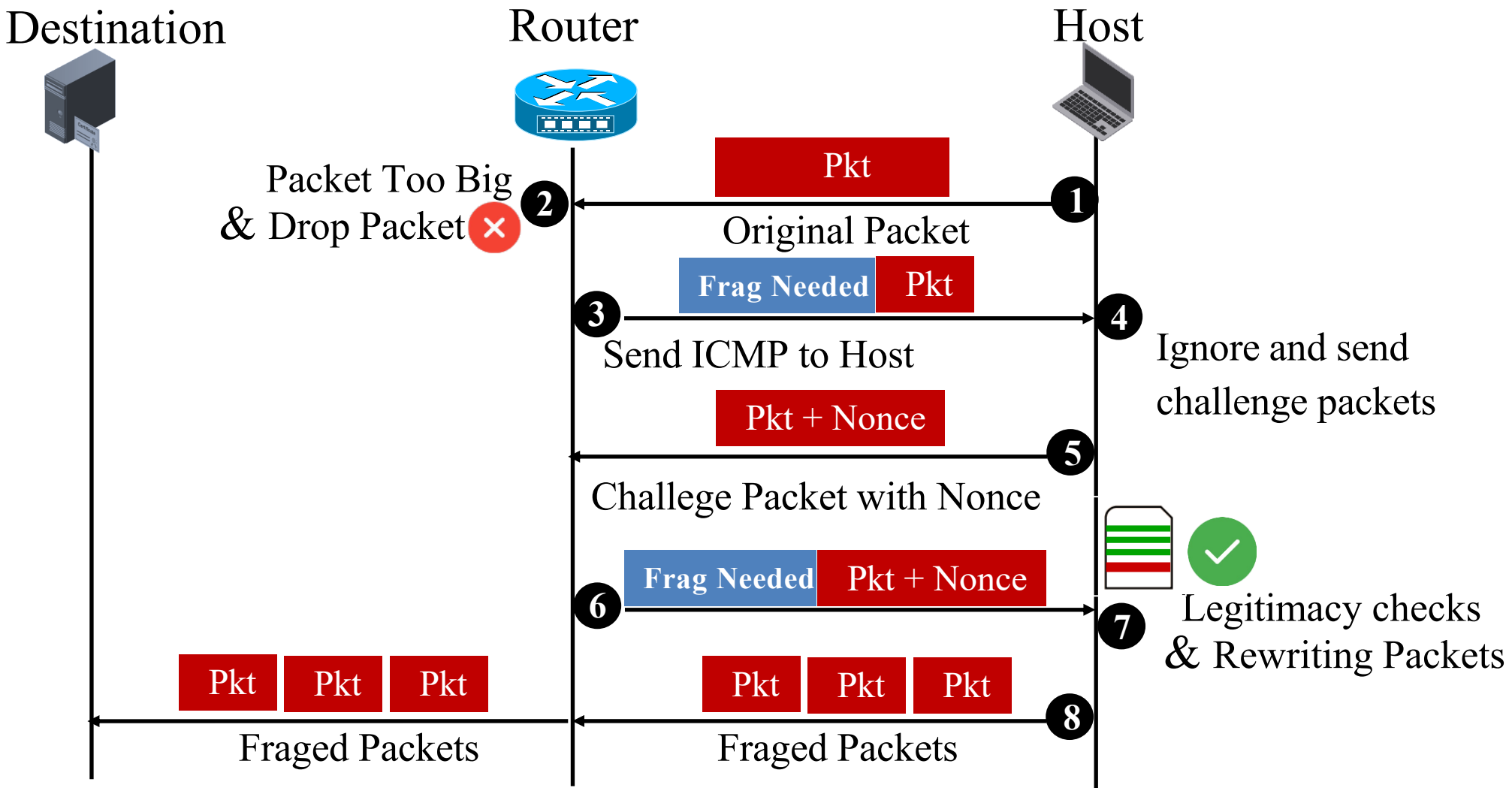

Considerations

- Authentication Strength
  - Utilizing high-entropy random numbers to ensure that challenges are unpredictable and resistant to forgery.
- Replay Attack Mitigation
  - Assigning unique random numbers to each challenge and implementing expiration timers to mitigate the risk of replay attacks.
- Denial of Service Prevention
  - Rate limiting and challenge frequency controls should be implemented to prevent potential DoS attacks.
- Backward Compatibility
  - The proposed mechanism only requires updates solely to the ICMP error message verification on end hosts. Intermediate routing devices remain unaffected.

Next Step

- Collaboration is welcome!
- Your comments and suggestions are welcome

Thanks!