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**Analysis of BGP, LDP, PCEP and MSDP Issues According to KARP Design
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Abstract

This document analyzes BGP, LDP, PCEP and MSDP according to guidelines set forth in [section 4.2](#) of Keying and Authentication for Routing Protocols Design Guidelines [[RFC6518](#)].

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119](#) [[RFC2119](#)].

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1. Introduction

In March 2006 the Internet Architecture Board (IAB) in its "Unwanted Internet Traffic" workshop documented in Report from the IAB workshop on Unwanted Traffic March 9-10, 2006 [[RFC4948](#)] described an attack on core routing infrastructure as an ideal attack with the most amount of damage. Four main steps were identified for that tightening:

1. Create secure mechanisms and practices for operating routers.
2. Clean up the Internet Routing Registry [IRR] repository, and securing both the database and the access, so that it can be used for routing verifications.
3. Create specifications for cryptographic validation of routing message content.
4. Secure the routing protocols' packets on the wire.

This document looking at the last bullet performs an initial analysis of the current state of BGP, LDP, PCEP and MSDP according to the requirements of KARP Design Guidelines [[RFC6518](#)]. This draft builds on several previous analysis efforts into routing security. The OPSEC working group published Issues with existing Cryptographic Protection Methods for Routing Protocols [[RFC6039](#)] an analysis of cryptographic issues with routing protocols and Analysis of OSPF Security According to KARP Design Guide [[draft-ietf-karp-ospf-analysis-03](#)].

[Section 2](#) of this document looks at the current state of security for the four routing protocols. [Section 3](#) examines what the optimal state would be for the four routing protocols according to KARP Design Guidelines [[RFC6518](#)] and [Section 4](#) does a analysis of the gap between the existing state and the optimal state of the protocols and suggests some areas where improvement is needed.

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1.2. Abbreviations

BGP - Border Gateway Protocol

DoS - Denial of Service

KARP - Key and Authentication for Routing Protocols

KDF - Key Derivation Function

KEK - Key Encrypting Key

KMP - Key Management Protocol

LDP - Label Distribution Protocol

LSR - Label Switch Routers

MAC - Message Authentication Code

MKT - Master Key Tuple

MSDP - Multicast Source Distribution Protocol

MD5 - Message Digest algorithm 5

OSPF - Open Shortest Path First

PCEP - Path Computation Element Protocol

TCP - Transmission Control Protocol

UDP - User Datagram Protocol

2. Current State of BGP, LDP, PCEP and MSDP

This section looks at the current state of transport protocol and any authentication mechanisms used by the protocol. It describes the current security mechanisms if any used by BGP, LDP, PCEP and MSDP.

2.1. Transport layer

At a transport layer, routing protocols are subject to a variety of DoS attacks as outlined in Internet Denial-of-Service Considerations [[RFC4732](#)]. Such attacks can cause the routing protocol to become congested with the result that routing updates are supplied too slowly to be useful. In extreme cases, these attacks prevent routes from converging after a change.

Routing protocols use several methods to protect themselves. Those that use TCP as a transport protocol use access lists to accept packets only from known sources. These access lists also help protect edge routers from attacks originating from outside the protected domain. In addition for edge routers running eBGP, TCP LISTEN is run only on interfaces on which its peers have been discovered or via which routing sessions are expected (as specified in router configuration databases).

GTSM [[RFC5082](#)] describes a generalized Time to Live (TTL) security mechanism to protect a protocol stack from CPU-utilization based attacks. TCP Robustness [[RFC5961](#)] recommends some TCP level mitigations against spoofing attacks targeted towards long-lived routing protocol sessions.

Even when BGP, LDP, PCEP and MSDP sessions use access lists they are subject to spoofing and man in the middle attacks. Authentication and integrity checks allow the receiver of a routing protocol update to know that the message genuinely comes from the node that purports to have sent it, and to know whether the message has been modified. Sometimes routers can be subjected to a large number of authentication and integrity requests, exhausting connection resources on the router in a way that deny genuine requests.

TCP MD5 [[RFC2385](#)] deprecated, but widely used, specifies a mechanism to protect BGP and other TCP based routing protocols via the TCP MD5 option. TCP MD5 option provides a way for carrying an MD5 digest in a TCP segment. This digest acts like a signature for that segment, computed using information known only to the connection end points. The MD5 key used to compute the digest is stored locally on the router. This option is used by routing protocols to provide for session level protection against the introduction of spoofed TCP segments into any existing TCP streams, in particular TCP Reset

segments. TCP MD5 does not provide a generic mechanism to support key roll-over.

The Message Authentication Codes (MACs) used by the TCP MD5 option is considered too weak both because of the use of the hash function and because of the way the secret key used by TCP MD5 is managed. TCP-AO [RFC5925] and its companion document Crypto Algorithms for TCP-AO [RFC5926] describe steps towards correcting both the MAC weakness and the management of secret keys. For MAC it specifies two MAC algorithms that MUST be supported. They are HMAC-SHA-1-96 as specified in HMAC [RFC2104] and AES-128-CMAC-96 as specified in NIST-SP800-38B [NIST-SP800-38B]. Cryptographic research suggests that both these MAC algorithms defined are fairly secure. TCP-AO allows additional MACs to be added in the future.

2.2. Keying mechanisms

For TCP-AO [RFC5925] there is no Key Management Protocol (KMP) used to manage the keys that are employed to generate the Message Authentication Code (MAC). TCP-AO allows for a master key to be configured manually or for it to be managed via a out of band mechanism.

It should be noted that most routers configured with static keys have not seen the key changed ever. The common reason given for not changing the key is the difficulty in coordinating the change between pairs of routers when using TCP MD5. It is well known that longer the same key is used, higher is the chance that it can be guessed or exposed e.g. when an administrator with knowledge of the keys leaves the company.

For point-to-point key management IKEv2 [RFC5996] provides for automated key exchange under a SA and can be used for a comprehensive Key Management Protocol (KMP) solution.

2.3. LDP

[Section 5](#) of LDP [RFC5036] states that LDP is subject to two different types of attacks: spoofing, and denial of service attacks. In addition, labels are distributed in the clear, enabling hackers to see what labels are being exchanged that could then be used to launch an attack.

2.3.1. Spoofing attacks

A spoofing attack against LDP can occur both during the discovery phase and during the session communication phase.

2.3.1.1. Discovery exchanges using UDP

Label Switching Routers (LSRs) indicate their willingness to establish and maintain LDP sessions by periodically sending Hello messages. Receipt of a Hello message serves to create a new "Hello adjacency", if one does not already exist, or to refresh an existing one.

Unlike all other LDP messages, the Hello messages are sent using UDP. This means that they cannot benefit from the security mechanisms available with TCP. LDP [[RFC5036](#)] does not provide any security mechanisms for use with Hello messages except for some configuration which may help protect against bogus discovery events. These configurations include directly connected links and interfaces. Routers that do not use directly connected links have to use Extended Hello messages.

Spoofing a Hello packet for an existing adjacency can cause the adjacency to time out and result in termination of the associated session. This can occur when the spoofed Hello message specifies a small Hold Time, causing the receiver to expect Hello messages within this interval, while the true neighbor continues sending Hello messages at the lower, previously agreed to frequency.

Spoofing a Hello packet can also cause the LDP session to be terminated. This can occur when the spoofed Hello specifies a different Transport Address from the previously agreed one between neighbors. Spoofed Hello messages are observed and reported as real problem in production networks.

2.3.1.2. Session communication using TCP

LDP like other TCP based routing protocols specifies use of the TCP MD5 Signature Option to provide for the authenticity and integrity of session messages. As stated above, MD5 authentication is considered too weak for this application. A stronger hashing algorithm e.g SHA1, which is supported by TCP-AO [[RFC5925](#)] could be deployed to take care of the weakness.

Alternatively, one could move to using TCP-AO which provides for stronger MACs, makes it easier to setup manual keys and protects against replays.

2.3.2. Privacy Issues

LDP provides no mechanism for protecting the privacy of label distribution. The security requirements of label distribution are similar to other routing protocols that need to distribute routing

information and as such LDP is vulnerable to the same extent as other routing protocols that distribute their routing information in the clear.

2.3.3. Denial of Service Attacks

LDP is subject to Denial of Service (DoS) attacks both in its discovery mode and in session mode.

The discovery mode attack is similar to the spoofing attack except that when the spoofed Hello messages are sent with a high enough frequency, it can cause the adjacency to time out.

2.4. PCEP

Attacks on PCEP [[RFC5440](#)] may result in damage to active networks. These include computation responses, which if changed can cause protocols like LDP to setup sub-optimal or inappropriate LSPs. In addition, PCE itself can be attacked by a variety of DoS attacks. Such attacks can cause path computations to be supplied too slowly to be of any value particularly as it relates to recovery or establishment of LSPs.

As the RFC states, PCEP could be the target of the following attacks.

- o Spoofing (PCC or PCE implementation)
- o Snooping (message interception)
- o Falsification
- o Denial of Service

According to the RFC, inter-AS scenarios when PCE-to-PCE communication is required, attacks may be particularly significant with commercial as well as service-level implications.

Additionally, snooping of PCEP requests and responses may give an attacker information about the operation of the network. By viewing the PCEP messages an attacker can determine the pattern of service establishment in the network and can know where traffic is being routed, thereby making the network susceptible to targeted attacks and the data within specific LSPs vulnerable.

Ensuring PCEP communication privacy is of key importance, especially in an inter-AS context, where PCEP communication end-points do not reside in the same AS. An attacker that intercepts a PCE message could obtain sensitive information related to computed paths and

resources.

[2.5.](#) MSDP

Similar to BGP and LDP, MSDP uses TCP MD5 [[RFC2385](#)] to protect TCP sessions via the TCP MD5 option. But with a weak MD5 authentication, TCP MD5 is not considered strong enough for this application.

MSDP also advocates imposing a limit on number of source address and group addresses (S,G) that can be stored within the protocol and thereby mitigate state explosion due to any denial of service and other attacks.

3. Optimal State for BGP, LDP, PCEP, and MSDP

The ideal state for BGP, LDP, PCEP and MSDP protocols are when they can withstand any of the known types of attacks.

Additionally, Key Management Protocol (KMP) for the routing sessions should help negotiate unique, pair wise random keys without administrator involvement. It should also negotiate Security Association (SA) parameter required for the session connection, including key life times. It should keep track of those lifetimes and negotiate new keys and parameters before they expire and do so without administrator involvement. In the event of a breach, including when an administrator with knowledge of the keys leaves the company, the keys should be changed immediately.

The DoS attacks for BGP, LDP, PCEP and MSDP are attacks to the transport protocol, TCP for the most part and UDP in case of discovery phase of LDP. TCP and UDP should be able to withstand any of DoS scenarios by dropping packets that are attack packets in a way that does not impact legitimate packets.

The routing protocols should provide a mechanism to authenticate the routing information carried within the payload.

3.1. LDP

For spoofing attacks that LDP is vulnerable to during the discovery phase, LDP should be able to determine the authenticity of the neighbors sending the Hello message.

There is currently no requirement to protect the privacy of label distribution as labels are carried in the clear like other routing information.

4. Gap Analysis for BGP, LDP, PCEP and MSDP

This section outlines the differences between the current state of the routing protocol and the desired state as outlined in [section 4.2](#) of KARP Design Guidelines [[RFC6518](#)]. As that document states, these routing protocols fall into the category of one-to-one peering messages and will use peer keying protocol. It covers issues that are common to the four protocols in this section, leaving protocol specific issues to sub-sections.

At a transport level the routing protocols are subject to some of the same attacks that TCP applications are subject to. These include DoS and spoofing attacks. Internet Denial-of-Service Considerations [[RFC4732](#)] outlines some solutions. Defending TCP Against Spoofing Attacks [[RFC4953](#)] recommends ways to prevent spoofing attacks. In addition Improving TCP's Robustness to Blind In-Window Attacks. [[RFC5961](#)] should also be followed and implemented to strengthen TCP.

From a security perspective there is lack of comprehensive KMP. As an example TCP-AO [[RFC5925](#)], talks about coordinating keys derived from MKT between endpoints, but the MKT itself has to be configured manually or through a out of band mechanism. Also TCP-AO does not address the issue of connectionless reset, as it applies to routers that do not store MKT across reboots.

Authentication, tamper protection, and encryption all require the use of keys by sender and receiver. An automated KMP therefore has to include a way to distribute MKT between two end points with little or no administration overhead. It has to cover automatic key rollover. It is expected that authentication will cover the packet, i.e. the payload and the TCP header and will not cover the frame i.e. the link layer 2 header.

There are two methods of automatic key rollover. Implicit key rollover can be initiated after certain volume of data gets exchanged or when a certain time has elapsed. This does not require explicit signaling nor should it result in a reset of the TCP connection in a way that the links/adjacencies are affected. On the other hand, explicit key rollover requires a out of band key signaling mechanism. It can be triggered by either side and can be done anytime a security parameter changes e.g. an attack has happened, or a system administrator with access to the keys has left the company. An example of this is IKEv2 [[RFC5996](#)] but it could be any other new mechanisms also.

As stated earlier TCP-AO [[RFC5925](#)] and its accompanying document Crypto Algorithms for TCP-AO [[RFC5926](#)] suggest that two MAC algorithms that MUST be supported are HMAC-SHA-1-96 as specified in

HMAC [[RFC2104](#)] and AES-128-CMAC-96 as specified in NIST-SP800-38B [[NIST-SP800-38B](#)].

There is a need to protect authenticity and validity of the routing/label information that is carried in the payload of the sessions. However, that is outside the scope of this document at this time and is being addressed by SIDR WG. Similar mechanisms could be used for intra-domain protocols.

[4.1.](#) LDP

As described in LDP [[RFC5036](#)], the threat of spoofed Basic Hellos can be reduced by accepting Basic Hellos on interfaces that LSRs trust, employing GTSM [[RFC5082](#)] and ignoring Basic Hellos not addressed to the "all routers on this subnet" multicast group. Spoofing attacks via Extended Hellos are potentially a more serious threat. An LSR can reduce the threat of spoofed Extended Hellos by filtering them and accepting Hellos from sources permitted by an access lists. However, performing the filtering using access lists requires LSR resource, and the LSR is still vulnerable to the IP source address spoofing. Spoofing attacks can be solved by being able to authenticate the Hello messages, and an LSR can be configured to only accept Hello messages from specific peers when authentication is in use.

LDP Hello Cryptographic Authentication [[draft-zheng-mpls-ldp-hello-crypto-auth-04](#)] suggest a new Cryptographic Authentication TLV that can be used as an authentication mechanism to secure Hello messages.

[4.2.](#) PCEP

PCE discovery according to its RFC is a significant feature for the successful deployment of PCEP in large networks. This mechanism allows a PCC to discover the existence of suitable PCEs within the network without the necessity of configuration. It should be obvious that, where PCEs are discovered and not configured, the PCC cannot know the correct key to use. There are different approaches to retain some aspect of security, but all of them require use of a keys and a keying mechanism, the need for which has been discussed above.

5. Transition and Deployment Considerations

As stated in KARP Design Guidelines [[RFC6518](#)] it is imperative that the new authentication and security mechanisms defined support incremental deployment, as it is not feasible to deploy the new routing protocol authentication mechanism overnight.

Typically authentication and security in a peer-to-peer protocol requires that both parties agree to the mechanisms that will be used. If an agreement is not reached the setup of the new mechanism will fail or will be deferred. Upon failure, the routing protocols can fallback to the mechanisms that were already in place e.g. use static keys if that was the mechanism in place. It is usually not possible for one end to use the new mechanism while the other end uses the old. Policies can be put in place to retry upgrading after a said period of time, so a manual coordination is not required.

If the automatic KMP requires use of public/private keys to exchange key material, the required CA root certificates may need to be installed to verify authenticity of requests initiated by a peer. Such a step does not require coordination with the peer except to decide what CA authority will be used.

6. Security Requirements

This section describes requirements for BGP, LDP, PCEP and MSDP security that should be met within the routing protocol.

As with all routing protocols, they need protection from both on-path and off-path blind attacks. A better way to protect them would be with per-packet protection using a cryptographic MAC. In order to provide for the MAC, keys are needed.

Once keys are used, mechanisms are required to support key rollover. This should cover both manual and automatic key rollover. Multiple approaches could be used. However since the existing mechanisms provide a protocol field to identify the key as well as management mechanisms to introduce and retire new keys, focusing on the existing mechanism as a starting point is prudent.

Finally, replay protection is required. The replay mechanism needs to be sufficient to prevent an attacker from creating a denial of service or disrupting the integrity of the routing protocol by replaying packets. It is important that an attacker not be able to disrupt service by capturing packets and waiting for replay state to be lost.

7. Acknowledgements

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