Bro Internet Content Adaptation Protocol (ICAP) Analyzer

A Novel Method for Monitoring HTTPS Traffic in Plain-Text

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Presentation for

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Problem Statement

Encrypted Web Traffic

- Transport layer encryption (HTTPS)
- Status quo for search engines, web mail, etc.
- Blind spot for typical network security & monitoring
- Potential vector for external and internal cyber threats
- Majority of web traffic

Countermeasure

- Best practice... SSL/TLS-interception security device
- Or perhaps... Web proxy w/content inspection?

Bro ICAP Analyzer

Outline

- **ICAP**
  - Background
  - Basic Operation
  - Web Proxies, Content Inspection & ICAP
  - References
- **Bro ICAP Analyzer**
  - Analyzing ICAP
  - Creating the Bro Analyzer via BinPAC
  - Caveats & Limitation
- **Recommendations for Future Work**

Internet Content Adaptation Protocol

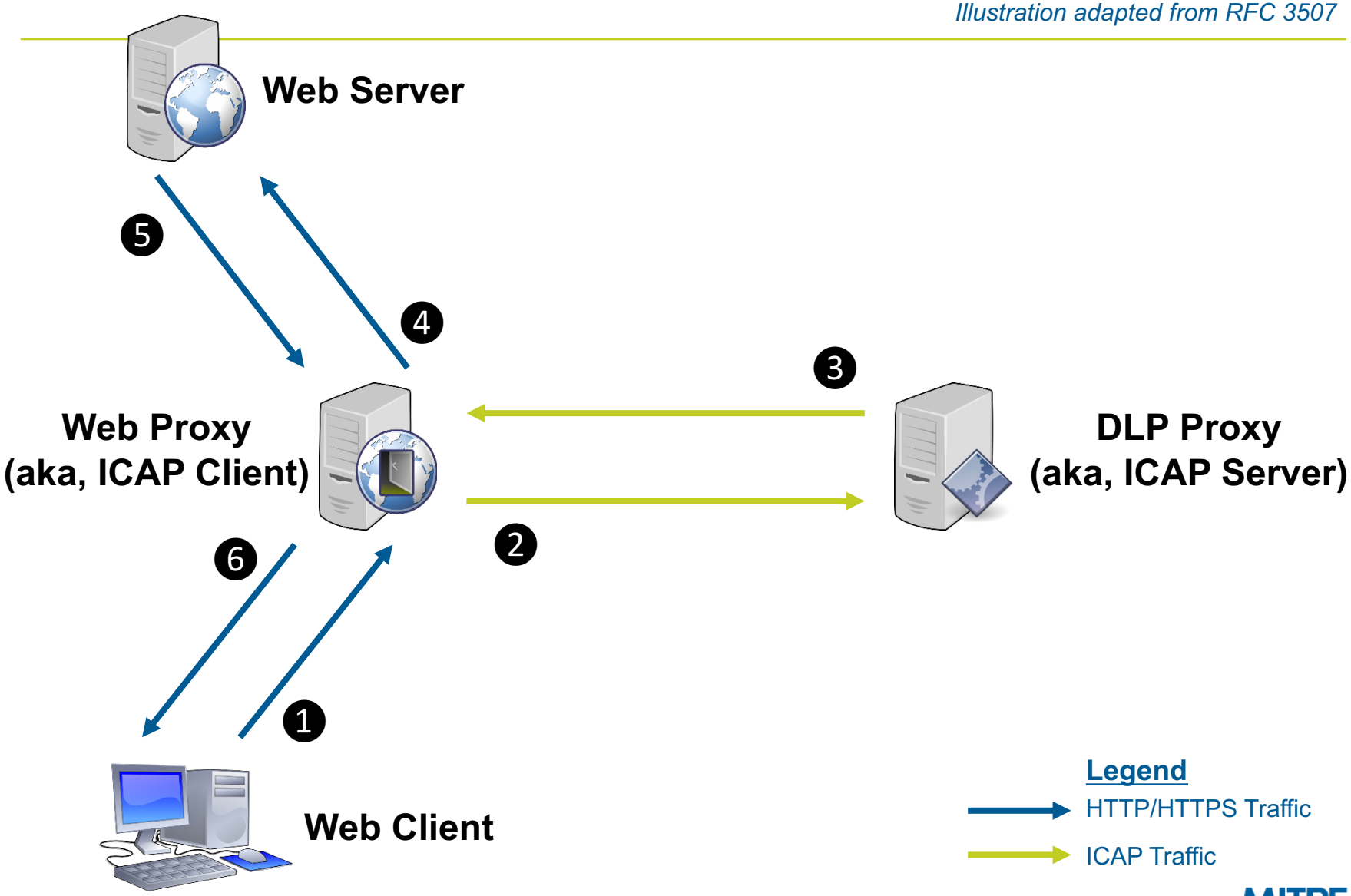
- **Internet Engineering Task Force (IETF) Request for Comments (RFC) 3507**
  - Simple object-based content vectoring for HTTP
  - Content modification of either HTTP request/response messages
  - Syntax similar to HTTP
  - TCP port 1344
- **Common Implementations**
  - Web proxy devices w/content inspection service
    - Anti-Virus (AV) / Malware
    - Data Loss Prevention (DLP)

ICAP Operation

- **Request Modification (REQMOD)**
  - Modifies HTTP request messages
  - ICAP payload:
    - HTTP request header
    - HTTP request body [chunk-encoded]
- **Response Modification (RESPMOD)**
  - Modifies HTTP response messages
  - ICAP payload:
    - HTTP request header
    - HTTP response header
    - HTTP response body [chunk-encoded]

ICAP Request Modification

Illustration adapted from RFC 3507



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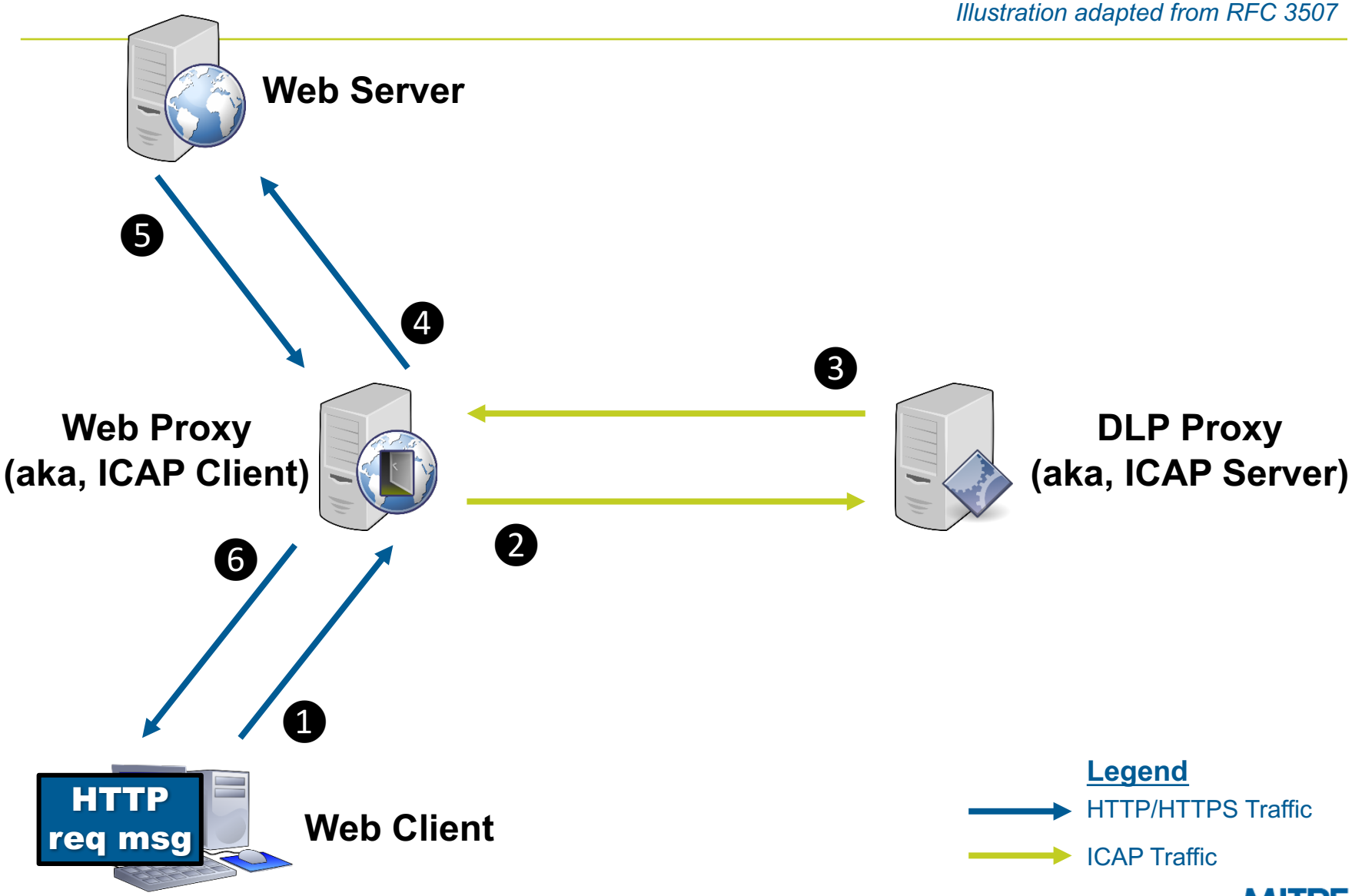
ICAP Request Modification

Illustration adapted from RFC 3507



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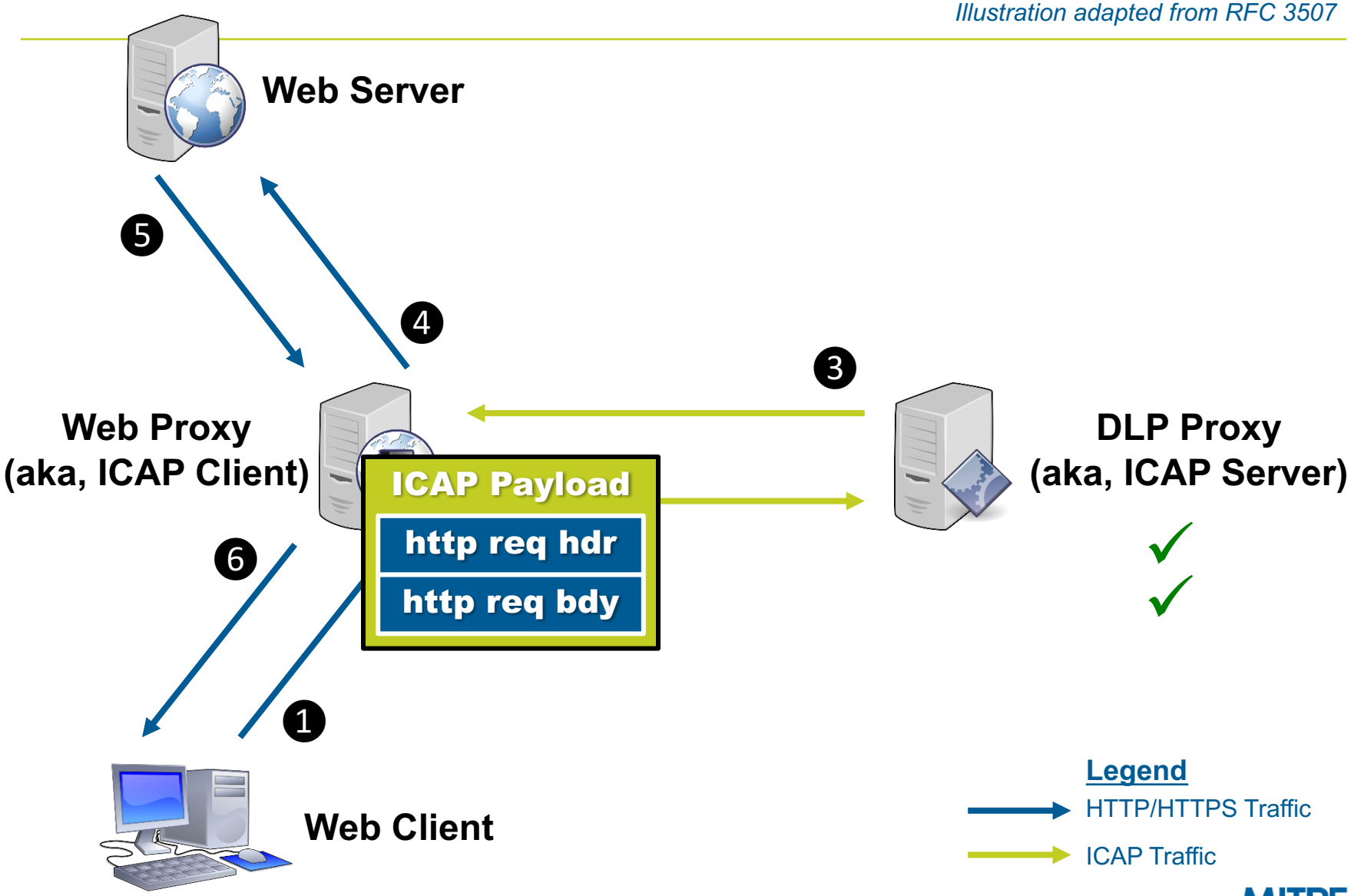
ICAP Request Modification

Illustration adapted from RFC 3507



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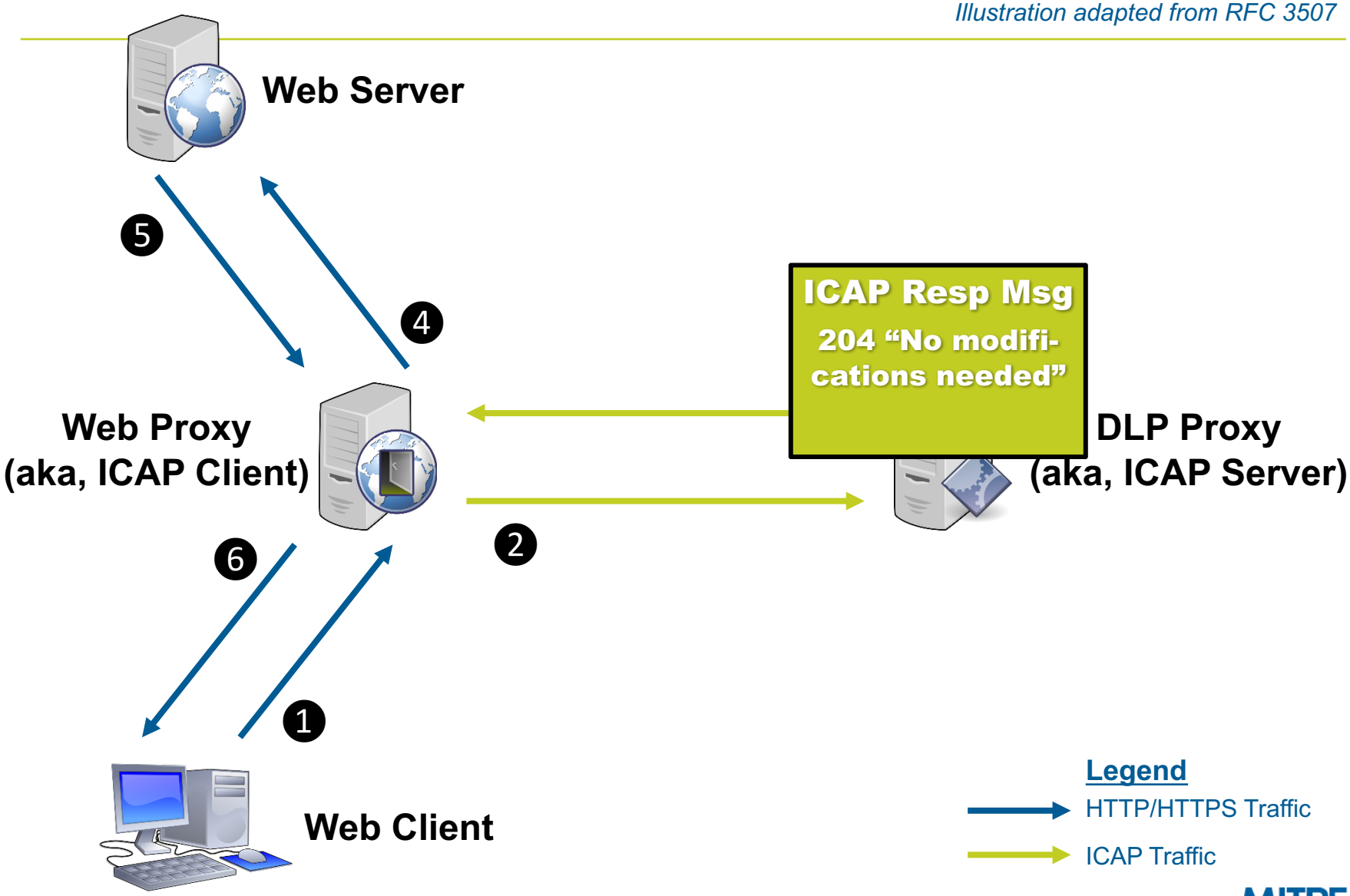
ICAP Request Modification

Illustration adapted from RFC 3507



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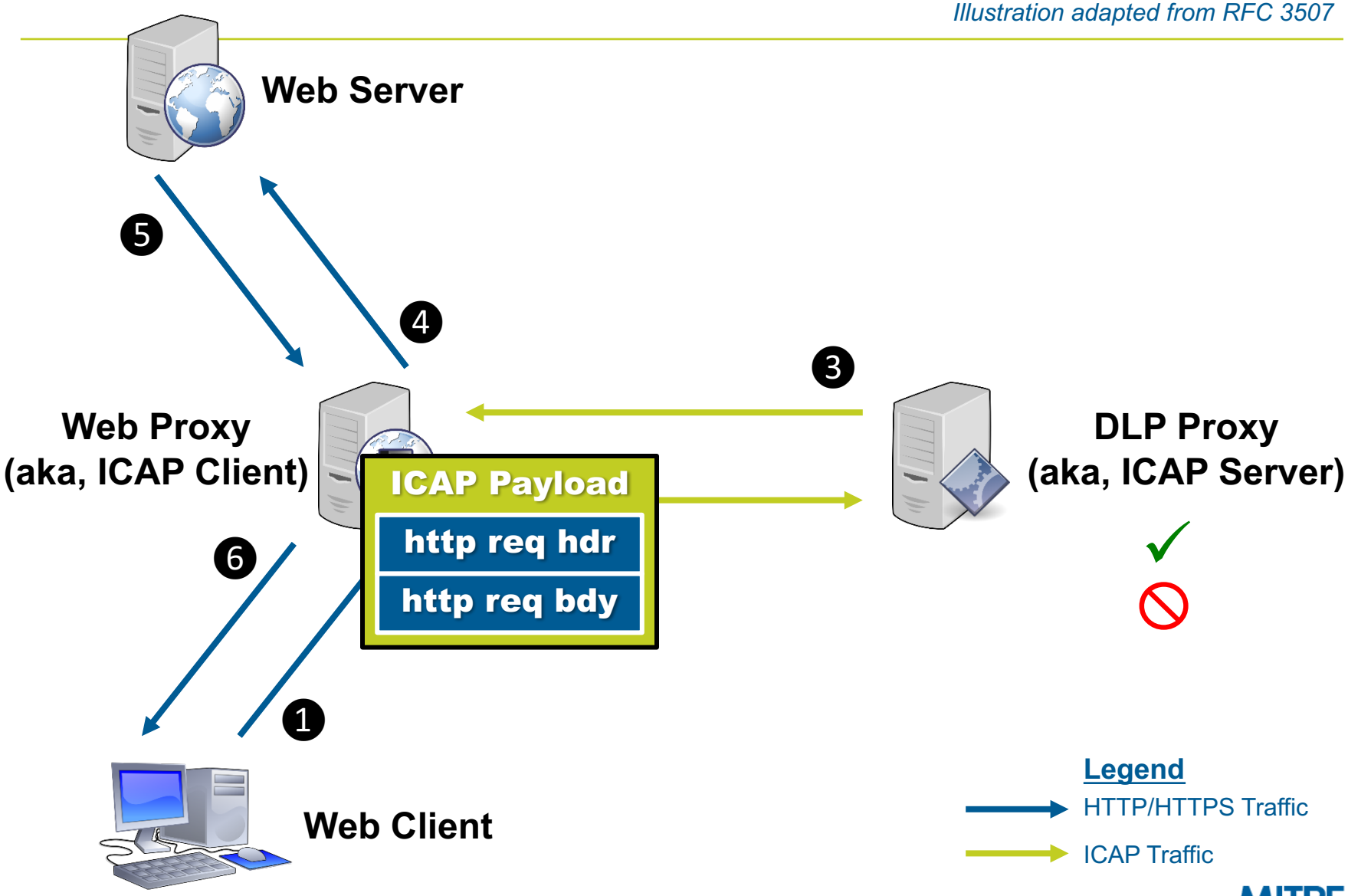
ICAP Request Modification

Illustration adapted from RFC 3507



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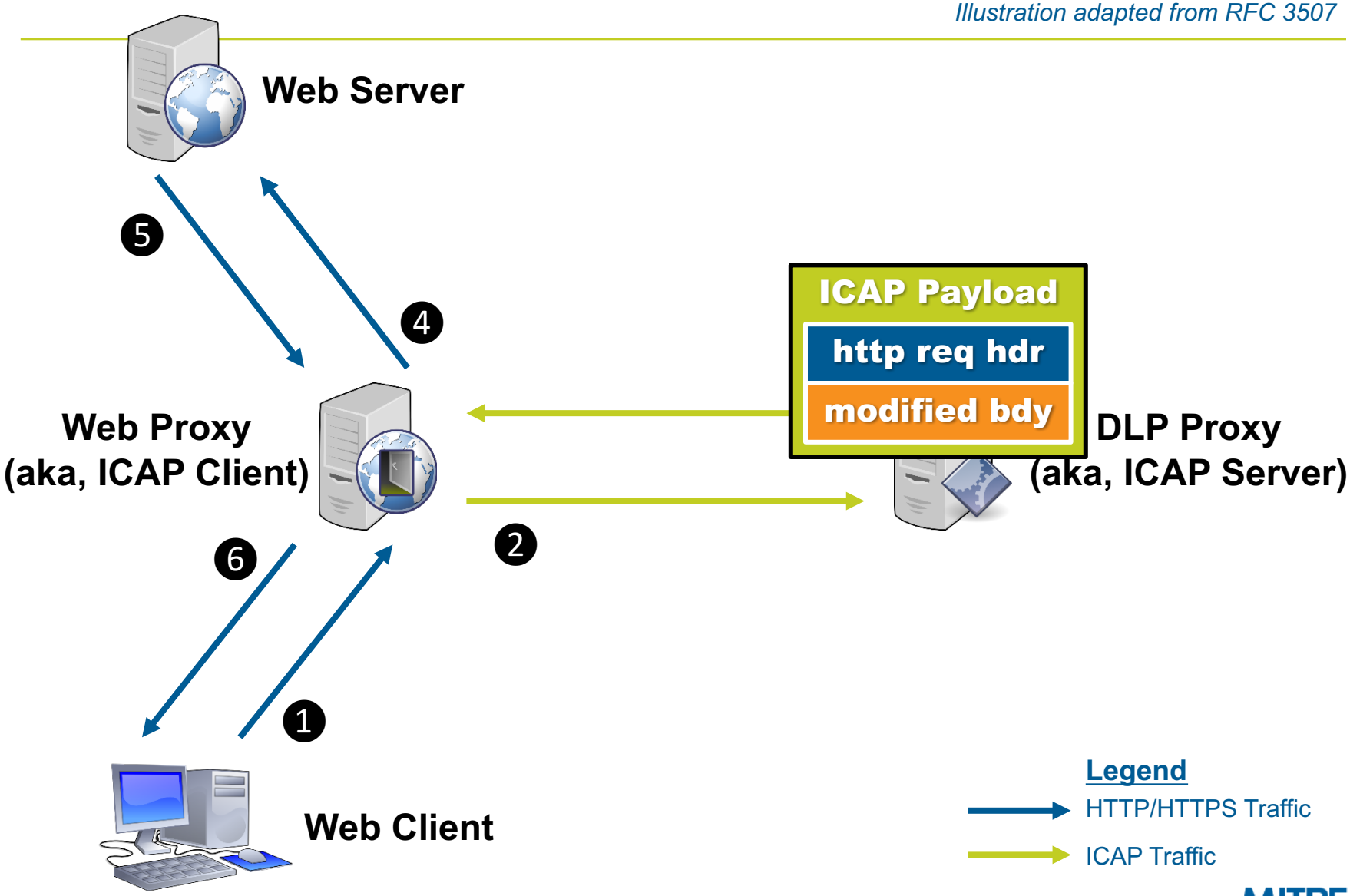
ICAP Request Modification

Illustration adapted from RFC 3507



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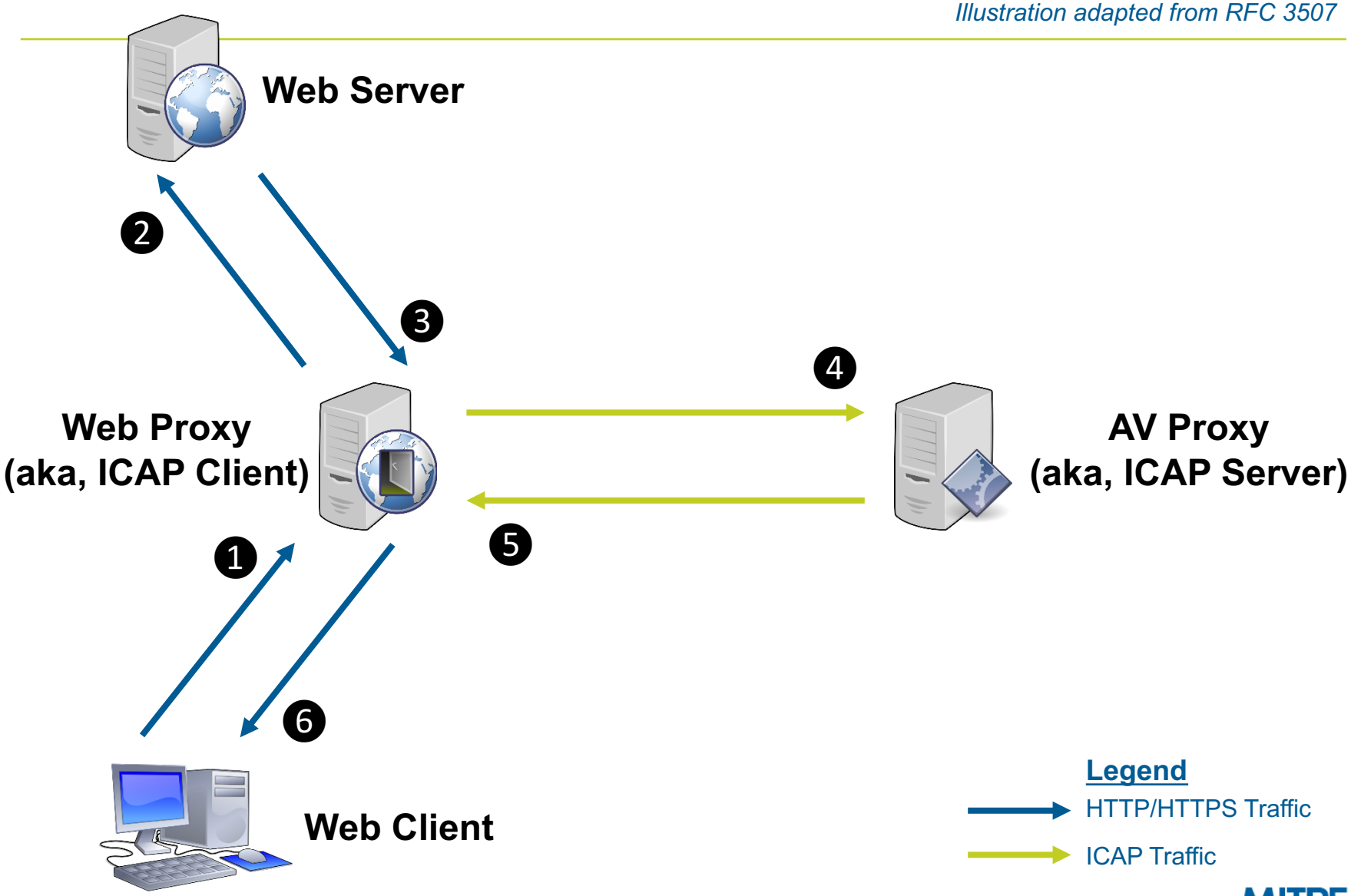
ICAP Response Modification

Illustration adapted from RFC 3507



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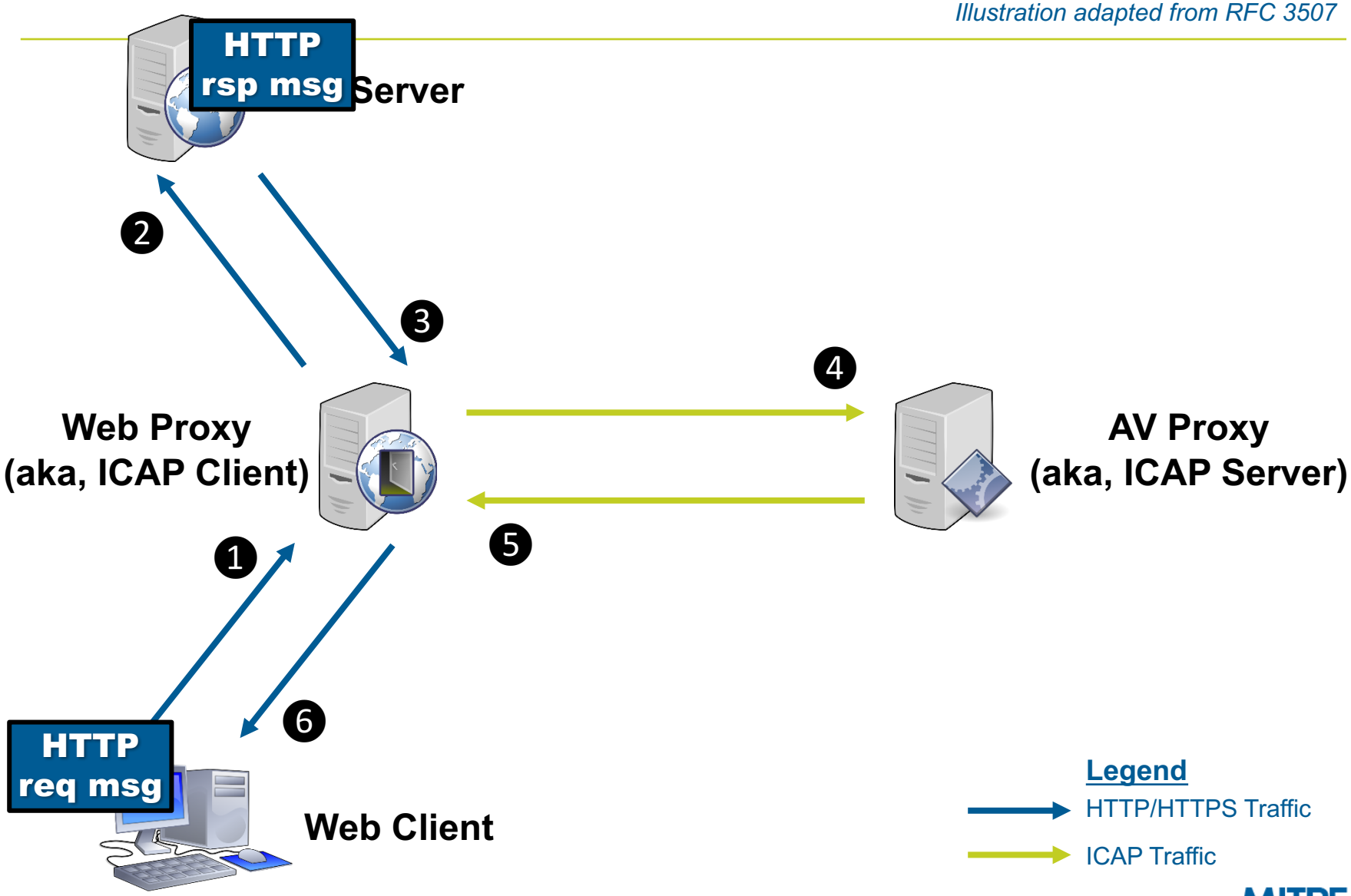
ICAP Response Modification

Illustration adapted from RFC 3507



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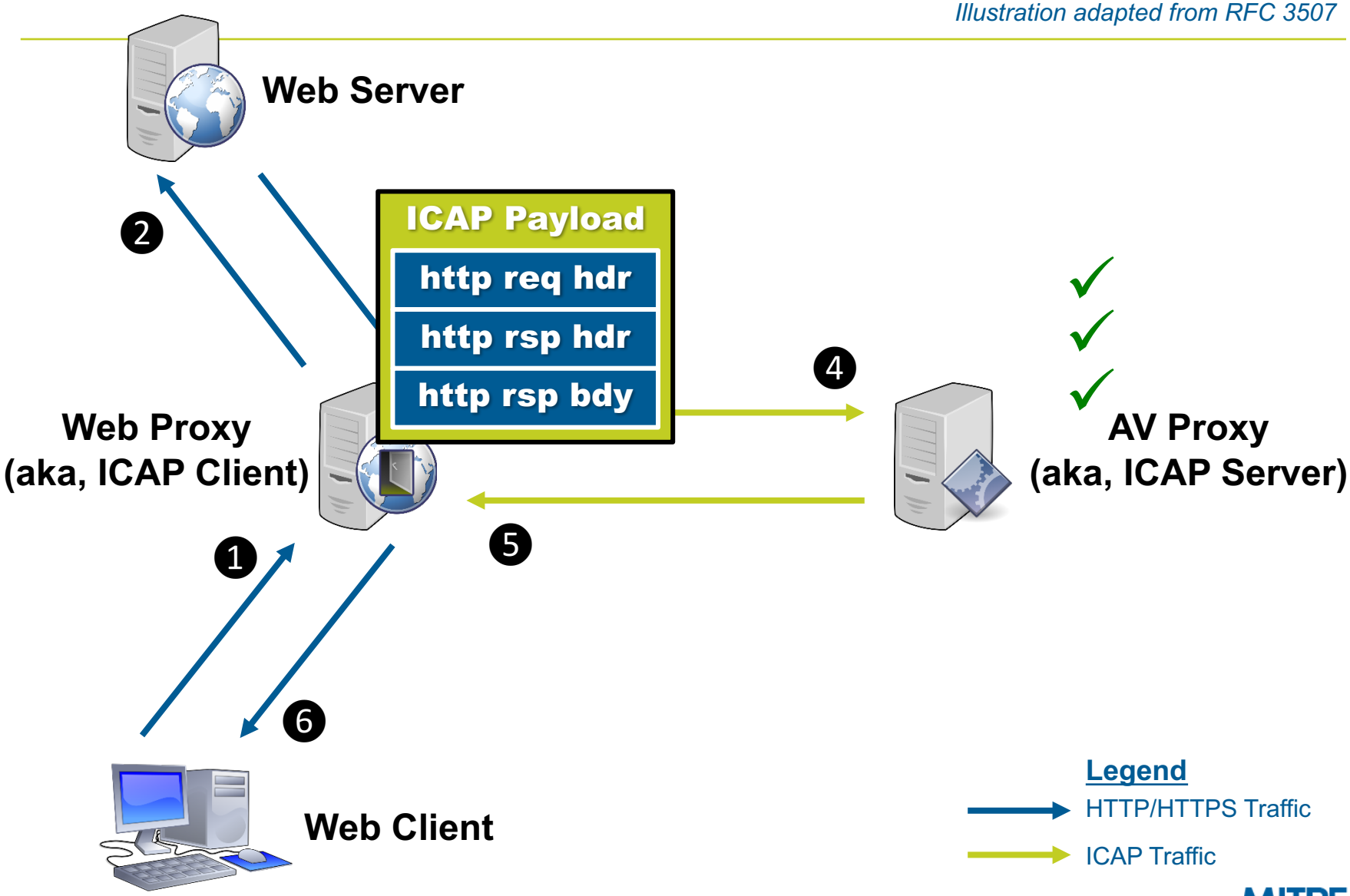
ICAP Response Modification

Illustration adapted from RFC 3507



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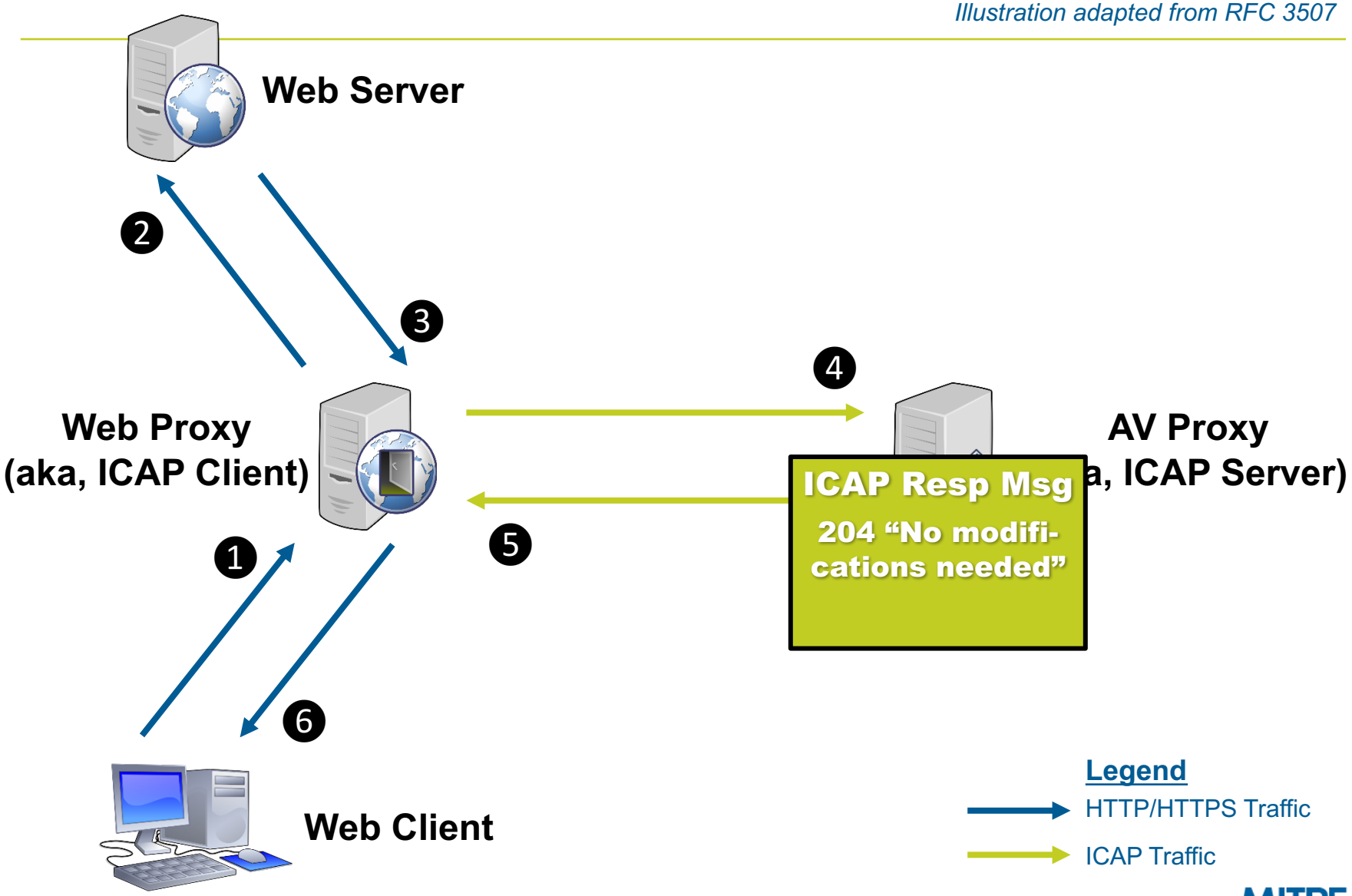
ICAP Response Modification

Illustration adapted from RFC 3507



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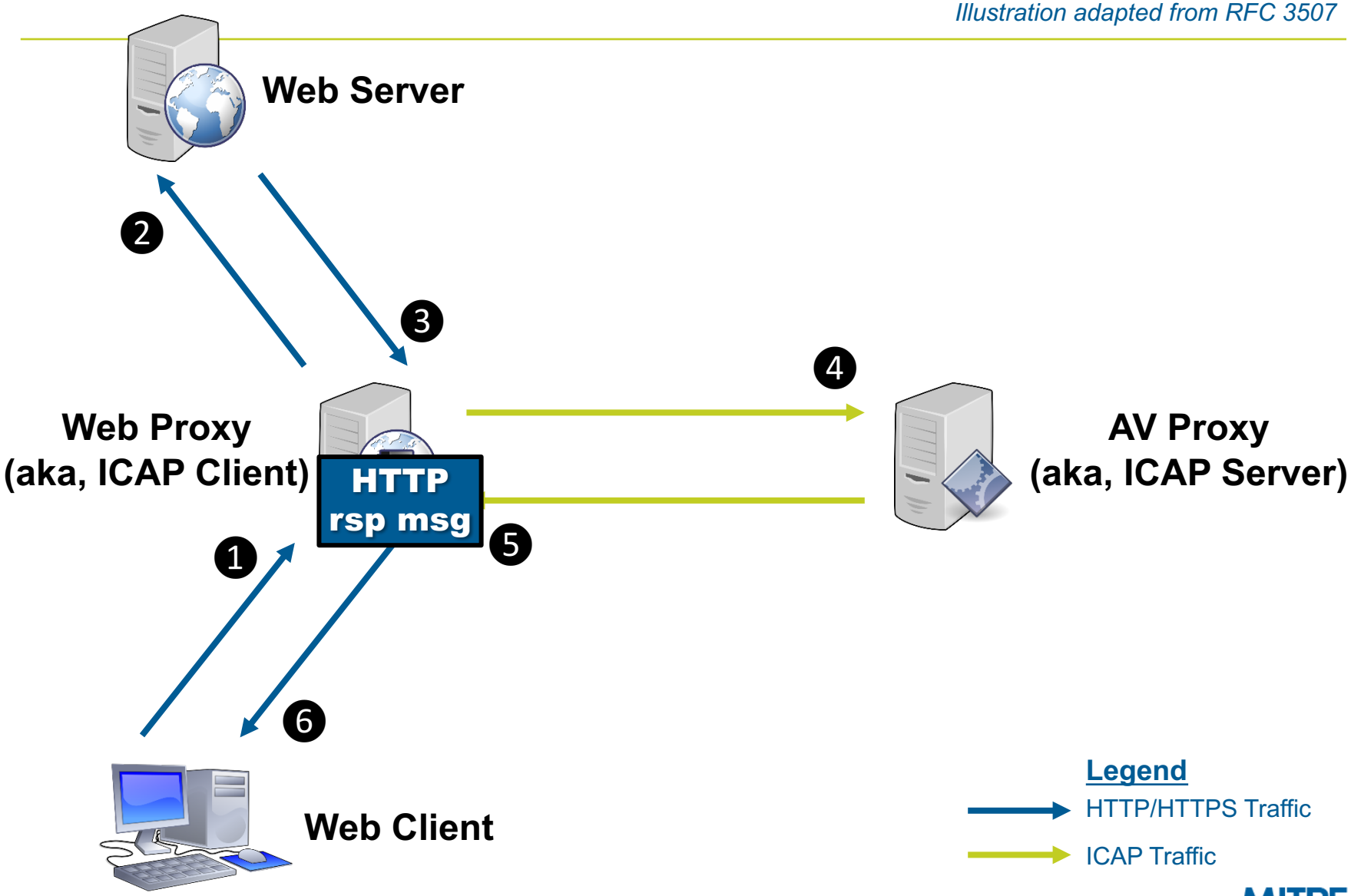
ICAP Response Modification

Illustration adapted from RFC 3507



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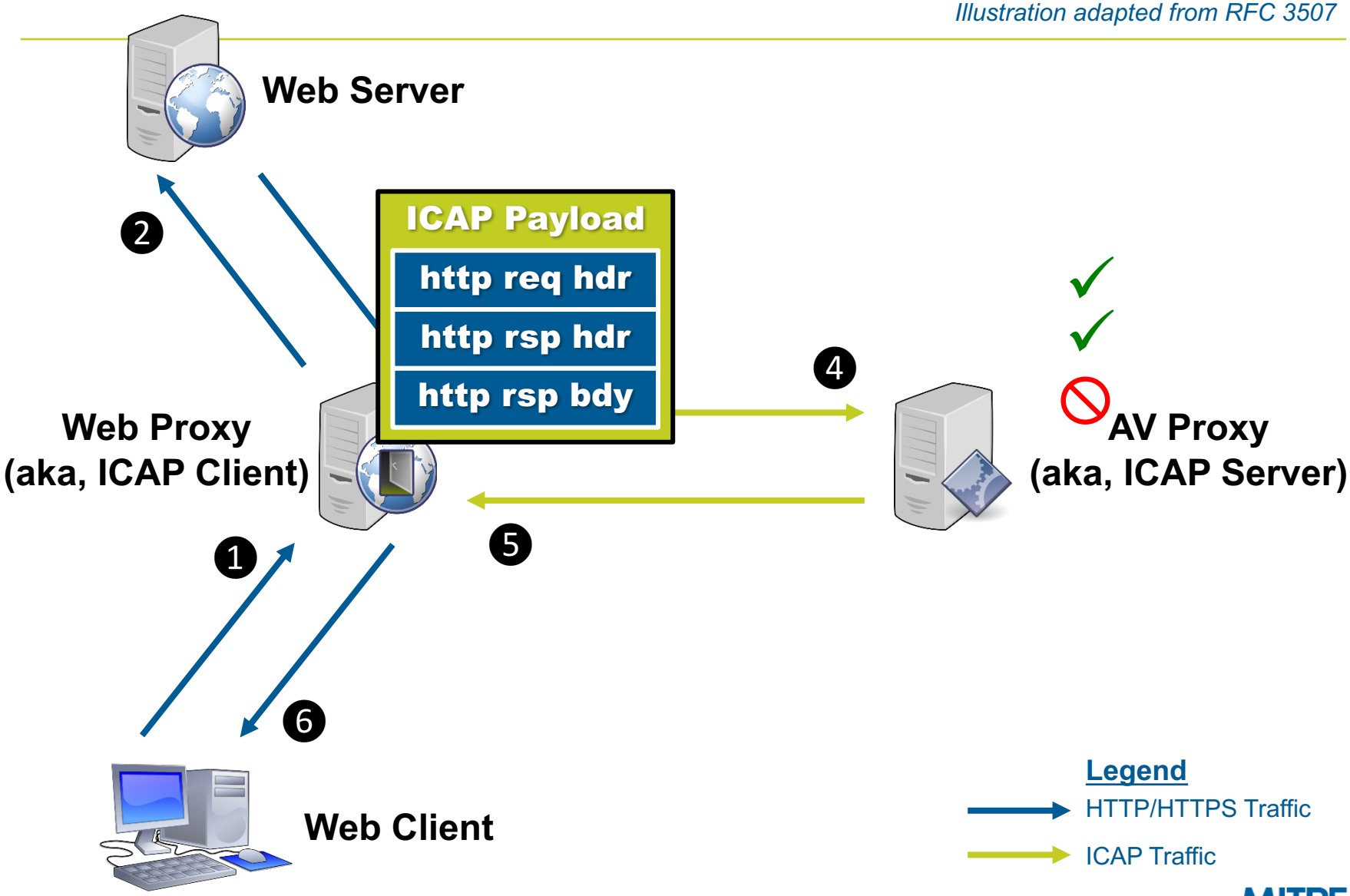

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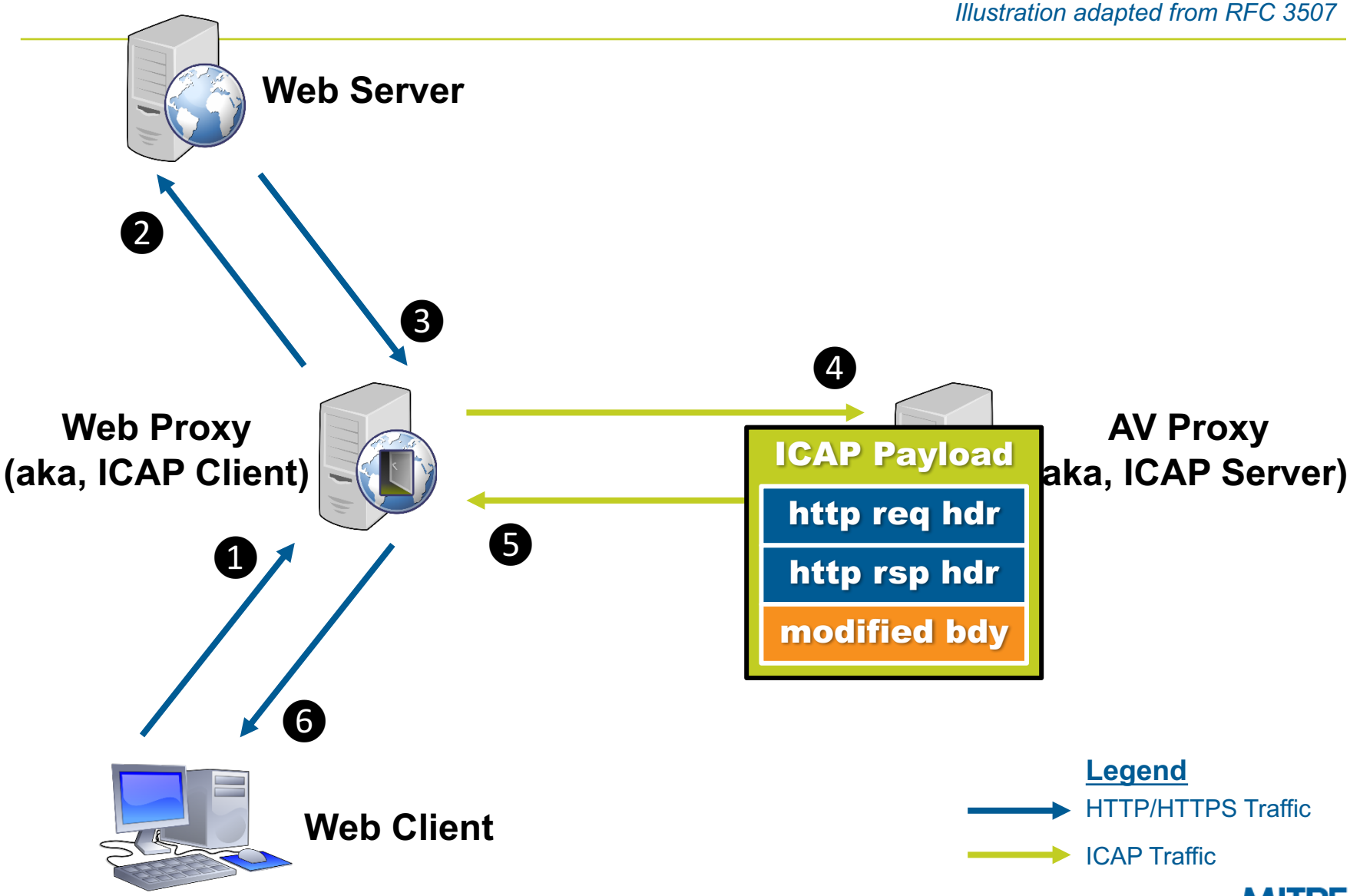

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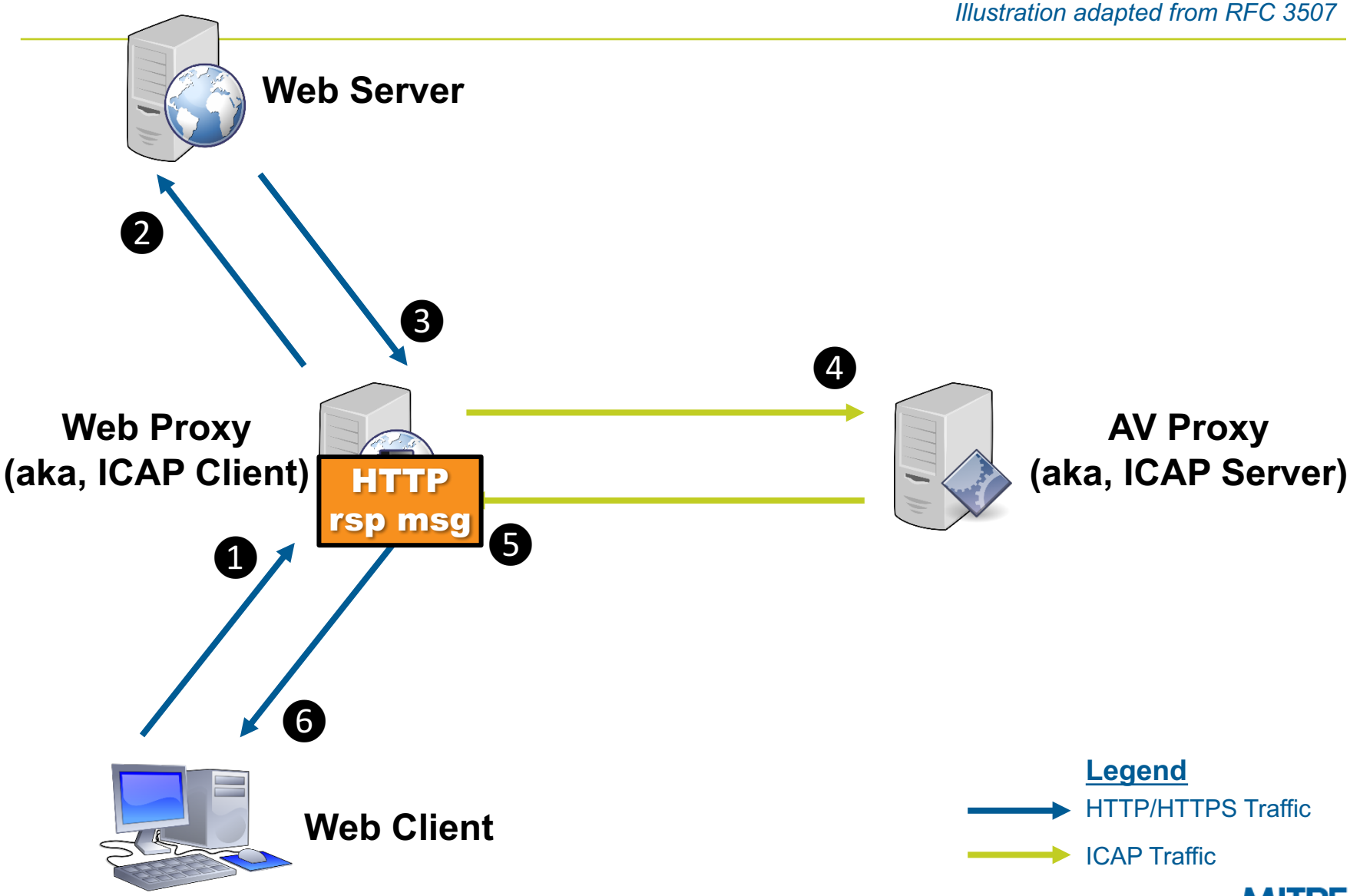

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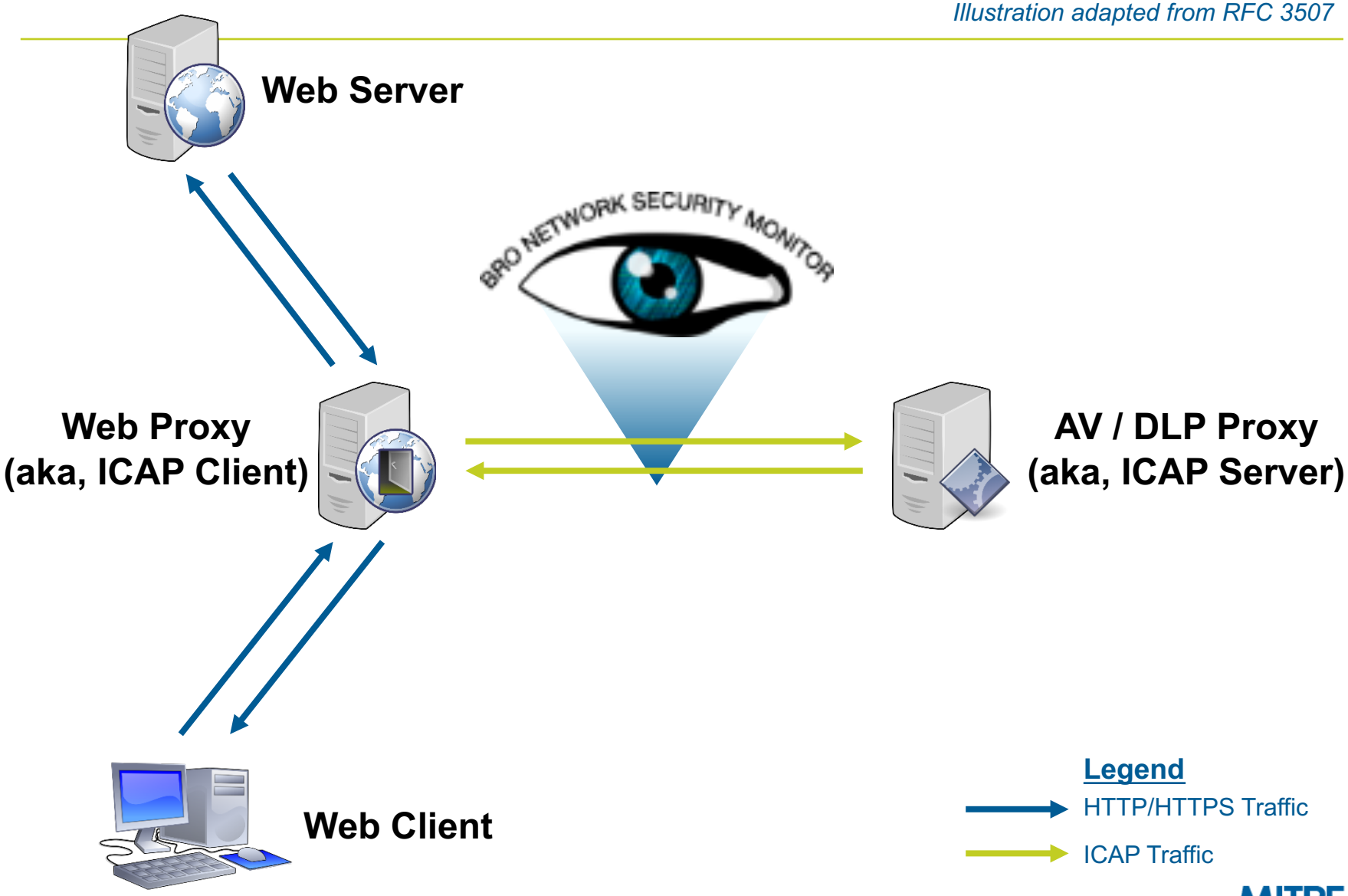
The Bro ICAP Analyzer

Illustration adapted from RFC 3507



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ICAP References

[1] Internet Content Adaptation Protocol (ICAP)

- Request for Comments (RFC) 3507
- J. Elson & A. Cerpa (2003 April)
  - https://tools.ietf.org/html/rfc3507

[2] ICAP Extensions

- IETF Draft
- M. Stecher et al. (2003 April)
  - https://tools.ietf.org/html/draft-stecher-icap-subid-00

[3] ICAP Partial Content Extension

- Draft (unofficial)
- M. Stecher & A. Rousskov (2010 May)
  - http://www.icap-forum.org/documents/specification/draft-icap-ext-partial-content-07.txt

ICAP References – *cont.*

[4] ICAP Errata

- Measurement Factory (© 2014)
  - http://www.measurement-factory.com/std/icap

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The Bro ICAP Analyzer

Objectives

- Monitor link between web proxy and AV/DLP proxy
  - IPs & Ports, Connection IDs
- Extract HTTPS messages from ICAP payload
  - Analyze ICAP headers
  - Generate icap.log
- Invoke the Bro HTTP analyzer
  - Invokes MIME analyzer, File analyzer, and...
  - Generates http.log, files.log, conn.log, and...

Analyzing ICAP Requests & Responses

- **ICAP Methods**
  - REQMOD
  - RESPMOD
  - OPTIONS
  - LOG *

** LOG defined in [2] ICAP Extensions*

- **ICAP Status Codes**
  - 1xx Informational
  - 2xx Success → 204 No modifications needed
  - 3xx Redirection
  - 4xx Client errors
  - 5xx Server errors

Analyzing ICAP Headers

Headers defined in [1] RFC 3507

ICAP Request Headers	ICAP Response Headers	ICAP Options Headers
Allow		Allow
Authorization		
Cache-Control	Cache-Control	
Connected	Connected	
Date	Date	Date
Encapsulated	Encapsulated	Encapsulated
Expires	Expires	
From		
Host	ISTag	ISTag
		Max-Connections
		Methods
		Opt-body-type
		Options-TTL
Pragma	Pragma	
Preview		Preview
Referer	Server	Service
		Service-ID
Trailer	Trailer	Transfer-Preview
Upgrade	Upgrade	Transfer-Ignore
User-Agent		Transfer-Complete

Analyzing Extended Headers

ICAP Request Extensions	ICAP Response Extensions	ICAP Options Extensions
X-Authenticated-User	X-ICAP-Profile	X-Include
X-Authenticated-Groups	X-Attribute	Attribute-List resp body
X-Client-IP	X-Attribute-Cacheability	
X-Server-IP	X-Attribute-Prefix	
X-Subscriber-ID	X-Infection-Found	
X-LOG-[service-ID]	X-Violations-Found	
	X-Virus-ID	
New Method: LOG	X-Response-Info	
LOG-[service-ID]	X-Response-Desc	

Headers defined in [2] ICAP Extensions

ICAP Request Extensions	ICAP Response Extensions	ICAP Options Extensions
x-patience	use-original-body	'Allow' header allowed
'Allow: 206'		
'Allow: NNN', where NNN can be any token		

Headers defined in [3] ICAP Partial Content Extension

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Analyzing Packet Captures

RESPMOD *Request* Packet

```
ICAP_Request_Line
{       ICAP Method
        ICAP URI
        ICAP Version                    }
ICAP_Headers
{       Host
        X-Scan-Progress-Interval
        X-Client-IP
        X-Server-IP
        X-Authenticated-User
        Allow
        Encapsulated                    }
ICAP_Payload
{       HTTP Request Header
        HTTP Response Header
        HTTP Response Body              }
```

RESPMOD *Reply* Packet

```
ICAP_Response_Line
{       ICAP Version
        ICAP Status Code
        ICAP Reason                     }
ICAP_Headers
{       Date
        Service
        ISTag
        Service-ID
        X-Scan-Progress
        X-Apparent-Data-Types           }
ICAP_Payload, if applicable
{       HTTP Response Header
        HTTP Response Body              }
```

The Encapsulated Header

Per RFC 3507 [pg 17]

```
REQMOD request:          [req-hdr] req-body
REQMOD response:         {[req-hdr] req-body} ||
                         {[rsp-hdr] rsp-body}
RESPMOD request:         [req-hdr] [rsp-hdr] rsp-body
RESPMOD response:        [rsp-hdr] [rsp-body]

OPTIONS response:        opt-body || null-body
```

NOTE: only one (1) body can be encapsulated within ICAP payload.

Example:

```
RESPMOD request:
Encapsulated: req-hdr=0, rsp-hdr=440, rsp-body=990\x0d\x0a
```


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Building the Bro ICAP Analyzer

- **Platform**
  - Linux CentOS 6.7 Server
  - 8-core CPU
  - Two 1-Gbps NIC

- **Bro**
  - Version 2.4.1
  - Local Cluster
    - 1 Manager, 1 Proxy
    - 6 Workers [pin_cpus=2,3,4,5,6,7]
  - PF_RING

Building the Bro ICAP Analyzer

- **BinPAC**
  - Version 0.44
    - https://www.bro.org/downloads/binpac-0.44.tar.gz
  - BinPAC QuickStart Guide
    - https://github.com/grigorescu/binpac_quickstart/archive/master.zip

Building the Bro ICAP Analyzer

Source Files	Description
❖ *C++, BIF & BinPAC Files*	*src/analyzer/protocol/icap/*
CMakeLists.txt	Indicates which compiler to use against which source-code files (C++ or BIF or BinPAC compiler).
ICAP.cc & .h	Defines C++ class ICAP_Analyzer.
Plugin.cc	Defines C++ class Bro_ICAP::Plugin.
events.bif	Declares events generated by the ICAP analyzer.
icap.pac	Top-level BinPAC declarations.
icap-protocol.pac	Protocol-specific BinPAC declarations, defines data elements based on RFC 3507.
icap-analyzer.pac	Additional code launched after protocol-specific data elements are parsed, throws ICAP events.
icap-analyzer-http.pac	Additional code to assist processing and invoking the HTTP analyzer.
icap-analyzer-utils.pac	Additional code to perform useful functions.
❖ *Scriptland Files*	*scripts/base/protocols/icap/*
main.bro	Bro script that handles and logs ICAP events.
dpd.sig	Bro dynamic protocol detection (DPD) script file is used to detect the ICAP protocol over a non-standard port.
__load__.bro	Declares which ICAP-related scripts to load at Bro startup. By default, both 'main.bro' and 'dpd.sig' are loaded at startup.

Build Files	Description
❖ *BIF Files*	*build/src/analyzer/protocol/icap/*
events.bif.cc events.bif.h events.bif.init.cc events.bif.register.cc	Auto-generated by BIF compiler and moved into the Bro build tree.
❖ *BinPAC Files*	*build/src/analyzer/protocol/icap/*
icap_pac.cc Icap_pac.h	Auto-generated by BinPAC compiler and moved into the Bro build tree.

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Bro ICAP Events & Weird Log

Bro ICAP Events	Description
icap_request_line	Generated after REQUEST LINE is parsed
icap_response_line	Generated after RESPONSE LINE is parsed
icap_header	Generated after HEADER field is parsed
icap_options	Generated after OPTIONS BODY is parsed
icap_body_weird	Generated if unexpected BODY format encountered
icap_chunk_weird	Generated if sum of chunks not equal to HTTP 'content-length'
icap_error	Generated for errors when decoding ICAP Requests & Responses
icap_done	Generated after a complete ICAP transaction: ❖ ICAP Request followed by ICAP Response; and ❖ After invoking HTTP analyzer.

Bro ICAP Weird	Description
Unrecognized ICAP Methods	ICAP_WEIRD: unknown ICAP method <string>
Unrecognized ICAP Versions	ICAP_WEIRD: unknown ICAP version <string>
Unrecognized ICAP Status Codes	ICAP_WEIRD: unknown ICAP status code <string>
Unrecognized ICAP Header Names	ICAP_WEIRD: header: <string_1> : <string_2> :: method : <string_3> : is_orig : <string_4>
Unrecognized ICAP Body Format	ICAP_WEIRD: unknown ICAP body format <string_1> :: method : <string_2> : is_orig : <string_3>

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BinPAC Files: icap.pac & icap-protocol.pac

icap.pac

```
enum ICAP_MSG_BODY_TYPES {
        BODY_TYPE_NONE,     # Message Body not present.
        BODY_TYPE_ACD,      # RESPMOD: (a) req-hdr, (c) rsp-hdr, (d) rsp-body
        BODY_TYPE_AC,       # RESPMOD: (a) req-hdr, (c) rsp-hdr, (f) null-body
        BODY_TYPE_CD,       # RESPMOD: (c) rsp-hdr, (d) rsp-body
        BODY_TYPE_D,        # RESPMOD: (d) rsp-body
        BODY_TYPE_AB,       # REQMOD:  (a) req-hdr, (b) req-body
        BODY_TYPE_A,        # REQMOD:  (a) req-hdr, (f) null-body
        BODY_TYPE_B,        # REQMOD:  (b) req-body
        BODY_TYPE_OPTS,     # OPTIONS: (e) opt-body
        BODY_TYPE_WEIRD,    # Unexpected body format
}
```

icap-protocol.pac

```
ICAP_Request {
        ICAP_Request_Line
        ICAP_Message
}

ICAP_Response {
        ICAP_Response_Line
        ICAP_Message
}

ICAP_Message {
        ICAP_Headers
        ICAP_Body
}

ICAP_Request_Line {
        ICAP_Method
        ICAP_URI
        ICAP_Version
}

ICAP_Response_Line {
        ICAP_Version
        ICAP_Status_Code
        ICAP_Reason
}

ICAP_Headers {
        Array of ICAP_Header
}
```


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BinPAC Files: icap-protocol.pac

icap-protocol.pac – *cont.*

```
type ICAP_Message(is_orig : bool) = record
{
        headers     : ICAP_Headers(is_orig);
        body        : case $context.flow.get_icap_body_type_from_encap_hdr(headers, is_orig) of
        {
                BODY_TYPE_ACD       -> acd      : ICAP_Body_acd(is_orig);
                BODY_TYPE_AC        -> ac       : ICAP_Body_ac(is_orig);
                BODY_TYPE_CD        -> cd       : ICAP_Body_cd(is_orig);
                BODY_TYPE_D         -> d        : ICAP_Body_d(is_orig);
                BODY_TYPE_AB        -> ab       : ICAP_Body_ab(is_orig);
                BODY_TYPE_A         -> a        : ICAP_Body_a(is_orig);
                BODY_TYPE_B         -> b        : ICAP_Body_b(is_orig);
                BODY_TYPE_OPTS      -> opts     : ICAP_Body_options(is_orig);
                default             -> none     : empty;
        };
};
```

```
type ICAP_Body_acd(is_orig : bool) = record
{
                encap_req_hdr       : ICAP_Encapsulated_Http_Headers;
                encap_rsp_hdr       : ICAP_Encapsulated_Http_Headers;
                encap_rsp_bdy       : ICAP_Chunks(is_orig);
};
```

BinPAC Files: icap-analyzer.pac & -utils.pac

icap-analyzer.pac		
proc_icap_request_line()	Event Generation: HTTP Injection:	icap_request_line none
proc_icap_response_line()	Event Generation: HTTP Injection:	icap_response_line none
proc_icap_header()	Event Generation: HTTP Injection:	icap_header none
proc_icap_body_xxx()	Event Generation: HTTP Injection:	none proc_http_invoke_analyzer
proc_icap_options()	Event Generation: HTTP Injection:	icap_options none
proc_icap_pdu()	Event Generation: HTTP Injection:	icap_done none

icap-analyzer-utils.pac		
get_icap_body_type_from_encap_hdr()	Event Generation: HTTP Injection:	icap_body_weird none

BinPAC Files: icap-analyzer-http.pac

icap-analyzer-http.pac	
proc_http_invoke_analyzer()	❖ Top-level function called by 'proc_icap_body_x'; ❖ Calls '_submit_all_headers' and '_submit_body'
proc_http_invoke_analyzer_submit_all_headers()	❖ Calls 'HTTP.cc :: HTTP_Analyzer::DeliverStream' to inject Headers into HTTP protocol analyzer ❖ Must submit each header field one-by-one
proc_http_invoke_analyzer_submit_body()	❖ Calls 'HTTP.cc :: HTTP_Analyzer::DeliverStream' to inject Body into HTTP protocol analyzer ❖ Must check original Transfer Encoding
proc_http_reassemble_body()	❖ Used only for the purpose of creating an HTTP Body that is *NOT* chunk-encoded ❖ Event Generation: icap_chunk_weird

ICAP.h

```
#include "analyzer/protocol/http/HTTP.h"

class ICAP_Analyzer ... {
public:
        static analyzer::Analyzer* HttpAnalyzer(Connection* conn) {
        return new analyzer::http::HTTP_Analyzer(conn);
        }
}
```


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BinPAC Files: Bugs & Challenges

Compiler Error in icap_pac.cc

icap.pac	Workaround
let body_ : int=BODY_TYPE_NONE	❖ Added global variable ‘body_’ within icap.pac ❖ Needed to fix a C-compiler error in 'icap_pac.cc :: ICAP_Message::ParseBuffer'. ❖ BinPAC compiler created the variable 'body_' in icap_pac.cc file but never defined it in icap_pac.cc or icap_pac.h.

BinPAC Files: Bugs & Challenges

ParseBuffer() Fails to Parse ‘chunk_data’

BIT-1500: “BinPAC Call to FlowBuffer::NewFrame with frame_length -1”

```
type TEST_Chunk = record {
        len_line      : bytestring &oneline;
        chunk_data    : bytestring &length = chunk_length;
        opt_crlf      : case chunk_length of {
                        0           -> none: empty;
                        default     -> crlf: bytestring &oneline;
        };
    } &let {
        chunk_length  : int = bytestring_to_int(len_line, 16); # in hexadecimal
};

type TEST_Chunks = record {
        chunks        : TEST_Chunk[] &until($element.chunk_length == 0);
};
```

Resolution (V. Grigorescu):

```
TEST_Chunk {
    TEST_Chunk_Size
    TEST_Chunk_Data
}
```

```
TEST_Chunk_Size {
    bytestring
}
```

```
TEST_Chunk_Data {
    bytestring &length =
    TEST_Chunk_Size;
}
```

Caveats & Limitations

Operational Testing

- Biased toward RESPMOD transactions
- REQMOD not yet observed/tested
- OPTIONS & Preview headers ignored

Bro Connection 4-tuples & Identifiers

- IP addresses derived from ICAP extended headers
- TCP port is always 1344
- Connection IDs overlap multiple unrelated user-sessions per ICAP session

Caveats & Limitations

- **REQMOD vs RESPMOD**
  - REQMOD yields HTTP request body
  - RESPMOD yields HTTP response body
  - Need both for full visibility

- **Transport Layer vs Application Layer Encryption**

Summary

- **Encrypted Web Traffic**
  - Blind spot for typical network security & monitoring
  - Majority of web traffic

- **Web proxy w/content inspection & SSL/TLS interception capabilities?**
  - If so... Bro ICAP Analyzer!
  - ICAP headers yield user ID and original IPs
  - ICAP payload yields decrypted copy of HTTPS messages

Future Work

- **REQMOD Testing**
- **Revisit/optimize BinPAC code:**
  - ICAP_Message & Encapsulated Headers
  - body_ global variable
- **Submit ICAP Analyzer to Bro Project Team**

Questions?

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Back-Up Slides

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