THE TCP AUTHENTICATION OPTION (TCP-AO)

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Why do we need TCP security?

MOTIVATION

- What are we protecting?
  - Long-lived TCP sessions
  - Examples
    - Routing protocols (BGP, LDP)
    - Long-lived TCP sessions between other applications
- What are we protecting against?
  - Blind insertion attacks
  - Replay attacks

BLIND INSERTION ATTACK ON A BGP SESSION

- Router A maintains a BGP session with Router B
  - They exchange many routes over many hours
- Node C sends a few packets per second to Router B for many hours
  - IP source address: Router A (spoofed)
  - Payload: TCP
    - RST bit set
    - Destination ports: BGP (179)
    - Random sequence numbers
- B discards most packets, because their sequence numbers are invalid
- Sooner or later, C sends a packet with a valid sequence number
- BGP session resets

TCP MD5

LEGACY SOLUTION: TCP-MD5 [RFC 2385]

- Sending and receiving nodes are configured with a pre-shared key
- Sending node procedures
  - Calculate a Message Authentication Code (MAC) for each TCP segment
    - Use MD5 to calculate MAC
    - Calculate MAC over the TCP segment and the pre-shared key
  - Include an MD5 Signature Option in each segment
    - MD5 Signature Option includes MAC
- Receiving node procedures
  - Calculate a MAC for each received TCP segment
  - Discard the packet if the calculated MAC does not match the received MAC

TCP-MD5 IS DEPRECATED

- New requirements
  - Change pre-shared keys without resetting TCP session
  - Support multiple authentication algorithms
- Pre-shared key change
  - It is difficult to change TCP-MD5 pre-shared keys without resetting the TCP session
  - It is difficult to reset TCP sessions that support BGP
  - Therefore, TCP-MD5 pre-shared keys were rarely changed
- Authentication algorithm agility
  - MD5 has been replaced by stronger authentication algorithms
  - Even stronger authentication algorithms are expected in the future

AND THEN THIS HAPPENED

- Monday, June 5 2006 - NANOG 37

  Ron Bonica - Authentication for TCP-based Routing and Management Protocols

- June 2010

  RFC5925 published

- Tuesday, June 26 2018 - NANOG 73

  Ignas Bagdonas - Lightning Talk: BGP Transport Security - Do You Care?

- Monday, October 19 2020 - NANOG 80

  Melchior Aelmans - It is time…to replace MD5

TCP Authentication Option

TCP-AO [RFC 5925] REPLACES TCP-MD5

- Supports
  - Pre-shared key change without resetting TCP session
  - Multiple authentication algorithms

TCP-AO CONCEPTS

- Master Key Tuple (MKT)
  - One or more MKTs are configured on each node
  - Used to derive traffic keys
- Traffic key
  - Used to generate a MAC for each TCP segment
- TCP-Authentication Option
  - Used to authenticate TCP segments
  - Contains a MAC, KeyID and RNextKeyID
    - KeyID identifies MKT and traffic key that were used to generate MAC
    - RNextKey identifies MKT and traffic key that the receiving node should use when generating a MAC for the next segment it sends

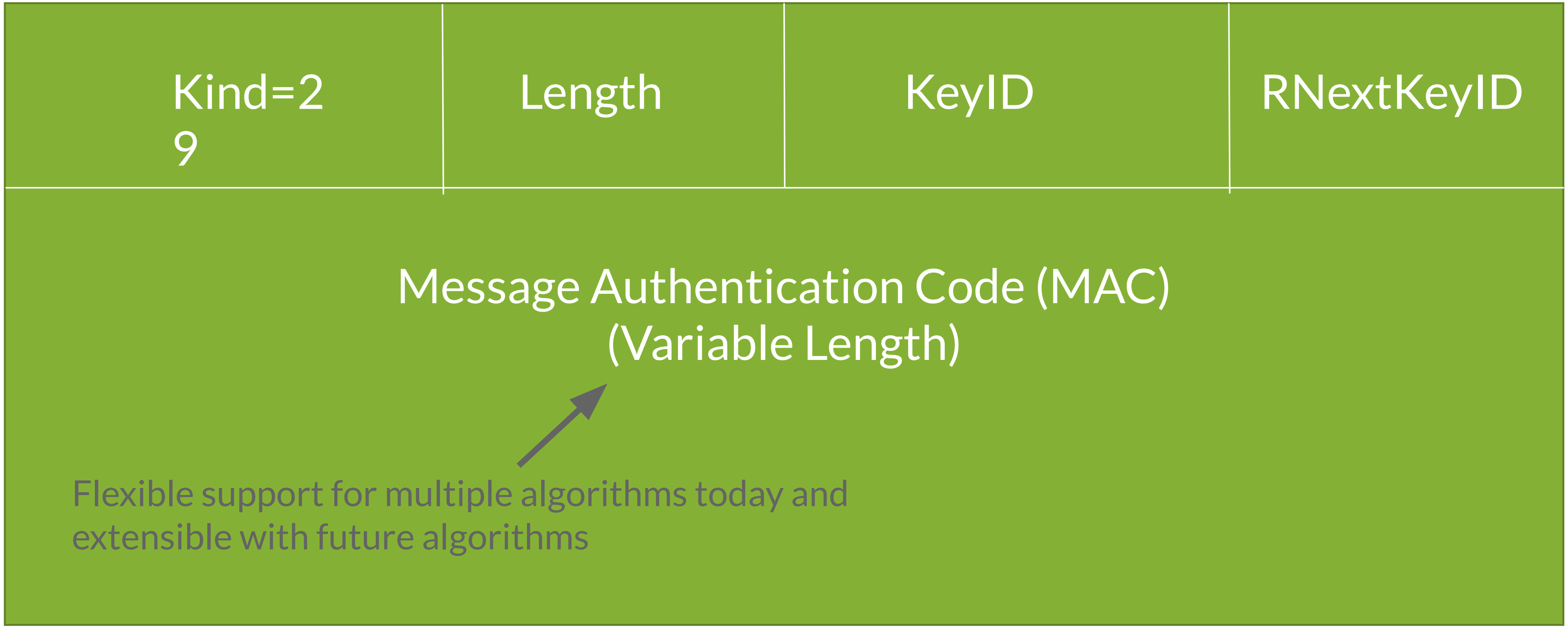
MKT CONTENTS

- A TCP connection identifier
  - Source address, destination address, source port, destination port
  - Wildcards allowed
- A TCP Options flag (determine which TCP options are covered by MAC)
- Identifiers
  - Sending: Used to generate KeyID on outbound segments
  - Receiving: Used to resolve KeyID on inbound segments
- An authentication algorithm
- Master key (i.e., keying material)
- A key derivation algorithm

TRAFFIC KEYS

- Four traffic keys are derived from each MKT
  - SEND_SYN
  - RECEIVE_SYN
  - SEND-OTHER
  - RECEIVE-OTHER

THE TCP AUTHENTICATION OPTION



Kind=29	Length	KeyID	RNextKeyID
Message Authentication Code (MAC) (Variable Length)			

Flexible support for multiple algorithms today and extensible with future algorithms

PULLING IT ALL TOGETHER: KEYING

- Each node is each configured with one or more MKTs
- Each node derives four traffic keys from each MKT
- Each node independently determines which MKT is active
  - Method is beyond the scope of RFC 5925
  - Many implementations specify a start-time and an end-time for each MKT

PULLING IT ALL TOGETHER: AUTHENTICATION

- Sending node procedures
  - Calculate a Message Authentication Code (MAC) for each TCP segment
    - Use the appropriate authentication algorithm
    - Calculate MAC over the TCP segment and an active traffic key
  - Include a TCP-AO in each segment
    - MD5 Signature Option includes MAC, KeyID and RNextKeyID
- Receiving node procedures
  - Calculate a MAC for each received TCP segment
    - Use algorithm and traffic key associated with the received KeyID
  - Discard the packet if the calculated MAC does not match the received MAC

IMPLEMENTATION STATUS AND FURTHER READING

Implementation status:

- Nokia: SR OS 16.0.R15, 19.10.R7 and 20.5.R1 (interop tested with Juniper)
- Cisco: Stable since IOS XR 6.6.3 and 7.0.1
- Juniper Networks: 20.3R1
- Huawei: targeted for Q2 2021
- Arista: "no comment on timelines”

Further information:

- Nokia & Juniper interoperability test: https://github.com/TCP-AO/Interoperability-testing
- Configuration examples: https://github.com/TCP-AO/Configuration-examples
- Routing Table Podcast starring Ron Bonica and Greg Hankins: https://anchor.fm/routing-table/episodes/The-TCP-Authentication-Option--why-do-we-need-it-and-will-it-replace-MD5----Greg-Hankins-Nokia-and-Ron-Bonica-Juniper-Networks-ekemrp

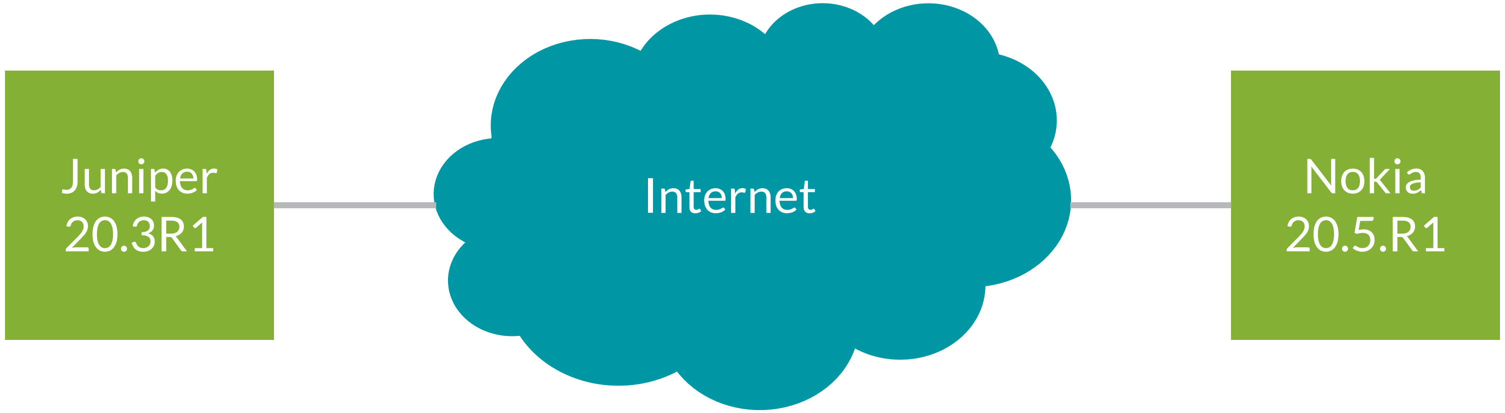
RELATIONSHIP WITH GTSM [RFC 5082]

- GTSM protects eBGP sessions
  - Sender sets TTL to 255
  - Receiver rejects packets containing eBGP if TTL is less than 254
- TCP-AO still needed to protect eBGP sessions from attackers that are one hop away
- TCP-AO still needed to protect iBGP sessions from internal attack

 Security best practices implement many layers of protection, don’t rely on just one mechanism!

Interoperability testing

JUNIPER AND NOKIA INTEROP TEST RESULTS



- Successful interop test using TCP-AO for BGP finished in June 2020
- Established multihop IPv4 and IPv6 BGP sessions over the Internet
- No need to meet or bring routers for testing in person
- Tested with HMAC-SHA-1-96 and AES-128-CMAC-96 algorithms

LESSONS LEARNED #1 – SEND AND RECEIVE ARE CONFIGURED FROM THE ROUTER'S PERSPECTIVE

Juniper

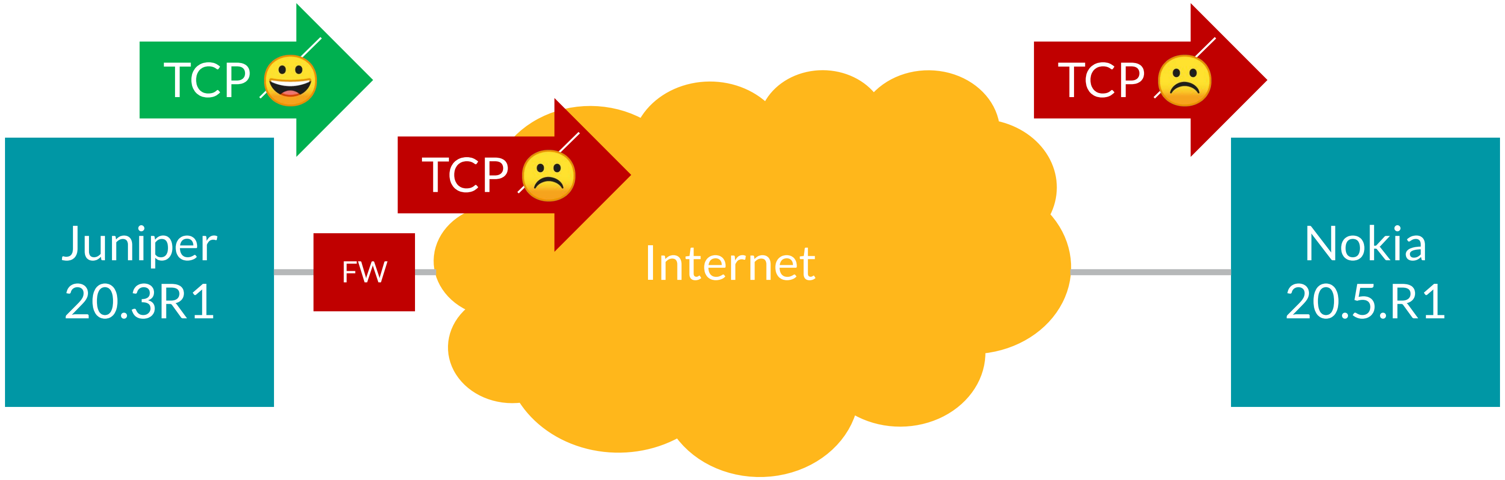
```
# show security authentication-key-chains
key-chain ao_aes_chain {
    key 0 {
        secret "$9$xk3NVYq.53/taZnCu1yrwYg4UHf5F/A0z3"; ##
SECRET-DATA
        start-time "2020-6-16.01:00:00 +0530";
        algorithm ao;
        ao-attribute {
            send-id 9;
            recv-id 2;
            tcp-ao-option enabled;
            cryptographic-algorithm  aes-128-cmac-96;
        }
    }
}
```

Nokia

```
configure system security {
    keychain "interoptest-aes" {
        tcp-option-number {
            receive tcp-ao
            send tcp-ao
        }
        receive {
            entry 9 {
                authentication-key
"yzClLKIFsAVR91AobUXUT/ppPzL7bVxBrNNg" hash
                algorithm  aes-128-cmac-96
                begin-time 2020-06-09T04:00:00.0Z
            }
        }
        send {
            entry 2 {
                authentication-key
"yzClLKIFsAVR91AobUXUT/ppPzL7bVxBrNNg" hash
                algorithm  aes-128-cmac-96
                begin-time 2020-06-09T04:00:00.0Z
            }
        }
    }
```

- Send and receive IDs must match each other
- TCP-AO supports multiple algorithms, make sure you are using are the same one

LESSONS LEARNED #2 – FIREWALLS MAY CHANGE TCP HEADERS



- The TCP MSS option was modified by a firewall in the path between the routers
- This caused the MAC calculation to fail on the receiver and the BGP session would not come up
- The TCP-AO option worked as expected to protect against modified packets!

CALL TO ACTION

Operators:

- Think about how TCP-AO fits into your overall routing security strategy
- Router vendor implementations are available now, start looking at them
- Ask for TCP-AO in RFPs/RFIs if it’s missing

Developers:

- There is no ecosystem of open source implementations and tools yet
- Need kernel implementations: Linux and *BSD
- Need support in tools: tcpdump, Wireshark, etc.
- Need features in routing implementations: BIRD, FRR, goBGP, OpenBGPD, etc.
- Juniper and Nokia can provide implementations for testing!

THANK YOU

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