New Results for the PTB-PTS Attack on Tunneling Gateways

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New Results for the PTB-PTS Attack on Tunneling Gateways

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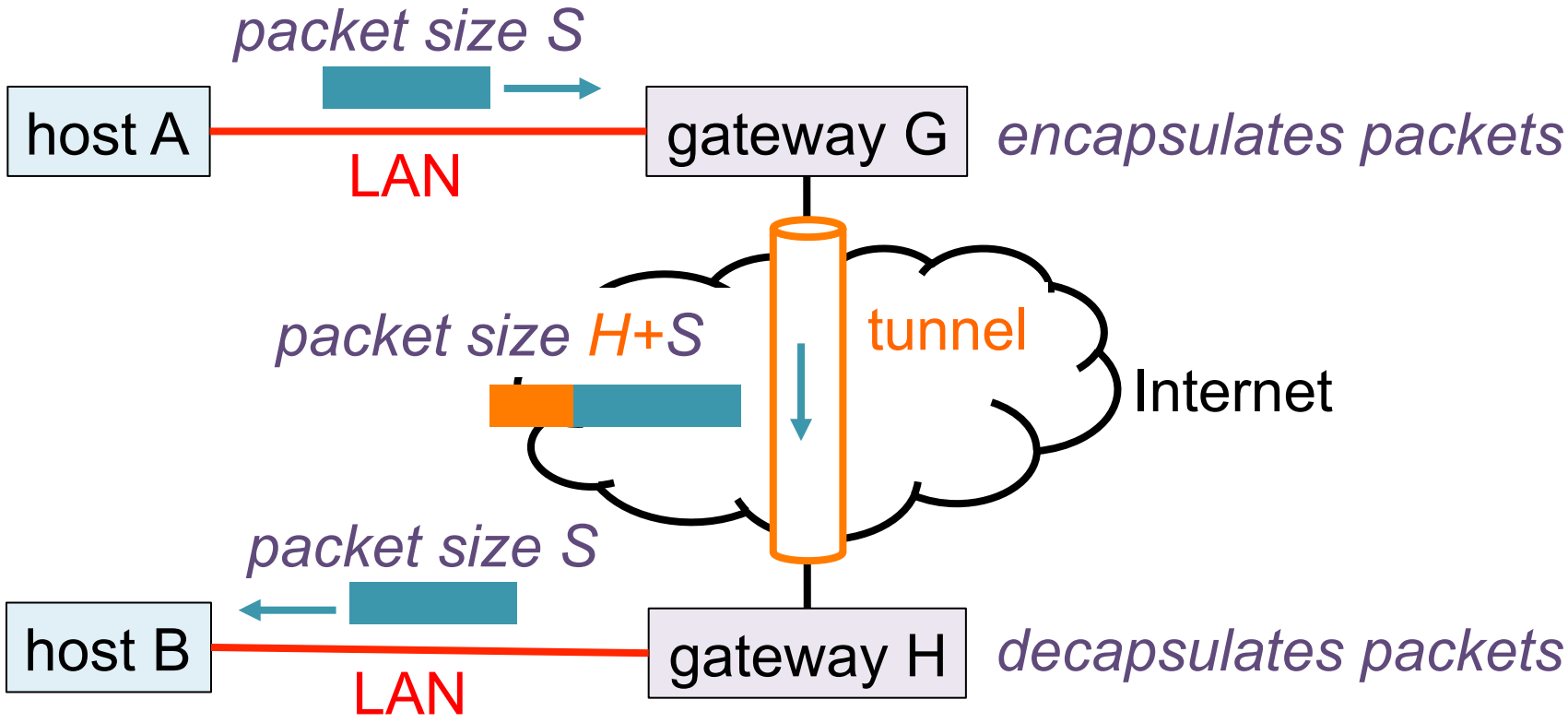
GreHack'15, Grenoble, November 20th 2015

Packet Too Big (PTB) or Packet Too Small (PTS)?

The underlying idea

About packet sizes and tunnel

- two gateways establish a tunnel to connect two remote LANs (or sites)

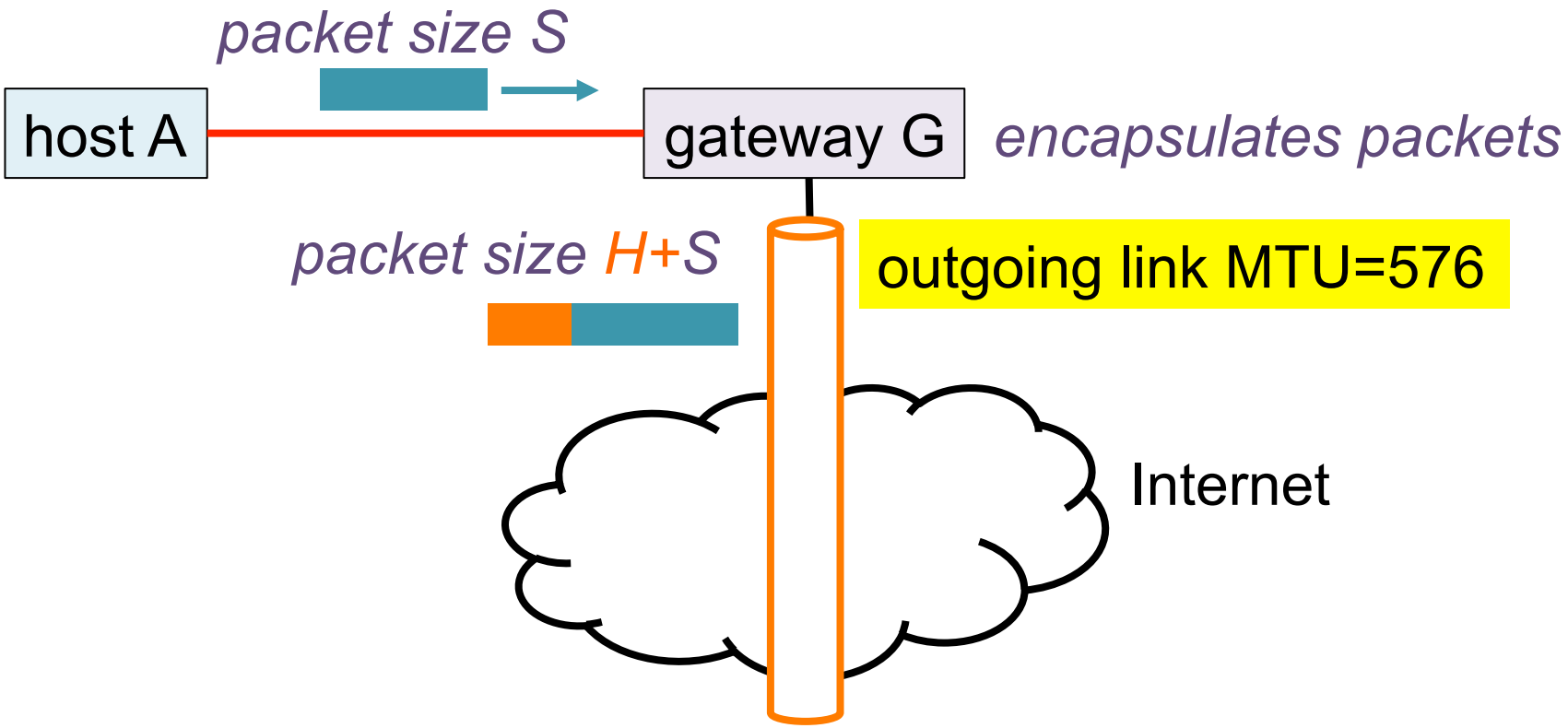


About packet sizes and tunnel… (cont')

- each link has a Maximum Transmission Unit (MTU)
  - **maximum allowed frame size on that link**
  - **e.g. 1500 bytes for Ethernet (i.e., 1460 b. or less at TCP level)**
- Path MTU (PMTU) is the min. MTU along the path
- a packet larger than a link's MTU is either
  - **dropped and an error ICMP "Packet Too Big" (PTB) message containing the MTU is returned to sender, or**
  - **fragmented if feasible (iff. IPv4 with DF bit clear)**
- each link MUST guaranty a minimum MTU
  - **IPv4 576 bytes**
  - **IPv6 1280 bytes**
  - **essentially here for performance reasons**

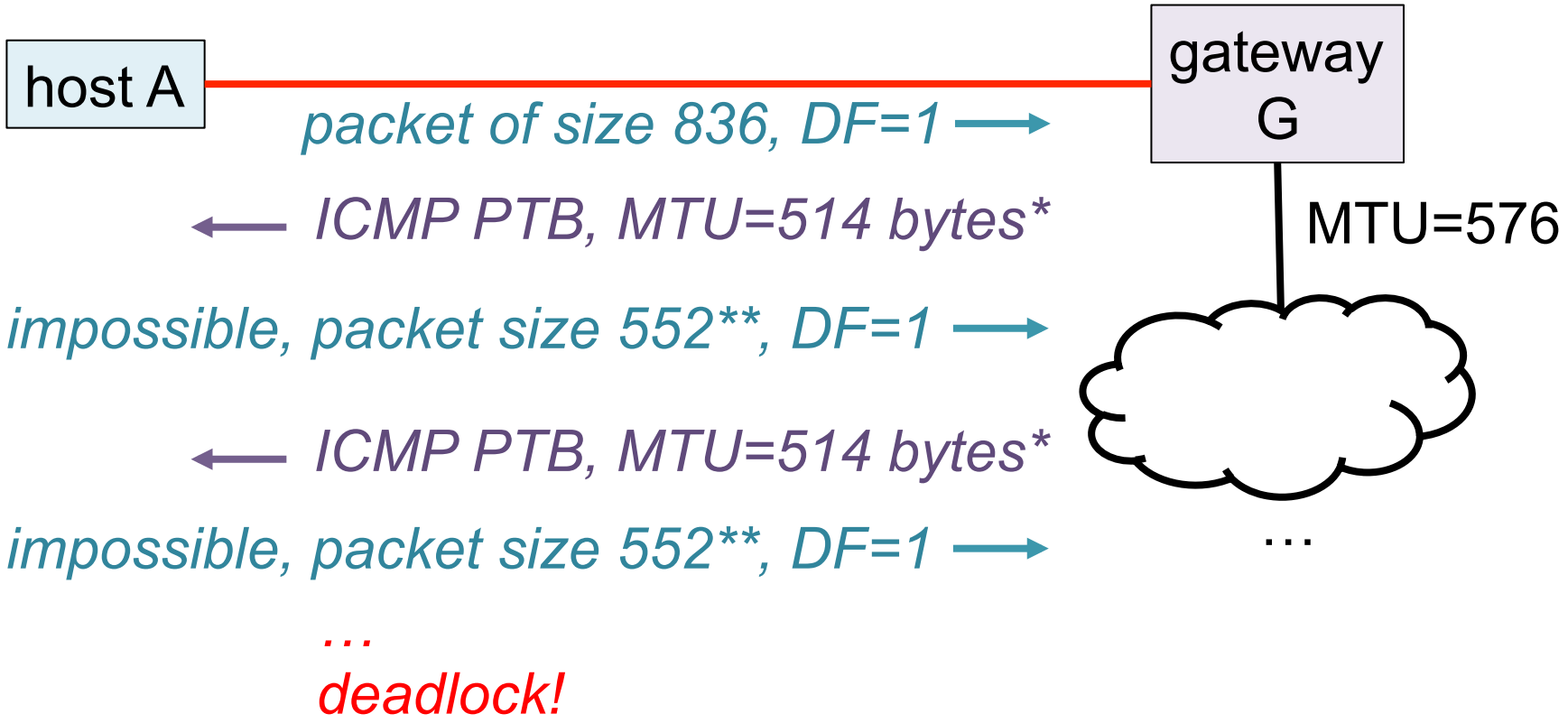
The issue

- what happens if G's outgoing link is already at MTU 576 bytes (IPv4)?
  - then we need H+S ≤ 576, which implies that S ≤ 576 - H



The issue – an experimental example

- G tunneling A's traffic using IPsec (Linux/Debian)



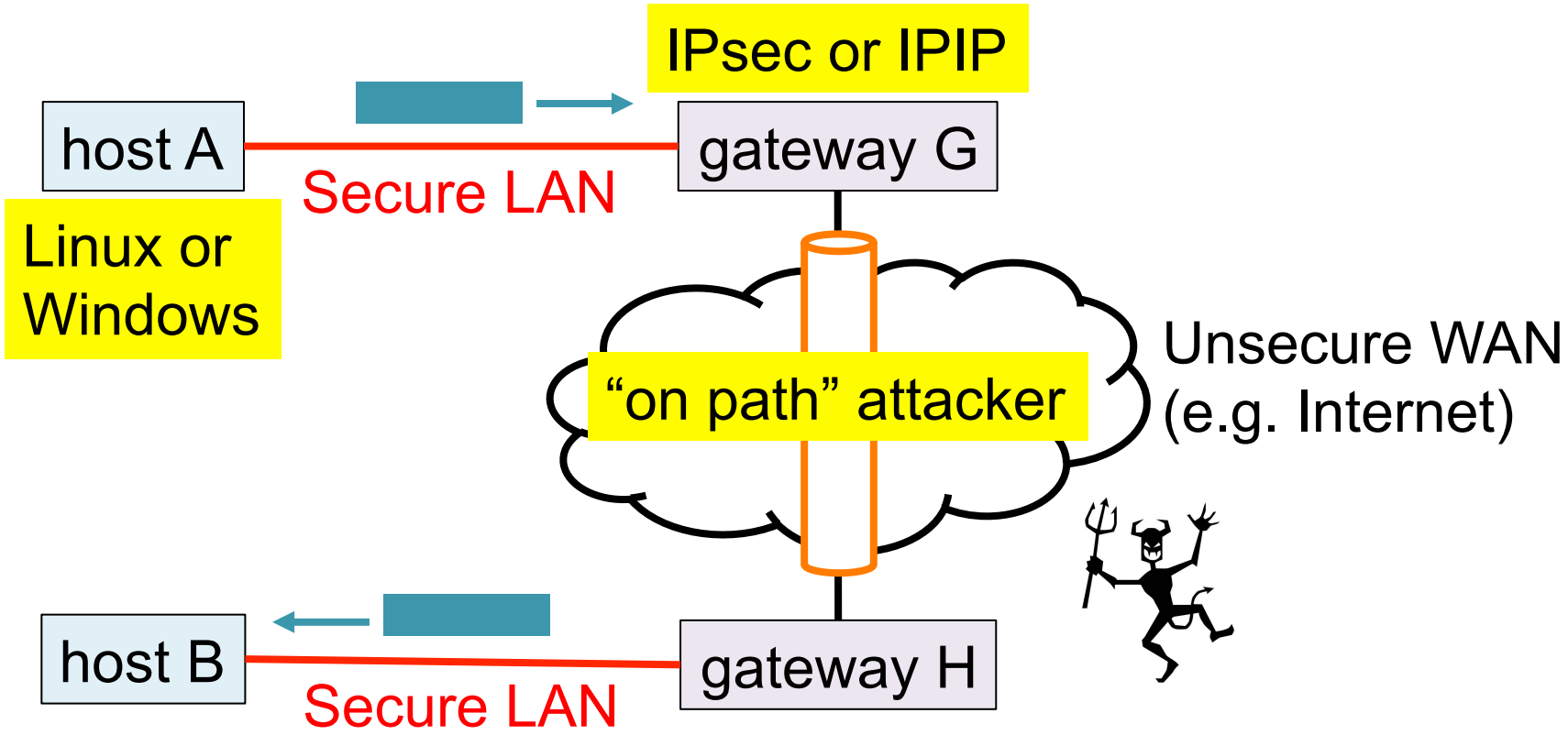
* 514 bytes because of IPsec ESP header

** 552 is minimum PMTU value on Linux/Debian

And now the exploit!

Attacker model

- "On path" attacker
  - Eavesdrop and inject traffic on the WAN
  - IPsec cryptographic ciphers deemed secure

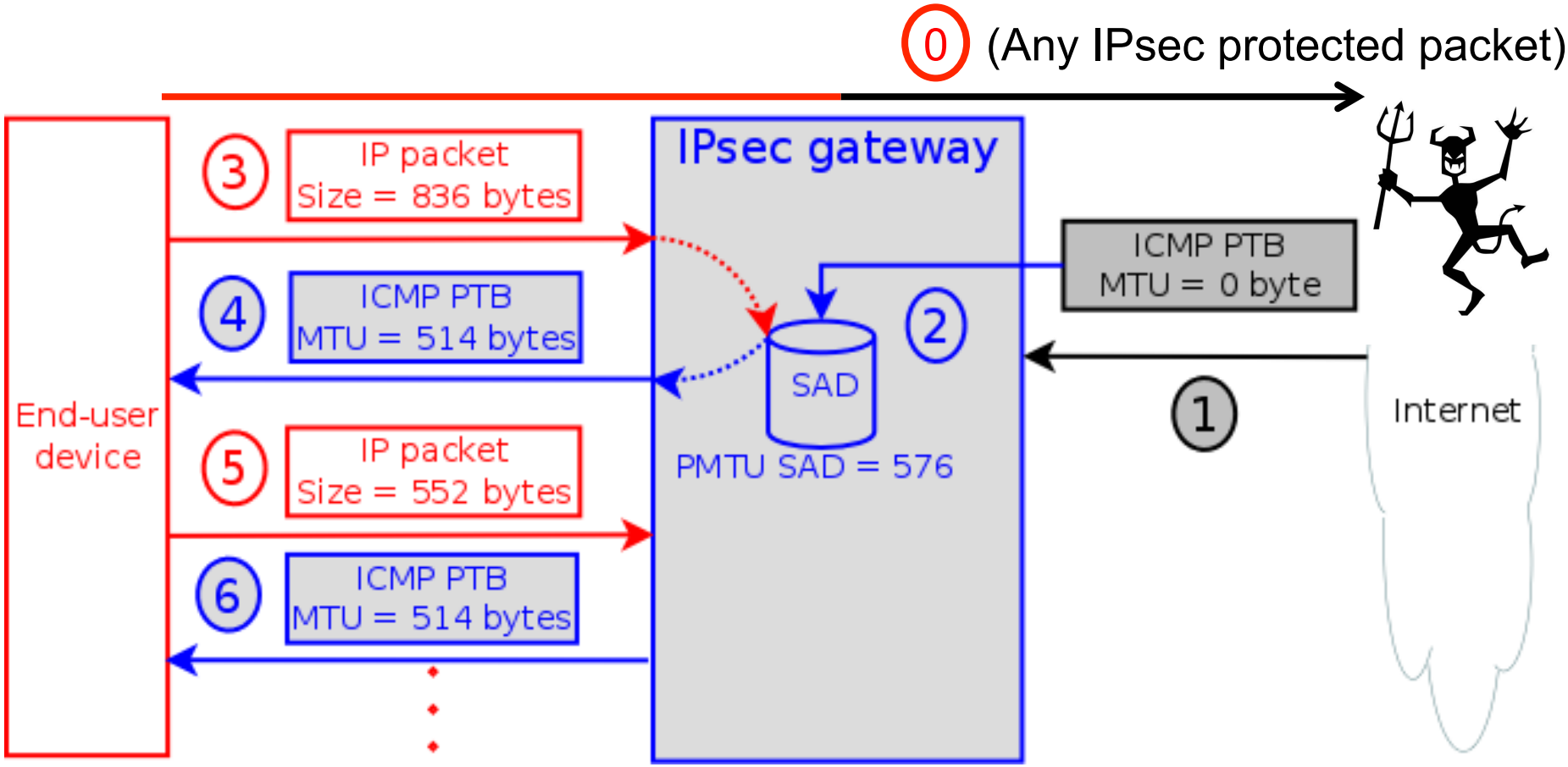


Description of the exploit

- Resetting gateway G's PMTU
  - the attacker needs to **be on the tunnel path**
    - **eavesdrops a tunneled packet**
    - **forges an ICMP PTB message**
      - Including a copy of the eavesdropped packet to bypass IPsec security check w.r.t. ICMP error messages
  - the attacker can use a compromised router…
  - … or be a simple host attached to a **non-encrypted WiFi**
    - **if a user uses a tunnel from a laptop (no gateway H) to a remote network, and is attached to a non-encrypted WiFi, then we can attack the remote tunnel gateway**
  - a **single** "well formed" ICMP PTB packet is sufficient to launch the attack!

Detail of the exploit

- Debian IPsec gateway
- Ubuntu client, TCP traffic, IPv4 with PMTUD

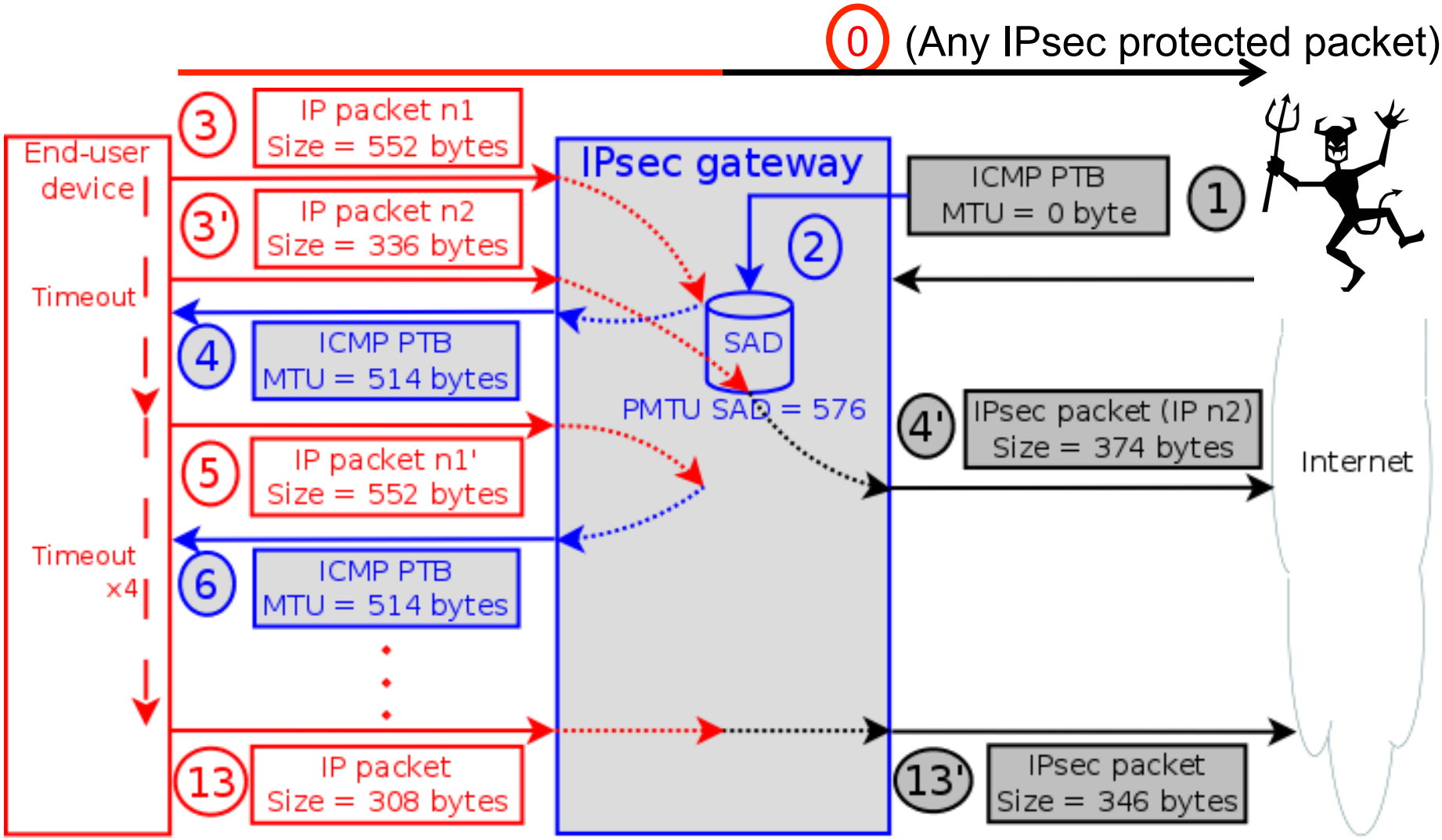


Another PMTU discovery to the rescue?

- Packetization Layer Path MTU Discovery (PLPMTUD)
  - Developed to mitigate ICMP “black holes”
    - **no dependency on ICMP any more**
  - Relies on “probes” and “feedbacks” to adjust packet sizes
  - compatible with TCP
    - **TCP ACK are used as feedbacks**
  - the TCP packet size can be reduced below the 576 minimum MTU (in IPv4) if needed
    - **e.g., 256 bytes + headers**

PLPMTUD only mitigates the exploit

- Ubuntu client, TCP traffic, IPv4 with PLPMTUD



Some additional tests

- UDP traffic with PMTUD
- IPv6
- Windows 7, with default configuration
- IPIP tunnel

Ubuntu client results

TCP, IPv4, PMTUD IPsec tunnel	**DoS:** no connection possible any more (TCP closes after 2 min.)
TCP, IPv4, PLPMTUD IPsec tunnel	**Major performance impacts:** 6.5s initial freeze, tiny packets (MSS = 256)
UDP, IPv4, PMTUD IPsec tunnel	**Major performance impacts:** tiny packets
TCP, IPv6, PMTUD IPsec tunnel	**DoS:** no connection possible any more (TCP closes after 2 min.)
TCP, IPv6, PLPMTUD IPsec tunnel	**Major performance impacts:** 3.3s initial freeze, small packets (MSS = 504)
TCP, IPv4, PMTUD IPIP tunnel	**Major performance impacts:** 7 min. initial freeze, tiny packets (MSS = 256)
TCP, IPv4, PLPMTUD IPIP tunnel	**Major performance impacts:** 6.7s initial freeze, small packets

Windows 7 client results

TCP, IPv4 IPsec tunnel	**Major performance impacts:** fragmented packets (548 and 120)
TCP, IPv6 IPsec tunnel	**DoS:** no connection possible any more (TCP closes after 21 sec.)
TCP, IPv4 IPIP tunnel	**DoS:** no connection possible any more (TCP closes after 35 sec.)

- Really strange behavior in TCP/IPv4/IPsec tests
  - Windows reset the “Don’t Fragment” bit after the first error
  - It keeps increasing TCP segment size… up to ~64 kB!!!
  - The gateway needs to fragment into smaller packet which is highly inefficient
- Similar results with Windows 10

Conclusions

A highly effective attack

- A **single** packet is enough to launch the attack
  - Only needs to eavesdrop one packet of the tunnel
- The gateway and client cannot agree
  - Once the attacker created confusion he can pull out
- Works on all client OSes
  - Highly effective, no matter the client configuration, leading either to DoS or major performance impacts
  - There is no good solution to deal with it!

Two issues highlighted

- Tunnels and small PMTU
  - The client rejects request to use an MTU smaller than the "minimum guaranteed"
    - **The client does not know this is motivated by IPsec or IPIP tunneling at the gateway**
    - **… and in any case it infringes the minimum MTU**

- Legitimacy of untrusted ICMP PTB packets
  - IPsec sanity check is not fully reliable and is by-passed if the attacker is on the path

Some counter-measures

- Trivial and unsatisfying
  - Ignore DF bit at a tunneling gateway
    - **E.g., as suggested by CISCO IPsec configuration guide!**
  - Ignore any ICMP PTB at the gateway and let clients use PLPMTUD
    - **But PLPMTUD won't work with UDP!**
- Two proposed counter-measures at a gateway
  - A gateway must not blindly accept an ICMP PTB advertising a tiny MTU
    - **The gateway needs room to add tunneling headers**
  - A gateway should assess untrusted ICMP PTB
    - **Add a probing scheme between tunneling gateways, similarly to PLPMTUD, to check the Path MTU**

Thank you