US009917856B2

(12) **United States Patent**
Ahn et al.

(10) **Patent No.: US 9,917,856 B2**
(45) **Date of Patent: Mar. 13, 2018**

(54) **RULE-BASED NETWORK-THREAT DETECTION FOR ENCRYPTED COMMUNICATIONS**

(71) Applicant: **Centripetal Networks, Inc.**, Herndon, VA (US)

(72) Inventors: **David K. Ahn**, Winston-Salem, NC (US); **Sean Moore**, Hollis, NH (US); **Douglas M. DiSabello**, Leesburg, VA (US)

(73) Assignee: **Centripetal Networks, Inc.**, Portsmouth, NH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/757,638**

(22) Filed: **Dec. 23, 2015**

(65) **Prior Publication Data**

US 2017/0187733 A1 Jun. 29, 2017

(51) **Int. Cl.**
H04L 29/06 (2006.01)
H04L 29/12 (2006.01)

(52) **U.S. Cl.**
CPC ***H04L 63/1425*** (2013.01); ***H04L 61/1511*** (2013.01); ***H04L 63/0263*** (2013.01); ***H04L 63/0281*** (2013.01); ***H04L 63/1416*** (2013.01); ***H04L 63/20*** (2013.01); ***H04L 69/22*** (2013.01)

(58) **Field of Classification Search**
USPC 713/153
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,098,172	A	8/2000	Coss et al.
6,147,976	A	11/2000	Shand et al.
6,226,372	B1	5/2001	Beebe et al.
6,317,837	B1	11/2001	Kenworthy
6,484,261	B1	11/2002	Wiegel
6,611,875	B1	8/2003	Chopra et al.
6,662,235	B1	12/2003	Callis et al.
7,089,581	B1	8/2006	Nagai et al.

(Continued)

FOREIGN PATENT DOCUMENTS

AU	2005328336	B2	9/2011
AU	2006230171	B2	6/2012

(Continued)

OTHER PUBLICATIONS

Apr. 15, 2016—(US) Notice of Allowance—U.S. Appl. No. 14/855,374.

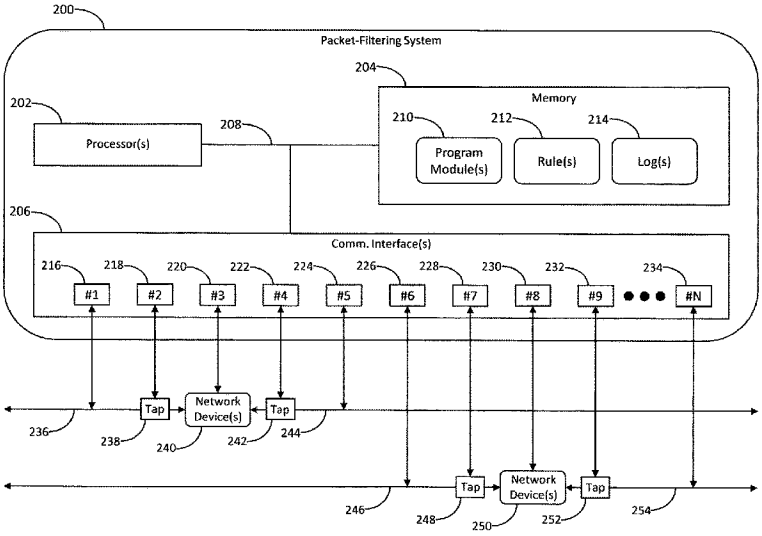
(Continued)

Primary Examiner — Jason Lee
(74) *Attorney, Agent, or Firm* — Banner & Witcoff, Ltd.

(57) **ABSTRACT**

A packet-filtering system configured to filter packets in accordance with packet-filtering rules may receive data indicating network-threat indicators and may configure the packet-filtering rules to cause the packet-filtering system to identify packets comprising unencrypted data, and packets comprising encrypted data. A portion of the unencrypted data may correspond to one or more of the network-threat indicators, and the packet-filtering rules may be configured to cause the packet-filtering system to determine, based on the portion of the unencrypted data, that the packets comprising encrypted data correspond to the one or more network-threat indicators.

25 Claims, 13 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

7,107,613 B1 9/2006 Chen et al.
7,215,637 B1 5/2007 Ferguson et al.
7,227,842 B1 6/2007 Ji et al.
7,237,267 B2 6/2007 Rayes et al.
7,263,099 B1 8/2007 Woo et al.
7,299,353 B2 11/2007 Le Pennec et al.
7,331,061 B1 2/2008 Ramsey et al.
7,478,429 B2 1/2009 Lyon
7,539,186 B2 5/2009 Aerrabotu et al.
7,610,621 B2 10/2009 Turley et al.
7,684,400 B2 3/2010 Govindarajan et al.
7,710,885 B2 5/2010 Ilnicki et al.
7,721,084 B2 5/2010 Salminen et al.
7,818,794 B2 10/2010 Wittman
7,954,143 B2 5/2011 Aaron
8,004,994 B1 8/2011 Darisi et al.
8,037,517 B2 10/2011 Fulp et al.
8,042,167 B2 10/2011 Fulp et al.
8,117,655 B2 2/2012 Spielman
8,176,561 B1 5/2012 Hurst et al.
8,306,994 B2 11/2012 Kenworthy
8,495,725 B2 7/2013 Ahn
8,726,379 B1 5/2014 Stiansen et al.
8,806,638 B1 8/2014 Mani
8,856,926 B2 10/2014 Narayanaswamy et al.
8,935,785 B2 1/2015 Pandrangi
9,094,445 B2 7/2015 Moore et al.
9,124,552 B2 9/2015 Moore
9,137,205 B2 9/2015 Rogers et al.
9,154,446 B2 10/2015 Gemelli et al.
9,160,713 B2 10/2015 Moore
2001/0039579 A1 11/2001 Trcka et al.
2001/0039624 A1 11/2001 Kellum
2002/0016858 A1 2/2002 Sawada et al.
2002/0038339 A1 3/2002 Xu
2002/0049899 A1 4/2002 Kenworthy
2002/0164962 A1 11/2002 Mankins et al.
2002/0165949 A1 11/2002 Na et al.
2002/0186683 A1 12/2002 Buck et al.
2002/0198981 A1 12/2002 Corl et al.
2003/0035370 A1 2/2003 Brustoloni
2003/0097590 A1 5/2003 Syvanne
2003/0105976 A1 6/2003 Copeland
2003/0120622 A1 6/2003 Nurmela et al.
2003/0123456 A1 7/2003 Denz et al.
2003/0142681 A1 7/2003 Chen et al.
2003/0145225 A1 7/2003 Bruton et al.
2003/0154297 A1 8/2003 Suzuki et al.
2003/0154399 A1 8/2003 Zuk et al.
2003/0188192 A1 10/2003 Tang et al.
2003/0212900 A1 11/2003 Liu et al.
2004/0010712 A1 1/2004 Hui et al.
2004/0073655 A1 4/2004 Kan et al.
2004/0088542 A1 5/2004 Daude et al.
2004/0093513 A1 5/2004 Cantrell et al.
2004/0098511 A1 5/2004 Lin et al.
2004/0151155 A1 8/2004 Jouppi
2004/0177139 A1 9/2004 Schuba et al.
2004/0193943 A1 9/2004 Angelino et al.
2004/0199629 A1* 10/2004 Bomer G06F 11/362 709/224
2004/0205360 A1 10/2004 Norton et al.
2004/0250124 A1 12/2004 Chesla et al.
2005/0010765 A1 1/2005 Swander et al.
2005/0024189 A1 2/2005 Weber
2005/0108557 A1 5/2005 Kayo et al.
2005/0114704 A1 5/2005 Swander
2005/0117576 A1 6/2005 McDysan et al.
2005/0125697 A1 6/2005 Tahara
2005/0138204 A1 6/2005 Iyer et al.
2005/0138353 A1* 6/2005 Spies H04L 63/0442 713/153
2005/0141537 A1 6/2005 Kumar et al.
2005/0183140 A1 8/2005 Goddard
2005/0229246 A1 10/2005 Rajagopal et al.
2005/0251570 A1 11/2005 Heasman et al.
2005/0286522 A1 12/2005 Paddon et al.
2006/0048142 A1 3/2006 Roese et al.
2006/0053491 A1 3/2006 Khuti et al.
2006/0070122 A1 3/2006 Bellovin
2006/0104202 A1 5/2006 Reiner
2006/0114899 A1 6/2006 Toumura et al.
2006/0136987 A1 6/2006 Okuda
2006/0137009 A1 6/2006 Chesla
2006/0146879 A1 7/2006 Anthias et al.
2006/0195896 A1 8/2006 Fulp et al.
2006/0212572 A1 9/2006 Afek et al.
2006/0248580 A1 11/2006 Fulp et al.
2006/0262798 A1 11/2006 Joshi et al.
2007/0083924 A1 4/2007 Lu
2007/0211644 A1 9/2007 Ottamalika et al.
2007/0240208 A1 10/2007 Yu et al.
2008/0005795 A1 1/2008 Acharya et al.
2008/0043739 A1 2/2008 Suh et al.
2008/0072307 A1 3/2008 Maes
2008/0077705 A1 3/2008 Li et al.
2008/0163333 A1 7/2008 Kasralikar
2008/0229415 A1 9/2008 Kapoor et al.
2008/0235755 A1 9/2008 Blaisdell et al.
2008/0279196 A1 11/2008 Friskney et al.
2008/0301765 A1 12/2008 Nicol et al.
2009/0138938 A1 5/2009 Harrison et al.
2009/0172800 A1 7/2009 Wool
2009/0222877 A1 9/2009 Diehl et al.
2009/0240698 A1 9/2009 Shukla et al.
2009/0328219 A1 12/2009 Narayanaswamy
2010/0011433 A1 1/2010 Harrison et al.
2010/0011434 A1 1/2010 Kay
2010/0082811 A1 4/2010 Van Der Merwe et al.
2010/0095367 A1 4/2010 Narayanaswamy
2010/0107240 A1 4/2010 Thaler et al.
2010/0132027 A1 5/2010 Ou
2010/0199346 A1 8/2010 Ling et al.
2010/0211678 A1 8/2010 McDysan et al.
2010/0232445 A1 9/2010 Bellovin
2010/0242098 A1 9/2010 Kenworthy
2010/0268799 A1 10/2010 Maestas
2010/0296441 A1 11/2010 Barkan
2010/0303240 A1 12/2010 Beachem et al.
2011/0055916 A1 3/2011 Ahn
2011/0055923 A1 3/2011 Thomas
2011/0088092 A1 4/2011 Nguyen et al.
2011/0141900 A1 6/2011 Jayawardena et al.
2011/0185055 A1 7/2011 Nappier et al.
2011/0270956 A1 11/2011 McDysan et al.
2012/0023576 A1* 1/2012 Sorensen G06F 21/577 726/22
2012/0106354 A1 5/2012 Pleshek et al.
2012/0113987 A1 5/2012 Riddoch et al.
2012/0240135 A1 9/2012 Risbood et al.
2012/0264443 A1 10/2012 Ng et al.
2012/0314617 A1 12/2012 Erichsen et al.
2012/0331543 A1 12/2012 Bostrom et al.
2013/0047020 A1 2/2013 Hershko et al.
2013/0059527 A1 3/2013 Hasesaka et al.
2013/0061294 A1 3/2013 Kenworthy
2013/0117852 A1 5/2013 Stute
2013/0254766 A1 9/2013 Zuo et al.
2013/0305311 A1 11/2013 Puttaswamy Naga et al.
2014/0075510 A1 3/2014 Sonoda et al.
2014/0115654 A1 4/2014 Rogers et al.
2014/0201123 A1 7/2014 Ahn et al.
2014/0215574 A1 7/2014 Erb et al.
2014/0281030 A1 9/2014 Cui et al.
2014/0283004 A1 9/2014 Moore
2014/0283030 A1 9/2014 Moore et al.
2014/0317397 A1 10/2014 Martini
2014/0366132 A1 12/2014 Stiansen et al.
2015/0207813 A1* 7/2015 Reybok G06F 21/552 726/22
2015/0237012 A1 8/2015 Moore
2015/0304354 A1 10/2015 Rogers et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2015/0334125	A1	11/2015	Bartos et al.
2015/0350229	A1	12/2015	Mitchell
2015/0373043	A1	12/2015	Wang et al.

FOREIGN PATENT DOCUMENTS

CA	2600236	A1	10/2006
EP	1006701	A2	6/2000
EP	1313290	A1	5/2003
EP	1484884	A2	12/2004
EP	1677484	A2	7/2006
EP	2385676	A1	11/2011
EP	2498442	A1	9/2012
EP	1864226	B1	5/2013
KR	20010079361	A	8/2001
WO	2005046145	A1	5/2005
WO	2006093557	A2	9/2006
WO	2006105093	A2	10/2006
WO	2007109541	A2	9/2007
WO	2011038420	A2	3/2011
WO	2012146265	A1	11/2012

OTHER PUBLICATIONS

ISR for PCT/US2013/057502, dated Nov. 7, 2013.
International Search Report off International Application No. PCT/US2014/023286, dated Jun. 24, 2014.
ISR off International Application No. PCT/US2013/072566, dated Mar. 24, 2014.
ISR off International Application No. PCT/US2014/027723, dated Jun. 26, 2014.
"Control Plane Policing Implementation Best Practices"; Cisco Systems; Mar. 13, 2013; <https://web.archive.org/web/20130313135143/http:www.cisco.com/web/about/security/intelligence/coppwp_gs.html>.
Reumann, John; "Adaptive Packet Filters"; IEEE, 2001, Department of Electrical Engineering and Computer Science, the University of Michigan, Ann Arbor, MI.
Greenwald, Michael; "Designing an Academic Firewall: Policy, Practice, and Experience with SURF"; IEEE, Proceedings of SNDSS, 1996.
Mizuno et al., A New Remote Configurable Firewall System for Home-use Gateways, Jan. 2005. Second IEEE Consumer Communications and Networking Conference, pp. 599-601.
"SBIR Case Study: Centripetal Networks Subtitle: How CNI Leveraged DHS S&T SBIR Funding to Launch a Successful Cyber Security Division 2012 Principal Investigators' Meeting"; Sean Moore, Oct. 10, 2014.
John Kindervag; "Build Security Into Your Network's DNA: The Zero Trust Network Architecture", Forrester Research Inc.; Nov. 5, 2010, pp. 1-26.
Palo Alto Networks; "Designing a Zero Trust Network With Next-Generation Firewalls"; pp. 1-10; last viewed on Oct. 21, 2012.
Jan. 11, 2016—(US) Non Final Rejection—U.S. Appl. No. 14/698,560.
Apr. 27, 2011—(WO) International Search Report and Written Opinion—App PCT/US2010/054520.
Mar. 4, 2011—(US) Notice of Allowance—U.S. Appl. No. 11/316,331.
Mar 3, 2011—(EP) Communication Pursuant to Rules 70(2) and 70a(2)—App 06758213.0.
Feb. 14, 2011—(EP) Search Report—App 06758213.0.
Fulp, Errin: "Errin Fulp," XP002618346, www.cs.wfu.edu/fulp/ewfPub.html, pp. 1-5 (Copyright 2010).
Sep. 30, 2010—(US) Office Action—U.S. Appl. No. 11/390,976.
Sep. 10, 2010—(AU) Office Action—App 2006230171.
Aug. 20, 2010—(AU) Office Action—App 2005328336.
Jun. 23, 2010—(US) Final Rejection—U.S. Appl. No. 11/316,331.
Apr. 29, 2010—(US) Interview Summary—U.S. Appl. No. 11/390,976.
Mar. 26, 2010—(US) Final Rejection—U.S. Appl. No. 11/390,976.
Sep. 14, 2009 (US) Office Action—U.S. Appl. No. 11/316,331.
Jun. 24, 2009—(US) Office Action—U.S. Appl. No. 11/390,976.
Jul. 3, 2008—(WO) Written Opinion of the International Searching Authority—App PCT/US06/11291.
Aug. 31, 2007—(EP) Communication Pursuant to Rules 109 and 110—App 05857614.1.
Acharya et al, "OPTWALL: A Hierarchical Traffic-Aware Firewall," Department of Computer Science, Telecommunications Program, University of Pittsburgh, pp. 1-11 (2007).
Sep. 11, 2006—(WO) Written Opinion of the International Searching Authority—App PCT/US05/47008.
Tarsa et al., "Balancing Trie-Based Policy representations for Network Firewalls," Department of Computer Science, Wake Forest University, pp. 1-6 (2006).
Fulp, "Trie-Based Policy Representations for Network Firewalls," Proceedings of the IEEE International Symposium on Computer Communications (2005).
E. Fulp, "Optimization of Network Firewall Policies Using Ordered Sets and Directed Acyclical Graphs", Technical Report, Computer Solent Department, Wake Forest University, Jan. 2004.
E. Fulp et al., "Network Firewall Policy Tries", Technical Report, Computer Science Department, Wake Forest University, 2004.
E. Al-Shaer et al., "Modeling and Management of Firewall Policies", IEEE Transactions on Network and Service Management, 1(1): 2004.
E.W. Fulp, "Firewall Architectures for High Speed Networks", U.S. Department of Energy Grant Application, Funded Sep. 2003.
E. Al-Shaer et al., "Firewall Policy Advisor for Anomaly Discovery and Rule Editing", Proceedings of the IFIP/IEEE International Symposium on Integrated Network Management, 2003.
V.P. Ranganath, "A Set-Based Approach to Packet Classification", Proceedings of the IASTED International Conference on Parallel and Distributed Computing and Systems, 889-894, 2003.
M. Christiansen et al., "Using IDDsfor Packet Filtering", Technical Report, BRICS, Oct. 2002.
Lee et al., "Development Framework for Firewall Processors," IEEE, pp. 352-355 (2002).
L. Qui et al., "Fast Firewall Implementations for Software and Hardware-Based Routers", Proceedings of ACM Sigmetrics, Jun. 2001.
D. Eppstein et al., "Internet Packet Filter Management and Rectangle Geometry", Proceedings of the Symposium on Discrete Algorithms, 827-835, 2001.
E. Fulp, "Preventing Denial of Service Attacks on Quality of Service", Proceedings of the 2001 DARPA Information Survivability Conference and Exposition II, 2001.
S. Goddard et al., "An Unavailability Analysis of Firewall Sandwich Configurations", Proceedings of the 6th IEEE Symposium on High Assurance Systems Engineering, 2001.
G.V. Rooij, "Real Stateful TCP Packet Filtering in IP Filter", Proceedings of the 10th USENIX Security Symposium, 2001.
P. Warkhede et al., "Fast Packet Classification for Two-Dimensional Conflict-Free Filters", Proceedings of IEEE INFOCOM, 1434-1443, 2001.
D. Decasper et al., "Router Plugins: A Software Architecture for Next-Generation Routers", IEEE/ACM Transactions on Networking, 8(1): Feb. 2000.
A. Feldmann et al., "Tradeoffs for Packet Classification", Proceedings of the IEEE INFOCOM, 397-413, 2000.
X. Gan et al., "LSMAC vs. LSNAT: Scalable Cluster-based Web servers", Journal of Networks, Software Tools, and Applications, 3(3): 175-185, 2000.
A. Hari et al., "Detecting and Resolving Packet Filter Conflicts", Proceedings of IEEE INFOCOM, 1203-1212, 2000.
O. Paul et al., "A full Bandwidth ATM Firewall", Proceedings of the 6th European Symposium on Research in Computer Security ESORICS'2000, 2000.
J. Xu et al., "Design and Evaluation of a High-Performance ATM Firewall Switch and Its Applications", IEEE Journal on Selected Areas in Communications, 17(6): 1190-1200, Jun. 1999.

(56) **References Cited**

OTHER PUBLICATIONS

C. Benecke, "A Parallel Packet Screen for High Speed Networks", Proceedings of the 15th Annual Computer Security Applications Conference, 1999.
R. Funke et al., "Performance Evaluation of Firewalls in Gigabit-Networks", Proceedings of the Symposium on Performance Evaluation of Computer and Telecommunication Systems, 1999.
S. Suri et al., "Packet Filtering in High Speed Networks", Proceedings of the Symposium on Discrete Algorithms, 969-970, 1999.
J. Ellermann et al., "Firewalls for ATM Networks", Proceedings of INFOSEC'COM, 1998.
V. Srinivasan et al., "Fast and Scalable Layer Four Switching", Proceedings of ACM SIGCOMM, 191-202, 1998.
M. Degermark et al., "Small Forwarding Tables for Fast Routing Lookups", Proceedings of ACM SIGCOMM, 4-13, 1997.
S,M. Bellovin et al., "Network Firewalls", IEEE Communications Magazine, 50-57, 1994.
W.E. Leland et al., "On the Self-Similar Nature of Ethernet Traffic", IEEE Transactions on Networking, 2(1); 15, 1994.
G. Brightwell et aL, "Counting Linear Extensions is #P-Complete", Proceedings of the Twenty-Third Annual ACM Symposium on Theory of Computing, 1991.
M. Al-Suwaiyel et al., "Algorithms for Tile Compaction", ACM Transactions on Database Systems, 9(2): 243-263, Jun. 1984.
D. Corner, "Analysis of a Heuristic for Full Tile Minimization", ACM Transactions on Database Systems, 6(3): 513-537, Sep. 1981.
R.L. Graham et al., "Optimization and Approximation in Deterministic Sequencing and Scheduling: A Survey", Annals of Discrete Mathematics, 5: 287-326, 1979.
E.L. Lawler, "Sequencing Jobs to Minimize Total Weighted Completion oTime Subject to Precedence Constraints", Annals of Discrete Mathematics, 2: 75-90, 1978.
J.K. Lenstra et al., "Complexity of Scheduling Under Precedence Constraints", Operations Research, 26(1): 22-35,1978.
R. Rivest, "On Self-Organizing Sequential Search Heuristics", Communications of the ACM, 19(2): 1976.
W.E. Smith, "Various Optimizers for Single-Stage Productions", Naval Research Logistics Quarterly, 3: 59-66, 1956.
Bellion, "High Performance Packet Classification", http://www.hipac.org (Publication Date Unknown).
Oct. 18, 2011—(EP) Communication Pursuant to Article 94(3)—App 06 758 213.0.
Jun. 9, 2011—(US) Notice of Allowance—U.S. Appl. No. 11/390,976.
Jun. 26, 2012—(EP) Extended Search Report—App 05857614.1.
Jun. 9, 2012—(AU) Notice of Acceptance—App 2006230171.
Nov. 11, 2011—(AU) Second Office Action—App 2006230171.
Jan. 17, 2013—(CA) Office Action—App 2,600,236.
Jan. 16, 2013—(CA) Office Action—App 2,594,020.
Nov. 20, 2012—(EP) Communication under rule 71(3)—App 06 758 213.0.
Apr. 18, 2013—(EP) Decision to Grant a European Patent—App 06758212.0.
Aug. 25, 2011—(US) Non Final Rejection—U.S. Appl. No. 12/871,806.
Feb. 6, 2012—(US) Final Rejection—U.S. Appl. No. 12/871,806.
Aug. 7, 2012—(US) Non Final Rejection—U.S. Appl. No. 12/871,806.
Nov. 26, 2012—(US) Final Rejection—U.S. Appl. No. 12/871,806.
Apr. 4, 2013—(US) Notice of Allowance—U.S. Appl. No. 12/871,806.
Jan. 14, 2015—(EP) Extended Search Report—App 10819667.6.
May 26, 2014—(CA) Office Action—App 2010297968.
May 25, 2015—(AU) Notice of Acceptance—App 2010297968.
May 14, 2015—(US) Non Final Rejection—U.S. Appl. No. 13/940,240.
Nov. 27, 2015—(US) Final Rejection—U.S. Appl. No. 13/940,240.
Jul. 10, 2015—(WO) Communication Relating to the Results of the Partial International Search for International App—PCT/US2015/024691.
Jul. 23, 2015—(WO) International Preliminary Report on Patentability—App PCT/US2013/072566.
Jan. 28, 2016—(WO) International Search Report and Written Opinion—App PCT/US2015/062691.
International Search Report and Written Opinion for International App. No. PCT/US2015/024691, dated Sep. 16, 2015.
International Preliminary Report on Patentability for International App. No. PCT/US2013/057502, dated Apr. 28, 2015.
International Preliminary Report on Patentability for International App. No. PCT/US2014/023286, dated Sep. 15, 2015.
International Preliminary Report on Patentability for International App. No. PCT/US2014/027723, dated Sep. 15, 2015.
Dec. 22, 2015—(US) Final Office Action—U.S. Appl. No. 14/714,207.
Feb. 26, 2016—(US) Non Final Office Action—U.S. Appl. No. 14/253,992.
Nov. 2, 2015—(AU) Office Action—App 2013372879.
Apr. 26, 2016—(US) Office Action—U.S. Appl. No. 14/745,207.
May 6, 2016—(US) Office Action—U.S. Appl. No. 14/714,207.
May 13, 2016—(US) Office Action—U.S. Appl. No. 13/940,240.
Jun. 14, 2016—(US) Office Action—U.S. Appl. No. 14/625,486.
Feb. 25, 2016—(AU) Office Action—App 2014249055.
Feb. 24, 2016—(AU) Office Action—App 2014228257.
Jun. 9, 2016—(WO) International Search Report—PCT/US2016/026339.
Jun. 16, 2016—(CA) Office Action—App 2,888,935.
Jul. 11, 2016—(EP) Office Action—App 14720824.3.
Jul. 22, 2016—(US) Office Action—U.S. Appl. No. 14/921,718.
Jul. 20, 2016—(AU) Office Action—App 2013335255.
Oct. 5, 2016—(US) Notice of Allowance—U.S. Appl. No. 14/698,560.
Sep. 13, 2016—(CA) Office Action—App 2,902,206.
Sep. 14, 2016—(CA) Office Action—App 2,897,737.
Sep. 26, 2016—(CA) Office Action—App 2,902,158.
Oct. 26, 2016—(US) Office Action—U.S. Appl. No. 13/940,240.
Nov. 21, 2016—(US) Office Action—U.S. Appl. No. 14/745,207.
Dec. 5, 2016—(US) Notice of Allowance—U.S. Appl. No. 14/714,207.
Singh, Rajeev et al. "Detecting and Reducing the Denial of Service attacks in WLANs", Dec. 2011, World Congress on Information and Communication TEchnologies, pp. 968-973.
Feb. 10, 2017—(US) Notice of Allowance—U.S. Appl. No. 14/625,486.
Feb. 15, 2017—(US) Notice of Allowance—U.S. Appl. No. 14/921,718.
Mar. 6, 2017—(WO) International Search Report and Written Opinion—App PCT/US2016/068008.
Jun. 7, 2017—(US) Office Action—U.S. Appl. No. 14/745,207.
Sep. 4, 2015 (US) Notice of Allowance—U.S. Appl. No. 14/702,755.
Jun. 7, 2017—(WO) International Search Report and Written Opinion—App PCT/US2016/067111.

* cited by examiner

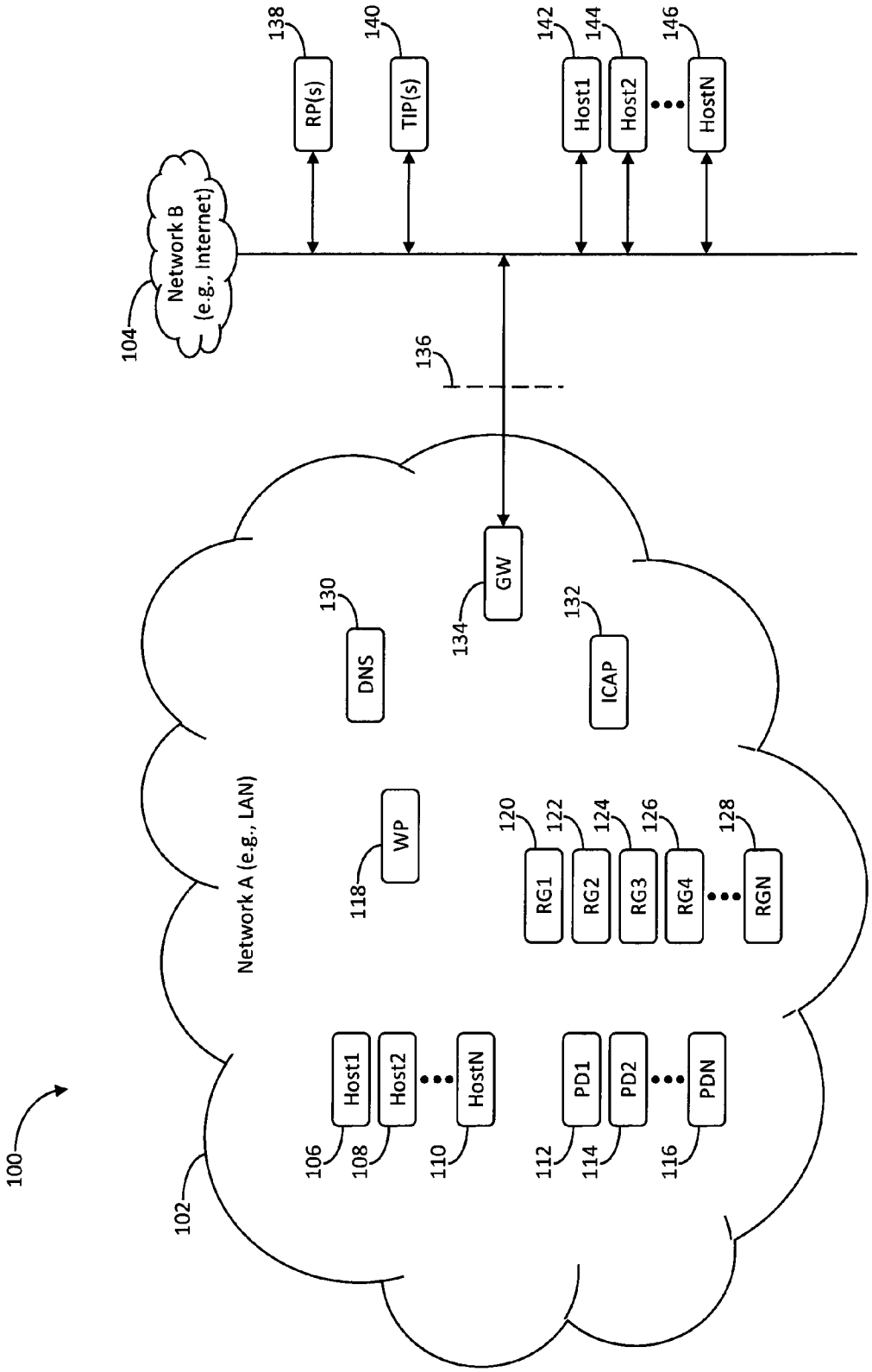

100
102
Network A (e.g., LAN)
Host1
Host2
HostN
106
108
110
PD1
PD2
PDN
112
114
116
118
WP
120
RG1
122
RG2
124
RG3
126
RG4
128
RGN
130
DNS
132
ICAP
134
GW
136
104
Network B
(e.g., Internet)
138
RP(s)
140
TIP(s)
142
Host1
144
Host2
146
HostN

FIG. 1

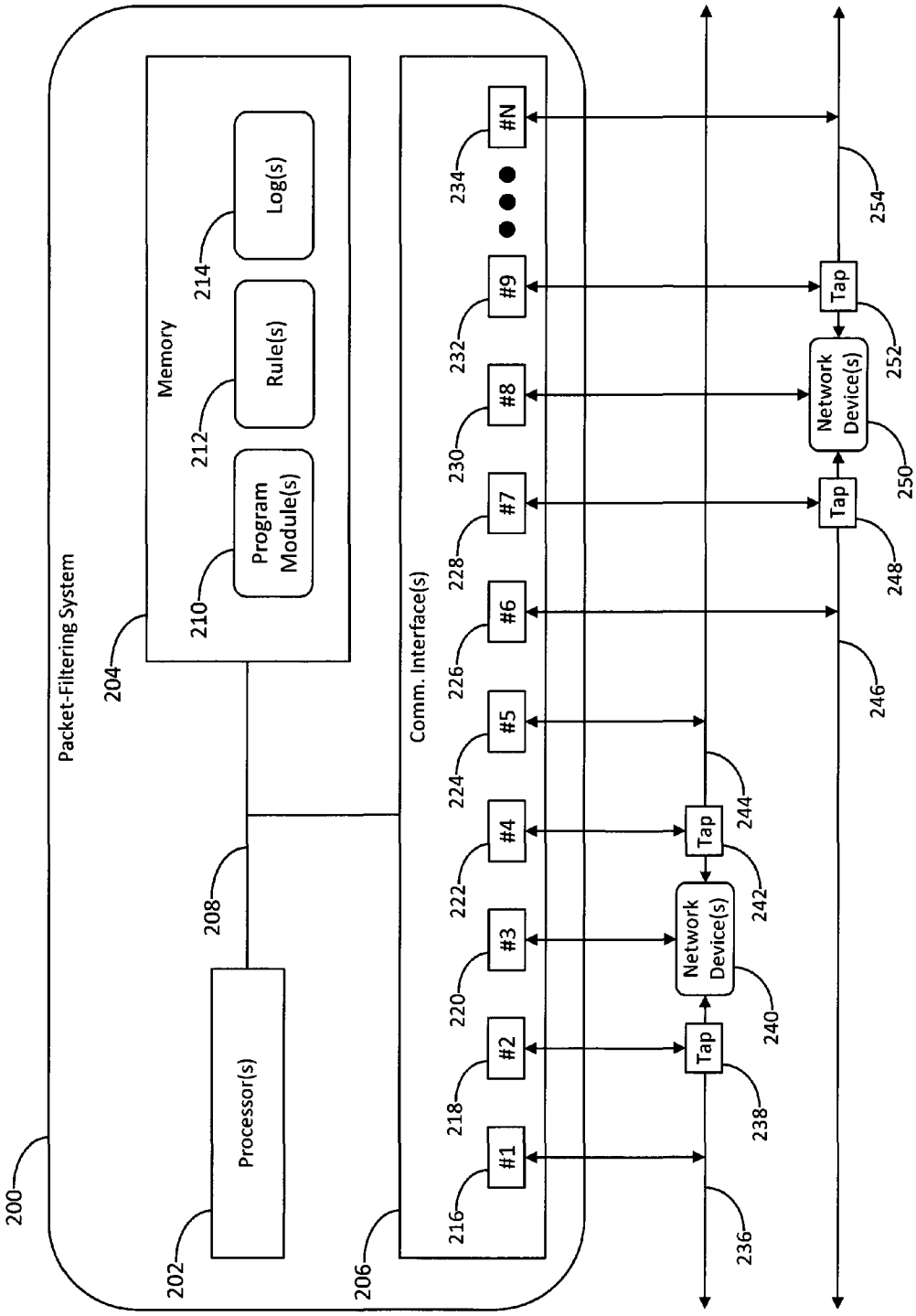

Packet-Filtering System
200
Memory
204
Program Module(s)
210
Rule(s)
212
Log(s)
214
Processor(s)
202
208
Comm. Interface(s)
206
#1
216
#2
218
#3
220
#4
222
#5
224
#6
226
#7
228
#8
230
#9
232
#N
234
Tap
238
Network Device(s)
240
Tap
242
236
244
Tap
248
Network Device(s)
250
Tap
252
246
254

FIG. 2

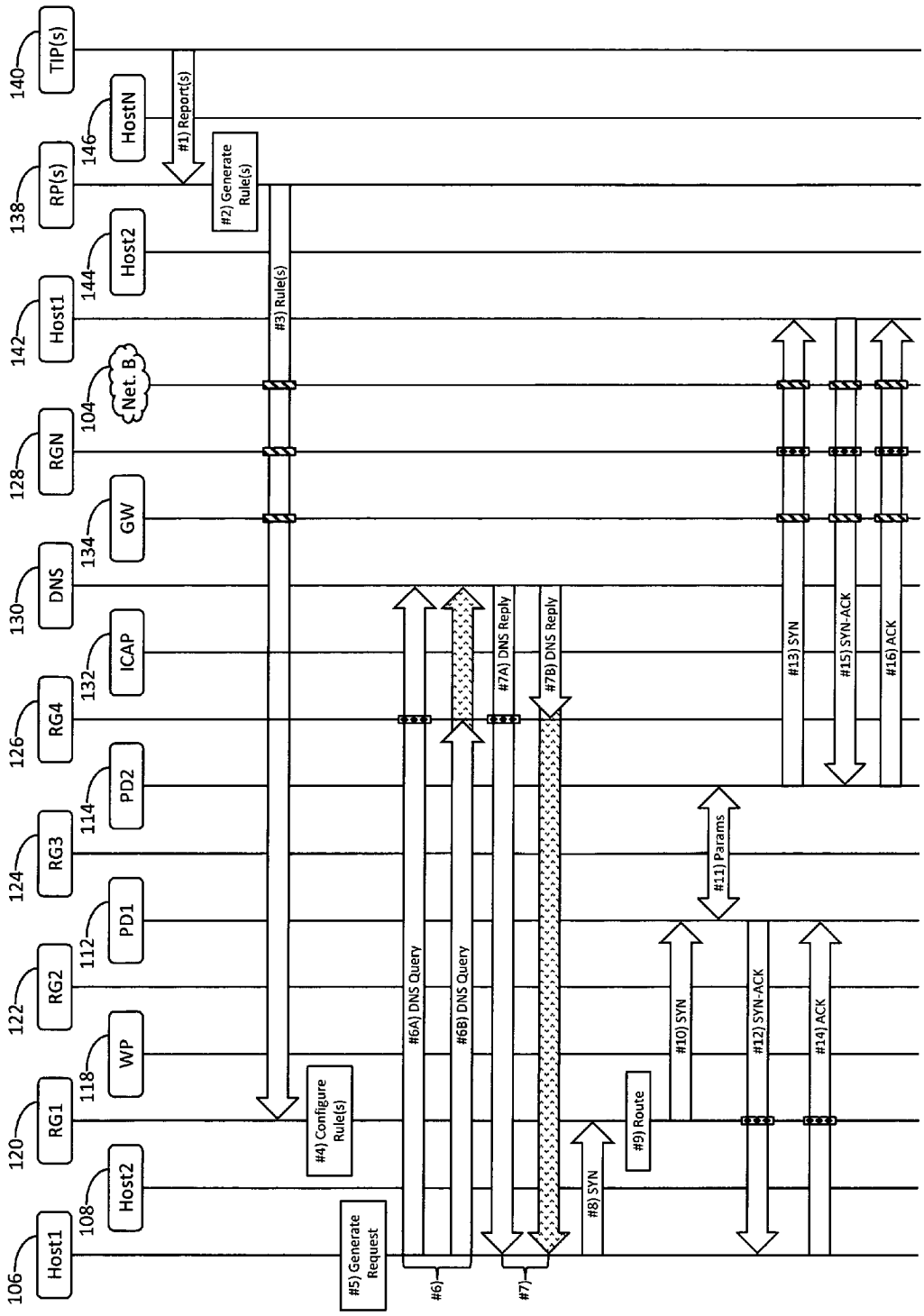

106 Host1
108 Host2
120 RG1
118 WP
122 RG2
112 PD1
124 RG3
114 PD2
126 RG4
132 ICAP
130 DNS
134 GW
128 RGN
104 Net. B
142 Host1
144 Host2
138 RP(s)
146 HostN
140 TIP(s)
#1) Report(s)
#2) Generate Rule(s)
#3) Rule(s)
#4) Configure Rule(s)
#5) Generate Request
#6) DNS Query
#6B) DNS Query
#7A) DNS Reply
#7B) DNS Reply
#8) SYN
#9) Route
#10) SYN
#11) Params
#12) SYN-ACK
#13) SYN
#14) ACK
#15) SYN-ACK
#16) ACK

FIG. 3A

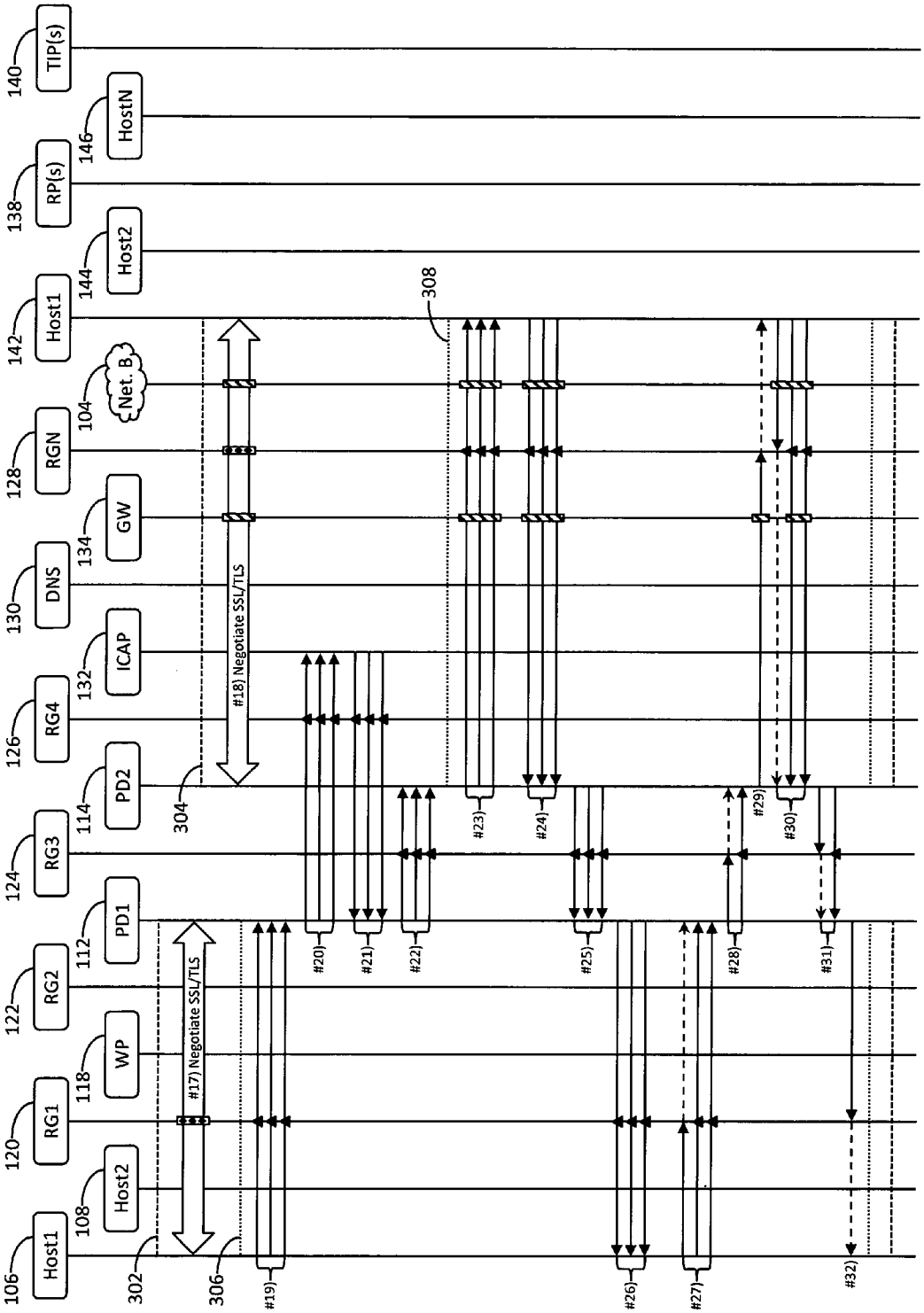

106 Host1
108 Host2
120 RG1
118 WP
122 RG2
112 PD1
124 RG3
114 PD2
126 RG4
132 ICAP
130 DNS
134 GW
128 RGN
104 Net. B
142 Host1
144 Host2
138 RP(s)
146 HostN
140 TIP(s)
302
304
306
308
#17) Negotiate SSL/TLS
#18) Negotiate SSL/TLS
#19)
#20)
#21)
#22)
#23)
#24)
#25)
#26)
#27)
#28)
#29)
#30)
#31)
#32)

FIG. 3B

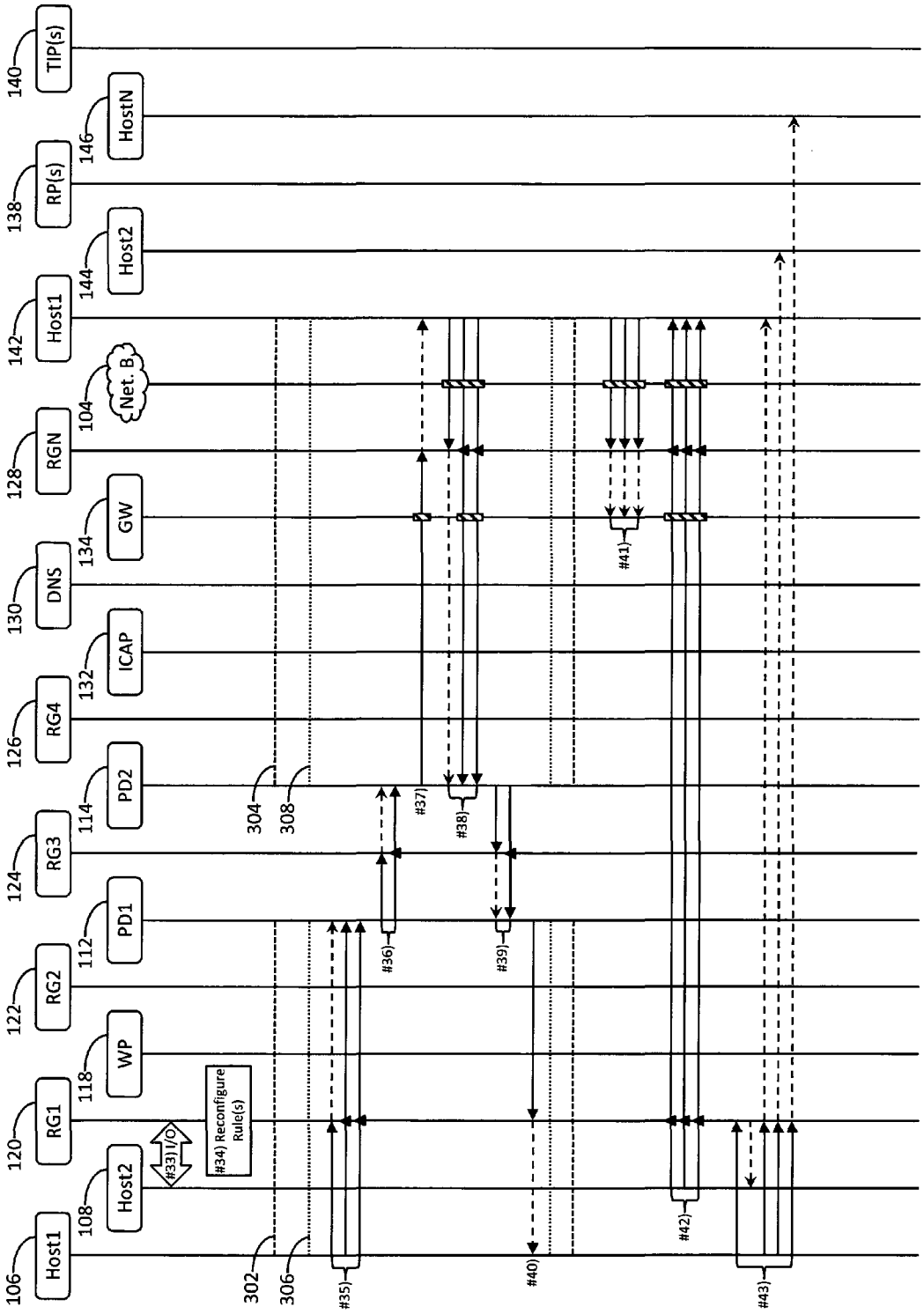

106 Host1
108 Host2
120 RG1
122 RG2
124 RG3
126 RG4
130 DNS
128 RGN
142 Host1
138 RP(s)
140 TIP(s)
118 WP
112 PD1
114 PD2
132 ICAP
134 GW
104 Net. B
144 Host2
146 HostN
#33) I/O
#34) Reconfigure Rule(s)
302
304
306
308
#35)
#36)
#37)
#38)
#39)
#40)
#41)
#42)
#43)

FIG. 3C

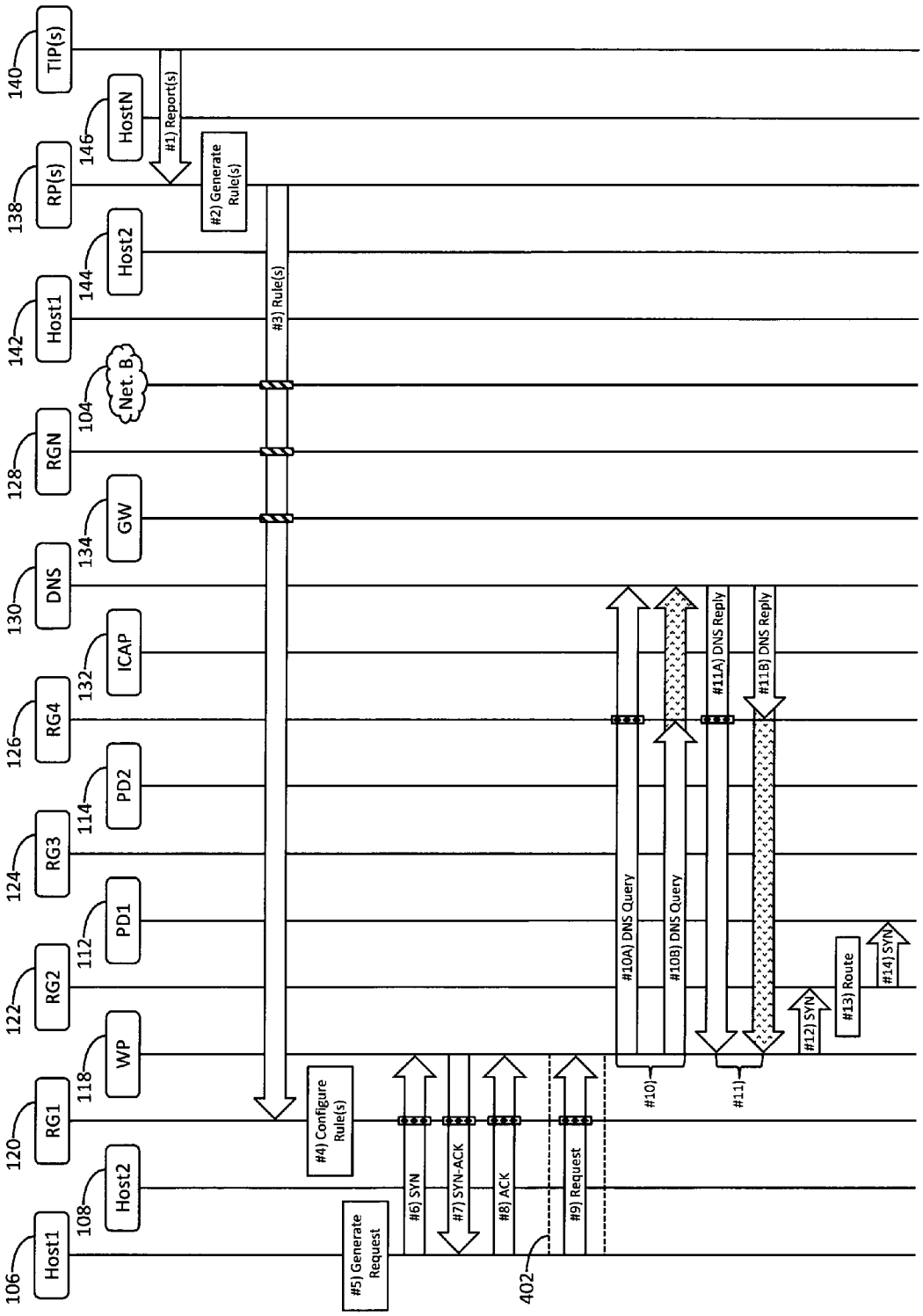

TIP(s)
140
HostN
146
RP(s)
138
Host2
144
Host1
142
Net. B
104
RGN
128
GW
134
DNS
130
ICAP
132
RG4
126
PD2
114
RG3
124
PD1
112
RG2
122
WP
118
RG1
120
Host2
108
Host1
106
#1) Report(s)
#2) Generate Rule(s)
#3) Rule(s)
#4) Configure Rule(s)
#5) Generate Request
#6) SYN
#7) SYN-ACK
#8) ACK
#9) Request
402
#10A) DNS Query
#10B) DNS Query
#10)
#11A) DNS Reply
#11B) DNS Reply
#11)
#12) SYN
#13) Route
#14) SYN

FIG. 4A

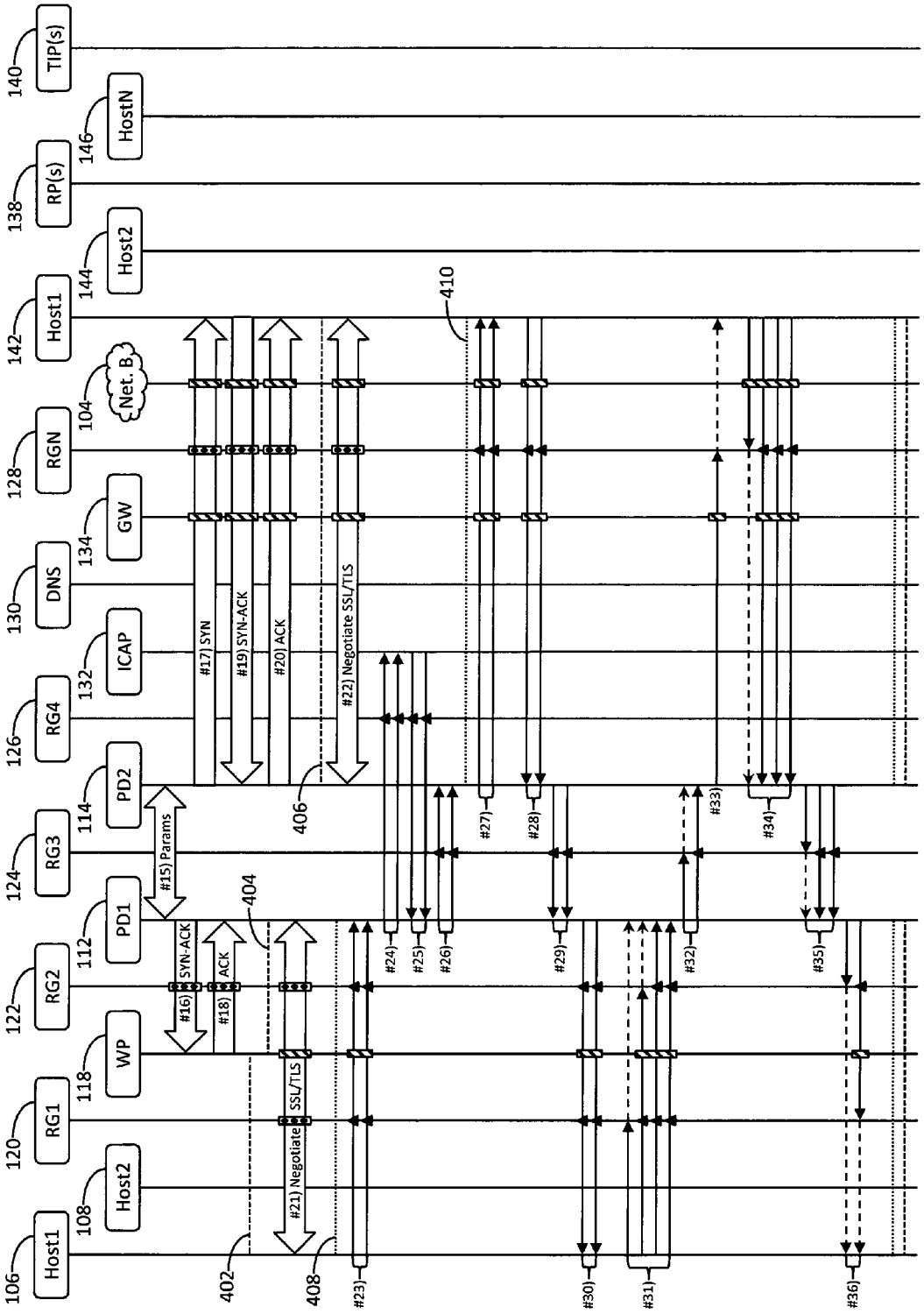

106 Host1
108 Host2
120 RG1
118 WP
122 RG2
112 PD1
124 RG3
114 PD2
126 RG4
132 ICAP
130 DNS
134 GW
128 RGN
104 Net. B
142 Host1
144 Host2
138 RP(s)
146 HostN
140 TIP(s)
#15) Params
#16) SYN-ACK
#17) SYN
#18) ACK
#19) SYN-ACK
#20) ACK
#21) Negotiate SSL/TLS
#22) Negotiate SSL/TLS
#23)
#24)
#25)
#26)
#27)
#28)
#29)
#30)
#31)
#32)
#33)
#34)
#35)
#36)
402
404
406
408
410

FIG. 4B

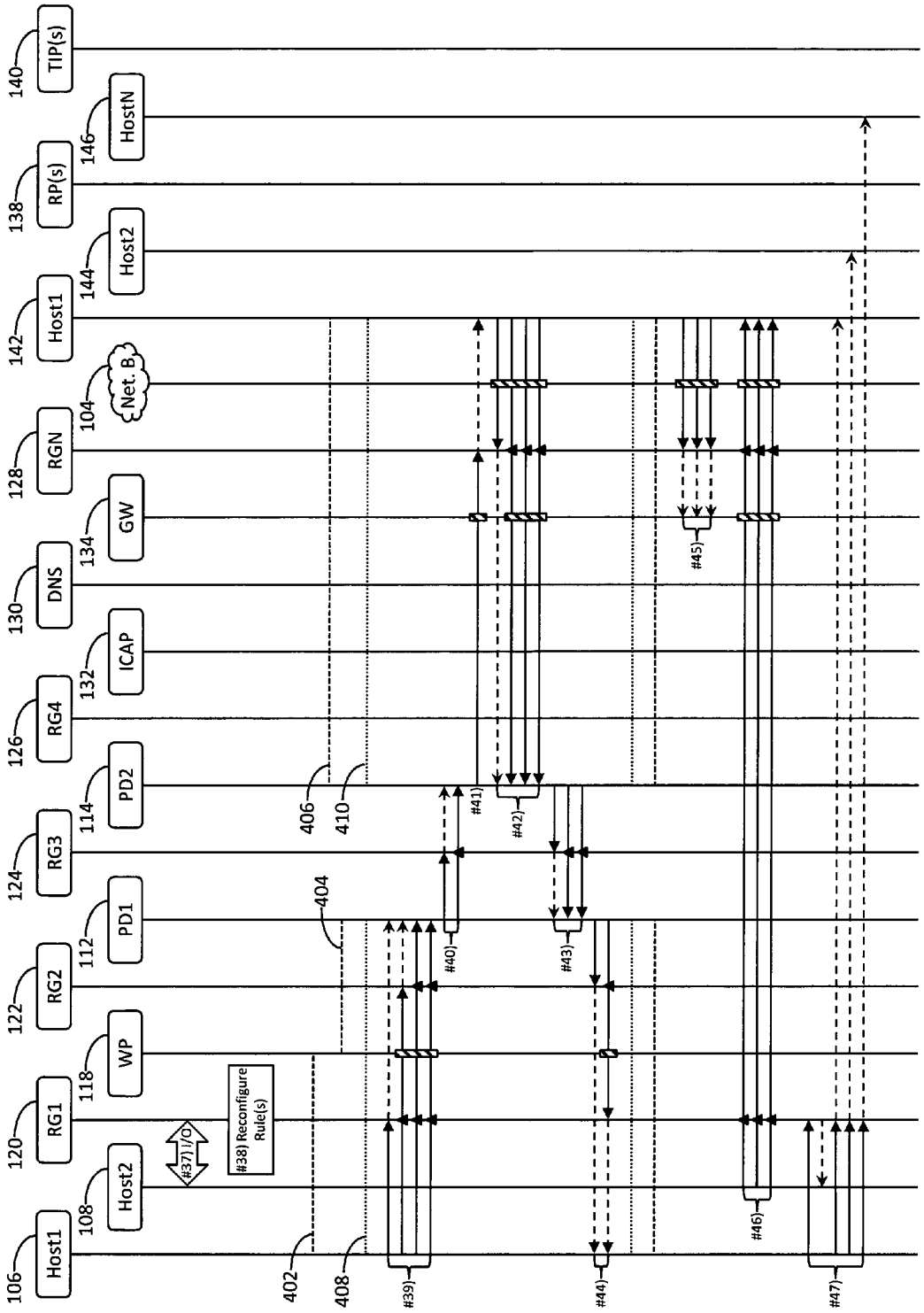

106 Host1
108 Host2
120 RG1
118 WP
122 RG2
112 PD1
124 RG3
114 PD2
126 RG4
132 ICAP
130 DNS
134 GW
128 RGN
104 Net. B
142 Host1
144 Host2
138 RP(s)
146 HostN
140 TIP(s)
#37) I/O
#38) Reconfigure Rule(s)
402
404
406
408
410
#39)
#40)
#41)
#42)
#43)
#44)
#45)
#46)
#47)

FIG. 4C

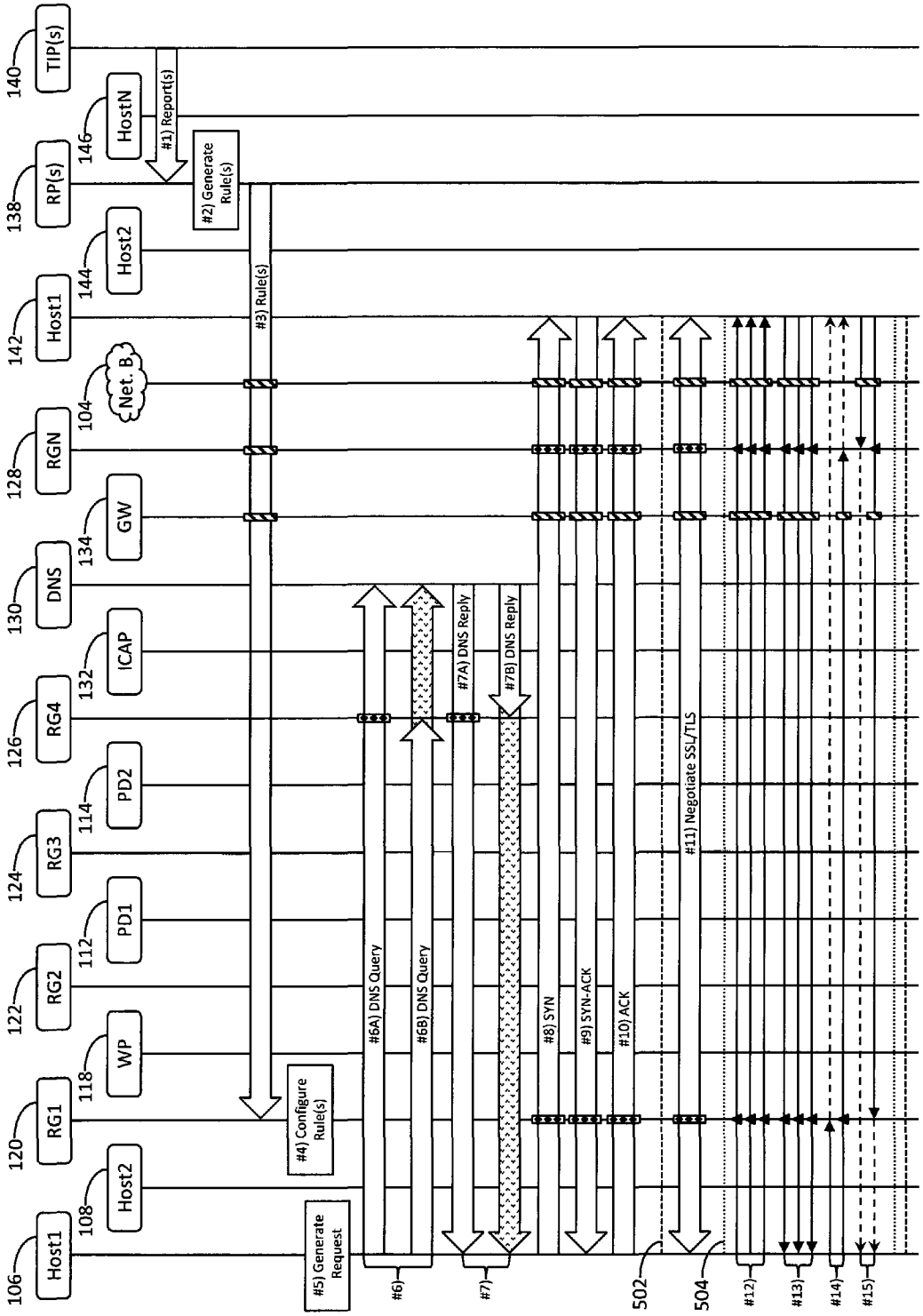

106 Host1
108 Host2
120 RG1
118 WP
122 RG2
112 PD1
124 RG3
114 PD2
126 RG4
132 ICAP
130 DNS
134 GW
128 RGN
104 Net. B
142 Host1
144 Host2
138 RP(s)
146 HostN
140 TIP(s)
#1) Report(s)
#2) Generate Rule(s)
#3) Rule(s)
#4) Configure Rule(s)
#5) Generate Request
#6A) DNS Query
#6B) DNS Query
#7A) DNS Reply
#7B) DNS Reply
#8) SYN
#9) SYN-ACK
#10) ACK
#11) Negotiate SSL/TLS
#6)
#7)
502
504
#12)
#13)
#14)
#15)

FIG. 5A

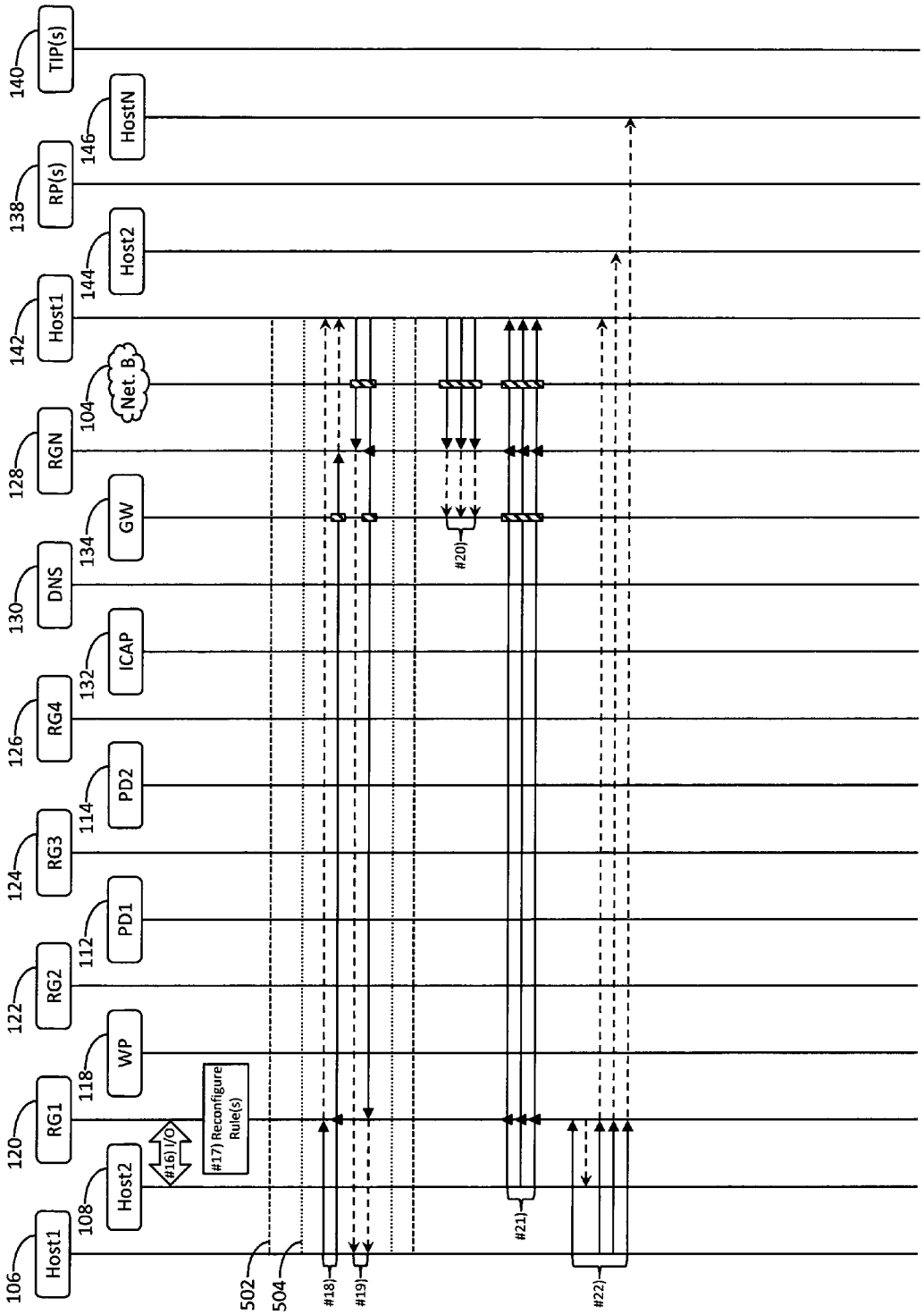

106 Host1
108 Host2
120 RG1
122 RG2
124 RG3
126 RG4
130 DNS
128 RGN
142 Host1
138 RP(s)
140 TIP(s)
118 WP
112 PD1
114 PD2
132 ICAP
134 GW
104 Net. B
144 Host2
146 HostN
#16) I/O
#17) Reconfigure Rule(s)
502
504
#18)
#19)
#20)
#21)
#22)

FIG. 5B

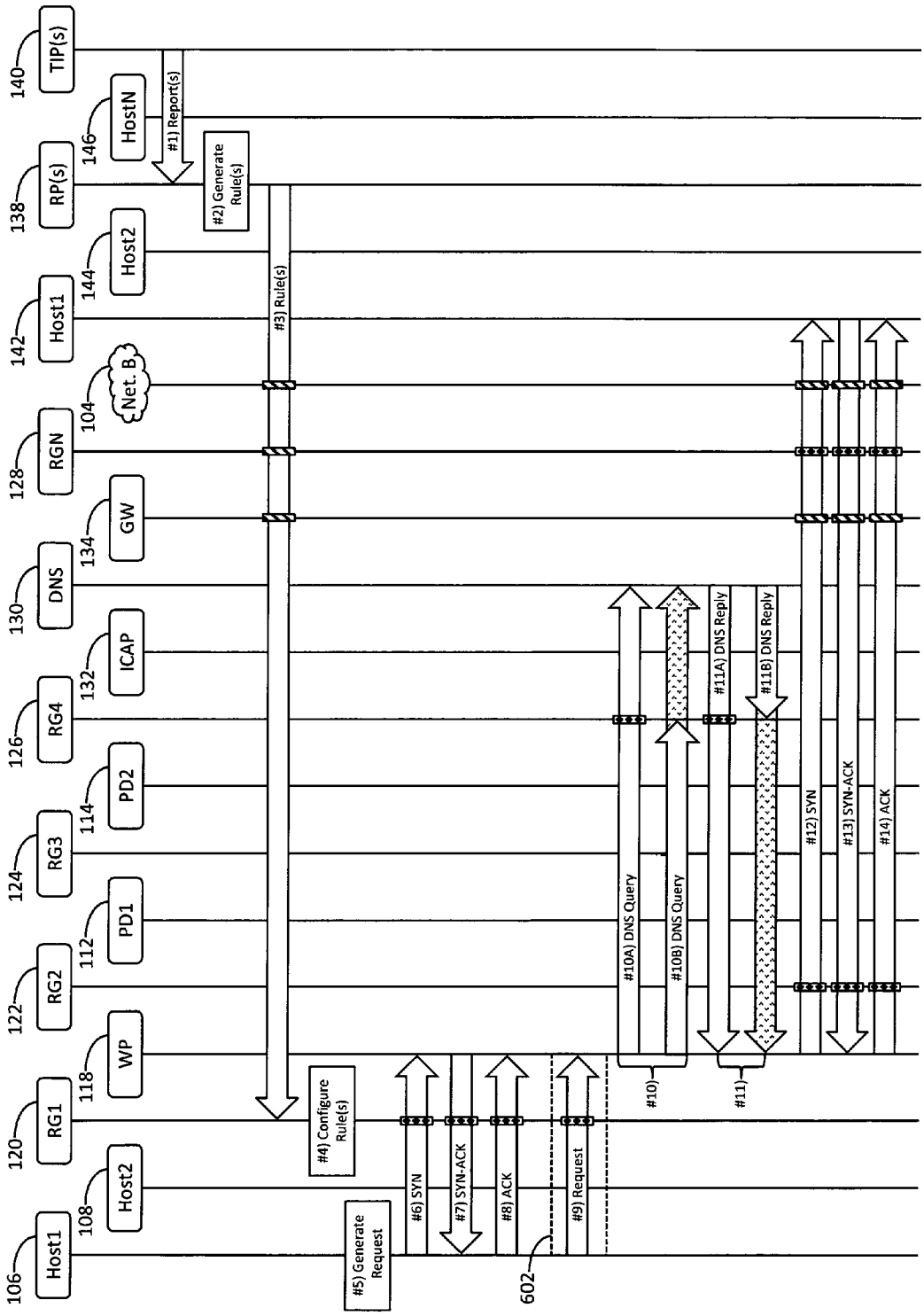

TIP(s)
140
HostN
146
#1) Report(s)
RP(s)
138
#2) Generate Rule(s)
Host2
144
#3) Rule(s)
Host1
142
Net. B
104
RGN
128
GW
134
DNS
130
ICAP
132
RG4
126
PD2
114
RG3
124
PD1
112
RG2
122
WP
118
RG1
120
Host2
108
Host1
106
#4) Configure Rule(s)
#5) Generate Request
#6) SYN
#7) SYN-ACK
#8) ACK
#9) Request
602
#10A) DNS Query
#10B) DNS Query
#10)
#11A) DNS Reply
#11B) DNS Reply
#11)
#12) SYN
#13) SYN-ACK
#14) ACK

FIG. 6A

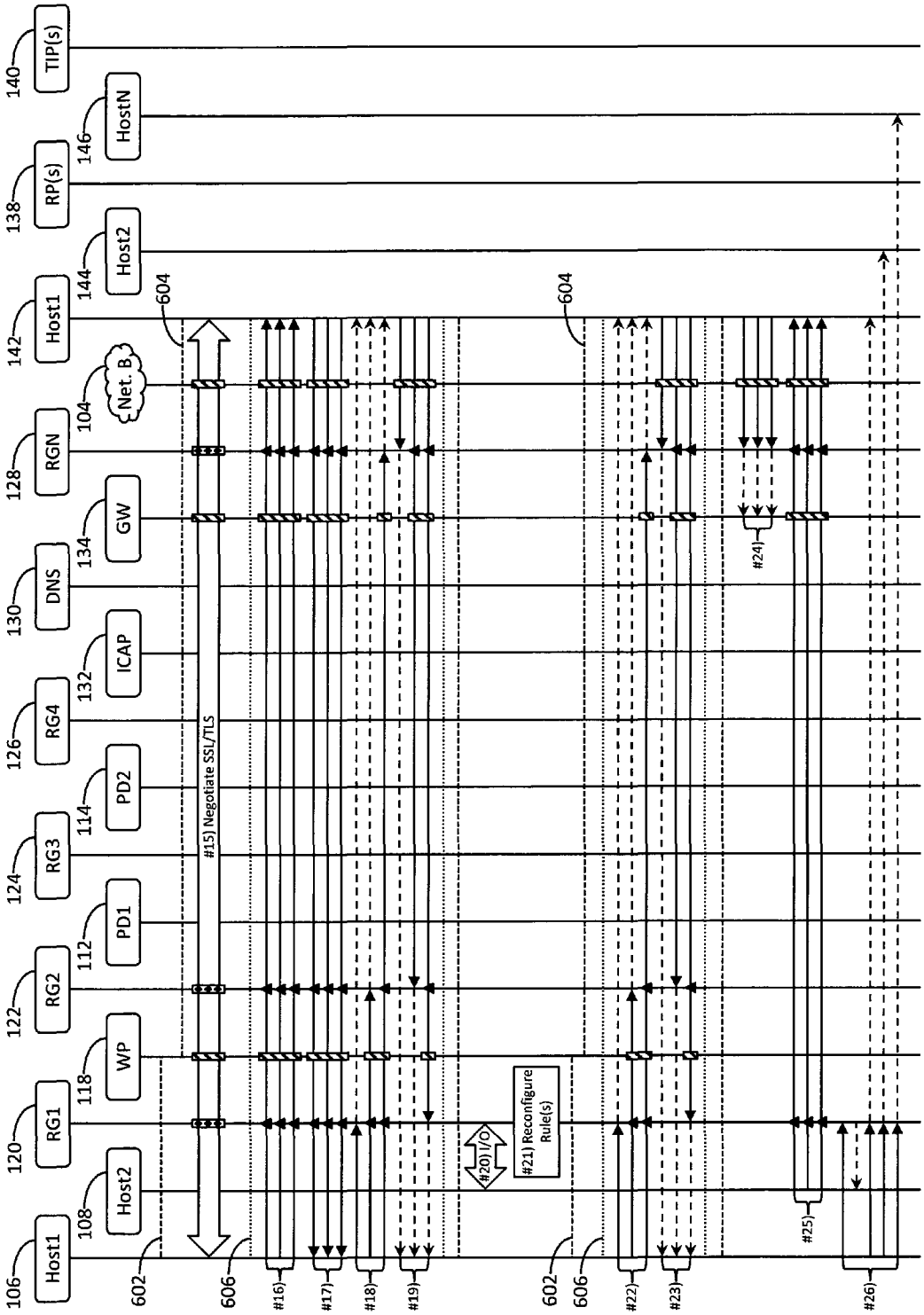

106 Host1
108 Host2
120 RG1
118 WP
122 RG2
112 PD1
124 RG3
114 PD2
126 RG4
132 ICAP
130 DNS
134 GW
128 RGN
104 Net. B
142 Host1
144 Host2
138 RP(s)
146 HostN
140 TIP(s)
602
604
606
#15) Negotiate SSL/TLS
#16)
#17)
#18)
#19)
#20) I/O
#21) Reconfigure Rule(s)
#22)
#23)
#24)
#25)
#26)

FIG. 6B

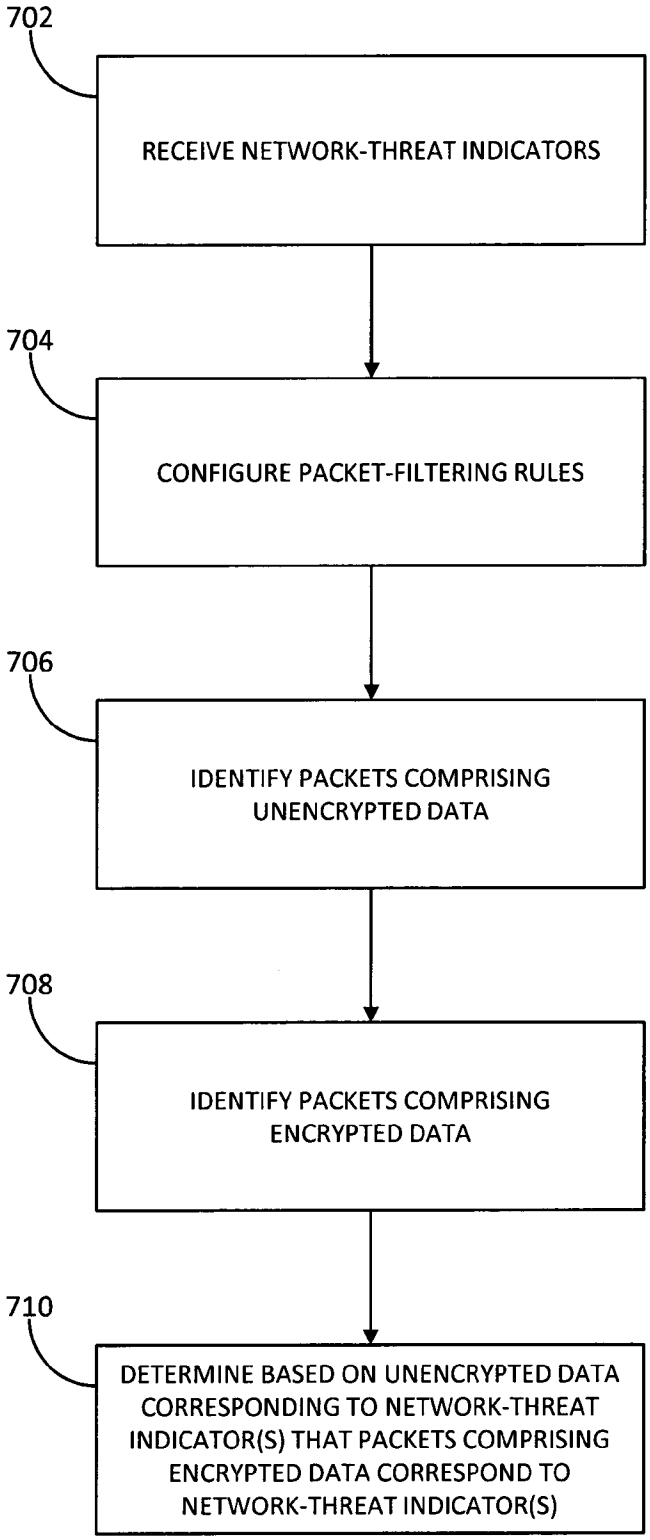

702
RECEIVE NETWORK-THREAT INDICATORS
704
CONFIGURE PACKET-FILTERING RULES
706
IDENTIFY PACKETS COMPRISING UNENCRYPTED DATA
708
IDENTIFY PACKETS COMPRISING ENCRYPTED DATA
710
DETERMINE BASED ON UNENCRYPTED DATA CORRESPONDING TO NETWORK-THREAT INDICATOR(S) THAT PACKETS COMPRISING ENCRYPTED DATA CORRESPOND TO NETWORK-THREAT INDICATOR(S)

FIG. 7

RULE-BASED NETWORK-THREAT DETECTION FOR ENCRYPTED COMMUNICATIONS

BACKGROUND

Network security is becoming increasingly important as the information age continues to unfold. Network threats may take a variety of forms (e.g., unauthorized requests or data transfers, viruses, malware, large volumes of traffic designed to overwhelm resources, and the like). Network-threat services provide information associated with network threats, for example, reports that include listings of network-threat indicators (e.g., network addresses, domain names, uniform resource identifiers (URIs), and the like). Such information may be utilized to identify network threats. Encrypted communications, however, may obfuscate data corresponding to network threats. Accordingly, there is a need for rule-based network-threat detection for encrypted communications.

SUMMARY

The following presents a simplified summary in order to provide a basic understanding of some aspects of the disclosure. It is intended neither to identify key or critical elements of the disclosure nor to delineate the scope of the disclosure. The following summary merely presents some concepts of the disclosure in a simplified form as a prelude to the description below.

Aspects of this disclosure relate to rule-based network-threat detection for encrypted communications. In accordance with embodiments of the disclosure, a packet-filtering system configured to filter packets in accordance with packet-filtering rules may receive data indicating network-threat indicators and may configure the packet-filtering rules to cause the packet-filtering system to identify packets comprising unencrypted data, and packets comprising encrypted data. A portion of the unencrypted data may correspond to one or more of the network-threat indicators, and the packet-filtering rules may be configured to cause the packet-filtering system to determine, based on the portion of the unencrypted data, that the packets comprising encrypted data correspond to the one or more network-threat indicators.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure is pointed out with particularity in the appended claims. Features of the disclosure will become more apparent upon a review of this disclosure in its entirety, including the drawing figures provided herewith.

Some features herein are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings, in which like reference numerals refer to similar elements, and wherein:

FIG. **1** depicts an illustrative environment for rule-based network-threat detection for encrypted communications in accordance with one or more aspects of the disclosure;

FIG. **2** depicts an illustrative packet-filtering system for rule-based network-threat detection for encrypted communications in accordance with one or more aspects of the disclosure;

FIGS. **3**A-C, **4**A-C, **5**A-B, and **6**A-B depict illustrative event sequences for rule-based network-threat detection for encrypted communications in accordance with one or more aspects of the disclosure; and

FIG. **7** depicts an illustrative method for rule-based network-threat detection for encrypted communications in accordance with one or more aspects of the disclosure.

DETAILED DESCRIPTION

In the following description of various illustrative embodiments, reference is made to the accompanying drawings, which form a part hereof, and in which is shown, by way of illustration, various embodiments in which aspects of the disclosure may be practiced. It is to be understood that other embodiments may be utilized, and structural and functional modifications may be made, without departing from the scope of the disclosure.

Various connections between elements are discussed in the following description. These connections are general and, unless specified otherwise, may be direct or indirect, wired or wireless. In this respect, the specification is not intended to be limiting.

FIG. **1** depicts an illustrative environment for rule-based network-threat detection for encrypted communications in accordance with one or more aspects of the disclosure. Referring to FIG. **1**, environment **100** may include networks **102** and **104**. Network **102** may comprise one or more networks (e.g., Local Area Networks (LANs), Wide Area Networks (WANs), Virtual Private Networks (VPNs), or combinations thereof) associated with one or more individuals or entities (e.g., governments, corporations, service providers, or other organizations). Network **104** may comprise one or more networks (e.g., LANs, WANs, VPNs, or combinations thereof) that interface network **102** with one or more other networks (not illustrated). For example, network **104** may comprise the Internet, a similar network, or portions thereof.

Environment **100** may also include one or more hosts, such as computing or network devices (e.g., servers, desktop computers, laptop computers, tablet computers, mobile devices, smartphones, routers, gateways, firewalls, switches, access points, or the like). For example, network **102** may include hosts **106**, **108**, and **110**, proxy devices **112**, **114**, and **116**, web proxy **118**, rule gates **120**, **122**, **124**, **126**, and **128**, domain name system (DNS) **130**, Internet content adaptation protocol (ICAP) server **132**, and gateway **134**. As used herein, "host" (or "hosts") refers to any type of network device (or node) or computing device; while such devices may be assigned (or configured to be assigned) one or more network-layer addresses, the term "host" (or "hosts") does not imply such devices necessarily are assigned (or configured to be assigned) one or more network-layer addresses.

Gateway **134** may be located at border **136** between networks **102** and **104** and may interface network **102** or one or more hosts located therein with network **104** or one or more hosts located therein. For example, network **104** may include one or more rule providers **138**, one or more threat-intelligence providers **140**, and hosts **142**, **144**, and **146**, and gateway **134** may interface hosts **106**, **108**, and **110**, proxy devices **112**, **114**, and **116**, web proxy **118**, rule gates **120**, **122**, **124**, **126**, and **128**, DNS **130**, and ICAP server **132** with rule providers **138**, threat-intelligence providers **140**, and hosts **142**, **144**, and **146**.

FIG. **2** depicts an illustrative packet-filtering system for rule-based network-threat detection for encrypted communications in accordance with one or more aspects of the disclosure. Referring to FIG. **2**, packet-filtering system **200** may be associated with network **102** and may include one or more of rule gates **120**, **122**, **124**, **126**, and **128**. Packet-filtering system **200** may comprise one or more processors

202, memory 204, one or more communication interfaces 206, and data bus 208. Data bus 208 may interface processors 202, memory 204, and communication interfaces 206. Memory 204 may comprise one or more program modules 210, rules 212, and logs 214. Program modules 210 may comprise instructions that when executed by processors 202 cause packet-filtering system 200 to perform one or more of the functions described herein. Rules 212 may comprise one or more packet-filtering rules in accordance with which packet-filtering system 200 is configured to filter packets received via communication interfaces 206. Logs 214 may include one or more entries generated by processors 202 in accordance with rules 212 for packets received by packet-filtering system 200 via communication interfaces 206.

Communication interfaces 206 may interface packet-filtering system 200 with one or more communication links of environment 100 (e.g., of networks 102 and 104). In some embodiments, one or more of communication interfaces 206 may interface directly with a communication link of environment 100. For example, interfaces 216 and 224 may interface directly with links 236 and 244, respectively. In some embodiments, one or more of communication interfaces 206 may interface indirectly with a communication link of environment 100. For example, interface 220 may interface with links 236 and 244 via one or more network devices 240. Network devices 240 may provide interface 220 with access to (or copies of) packets traversing one or more of links 236 and 244, for example, via a switched port analyzer (SPAN) port of network devices 240. Additionally or alternatively, interfaces 218 and 222 may interface with links 236 and 244 via tap devices 238 and 242. For example, packet-filtering system 200 may provision tap device 238 with one or more of rules 212 configured to cause tap device 238 to identify packets traversing link 236 that correspond to specified criteria and route (or forward) the packets (or copies thereof) to interface 218, and packet-filtering system 200 may provision tap device 242 with one or more of rules 212 configured to cause tap device 242 to identify packets traversing link 244 that correspond to specified criteria and route (or forward) the packets (or copies thereof) to interface 222. Similarly, interfaces 226 and 234 may interface directly with links 246 and 254, respectively; network devices 250 may provide interface 230 with access to (or copies of) packets traversing one or more of links 246 and 254; packet-filtering system 200 may provision tap device 248 with one or more of rules 212 configured to cause tap device 248 to identify packets traversing link 246 that correspond to specified criteria and route (or forward) the packets (or copies thereof) to interface 228; and packet-filtering system 200 may provision tap device 252 with one or more of rules 212 configured to cause tap device 252 to identify packets traversing link 254 that correspond to specified criteria and route (or forward) the packets (or copies thereof) to interface 232. In some embodiments, packet-filtering system 200 may comprise one or more of tap devices 238, 242, 248, and 252 or network devices 240 and 250.

FIGS. 3A-C, 4A-C, 5A-B, and 6A-B depict illustrative event sequences for rule-based network-threat detection for encrypted communications in accordance with one or more aspects of the disclosure. The depicted steps are merely illustrative and may be omitted, combined, or performed in an order other than that depicted; the numbering of the steps is merely for ease of reference and does not imply any particular ordering is necessary or preferred.

Referring to FIG. 3A, at step #1, threat-intelligence providers 140 may communicate one or more threat-intelligence reports to rule providers 138. The threat-intelligence reports may include one or more network-threat indicators, for example, domain names (e.g., fully qualified domain names (FQDNs)), URIs, network addresses, or the like. At step #2, rule providers 138 may utilize the threat-intelligence reports to generate one or more packet-filtering rules configured to identify packets comprising data corresponding to the network-threat indicators. At step #3, rule providers 138 may communicate the packet-filtering rules to rule gate 120. As indicated by the crosshatched boxes over the lines extending downward from network 104, rule gate 128, and gateway 134, the packet-filtering rules may traverse network 104, rule gate 128, and gateway 134. For example, network 104 and gateway 134 may interface rule providers 138 and rule gate 120, and rule gate 128 may interface a communication link interfacing network 104 and gateway 134. Rule gate 120 may receive the packet-filtering rules generated by rule providers 138 and, at step #4, may utilize the received packet-filtering rules to configure rules 212 to cause packet-filtering system 200 to identify packets comprising data corresponding to at least one of the plurality of network-threat indicators.

At step #5, host 106 may generate a request. For example, host 106 may execute a web browser, and the web browser may generate a request in response to user input (e.g., navigation of the web browser to a URI). The request may comprise a domain name, and host 106 may generate a DNS query comprising the domain name and, at step #6, may communicate the DNS query toward DNS 130. Rule gate 126 may interface a communication link interfacing host 106 and DNS 130, the domain name included in the request may correspond to one or more of the network-threat indicators, and rules 212 may be configured to cause rule gate 126 to one or more of identify one or more packets comprising the DNS query, determine that the packets comprise the domain name corresponding to the network-threat indicators, and responsive to one or more of identifying the packets or determining that the packets comprise the domain name corresponding to the network-threat indicators, one or more of log (as indicated by the diamond-patterned box over the line extending downward from rule gate 126) or drop the packets. Rule gate 126 may generate log data (e.g., one or more entries in logs 214) for the packets. For example, the packets may comprise a network address of host 106 (e.g., as a source address in their network-layer headers), and rule gate 126 may generate log data indicating the network address of host 106. As depicted by step #6A, the packets may be communicated to DNS 130. In some embodiments, rules 212 may be configured to cause rule gate 126 to, responsive to one or more of identifying the packets or determining that the packets comprise the domain name corresponding to the network-threat indicators, drop the packets, preventing them from reaching DNS 130, as depicted by step #6B.

DNS 130 may generate a reply to the DNS query and, at step #7, may communicate the reply toward host 106. The reply may comprise the domain name corresponding to the network-threat indicators, and rules 212 may be configured to cause rule gate 126 to one or more of identify one or more packets comprising the reply, determine that the packets comprise the domain name corresponding to the network-threat indicators, and responsive to one or more of identifying the packets or determining that the packets comprise the domain name corresponding to the network-threat indicators, one or more of log or drop the packets. Rule gate 126 may generate log data (e.g., one or more entries in logs 214) for the packets. For example, the packets may comprise the network address of host 106 (e.g., as a destination address in

their network-layer headers), and rule gate **126** may generate log data indicating the network address of host **106**. Similarly, the domain name may correspond to host **142**, the packets may comprise a network address of host **142** (e.g., DNS **130** may have resolved the domain name included in the query to the network address of host **142**), and rule gate **126** may generate log data indicating the network address of host **142**. As depicted by step #7A, the packets may be communicated to host **106**. In some embodiments, rules **212** may be configured to cause rule gate **126** to, responsive to determining that the packets comprise the domain name corresponding to the network-threat indicators, drop the packets, preventing them from reaching host **106**, as depicted by step #7B.

Packet-filtering system **200** may be configured to correlate packets identified by packet-filtering system **200** (e.g., the packets comprising the reply to the DNS query) with packets previously identified by packet-filtering system **200** (e.g., the packets comprising the DNS query). For example, packet-filtering system **200** may be configured to determine that packets identified by packet-filtering system **200** (e.g., the packets comprising the reply to the DNS query) are one or more of associated with, related to, or the product of packets previously identified by packet-filtering system **200** (e.g., the packets comprising the DNS query). Packet-filtering system **200** may be configured to correlate packets identified by packet-filtering system **200** with packets previously identified by packet-filtering system **200** based on data stored in logs **214** (e.g., the log data generated by rule gate **126** in steps #**6** and #**7**).

For example, for one or more packets logged by packet-filtering system **200** (e.g., the packets comprising the DNS query or the packets comprising the reply to the DNS query), logs **214** may comprise one or more entries indicating one or more of network-layer information (e.g., information derived from one or more network-layer header fields of the packets, such as a protocol type, a destination network address, a source network address, a signature or authentication information (e.g., information from an Internet protocol security (IPsec) encapsulating security payload (ESP)), or the like), transport-layer information (e.g., a destination port, a source port, a checksum or similar data (e.g., error detection or correction values, such as those utilized by the transmission control protocol (TCP) or the user datagram protocol (UDP)), or the like), application-layer information (e.g., information derived from one or more application-layer header fields of the packets, such as a domain name, a uniform resource locator (URL), a uniform resource identifier (URI), an extension, a method, state information, media-type information, a signature, a key, a timestamp, an application identifier, a session identifier, a flow identifier, sequence information, authentication information, or the like), other data in the packets (e.g., payload data), or one or more environmental variables (e.g., information associated with but not solely derived from the packets themselves, such as one or more arrival (or receipt) or departure (or transmission) times of the packets (e.g., at or from one or more of rule gates **120**, **122**, **124**, **126**, or **128**, tap devices **238**, **242**, **248**, or **252**, or network devices **240** or **250**), one or more ingress or egress identifiers (e.g., associated with one or more physical or logical network interfaces, ports, or communication-media types of one or more of rule gates **120**, **122**, **124**, **126**, or **128**, tap devices **238**, **242**, **248**, or **252**, or network devices **240** or **250** via which the packets were one or more of received or transmitted), one or more device identifiers (e.g., associated with one or more of rule gates **120**, **122**, **124**, **126**, or **128**, tap devices **238**, **242**, **248**, or **252**, or network devices **240** or **250** via which the packets were one or more of received or transmitted), or the like), and packet-filtering system **200** may utilize such entries to correlate one or more packets identified by packet-filtering system **200** with one or more packets previously identified by packet-filtering system **200**.

In some embodiments, packet-filtering system **200** may implement one or more aspects of the technology described in U.S. patent application Ser. No. 14/618,967, filed Feb. 10, 2015, and entitled "CORRELATING PACKETS IN COMMUNICATIONS NETWORKS," the disclosure of which is incorporated by reference herein in its entirety and made part hereof, or similar technology (e.g., to correlate one or more packets identified by packet-filtering system **200** with one or more packets previously identified by packet-filtering system **200**).

Host **106** may generate one or more packets destined for host **142** comprising data (e.g., a TCP:SYN handshake message) configured to establish a connection (e.g., a TCP connection or tunnel) between hosts **106** and **142** and, at step #**8**, may communicate the packets toward host **142**. Rule gate **120** may interface a communication link interfacing hosts **106** and **142**, and rules **212** may be configured to cause rule gate **120** to one or more of identify the packets or determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more of the packets comprising the DNS query or the reply to the DNS query based on data stored in logs **214** (e.g., the log data generated by rule gate **126** in one or more of steps #**6** or #**7**).

At step #**9**, rule gate **120** may route the packets comprising the data configured to establish the connection between hosts **106** and **142** to proxy device **112** and, at step #**10**, may communicate the packets to proxy device **112**. For example, rules **212** may be configured to cause rule gate **120** to route the packets to proxy device **112** based on data in the packets, for example, one or more ports (e.g., port **443**) indicated by transport-layer headers in the packets, indicating the connection between hosts **106** and **142** will be utilized to establish an encrypted communication session or tunnel (e.g., a session established in accordance with the transport layer security (TLS) protocol, secure sockets layer (SSL) protocol, secure shell (SSH) protocol, or the like). In some embodiments, rules **212** may be configured to cause rule gate **120** to route the packets to proxy device **112** based on a determination that one or more of hosts **106** or **142** is associated with a network address for which rules **212** indicate encrypted communications should be established via one or more of proxy devices **112**, **114**, or **116**. For example, proxy devices **112**, **114**, and **116** may be part of a proxy system (e.g., a SSL/TLS proxy system) that enables packet-filtering system **200** to filter packets comprising encrypted data based on information within the encrypted data, and rules **212** may be configured to cause rule gate **120** to route the packets to proxy device **112** based on a determination that host **142** is associated with a network address of a domain corresponding to the network-threat indicators.

Additionally or alternatively, network **102** may include one or more hosts for which rules **212** indicate connections utilized to establish encrypted communication sessions (e.g., connections with hosts corresponding to network-threat indicators) should be established via one or more of proxy devices **112**, **114**, or **116**, as well as one or more hosts for which rules **212** indicate connections utilized to establish encrypted communication sessions should not be established

via one or more of proxy devices **112**, **114**, and **116**, for example, hosts that generate sensitive data (e.g., personally identifiable information (PII)), inspection of which may present privacy or regulatory concerns (e.g., data subject to the health insurance portability and accountability act (HIPAA), or the like), and rules **212** may be configured to cause rule gate **120** to route the packets to proxy device **112** based on a determination that host **106** is associated with a network address for which rules **212** indicate encrypted communications should be established via one or more of proxy devices **112**, **114**, or **116**.

For example, link **236** may interface host **106** with rule gate **120**, link **244** may interface rule gate **120** with host **142**, link **246** may interface rule gate **120** with proxy device **112**, link **254** may interface proxy devices **112** and **114** and may comprise a communication link internal to a proxy system comprising proxy devices **112** and **114**, and rules **212** may be configured to cause rule gate **120** to route (or redirect) packets received from host **106** via one or more of interfaces **216**, **218**, or **220** and destined for host **142** (or a portion thereof (e.g., packets comprising data configured to establish a connection between hosts **106** and **142** and indicating the connection will be utilized to establish an encrypted communication session)) to host **142** via interface **226**. Additionally or alternatively, rules **212** may be configured to cause rule gate **120** to forward copies of (or mirror) packets received from host **106** via one or more of interfaces **216**, **218**, **220**, or **222** and destined for host **142** (or a portion thereof (e.g., packets comprising data configured to establish a connection between hosts **106** and **142** and indicating the connection will be utilized to establish an encrypted communication session)) to proxy device **112** via interface **226**.

At step #**11**, proxy devices **112** and **114** may exchange one or more parameters determined from the packets comprising the data configured to establish the connection between hosts **106** and **142**, for example, one or more network addresses in network-layer headers of the packets (e.g., network addresses of hosts **106** and **142**) or ports indicated by transport-layer headers in the packets (e.g., indicating the type of encrypted communication session the connection will be utilized to establish). Proxy device **112** may utilize the parameters to generate packets comprising data configured to establish a connection between proxy device **112** and host **106** (e.g., a TCP:SYN-ACK handshake message) and, at step #**12**, may communicate the packets to host **106**. Rules **212** may be configured to cause rule gate **120** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more of the packets comprising the DNS query or the reply to the DNS query based on data stored in logs **214** (e.g., the log data generated by rule gate **126** in one or more of steps #**6** or #**7**), and one or more of log or drop the packets.

Similarly, proxy device **114** may utilize the parameters to generate packets comprising data configured to establish a connection between proxy device **114** and host **142** (e.g., a TCP:SYN handshake message) and, at step #**13**, may communicate the packets to host **142**. Rule gate **128** may interface a communication link interfacing proxy device **114** and host **142**, and rules **212** may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of steps #**6**, #**7**, or #**12**), and one or more of log or drop the packets.

Responsive to receiving the packets from proxy device **112**, host **106** may generate packets comprising data configured to establish the connection between proxy device **112** and host **106** (e.g., a TCP:ACK handshake message) and, at step #**14**, may communicate the packets to proxy device **112**. Rules **212** may be configured to cause rule gate **120** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of steps #**6**, #**7**, #**12**, or #**13**), and one or more of log or drop the packets.

Responsive to receiving the packets from proxy device **114**, host **142** may generate packets comprising data configured to establish the connection between proxy device **114** and host **142** (e.g., a TCP:SYN-ACK handshake message) and, at step #**15**, may communicate the packets to proxy device **114**. Rules **212** may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-14**), and one or more of log or drop the packets.

Responsive to receiving the packets from host **142**, proxy device **114** may generate packets comprising data configured to establish the connection between proxy device **114** and host **142** (e.g., a TCP:ACK handshake message) and, at step #**16**, may communicate the packets to host **142**. Rules **212** may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-15**), and one or more of log or drop the packets.

Referring to FIG. **3**B, proxy device **112** may receive the packets comprising data configured to establish the connection between proxy device **112** and host **106** communicated by host **106** in step #**14**, and connection **302** (e.g., a TCP connection) between proxy device **112** and host **106** may be established. Similarly, host **142** may receive the packets comprising data configured to establish the connection between proxy device **114** and host **142** communicated by proxy device **114** in step #**16**, and connection **304** (e.g., a TCP connection) between proxy device **114** and host **142** may be established.

At step #**17**, proxy device **112** and host **106** may communicate packets comprising data configured to establish encrypted communication session **306** (e.g., a SSL/TLS

session) between proxy device **112** and host **106** via connection **302**. Rules **212** may be configured to cause rule gate **120** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-16**), and one or more of log or drop the packets. Additionally or alternatively, rules **212** may be configured to cause rule gate **120** to one or more of identify the packets or determine that the packets comprise data corresponding to the network-threat indicators based on data included in the packets. For example, in some embodiments, host **106** may comprise a client (e.g., web browser), host **142** may comprise a server (e.g., web server), the packets may comprise one or more handshake messages configured to establish session **306** that comprise unencrypted data including a domain name corresponding to the network-threat indicators, for example, a hello message generated by the client (e.g., including the domain name in the server name indication extension, or the like) or a certificate message generated by the server (e.g., including the domain name in one or more of the subject common name field or the extension subjectAltName (of type dNSName), or the like), and rules **212** may be configured to cause rule gate **120** to one or more of identify the packets or determine that the packets comprise data corresponding to the network-threat indicators based on data included in the one or more handshake messages configured to establish session **306**. In such embodiments, rules **212** may be configured to cause packet-filtering system **200** to one or more of identify the packets or determine that the packets comprise data corresponding to the network-threat indicators based on the certificate message comprising other data (e.g., in addition to or in lieu of the domain name) corresponding to one or more of the network-threat indicators, for example, data indicating at least one of a serial number (or type thereof) indicated by rules **212**, an issuer (or type thereof) indicated by rules **212**, a validity time-range (or type thereof) indicated by rules **212**, a key (or type thereof) indicated by rules **212**, a digital signature (e.g., fingerprint) (or type thereof) indicated by rules **212**, or a signing authority (or type thereof) indicated by rules **212**.

Similarly, at step #**18**, proxy device **114** and host **142** may communicate packets comprising data configured to establish encrypted communication session **308** (e.g., a SSL/TLS session) between proxy device **114** and host **142** via connection **304**, and rules **212** may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-17**) or the packets comprising one or more handshake messages configured to establish session **308** that comprise unencrypted data (e.g., including the domain name) corresponding to the network-threat indicators, and one or more of log or drop the packets.

Host **106** may generate packets comprising data encrypted in accordance with one or more parameters of session **306** and, at step #**19**, may communicate the packets to proxy device **112** via session **306**. Rules **212** may be configured to cause rule gate **120** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-18**), and one or more of log (as indicated by the triangles over the line extending downward from rule gate **120**) or drop the packets.

Proxy device **112** may receive the packets and decrypt the data in accordance with the parameters of session **306**. The packets may comprise a request (e.g., a hypertext transfer protocol (HTTP) request), and proxy device **112** may comprise an ICAP client, which, at step #**20**, may communicate the packets to ICAP server **132**. Rule gate **126** may interface a communication link interfacing proxy device **112** and ICAP server **132**, and rules **212** may be configured to cause rule gate **126** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-19**), and one or more of log or drop the packets.

ICAP server **132** may generate packets comprising data responsive to the request (e.g., a response, modified request, or the like) and, at step #**21**, may communicate the packets to proxy device **112**. Rules **212** may be configured to cause rule gate **126** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-20**), and one or more of log or drop the packets. Additionally or alternatively, rules **212** may be configured to cause rule gate **126** to one or more of identify the packets or determine that the packets comprise data corresponding to the network-threat indicators based on data included in the packets, for example, the data responsive to the request (e.g., a modified request) may comprise data (e.g., a domain name, URI, or the like) corresponding to the network-threat indicators.

Proxy device **112** may generate packets (e.g., based on the data generated by ICAP server **132**) and, at step #**22**, may communicate the packets to proxy device **114**. Rule gate **124** may interface a communication link internal to the proxy system comprising proxy devices **112** and **114**, and thus packets traversing the communication link may comprise unencrypted data (e.g., rule gate **124** may be "the man in the middle" of proxy devices **112** and **114**), and rules **212** may be configured to cause rule gate **124** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-

threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-21**), and one or more of log or drop the packets.

Additionally or alternatively, rules **212** may be configured to cause rule gate **124** to one or more of identify the packets or determine that the packets comprise data corresponding to the network-threat indicators based on data included in the packets, for example, unencrypted data in the packets corresponding to one or more of the network-threat indicators. For example, in some embodiments, packet-filtering system **200** may implement one or more aspects of the technology described in U.S. patent application Ser. No. 13/795,822, filed Mar. 12, 2013, and entitled "FILTERING NETWORK DATA TRANSFERS," the disclosure of which is incorporated by reference herein in its entirety and made part hereof, or similar technology, and rules **212** may be configured to cause rule gate **124** to one or more of identify the packets or determine that the packets comprise data corresponding to the network-threat indicators based on the packets comprising one or more of a URI specified by rules **212**, data indicating a protocol version specified by rules **212**, data indicating a method specified by rules **212**, data indicating a request specified by rules **212**, or data indicating a command specified by rules **212**. Additionally or alternatively, rules **212** may be configured to cause rule gate **124** to one or more of identify the packets or determine that the packets comprise data corresponding to the one or more network-threat indicators based on unencrypted data in the packets comprising a URI meeting or exceeding a threshold size specified by rules **212** (e.g., a URI likely being utilized to exfiltrate data).

Proxy device **114** may receive the packets and generate one or more corresponding packets comprising data encrypted in accordance with one or more parameters of session **308** and, at step #**23**, may communicate the packets to host **142**. Rules **212** may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-22**), and one or more of log or drop the packets.

Host **142** may generate one or more packets comprising data encrypted in accordance with one or more parameters of session **308** and, at step #**24**, may communicate the packets to proxy device **114**. Rules **212** may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-23**), and one or more of log or drop the packets.

Proxy device **114** may receive the packets and generate one or more corresponding packets comprising unencrypted data and, at step #**25**, may communicate the packets to proxy device **112**. Rules **212** may be configured to cause rule gate **124** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-24**), and one or more of log or drop the packets.

Proxy device **112** may receive the packets and generate one or more corresponding packets comprising data encrypted in accordance with one or more parameters of session **306** and, at step #**26**, may communicate the packets to host **106**. Rules **212** may be configured to cause rule gate **120** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-25**), and one or more of log or drop the packets.

Host **106** may generate one or more packets comprising data encrypted in accordance with one or more parameters of session **306** and, at step #**27**, may communicate the packets toward proxy device **112**. Rules **212** may be configured to cause rule gate **120** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-26**), and one or more of log or drop the packets.

Proxy device **112** may receive one or more of the packets and generate one or more corresponding packets comprising unencrypted data and, at step #**28**, may communicate the packets toward proxy device **114**. Rules **212** may be configured to cause rule gate **124** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-27**), and one or more of log or drop the packets.

Proxy device **114** may receive one or more of the packets and generate one or more corresponding packets comprising data encrypted in accordance with one or more parameters of session **308** and, at step #**29**, may communicate the packets toward host **142**. Rules **212** may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or

more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-28**), and one or more of log or drop the packets.

Host **142** may generate one or more packets comprising data encrypted in accordance with one or more parameters of session **308** and, at step #**30**, may communicate the packets toward proxy device **114**. Rules **212** may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-29**), and one or more of log or drop the packets.

Proxy device **114** may receive one or more of the packets and generate one or more corresponding packets comprising unencrypted data and, at step #**31**, may communicate the packets toward proxy device **112**. Rules **212** may be configured to cause rule gate **124** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-30**), and one or more of log or drop the packets.

Proxy device **112** may receive one or more of the packets and generate one or more corresponding packets comprising data encrypted in accordance with one or more parameters of session **306** and, at step #**32**, may communicate the packets toward host **106**. Rules **212** may be configured to cause rule gate **120** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-31**), and one or more of log or drop the packets.

Referring to FIG. **3**C, at step #**33**, rule gate **120** may one or more of update a console (or interface) associated with packet-filtering system **200** running on host **108** or receive one or more updates to rules **212** via the console. For example, the console may provide data regarding one or more threats to network **102** corresponding to the network-threat indicators, and rule gate **120** may update the console based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-32**). In some embodiments, the console may provide data identifying network threats associated with one or more of hosts **106**, **108**, **110**, **142**, **144**, or **146**, and rule gate **120** may update data associated with one or more of hosts **106** or **142** based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-32**).

At step #**34**, rule gate **120** may reconfigure rules **212** based on one or more of updates received via the console or data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-32**). For example, packet-filtering system **200** may implement one or more aspects of the technology described in U.S. patent application Ser. No. 14/690,302, filed Apr. 17, 2015, and entitled "RULE-BASED NETWORK-THREAT DETECTION," the disclosure of which is incorporated by reference herein in its entirety and made part hereof, or similar technology, and rule gate **120** may reconfigure rules **212** based on one or more risk scores updated to reflect data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-32**).

Host **106** may generate one or more packets comprising data encrypted in accordance with one or more parameters of session **306** and, at step #**35**, may communicate the packets toward proxy device **112**. Rules **212** (e.g., one or more of rules **212** reconfigured in step #**34**) may be configured to cause rule gate **120** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, or **12-32**), and one or more of log or drop the packets.

Proxy device **112** may receive one or more of the packets and generate one or more corresponding packets comprising unencrypted data and, at step #**36**, may communicate the packets toward proxy device **114**. Rules **212** (e.g., one or more of rules **212** reconfigured in step #**34**) may be configured to cause rule gate **124** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, **12-32**, or **35**), and one or more of log or drop the packets.

Proxy device **114** may receive one or more of the packets and generate one or more corresponding packets comprising data encrypted in accordance with one or more parameters of session **308** and, at step #**37**, may communicate the packets toward host **142**. Rules **212** (e.g., one or more of rules **212** reconfigured in step #**34**) may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, **12-32**, **35**, or **36**), and one or more of log or drop the packets.

Host **142** may generate one or more packets comprising data encrypted in accordance with one or more parameters of session **308** and, at step #**38**, may communicate the packets toward proxy device **114**. Rules **212** (e.g., one or more of rules **212** reconfigured in step #**34**) may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, **12-32**, or **35-37**), and one or more of log or drop the packets.

Proxy device **114** may receive one or more of the packets and generate one or more corresponding packets comprising unencrypted data and, at step #**39**, may communicate the packets toward proxy device **112**. Rules **212** (e.g., one or more of rules **212** reconfigured in step #**34**) may be configured to cause rule gate **124** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, **12-32**, or **35-38**), and one or more of log or drop the packets.

Proxy device **112** may receive one or more of the packets and generate one or more corresponding packets comprising data encrypted in accordance with one or more parameters of session **306** and, at step #**40**, may communicate the packets toward host **106**. Rules **212** (e.g., one or more of rules **212** reconfigured in step #**34**) may be configured to cause rule gate **120** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, **12-32**, or **35-39**), and one or more of log or drop the packets.

Host **142** may generate one or more packets destined for one or more of hosts **106**, **108**, or **110** and, at step #**41**, may communicate the packets toward gateway **134**. Rules **212** (e.g., one or more of rules **212** reconfigured in step #**34**) may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, **12-32**, or **35-40**), and one or more of log or drop the packets.

Host **108** may generate one or more packets and, at step #**42**, may communicate the packets to host **142**. Rules **212** (e.g., one or more of rules **212** reconfigured in step #**34**) may be configured to cause rule gates **120** and **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, **12-32**, or **35-41**), and one or more of log or drop the packets.

Host **106** may generate one or more packets destined for hosts **108**, **142**, **144**, and **146** and, at step #**43**, may communicate the packets toward hosts **108**, **142**, **144**, and **146**. Rules **212** (e.g., one or more of rules **212** reconfigured in step #**34**) may be configured to cause rule gate **120** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6**, **7**, **12-32**, or **35-42**), and one or more of log or drop the packets.

Referring to FIG. **4**A, step #s **1-5** substantially correspond to step #s **1-5** of FIG. **3**A.

Host **106** (e.g., the web browser) may be configured to utilize web proxy **118** and responsive to the request, may generate packets comprising data configured to establish a connection between host **106** and web proxy **118** (e.g., a TCP:SYN handshake message) and, at step #**6**, may communicate the packets to web proxy **118**. Rule gate **120** may interface a communication link interfacing host **106** and web proxy **118**, and rules **212** may be configured to cause rule gate **120** to one or more of identify the packets, for example, based on one or more network addresses included in their network-layer headers (e.g., a network address of web proxy **118**) or one or more ports (e.g., port **80**) indicated by transport-layer headers in the packets, and one or more of log or drop the packets.

Responsive to receiving the packets from host **106**, web proxy **118** may generate packets comprising data configured to establish the connection between host **106** and web proxy **118** (e.g., a TCP:SYN-ACK handshake message) and, at step #**7**, may communicate the packets to host **106**. Rules **212** may be configured to cause rule gate **120** to one or more of identify the packets, for example, based on one or more network addresses included in their network-layer headers (e.g., a network address of web proxy **118**) or one or more ports (e.g., port **80**) indicated by transport-layer headers in the packets, and one or more of log or drop the packets.

Responsive to receiving the packets from web proxy **118**, host **106** may generate packets comprising data configured to establish the connection between host **106** and web proxy **118** (e.g., a TCP:ACK handshake message) and, at step #**8**, may communicate the packets to web proxy **118**. Rules **212** may be configured to cause rule gate **120** to one or more of identify the packets, for example, based on one or more network addresses included in their network-layer headers (e.g., a network address of web proxy **118**) or one or more ports (e.g., port **80**) indicated by transport-layer headers in the packets, and one or more of log or drop the packets.

Web proxy **118** may receive the packets from host **106**, and connection **402** (e.g., a TCP connection) between host **106** and web proxy **118** may be established. Host **106** may

generate packets comprising a request (e.g., an HTTP CONNECT request), and, at step #**9**, may communicate the packets to web proxy **118** via connection **402**. Rules **212** may be configured to cause rule gate **120** to one or more of identify the packets, for example, based on one or more network addresses included in their network-layer headers (e.g., a network address of web proxy **118**) or one or more ports (e.g., port **80**) indicated by transport-layer headers in the packets, determine the packets comprise data corresponding to the network-threat indicators, for example, a domain name (e.g., FQDN) in the request, and one or more of log or drop the packets.

Web proxy **118** may generate a DNS query comprising the domain name and, at step #**10**, may communicate the DNS query toward DNS **130**. The domain name included in the request may correspond to one or more of the network-threat indicators, and rules **212** may be configured to cause rule gate **126** to one or more of identify one or more packets comprising the DNS query, determine that the packets comprise the domain name corresponding to the network-threat indicators, and one or more of log or drop the packets. For example, the packets may comprise a network address of web proxy **118** (e.g., as a source address in their network-layer headers), and rule gate **126** may generate log data indicating the network address of web proxy **118**. As depicted by step #**10**A, the packets may be communicated to DNS **130**. In some embodiments, rules **212** may be configured to cause rule gate **126** to, responsive to determining that the packets comprise the domain name corresponding to the network-threat indicators, drop the packets, preventing them from reaching DNS **130**, as depicted by step #**10**B.

DNS **130** may generate a reply to the DNS query and, at step #**11**, may communicate the reply toward web proxy **118**. The reply may comprise the domain name corresponding to the network-threat indicators, and rules **212** may be configured to cause rule gate **126** to one or more of identify one or more packets comprising the reply, determine that the packets comprise the domain name corresponding to the network-threat indicators, and one or more of log or drop the packets. For example, the packets may comprise the network address of web proxy **118** (e.g., as a destination address in their network-layer headers), and rule gate **126** may generate log data indicating the network address of web proxy **118**. Similarly, the domain name may correspond to host **142**, the packets may comprise a network address of host **142** (e.g., DNS **130** may have resolved the domain name included in the query to the network address of host **142**), and rule gate **126** may generate log data indicating the network address of host **142**. As depicted by step #**11**A, the packets may be communicated to web proxy **118**. In some embodiments, rules **212** may be configured to cause rule gate **126** to, responsive to determining that the packets comprise the domain name corresponding to the network-threat indicators, drop the packets, preventing them from reaching web proxy **118**, as depicted by step #**11**B.

Web proxy **118** may generate one or more packets destined for host **142** comprising data (e.g., a TCP:SYN handshake message) configured to establish a connection (e.g., a TCP connection or tunnel) between web proxy **118** and host **142** and, at step #**12**, may communicate the packets toward host **142**. Rule gate **122** may interface a communication link interfacing web proxy **118** and host **142**, and rules **212** may be configured to cause rule gate **122** to one or more of identify the packets or determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more of the packets comprising the request, the DNS query, or the reply to the DNS query based on data stored in logs **214** (e.g., the log data generated by rule gates **120** and **126** in one or more of step #s **6-11**).

At step #**13**, rule gate **122** may route the packets comprising the data configured to establish the connection between web proxy **118** and host **142** to proxy device **112** and, at step #**14**, may communicate the packets to proxy device **112**. For example, rules **212** may be configured to cause rule gate **122** to route the packets to proxy device **112** based on data in the packets, for example, one or more ports (e.g., port **443**) indicated by transport-layer headers in the packets, indicating the connection between web proxy **118** and host **142** will be utilized to establish an encrypted communication session or tunnel (e.g., a session established in accordance with the transport layer security (TLS) protocol, secure sockets layer (SSL) protocol, secure shell (SSH) protocol, or the like).

Referring to FIG. **4**B, at step #**15**, proxy devices **112** and **114** may exchange one or more parameters determined from the packets comprising the data configured to establish the connection between web proxy **118** and host **142**, for example, one or more network addresses in network-layer headers of the packets (e.g., network addresses of web proxy **118** and host **142**) or ports indicated by transport-layer headers in the packets (e.g., indicating the type of encrypted communication session the connection will be utilized to establish). Proxy device **112** may utilize the parameters to generate packets comprising data configured to establish a connection between proxy device **112** and web proxy **118** (e.g., a TCP:SYN-ACK handshake message) and, at step #**16**, may communicate the packets to web proxy **118**. Rules **212** may be configured to cause rule gate **122** to one or more of identify the packets or determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more of the packets comprising the request, the DNS query, or the reply to the DNS query based on data stored in logs **214** (e.g., the log data generated by rule gates **120** and **126** in one or more of step #s **6-11**).

Similarly, proxy device **114** may utilize the parameters to generate packets comprising data configured to establish a connection between proxy device **114** and host **142** (e.g., a TCP:SYN handshake message) and, at step #**17**, may communicate the packets to host **142**. Rules **212** may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-11** or **16**), and one or more of log or drop the packets.

Responsive to receiving the packets from proxy device **112**, web proxy **118** may generate packets comprising data configured to establish the connection between proxy device **112** and web proxy **118** (e.g., a TCP:ACK handshake message) and, at step #**18**, may communicate the packets to proxy device **112**. Rules **212** may be configured to cause rule gate **122** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example,

by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-11**, **16**, or **17**), and one or more of log or drop the packets.

Responsive to receiving the packets from proxy device **114**, host **142** may generate packets comprising data configured to establish the connection between proxy device **114** and host **142** (e.g., a TCP:SYN-ACK handshake message) and, at step #**19**, may communicate the packets to proxy device **114**. Rules **212** may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-11** or **16-18**), and one or more of log or drop the packets.

Responsive to receiving the packets from host **142**, proxy device **114** may generate packets comprising data configured to establish the connection between proxy device **114** and host **142** (e.g., a TCP:ACK handshake message) and, at step #**20**, may communicate the packets to host **142**. Rules **212** may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-11** or **16-19**), and one or more of log or drop the packets.

Proxy device **112** may receive the packets comprising data configured to establish the connection between proxy device **112** and web proxy **118** communicated by web proxy **118** in step #**18**, and connection **404** (e.g., a TCP connection) between proxy device **112** and web proxy **118** may be established. Similarly, host **142** may receive the packets comprising data configured to establish the connection between proxy device **114** and host **142** communicated by proxy device **114** in step #**20**, and connection **406** (e.g., a TCP connection) between proxy device **114** and host **142** may be established.

At step #**21**, proxy device **112** and host **106** may communicate packets comprising data configured to establish encrypted communication session **408** (e.g., a SSL/TLS session) between proxy device **112** and host **106** via connections **402** and **404**. Rules **212** may be configured to cause one or more of rule gates **120** or **122** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-11** or **16-20**) or the packets comprising one or more handshake messages configured to establish session **408** that comprise unencrypted data (e.g., including the domain name) corresponding to the network-threat indicators, and one or more of log or drop the packets.

Similarly, at step #**22**, proxy device **114** and host **142** may communicate packets comprising data configured to establish encrypted communication session **410** (e.g., a SSL/TLS session) between proxy device **114** and host **142** via connection **406**, and rules **212** may be configured to cause rule gate **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-11** or **16-21**) or the packets comprising one or more handshake messages configured to establish session **410** that comprise unencrypted data (e.g., including the domain name) corresponding to the network-threat indicators, and one or more of log or drop the packets.

Referring to FIGS. **4**B-C, step #s **23-47** substantially correspond to step #s **19-43** of FIGS. **3**B-C; however, rules **212** may be configured to cause one or more of rule gates **120** or **122** to one or more of identify, drop, or log the packets communicated in one or more of step #s **23**, **30**, **31**, **36**, **39**, or **44** of FIGS. **4**B-C.

Referring to FIG. **5**A, step #s **1-7** substantially correspond to step #s **1-7** of FIG. **3**A.

Host **106** may generate one or more packets destined for host **142** comprising data (e.g., a TCP:SYN handshake message) configured to establish a connection (e.g., a TCP connection or tunnel) between hosts **106** and **142** and, at step #**8**, may communicate the packets to host **142**. Rules **212** may be configured to cause one or more of rule gates **120** or **128** to one or more of identify the packets or determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more of the packets comprising the DNS query or the reply to the DNS query based on data stored in logs **214** (e.g., the log data generated by rule gate **126** in one or more of steps #**6** or #**7**).

Responsive to receiving the packets from host **106**, host **142** may generate packets comprising data configured to establish the connection between hosts **106** and **142** (e.g., a TCP:SYN-ACK handshake message) and, at step #**9**, may communicate the packets to host **106**. Rules **212** may be configured to cause one or more of rule gates **120** or **128** to one or more of identify the packets or determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more of the packets comprising the DNS query or the reply to the DNS query based on data stored in logs **214** (e.g., the log data generated by rule gate **126** in one or more of steps #**6** or #**7**).

Responsive to receiving the packets from host **142**, host **106** may generate packets comprising data configured to establish the connection between hosts **106** and **142** (e.g., a TCP:ACK handshake message) and, at step #**10**, may communicate the packets to host **142**. Rules **212** may be configured to cause one or more of rule gates **120** or **128** to one or more of identify the packets or determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating

the packets with one or more of the packets comprising the DNS query or the reply to the DNS query based on data stored in logs **214** (e.g., the log data generated by rule gate **126** in one or more of steps #**6** or #**7**).

Host **142** may receive the packets comprising data configured to establish the connection between hosts **106** and **142** communicated by host **106** in step #**10**, and connection **502** (e.g., a TCP connection) between hosts **106** and **142** may be established.

At step #**11**, hosts **106** and **142** may communicate packets comprising data configured to establish encrypted communication session **504** (e.g., a SSL/TLS session) between hosts **106** and **142** via connection **502**. Rules **212** may be configured to cause one or more of rule gates **120** or **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-10**) or the packets comprising one or more handshake messages configured to establish session **504** that comprise unencrypted data (e.g., including the domain name) corresponding to the network-threat indicators, and one or more of log or drop the packets.

Host **106** may generate packets comprising data encrypted in accordance with one or more parameters of session **504** and, at step #**12**, may communicate the packets to host **142**. Rules **212** may be configured to cause one or more of rule gates **120** or **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-11**), and one or more of log or drop the packets.

Host **142** may generate packets comprising data encrypted in accordance with one or more parameters of session **504** and, at step #**13**, may communicate the packets to host **106**. Rules **212** may be configured to cause one or more of rule gates **120** or **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-12**), and one or more of log or drop the packets.

Host **106** may generate packets comprising data encrypted in accordance with one or more parameters of session **504** and, at step #**14**, may communicate the packets toward host **142**. Rules **212** may be configured to cause one or more of rule gates **120** or **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-13**), and one or more of log or drop the packets.

Host **142** may generate packets comprising data encrypted in accordance with one or more parameters of session **504** and, at step #**15**, may communicate the packets toward host **106**. Rules **212** may be configured to cause one or more of rule gates **120** or **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-14**), and one or more of log or drop the packets.

Referring to FIG. **5**B, steps #**16** and #**17** substantially correspond to steps #**33** and #**34** of FIG. **3**C.

Host **106** may generate packets comprising data encrypted in accordance with one or more parameters of session **504** and, at step #**18**, may communicate the packets toward host **142**. Rules **212** (e.g., one or more of rules **212** reconfigured in step #**17**) may be configured to cause one or more of rule gates **120** or **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-15**), and one or more of log or drop the packets.

Host **142** may generate packets comprising data encrypted in accordance with on or more parameters of session **504** and, at step #**19**, may communicate the packets toward host **106**. Rules **212** (e.g., one or more of rules **212** reconfigured in step #**17**) may be configured to cause one or more of rule gates **120** or **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-15** and **18**), and one or more of log or drop the packets.

Step #s **20-22** substantially correspond to step #s **41-43** of FIG. **3**C.

Referring to FIG. **6**A, step #s **1-11** substantially correspond to step #s **1-11** of FIG. **4**A.

Web proxy **118** may generate one or more packets destined for host **142** comprising data (e.g., a TCP:SYN handshake message) configured to establish a connection (e.g., a TCP connection or tunnel) between web proxy **118** and host **142** and, at step #**12**, may communicate the packets to host **142**. Rules **212** may be configured to cause one or more of rule gates **122** or **128** to one or more of identify the packets or determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more of the packets comprising the DNS query or the reply

to the DNS query based on data stored in logs **214** (e.g., the log data generated by rule gate **126** in one or more of steps #**10** or #**11**).

Responsive to receiving the packets from web proxy **118**, host **142** may generate packets comprising data configured to establish the connection between web proxy **118** and host **142** (e.g., a TCP:SYN-ACK handshake message) and, at step #**13**, may communicate the packets to web proxy **118**. Rules **212** may be configured to cause one or more of rule gates **122** or **128** to one or more of identify the packets or determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more of the packets comprising the DNS query or the reply to the DNS query based on data stored in logs **214** (e.g., the log data generated by rule gate **126** in one or more of steps #**10** or #**11**).

Responsive to receiving the packets from host **142**, web proxy **118** may generate packets comprising data configured to establish the connection between web proxy **118** and host **142** (e.g., a TCP:ACK handshake message) and, at step #**14**, may communicate the packets to host **142**. Rules **212** may be configured to cause one or more of rule gates **122** or **128** to one or more of identify the packets or determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more of the packets comprising the DNS query or the reply to the DNS query based on data stored in logs **214** (e.g., the log data generated by rule gate **126** in one or more of steps #**10** or #**11**).

Referring to FIG. **6**B, host **142** may receive the packets comprising data configured to establish the connection between web proxy **118** and host **142** communicated by web proxy **118** in step #**14**, and connection **604** (e.g., a TCP connection) between web proxy **118** and host **142** may be established.

At step #**15**, hosts **106** and **142** may communicate packets comprising data configured to establish encrypted communication session **606** (e.g., a SSL/TLS session) between hosts **106** and **142** via connections **602** and **604**. Rules **212** may be configured to cause one or more of rule gates **120**, **122**, or **128** to one or more of identify the packets, determine (e.g., based on one or more network addresses included in their network-layer headers) that the packets comprise data corresponding to the network-threat indicators, for example, by correlating the packets with one or more packets previously determined by packet-filtering system **200** to comprise data corresponding to the network-threat indicators based on data stored in logs **214** (e.g., log data generated by packet-filtering system **200** in one or more of step #s **6-15**) or the packets comprising one or more handshake messages configured to establish session **606** that comprise unencrypted data (e.g., including the domain name) corresponding to the network-threat indicators, and one or more of log or drop the packets.

Step #s **16-26** substantially correspond to step #s **12-22** of FIGS. **5**A-B; however, rules **212** may be configured to cause one or more of rule gates **120**, **122**, or **128** to one or more of identify, drop, or log the packets communicated in one or more of step #s **16-19**, **22**, or **23** of FIG. **6**B.

FIG. **7** depicts an illustrative method for rule-based network-threat detection for encrypted communications in accordance with one or more aspects of the disclosure. Referring to FIG. **7**, in step **702**, a packet-filtering system may receive data indicating network-threat indicators. For example, packet-filtering system **200** may receive packet-filtering rules generated by rule provides **138** based on network-threat indicators provided by threat-intelligence providers **140**. In step **704**, the packet-filtering system may configure packet-filtering rules in accordance with which it is configured to filter packets. For example, packet-filtering system **200** may configure rules **212**.

In step **706**, the packet-filtering system may identify packets comprising unencrypted data. For example, packet-filtering system **200** may identify packets comprising a DNS query, a reply to a DNS query, or a handshake message configured to establish an encrypted communication session. In step **708**, the packet-filtering system may identify packets comprising encrypted data. For example, packet-filtering system **200** may identify packets encrypted in accordance with one or more parameters of sessions **306**, **308**, **408**, **410**, **504**, or **606**.

In step **710**, the packet-filtering system may determine based on a portion of the unencrypted data corresponding to the network-threat indicators that the packets comprising encrypted data correspond to the network-threat indicators. For example, packet-filtering system **200** may determine that a domain name included in the DNS query, the reply to the DNS query, or the handshake message corresponds to the network-threat indicators, and packet-filtering system **200** may determine that one or more of the packets encrypted in accordance with the parameters of sessions **306**, **308**, **408**, **410**, **504**, or **606** correlate to one or more packets comprising the DNS query, the reply to the DNS query, or the one or more handshake messages.

The functions and steps described herein may be embodied in computer-usable data or computer-executable instructions, such as in one or more program modules, executed by one or more computers or other devices to perform one or more functions described herein. Generally, program modules include routines, programs, objects, components, data structures, etc. that perform particular tasks or implement particular abstract data types when executed by one or more processors in a computer or other data-processing device. The computer-executable instructions may be stored on a computer-readable medium such as a hard disk, optical disk, removable storage media, solid-state memory, RAM, etc. As will be appreciated, the functionality of the program modules may be combined or distributed as desired. In addition, the functionality may be embodied in whole or in part in firmware or hardware equivalents, such as integrated circuits, application-specific integrated circuits (ASICs), field-programmable gate arrays (FPGA), and the like. Particular data structures may be used to more effectively implement one or more aspects of the disclosure, and such data structures are contemplated to be within the scope of computer-executable instructions and computer-usable data described herein.

Although not required, one of ordinary skill in the art will appreciate that various aspects described herein may be embodied as a method, system, apparatus, or one or more computer-readable media storing computer-executable instructions. Accordingly, aspects may take the form of an entirely hardware embodiment, an entirely software embodiment, an entirely firmware embodiment, or an embodiment combining software, hardware, and firmware aspects in any combination.

As described herein, the various methods and acts may be operative across one or more computing devices and networks. The functionality may be distributed in any manner or may be located in a single computing device (e.g., a server, client computer, or the like).

Aspects of the disclosure have been described in terms of illustrative embodiments thereof. Numerous other embodiments, modifications, and variations within the scope and spirit of the appended claims will occur to persons of ordinary skill in the art from a review of this disclosure. For example, one of ordinary skill in the art will appreciate that the steps illustrated in the illustrative figures may be performed in other than the recited order and that one or more illustrated steps may be optional. Any and all features in the following claims may be combined or rearranged in any way possible.

What is claimed is:

1. A method comprising:

receiving, by a packet-filtering system comprising a hardware processor and a memory and configured to filter packets in accordance with a plurality of packet-filtering rules, data indicating a plurality of network-threat indicators, wherein at least one of the plurality of network-threat indicators comprises a domain name identified as a network threat;

identifying packets comprising unencrypted data;

identifying packets comprising encrypted data;

determining, by the packet-filtering system and based on a portion of the unencrypted data corresponding to one or more network-threat indicators of the plurality of network-threat indicators, packets comprising encrypted data that corresponds to the one or more network-threat indicators;

filtering, by the packet-filtering system and based on at least one of a uniform resource identifier (URI) specified by the plurality of packet-filtering rules, data indicating a protocol version specified by the plurality of packet-filtering rules, data indicating a method specified by the plurality of packet-filtering rules, data indicating a request specified by the plurality of packet-filtering rules, or data indicating a command specified by the plurality of packet-filtering rules:

packets comprising the portion of the unencrypted data that corresponds to one or more network-threat indicators of the plurality of network-threat indicators; and

the determined packets comprising the encrypted data that corresponds to the one or more network-threat indicators; and

routing, by the packet-filtering system, filtered packets to a proxy system based on a determination that the filtered packets comprise data that corresponds to the one or more network-threat indicators.

2. The method of claim **1**, wherein:

the packets comprising unencrypted data comprise one or more packets comprising at least one of a domain name system (DNS) query or a reply to the DNS query, the method further comprising:

determining that the at least one of the DNS query or the reply to the DNS query comprises the domain name identified as the network threat.

3. The method of claim **2**, wherein the portion of the unencrypted data comprises one or more network addresses included in the at least one of the DNS query or the reply to the DNS query, the method further comprising:

determining that the packets comprising encrypted data comprise one or more packet headers comprising at least one of the one or more network addresses.

4. The method of claim **2**, wherein the portion of the unencrypted data comprises one or more network addresses included in one or more headers of the one or more packets comprising the at least one of the DNS query or the reply to the DNS query, the method further comprising:

determining that the packets comprising encrypted data comprise one or more packet headers comprising at least one of the one or more network addresses.

5. The method of claim **4**, wherein the one or more network addresses comprise a network address of a web proxy that generated the DNS query in response to a request received from a host, the method further comprising:

identifying one or more packets comprising the request.

6. The method of claim **1**, wherein one or more packets, of the packets comprising unencrypted data, comprise data configured to establish an encrypted communication session between a first host and a second host, the method further comprising:

routing the one or more packets comprising data configured to establish the encrypted communication session between the first host and the second host to the proxy system.

7. The method of claim **6**, the method further comprising:

routing the one or more packets to the proxy system based on a determination that at least one of the first host or the second host corresponds to the domain name identified as the network threat.

8. The method of claim **6**, wherein:

the plurality of packet-filtering rules indicate:

one or more network addresses for which encrypted communications are to be established via the proxy system, and

one or more network addresses for which encrypted communications are to not be established via the proxy system, the method further comprising:

routing the one or more packets to the proxy system based on a determination that at least one of the first host or the second host corresponds to the one or more network addresses for which encrypted communications are to be established via the proxy system.

9. The method of claim **6**, wherein:

the packet-filtering system comprises:

one or more interfaces interfacing the packet-filtering system with one or more communication links interfacing the first host and the second host, and

one or more interfaces interfacing the packet-filtering system with the proxy system, the method further comprising:

redirecting packets received via the one or more interfaces interfacing the packet-filtering system with the one or more communication links interfacing the first host and the second host to the one or more interfaces interfacing the packet-filtering system with the proxy system.

10. The method of claim **6**, wherein:

the packet-filtering system comprises:

one or more interfaces interfacing the packet-filtering system with one or more communication links interfacing the first host and the second host, and

one or more interfaces interfacing the packet-filtering system with the proxy system, the method further comprising:

forwarding copies of packets received via the one or more interfaces interfacing the packet-filtering system with the one or more communication links interfacing the first host and the second host to the one or more interfaces interfacing the packet-filtering system with the proxy system.

11. The method of claim 6, the method further comprising:

identifying, via a communication link interfacing the first host and the proxy system, the packets comprising encrypted data; and

identifying, via an internal communication link of the proxy system, packets corresponding to the packets comprising encrypted data.

12. The method of claim 11, the method further comprising: identifying, via a communication link interfacing the proxy system and the second host, packets generated by the proxy system based on the packets corresponding to the packets comprising encrypted data.

13. The method of claim 6, the method further comprising:

generating, by the proxy system, one or more packets based on the filtered packets, comprising encrypted data, routed to the proxy system by the packet-filtering system;

responsive to determining that one or more packets generated by the proxy system correspond to one or more criteria specified by the plurality of packet-filtering rules, at least one of:

dropping the one or more packets generated by the proxy system;

logging the one or more packets generated by the proxy system;

dropping one or more other packets generated by the proxy system;

logging one or more other packets generated by the proxy system;

dropping one or more other packets comprising encrypted data; or

logging one or more other packets comprising encrypted data.

14. The method of claim 13, wherein the determining that one or more packets generated by the proxy system based on one or more of the packets comprising encrypted data correspond to one or more criteria specified by the plurality of packet-filtering rules comprises determining that the one or more packets generated by the proxy system comprise at least one of a uniform resource identifier (URI) specified by the plurality of packet-filtering rules, data indicating a protocol version specified by the plurality of packet-filtering rules, data indicating a method specified by the plurality of packet-filtering rules, data indicating a request specified by the plurality of packet-filtering rules, or data indicating a command specified by the plurality of packet-filtering rules.

15. The method of claim 13, wherein the determining comprises determining that the one or more packets generated by the proxy system comprise a uniform resource identifier (URI) meeting a threshold size specified by the plurality of packet-filtering rules.

16. The method of claim 6, the method further comprising: identifying, via a communication link interfacing the proxy system and an Internet content adaptation protocol (ICAP) server, one or more packets comprising at least one of an ICAP request, a response generated by the ICAP server, or a modified request generated by the ICAP server.

17. The method of claim 1, wherein the packets comprising encrypted data comprise packets received from a first host and destined for a second host, the method further comprising at least one of dropping or logging packets other than the packets comprising encrypted data based on a determination that the packets other than the packets comprising encrypted data were at least one of received from the second host or destined for the first host.

18. The method of claim 1, wherein:

the packets comprising unencrypted data comprise one or more packets comprising one or more handshake messages configured to establish an encrypted communication session between a client and a server, the method further comprising:

determining that the one or more handshake messages comprise the domain name identified as the network threat.

19. The method of claim 18, the method further comprising: responsive to determining that the one or more handshake messages comprise the domain name identified as the network threat, at least one of dropping or logging the packets comprising encrypted data.

20. The method of claim 18, wherein:

the one or more handshake messages comprise at least one of a hello message generated by the client or a certificate message generated by the server; and

the determining that the one or more handshake messages comprise the domain name identified as the network threat comprises determining the at least one of the hello message generated by the client or the certificate message generated by the server comprises the domain name identified as the network threat.

21. The method of claim 18, wherein the portion of the unencrypted data comprises one or more network addresses included in one or more headers of the one or more packets comprising the one or more handshake messages, the method further comprising

determining that the packets comprising encrypted data comprise one or more packet headers comprising at least one of the one or more network addresses.

22. The method of claim 21, wherein the one or more network addresses comprise a network address of the server and a network address of a web proxy, the method further comprising:

identifying one or more packets comprising one or more packet headers comprising the network address of the web proxy and a network address of the client; and

determining that the packets comprising encrypted data comprise one or more packet headers comprising the network address of the server and the network address of the client.

23. The method of claim 1, wherein the packets comprising unencrypted data comprise a certificate message for an encrypted communication session, the method further comprising:

at least one of dropping or logging one or more of the packets comprising encrypted data based on a determination that the certificate message comprises data indicating at least one of a serial number indicated by the plurality of packet-filtering rules, an issuer indicated by the plurality of packet-filtering rules, a validity time-range indicated by the plurality of packet-filtering rules, a key indicated by the plurality of packet-filtering rules, or a signing authority indicated by the plurality of packet-filtering rules.

24. A packet-filtering system comprising:

at least one hardware processor; and

memory storing instructions that when executed by the at least one hardware processor cause the packet-filtering system to:

receive data indicating a plurality of network-threat indicators, wherein at least one of the plurality of network-threat indicators comprise a domain name identified as a network threat;

identify packets comprising unencrypted data;

identify packets comprising encrypted data;

determine, based on a portion of the unencrypted data corresponding to one or more network-threat indicators of the plurality of network-threat indicators, packets comprising encrypted data that corresponds to the one or more network-threat indicators;

filter, based on at least one of a uniform resource identifier (URI) specified by a plurality of packet-filtering rules, data indicating a protocol version specified by the plurality of packet-filtering rules, data indicating a method specified by the plurality of packet-filtering rules, data indicating a request specified by the plurality of packet-filtering rules, or data indicating a command specified by the plurality of packet-filtering rules:

packets comprising the portion of the unencrypted data corresponding to one or more network-threat indicators of the plurality of network-threat indicators; and

the determined packets comprising the encrypted data that corresponds to the one or more network-threat indicators; and

route, by the packet-filtering system, filtered packets to a proxy system based on a determination that the filtered packets comprise data that corresponds to the one or more network-threat indicators.

25. One or more non-transitory computer-readable media comprising instructions that when executed by at least one hardware processor of a packet-filtering system cause the packet-filtering system to:

receive data indicating a plurality of network-threat indicators, wherein at least one of the plurality of network-threat indicators comprise a domain name identified as a network threat;

identify packets comprising unencrypted data;

identify packets comprising encrypted data;

determine, based on a portion of the unencrypted data corresponding to one or more network-threat indicators of the plurality of network-threat indicators, packets comprising encrypted data that corresponds to the one or more network-threat indicators;

filter, by the packet-filtering system and based on at least one of a uniform resource identifier (URI) specified by a plurality of packet-filtering rules indicating one or more of the plurality of network-threat indicators, data indicating a protocol version specified by the plurality of packet-filtering rules, data indicating a method specified by the plurality of packet-filtering rules, data indicating a request specified by the plurality of packet-filtering rules, or data indicating a command specified by the plurality of packet-filtering rules:

packets comprising the portion of the unencrypted data corresponding to one or more network-threat indicators of the plurality of network-threat indicators; and

the determined packets comprising the encrypted data that corresponds to the one or more network-threat indicators; and

route, by the packet-filtering system, filtered packets to a proxy system based on a determination that the filtered packets comprise data that corresponds to the one or more network-threat indicators.

* * * * *