

---

Stream: Internet Engineering Task Force (IETF)  
RFC: [9358](#)  
Category: Standards Track  
Published: February 2023  
ISSN: 2070-1721  
Authors: Y. Lee                      H. Zheng                      D. Ceccarelli  
                  *Samsung Electronics*    *Huawei Technologies*    *Cisco Systems*

# RFC 9358

## Path Computation Element Communication Protocol (PCEP) Extensions for Establishing Relationships between Sets of Label Switched Paths and Virtual Networks

---

### Abstract

This document describes how to extend the Path Computation Element Communication Protocol (PCEP) association mechanism introduced by RFC 8697 to further associate sets of Label Switched Paths (LSPs) with a higher-level structure such as a Virtual Network (VN) requested by a customer or application. This extended association mechanism can be used to facilitate control of a VN using the PCE architecture.

### Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at <https://www.rfc-editor.org/info/rfc9358>.

### Copyright Notice

Copyright (c) 2023 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Revised BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Revised BSD License.

## Table of Contents

1. Introduction
2. Terminology
3. Operation Overview
4. Extensions to PCEP
5. Security Considerations
6. IANA Considerations
  - 6.1. ASSOCIATION Object Type Indicator
  - 6.2. PCEP TLV Type Indicator
  - 6.3. PCEP Error
7. Manageability Considerations
  - 7.1. Control of Function and Policy
  - 7.2. Information and Data Models
  - 7.3. Liveness Detection and Monitoring
  - 7.4. Verification of Correct Operations
  - 7.5. Requirements on Other Protocols
  - 7.6. Impact on Network Operations
8. References
  - 8.1. Normative References
  - 8.2. Informative References

Contributors

Authors' Addresses

## 1. Introduction

The Path Computation Element Communication Protocol (PCEP) provides mechanisms for Path Computation Elements (PCEs) to perform path computations in response to requests from Path Computation Clients (PCCs) [RFC5440].

[RFC8051] describes general considerations for a stateful PCE deployment and examines its applicability and benefits as well as its challenges and limitations through a number of use cases. [RFC8231] describes a set of extensions to PCEP to provide stateful control. For its computations, a stateful PCE has access to not only the information carried by the network's Interior Gateway Protocol (IGP) but also the set of active paths and their reserved resources. The additional state allows the PCE to compute constrained paths while considering individual Label Switched Paths (LSPs) and their interactions.

[RFC8281] describes the setup, maintenance, and teardown of PCE-initiated LSPs under the stateful PCE model.

[RFC8697] introduces a generic mechanism to create a grouping of LSPs. This grouping can then be used to define associations between sets of LSPs or between a set of LSPs and a set of attributes.

[RFC8453] introduces a framework for Abstraction and Control of TE Networks (ACTN) and describes various VN operations initiated by a customer or application. A VN is a customer view of the TE network. Depending on the agreement between client and provider, various VN operations and VN views are possible.

[RFC8637] examines the PCE and ACTN architectures and describes how the PCE architecture is applicable to ACTN. [RFC6805] and [RFC8751] describe a hierarchy of stateful PCEs with the parent PCE coordinating multi-domain path computation functions between child PCEs, thus making it the base for PCE applicability for ACTN. As [RFC8751] explains, in the context of ACTN, the child PCE is identified with the Provisioning Network Controller (PNC), and the parent PCE is identified with the Multi-Domain Service Coordinator (MDSC).

In this context, there is a need to associate a set of LSPs with a VN "construct" to facilitate VN operations in the PCE architecture. This association allows a PCE to identify which LSPs belong to a certain VN. The PCE could then use this association to optimize all LSPs belonging to the VN at once. The PCE could further take VN-specific actions on the LSPs, such as relaxing constraints, taking policy actions, setting default behavior, etc.

This document specifies a PCEP extension to associate a set of LSPs based on their VN.

## 2. Terminology

This document uses terminology from [RFC4655], [RFC5440], [RFC6805], [RFC8231], and [RFC8453].

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

### 3. Operation Overview

As per [RFC8697], LSPs are associated with other LSPs with which they interact by adding them to a common association group.

An association group based on VN is useful for various optimizations that should be applied by considering all the LSPs in the association. This includes, but is not limited to, the following:

**Path Computation:** When computing a path for an LSP, it is useful to analyze the impact of this LSP on the other LSPs belonging to the same VN. The aim would be to optimize all LSPs belonging to the VN rather than a single LSP. Also, the optimization criteria (such as minimizing the load of the most loaded link (MLL) [RFC5541]) could be applied for all the LSPs belonging to the VN identified by the VN association.

**Path Reoptimization:** The PCE would like to use advanced path computation algorithms and optimization techniques that consider all the LSPs belonging to a VN and optimize them all together during the path reoptimization.

In this document, we define a new association group called the "VN Association Group (VNAG)". This grouping is used to define the association between a set of LSPs and a VN.

The ASSOCIATION object contains a field to identify the type of association, and this document defines a new Association Type value of 7 to indicate that the association is a "VN Association". The Association Identifier in the ASSOCIATION object is the VNAG Identifier and is handled in the same way as the generic Association Identifier defined in [RFC8697].

In this document, "VNAG object" refers to an ASSOCIATION object with the Association Type set to "VN Association" (7).

Local policies on the PCE define the computational and optimization behavior for the LSPs in the VN. An LSP **MUST NOT** belong to more than one VNAG. If an implementation encounters more than one VNAG object in a PCEP message, it **MUST** process the first occurrence, and it **MUST** ignore the others.

[RFC8697] specifies the mechanism by which a PCEP speaker can advertise which Association Types it supports. This is done using the ASSOC-Type-List TLV carried within an OPEN object. A PCEP speaker **MUST** include the VN Association Type (7) in the ASSOC-Type-List TLV before using the VNAG object in a PCEP message. As per [RFC8697], if the implementation does not support the VN Association Type, it will return a PCErr message with Error-Type=26 (Association Error) and Error-value=1 (Association Type is not supported).

The Association Identifiers (VNAG IDs) for this Association Type are dynamic in nature and created by the parent PCE (MDSC) based on the VN operations for the LSPs belonging to the same VN. Operator configuration of VNAG IDs is not supported, so there is no need for an Operator-configured Association Range to be set. Thus, the VN Association Type (7) **MUST NOT** be present in the Operator-configured Association Range TLV if that TLV is present in the OPEN object. If an implementation encounters the VN Association Type (7) in an Operator-configured Association Range TLV, it **MUST** ignore the associated Start-Assoc-ID and Range values.

This association is useful in a PCEP session between a parent PCE (MDSC) and a child PCE (PNC). When computing the path, the child PCE (PNC) refers to the VN association in the request from the parent PCE (MDSC) and maps the VN to the associated LSPs and network resources. From the perspective of the parent PCE, it receives a VN creation request from its customer, with the VN uniquely identified by the association parameters ([Section 6.1.4](#) of [\[RFC8697\]](#)) in the VNAG or the Virtual Network Identifier encoded in the VIRTUAL-NETWORK-TLV. This VN may comprise multiple LSPs in the network in a single domain or across multiple domains. The parent PCE sends a PCInitiate message with this association information in the VNAG object. This in effect binds an LSP that is to be instantiated at the child PCE with the VN. The VN association information **MUST** be included as a part of the first PCRpt message. [Figure 1](#) shows an example of a typical VN operation using PCEP. It is worth noting that in a multi-domain scenario, the different domains are controlled by different child PCEs. In order to set up the cross-domain tunnel, multiple segments need to be stitched by the border nodes in each domain that receive the instruction from their child PCE (PNC).

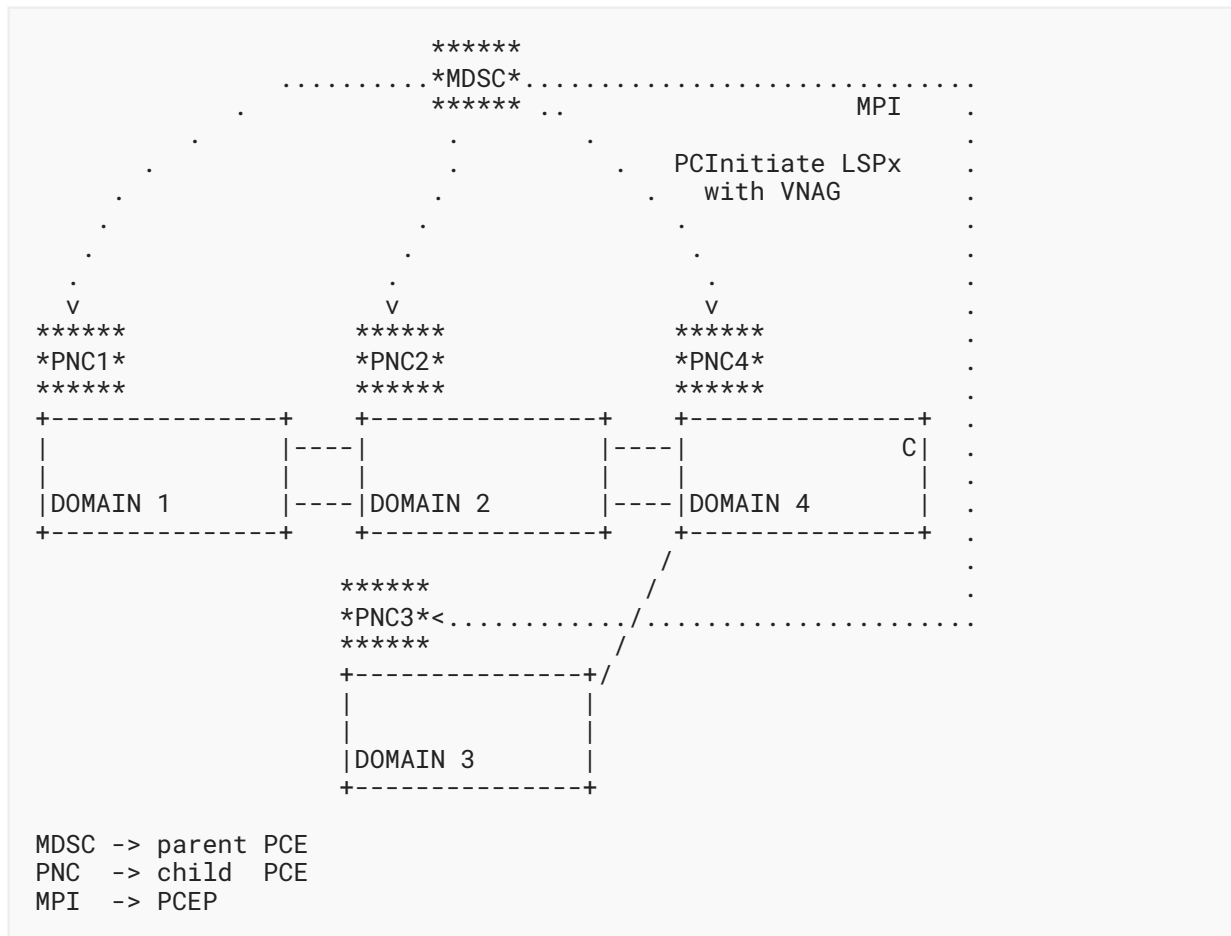


Figure 1: Example of VN Operations in H-PCE (Hierarchical PCE) Architecture

Whenever changes occur with the instantiated LSP in a domain network, the domain child PCE reports the changes using a PCRpt message in which the VNAG object indicates the relationship between the LSP and the VN.

Whenever an update occurs with VNs in the parent PCE (due to the customer's request), the parent PCE sends a PCUpd message to inform each affected child PCE of this change.

#### 4. Extensions to PCEP

The VNAG uses the generic ASSOCIATION object [RFC8697].

This document defines one new mandatory TLV called the "VIRTUAL-NETWORK-TLV". Optionally, the new TLV can be jointly used with the existing VENDOR-INFORMATION-TLV specified in [RFC7470] as described below:

VIRTUAL-NETWORK-TLV: Used to communicate the Virtual Network Identifier.

VENDOR-INFORMATION-TLV: Used to communicate arbitrary vendor-specific behavioral information, as described in [RFC7470].

The format of the VIRTUAL-NETWORK-TLV is as follows.

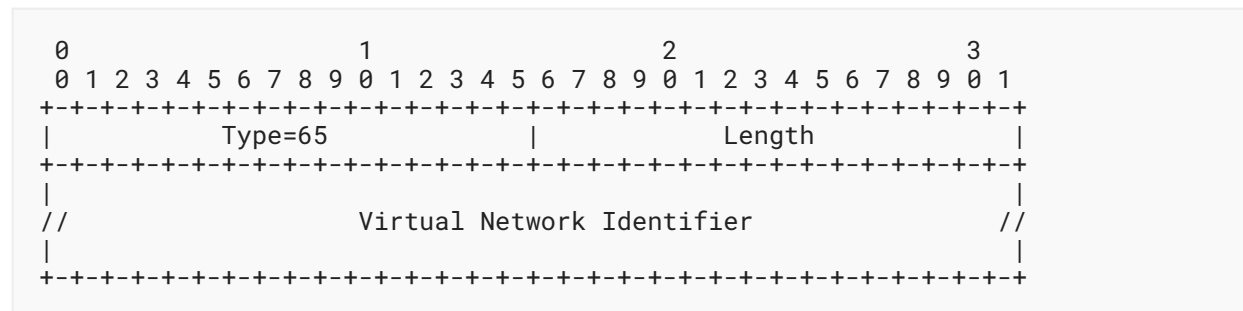


Figure 2: Format of the VIRTUAL-NETWORK-TLV

Type (16 bits): 65

Length (16 bits): Indicates the length of the value portion of the TLV in octets and **MUST** be greater than 0. The TLV **MUST** be zero-padded so that the TLV is 4-octet aligned.

Virtual Network Identifier (variable): A symbolic name for the VN that uniquely identifies the VN. It **SHOULD** be a string of printable ASCII [RFC0020] characters (i.e., 0x20 to 0x7E), without a NULL terminator. The Virtual Network Identifier is a human-readable string that identifies a VN. It can be specified with the association information, which may be conveyed in a VENDOR-INFORMATION-TLV. An implementation uses the Virtual Network Identifier to maintain a mapping to the VNAG and the LSPs associated with the VN. The Virtual Network Identifier **MAY** be specified by the customer, set via an operator policy, or auto-generated by the PCEP speaker.

The VIRTUAL-NETWORK-TLV **MUST** be included in VNAG object. If a PCEP speaker receives the VNAG object without the VIRTUAL-NETWORK-TLV, it **MUST** send a PCErr message with Error-Type=6 (Mandatory Object missing) and Error-value=18 (VIRTUAL-NETWORK-TLV missing) and close the session.

The format of VENDOR-INFORMATION-TLV is defined in [RFC7470].

If a PCEP speaker receives a VNAG object with a TLV that violates the rules specified in this document, the PCEP speaker **MUST** send a PCErr message with Error-Type=10 (Reception of an invalid object) and Error-value=11 (Malformed object) and **MUST** close the PCEP session.

## 5. Security Considerations

The security considerations described in [RFC5440], [RFC8231], and [RFC8281] apply to the extensions defined in this document as well.

This document introduces the VN Association Type (7) for the ASSOCIATION object. Additional security considerations related to LSP associations due to a malicious PCEP speaker are described in [RFC8697] and apply to the VN Association Type. Hence, securing the PCEP session using Transport Layer Security (TLS) [RFC8253] is **RECOMMENDED**.

## 6. IANA Considerations

### 6.1. ASSOCIATION Object Type Indicator

IANA has assigned the following new value in the "ASSOCIATION Type Field" subregistry within the "Path Computation Element Protocol (PCEP) Numbers" registry:

| Value | Name           | Reference |
|-------|----------------|-----------|
| 7     | VN Association | RFC 9358  |

Table 1

### 6.2. PCEP TLV Type Indicator

IANA has assigned the following new value in the "PCEP TLV Type Indicators" subregistry within the "Path Computation Element Protocol (PCEP) Numbers" registry:

| Value | Name                | Reference |
|-------|---------------------|-----------|
| 65    | VIRTUAL-NETWORK-TLV | RFC 9358  |

Table 2

### 6.3. PCEP Error

IANA has allocated the following new error value in the "PCEP-ERROR Object Error Types and Values" subregistry within the "Path Computation Element Protocol (PCEP) Numbers" registry:

| Error-Type | Meaning                  | Error-value                     | Reference |
|------------|--------------------------|---------------------------------|-----------|
| 6          | Mandatory Object missing | 18: VIRTUAL-NETWORK-TLV missing | RFC 9358  |

Table 3

## 7. Manageability Considerations

### 7.1. Control of Function and Policy

An operator **MUST** be allowed to mark LSPs that belong to the same VN. This could also be done automatically based on the VN configuration.



## 7.2. Information and Data Models

The PCEP YANG module [PCE-PCEP-YANG] should support the association between LSPs including VN association.

## 7.3. Liveness Detection and Monitoring

Mechanisms defined in this document do not imply any new liveness detection and monitoring requirements in addition to those already listed in [RFC5440].

## 7.4. Verification of Correct Operations

Mechanisms defined in this document do not imply any new operation verification requirements in addition to those already listed in [RFC5440].

## 7.5. Requirements on Other Protocols

Mechanisms defined in this document do not imply any new requirements on other protocols.

## 7.6. Impact on Network Operations

[RFC8637] describes the network operations when PCE is used for VN operations. Section 3 further specifies the operations when VN associations are used.

# 8. References

## 8.1. Normative References

- [RFC0020] Cerf, V., "ASCII format for network interchange", STD 80, RFC 20, DOI 10.17487/RFC0020, October 1969, <<https://www.rfc-editor.org/info/rfc20>>.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC5440] Vasseur, JP., Ed. and JL. Le Roux, Ed., "Path Computation Element (PCE) Communication Protocol (PCEP)", RFC 5440, DOI 10.17487/RFC5440, March 2009, <<https://www.rfc-editor.org/info/rfc5440>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.
- [RFC8231] Crabbe, E., Minei, I., Medved, J., and R. Varga, "Path Computation Element Communication Protocol (PCEP) Extensions for Stateful PCE", RFC 8231, DOI 10.17487/RFC8231, September 2017, <<https://www.rfc-editor.org/info/rfc8231>>.

- [RFC8253] Lopez, D., Gonzalez de Dios, O., Wu, Q., and D. Dhody, "PCEPS: Usage of TLS to Provide a Secure Transport for the Path Computation Element Communication Protocol (PCEP)", RFC 8253, DOI 10.17487/RFC8253, October 2017, <<https://www.rfc-editor.org/info/rfc8253>>.
- [RFC8281] Crabbe, E., Minei, I., Sivabalan, S., and R. Varga, "Path Computation Element Communication Protocol (PCEP) Extensions for PCE-Initiated LSP Setup in a Stateful PCE Model", RFC 8281, DOI 10.17487/RFC8281, December 2017, <<https://www.rfc-editor.org/info/rfc8281>>.
- [RFC8697] Minei, I., Crabbe, E., Sivabalan, S., Ananthakrishnan, H., Dhody, D., and Y. Tanaka, "Path Computation Element Communication Protocol (PCEP) Extensions for Establishing Relationships between Sets of Label Switched Paths (LSPs)", RFC 8697, DOI 10.17487/RFC8697, January 2020, <<https://www.rfc-editor.org/info/rfc8697>>.

## 8.2. Informative References

- [PCE-PCEP-YANG] Dhody, D., Ed., Beeram, V., Hardwick, J., and J. Tantsura, "A YANG Data Model for Path Computation Element Communications Protocol (PCEP)", Work in Progress, Internet-Draft, draft-ietf-pce-pcep-yang-20, 23 October 2022, <<https://datatracker.ietf.org/doc/html/draft-ietf-pce-pcep-yang-20>>.
- [RFC4655] Farrel, A., Vasseur, J.-P., and J. Ash, "A Path Computation Element (PCE)-Based Architecture", RFC 4655, DOI 10.17487/RFC4655, August 2006, <<https://www.rfc-editor.org/info/rfc4655>>.
- [RFC5541] Le Roux, JL., Vasseur, JP., and Y. Lee, "Encoding of Objective Functions in the Path Computation Element Communication Protocol (PCEP)", RFC 5541, DOI 10.17487/RFC5541, June 2009, <<https://www.rfc-editor.org/info/rfc5541>>.
- [RFC6805] King, D., Ed. and A. Farrel, Ed., "The Application of the Path Computation Element Architecture to the Determination of a Sequence of Domains in MPLS and GMPLS", RFC 6805, DOI 10.17487/RFC6805, November 2012, <<https://www.rfc-editor.org/info/rfc6805>>.
- [RFC7470] Zhang, F. and A. Farrel, "Conveying Vendor-Specific Constraints in the Path Computation Element Communication Protocol", RFC 7470, DOI 10.17487/RFC7470, March 2015, <<https://www.rfc-editor.org/info/rfc7470>>.
- [RFC8051] Zhang, X., Ed. and I. Minei, Ed., "Applicability of a Stateful Path Computation Element (PCE)", RFC 8051, DOI 10.17487/RFC8051, January 2017, <<https://www.rfc-editor.org/info/rfc8051>>.
- [RFC8453] Ceccarelli, D., Ed. and Y. Lee, Ed., "Framework for Abstraction and Control of TE Networks (ACTN)", RFC 8453, DOI 10.17487/RFC8453, August 2018, <<https://www.rfc-editor.org/info/rfc8453>>.

**[RFC8637]** Dhody, D., Lee, Y., and D. Ceccarelli, "Applicability of the Path Computation Element (PCE) to the Abstraction and Control of TE Networks (ACTN)", RFC 8637, DOI 10.17487/RFC8637, July 2019, <<https://www.rfc-editor.org/info/rfc8637>>.

**[RFC8751]** Dhody, D., Lee, Y., Ceccarelli, D., Shin, J., and D. King, "Hierarchical Stateful Path Computation Element (PCE)", RFC 8751, DOI 10.17487/RFC8751, March 2020, <<https://www.rfc-editor.org/info/rfc8751>>.

## Contributors

### **Dhruv Dhody**

Huawei Technologies  
Divyashree Technopark, Whitefield  
Bangalore 560066  
Karnataka  
India  
Email: [dhruv.ietf@gmail.com](mailto:dhruv.ietf@gmail.com)

### **Qin Wu**

Huawei Technologies  
China  
Email: [bill.wu@huawei.com](mailto:bill.wu@huawei.com)

### **Xian Zhang**

Huawei Technologies  
China  
Email: [zhang.xian@huawei.com](mailto:zhang.xian@huawei.com)

### **Adrian Farrel**

Old Dog Consulting  
Email: [adrian@olddog.co.uk](mailto:adrian@olddog.co.uk)

## Authors' Addresses

### **Young Lee**

Samsung Electronics  
Seoul  
Republic of Korea  
Email: [younglee.tx@gmail.com](mailto:younglee.tx@gmail.com)

**Haomian Zheng**

Huawei Technologies

H1, Huawei Xiliu Beipo Village Songshan Lake

Dongguan

Guangdong, 523808

China

Email: [zhenghaomian@huawei.com](mailto:zhenghaomian@huawei.com)**Daniele Ceccarelli**

Cisco Systems

Torshamnsgatan,48

Stockholm

Sweden

Email: [daniele.ietf@gmail.com](mailto:daniele.ietf@gmail.com)