Dynamic Routing for IPsec VPN Manageability: Current IETF Standards Activities

Paul Knight, Nortel Networks

Gregory Lebovitz, Netscreen Technologies

Lars Eggert, USC/ISI

Agenda

- **Introductions**
- Why we need dynamic routing in IPsec
- Difficulty of doing dynamic routing in IPsec
- Quick Review: IPsec Transport and Tunnel Modes
- Current Implementations of dynamic routing in IPsec
- What’s happening in IETF standards

Introductions

- Gregory M. Lebovitz
  - Architect, CTO Office, Netscreen Technologies
  - Design next generation feature sets and security solutions
  - gregory@netscreen.com
  - www.netscreen.com

Introductions

- Paul Knight
  - Standards Architect, Nortel Networks
  - Ensure that product plans incorporate standards, for interoperability
  - Promote innovative technologies as potential standards candidates
  - paul.knight@nortelnetworks.com
  - www.nortelnetworks.com

Introductions

- Lars Eggert <larse@isi.edu>
  - Ph.D. candidate, USC/ISI
- virtual networks since 1997
  - X-Bone, DynaBone, TetherNet
- other research
  - TCP, web caching, OS network issues
- http://www.isi.edu/larse/

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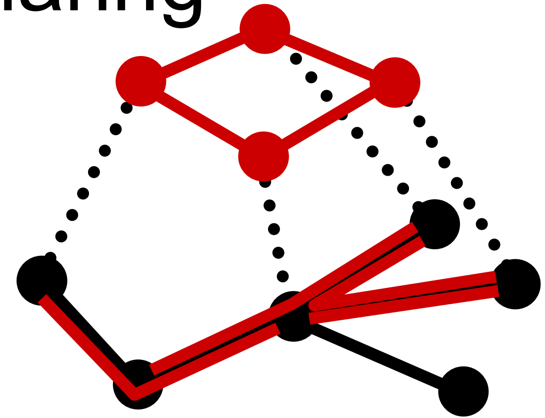
Virtual Network

- network equivalent of virtual memory
  - abstraction, protection, sharing
- network =
  hosts + routers + links



- virtual network =
  - virtual host → packet source/sink
  - virtual router → packet gateway
  - virtual link → tunnel X over Y
- **virtual Internet**: X = IP, Y = IP

Virtual Private Network

- **private** = secure links
  - authenticate tunnel ends + encrypt
- virtual private Internet
  - secure IPIP tunnels hop-by-hop
- security is link property
  - decoupled from topology
- IPsec tunnel mode?

IPsec VPN – Frame Relay Replacement

- IPsec-based VPN as a frame relay replacement
- Business drivers
  - Lower monthly operating costs
  - ROI in 4 to 6 months
- Need equivalent functionality at lower cost

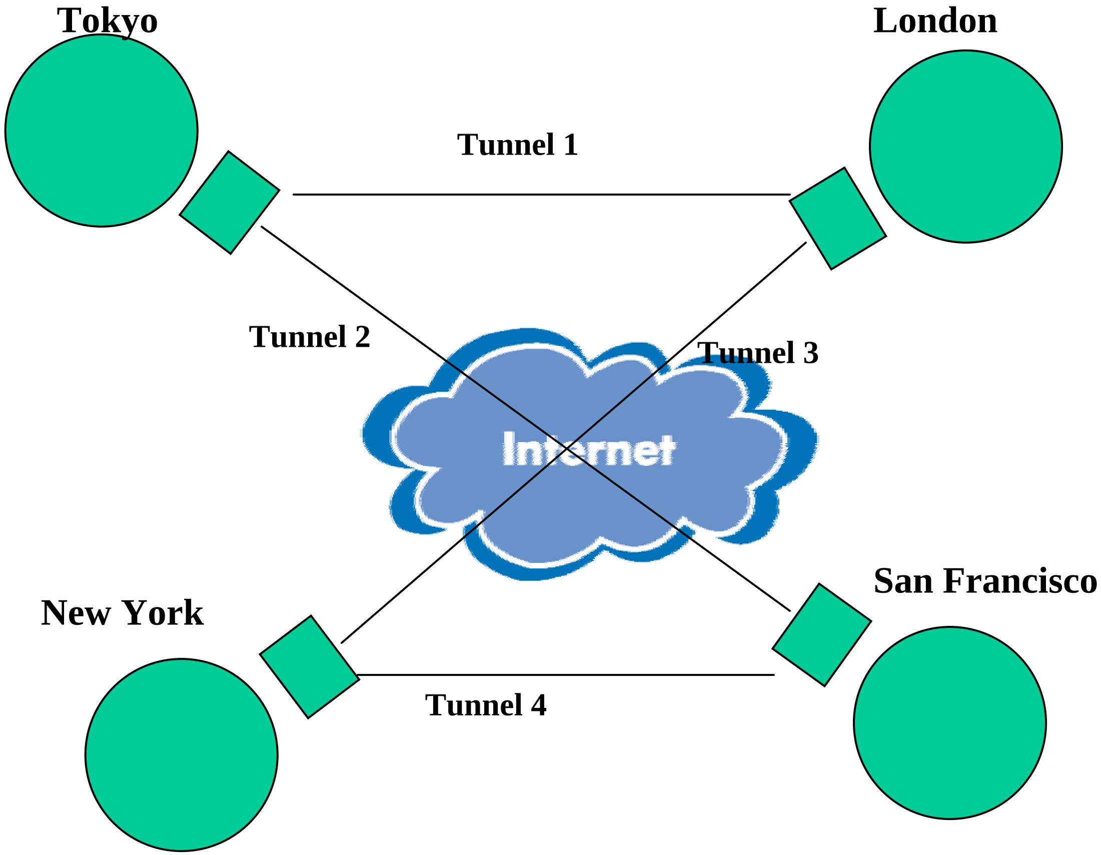
FR Features that Customers want: Can IPsec VPNs address them?

- Single physical connection with multiple virtual connections to remote sites
- **Privately** transport all internal networking information. Includes:
  - IP traffic
  - Private IP addressing schemes
  - non-IP traffic
  - IGP/EGP routing protocols
- CIR, assured level of performance (bandwidth)

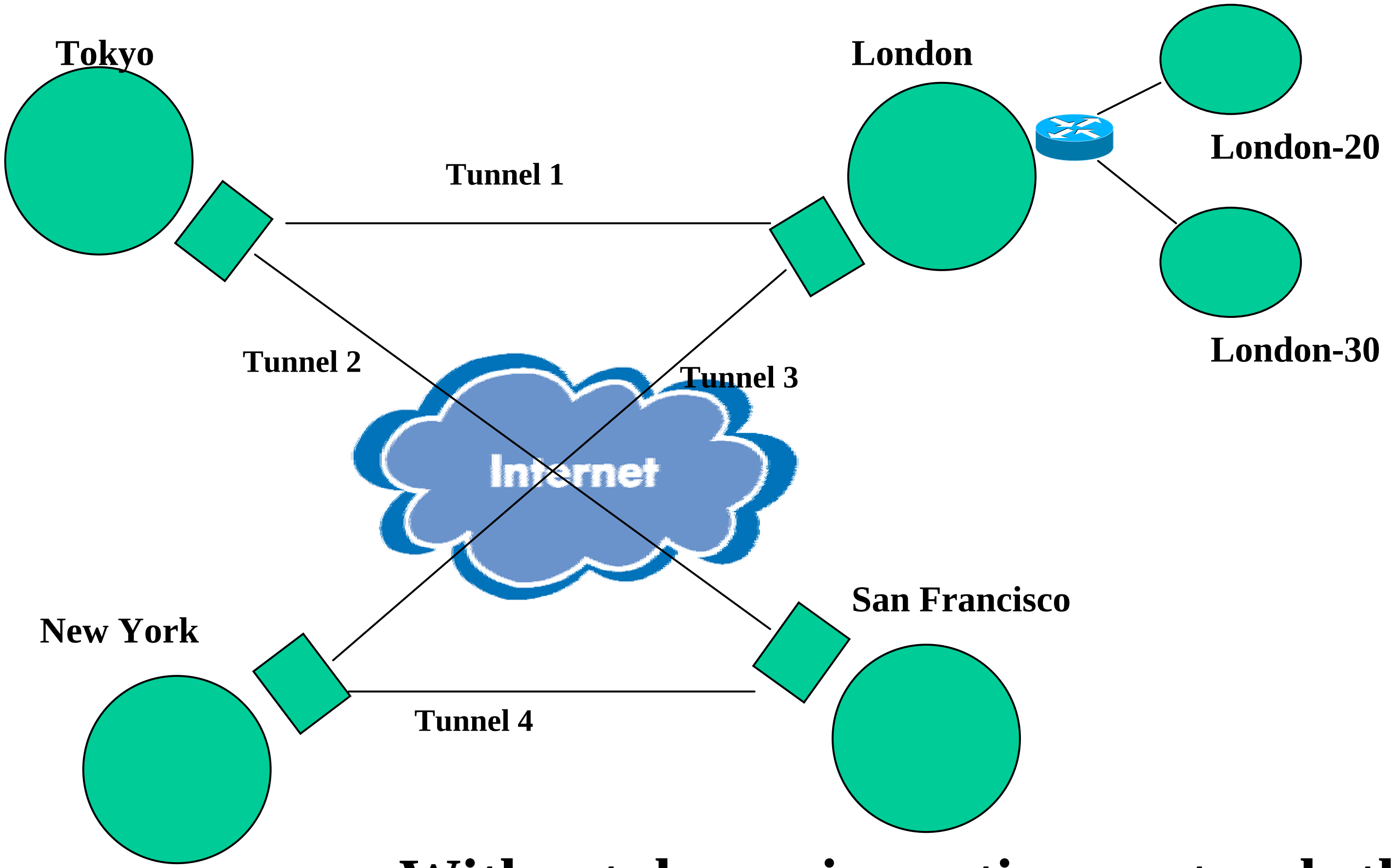
IPsec VPN vs. Frame Relay

Feature	**IPsec VPN**	**Frame**
Single phy w/ multiple virtual connections to remote sites.	➨	➨
Private Transport	+	➨
Private Addressing Schemes	➨	➨
Non-IP Traffic	➨ **(in tunnels)**	+
IGP/EGP Routing Protocols	➨	➨
CIR	-	+
COST	+++	--

Use Case 1 – New Networks Added to a Remote Site

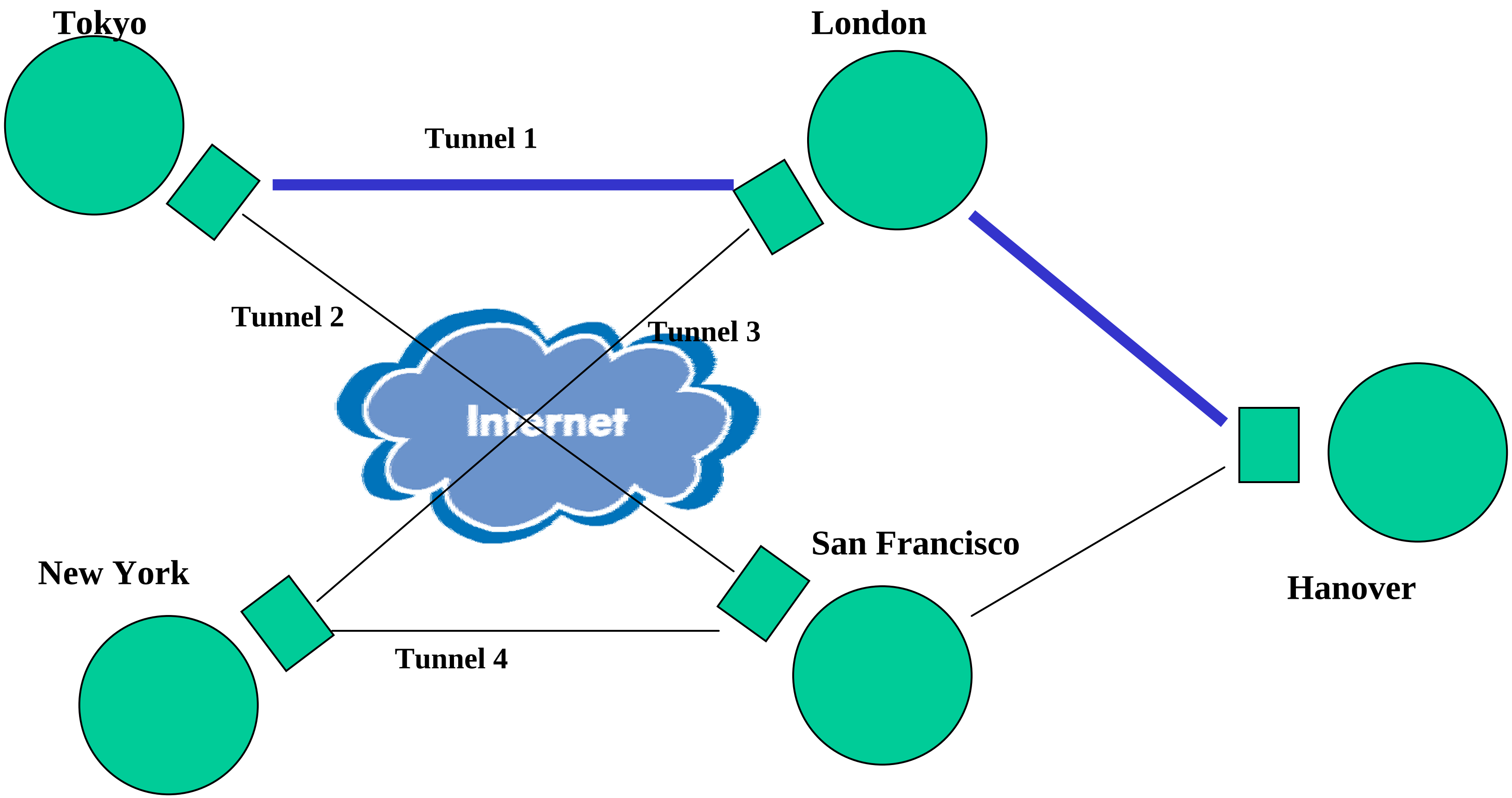


Use Case 1 – New Networks Added to a Remote Site

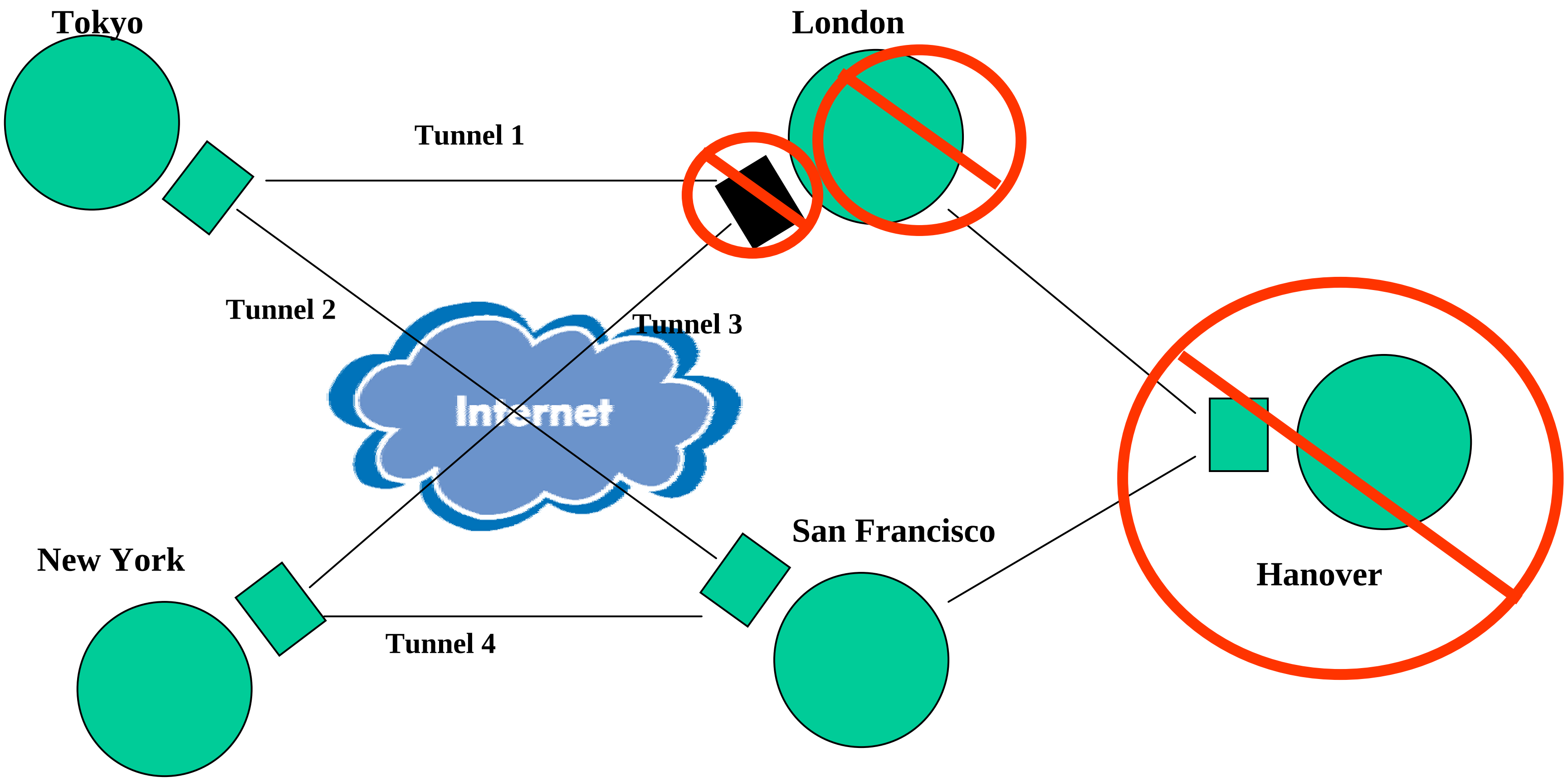


Without dynamic routing protocols through tunnels, none of the other Sites will be able to reach the London-20 and London-30 networks without configuration change.

Use Case 2 – Multiple Paths to Hanover

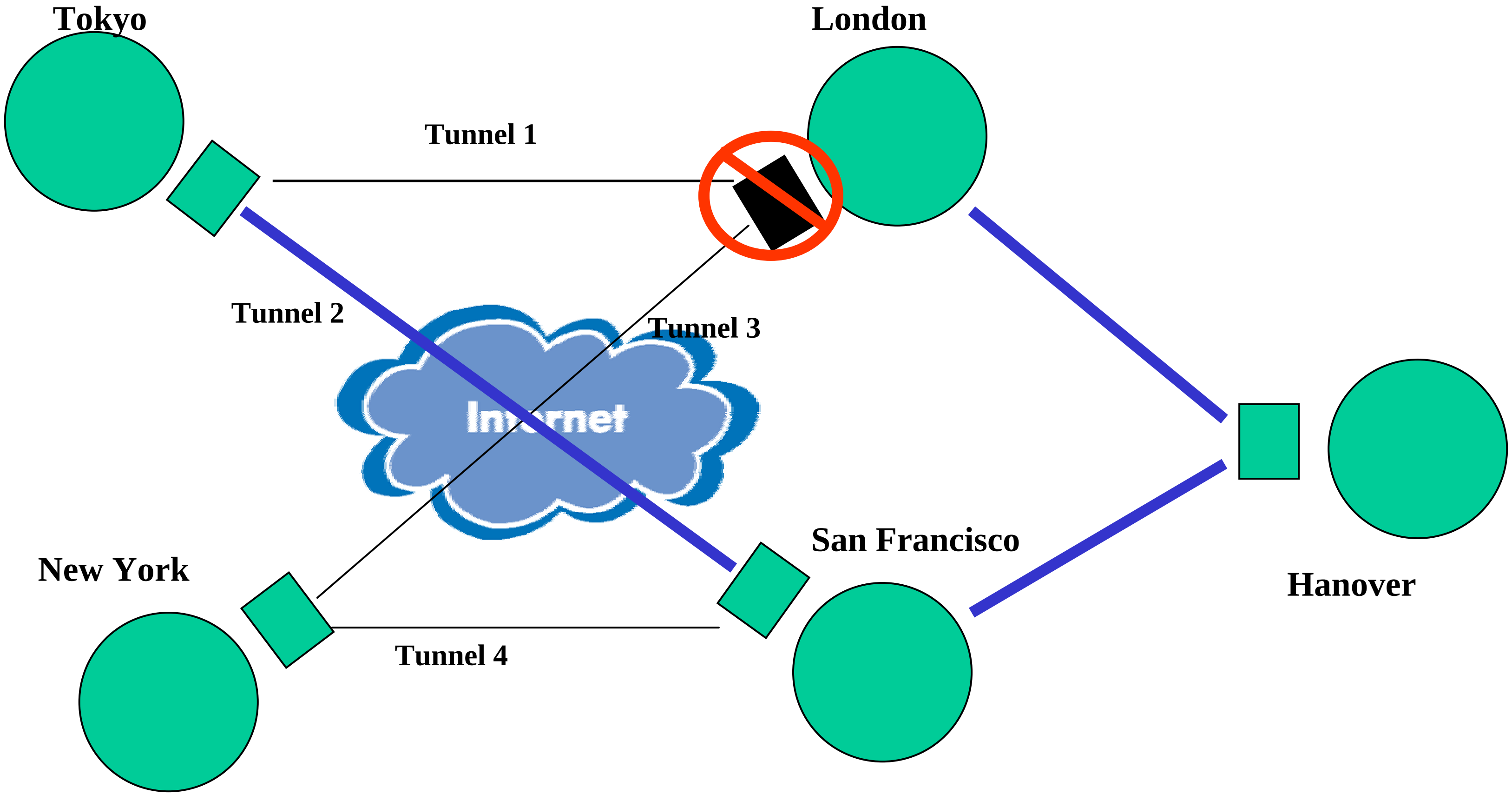


Use Case 2 – Without Dynamic Routing



Connectivity to both London and Hanover are lost.

Use Case 2 – With dynamic routing protocols



Connectivity to both London and Hanover are maintained.

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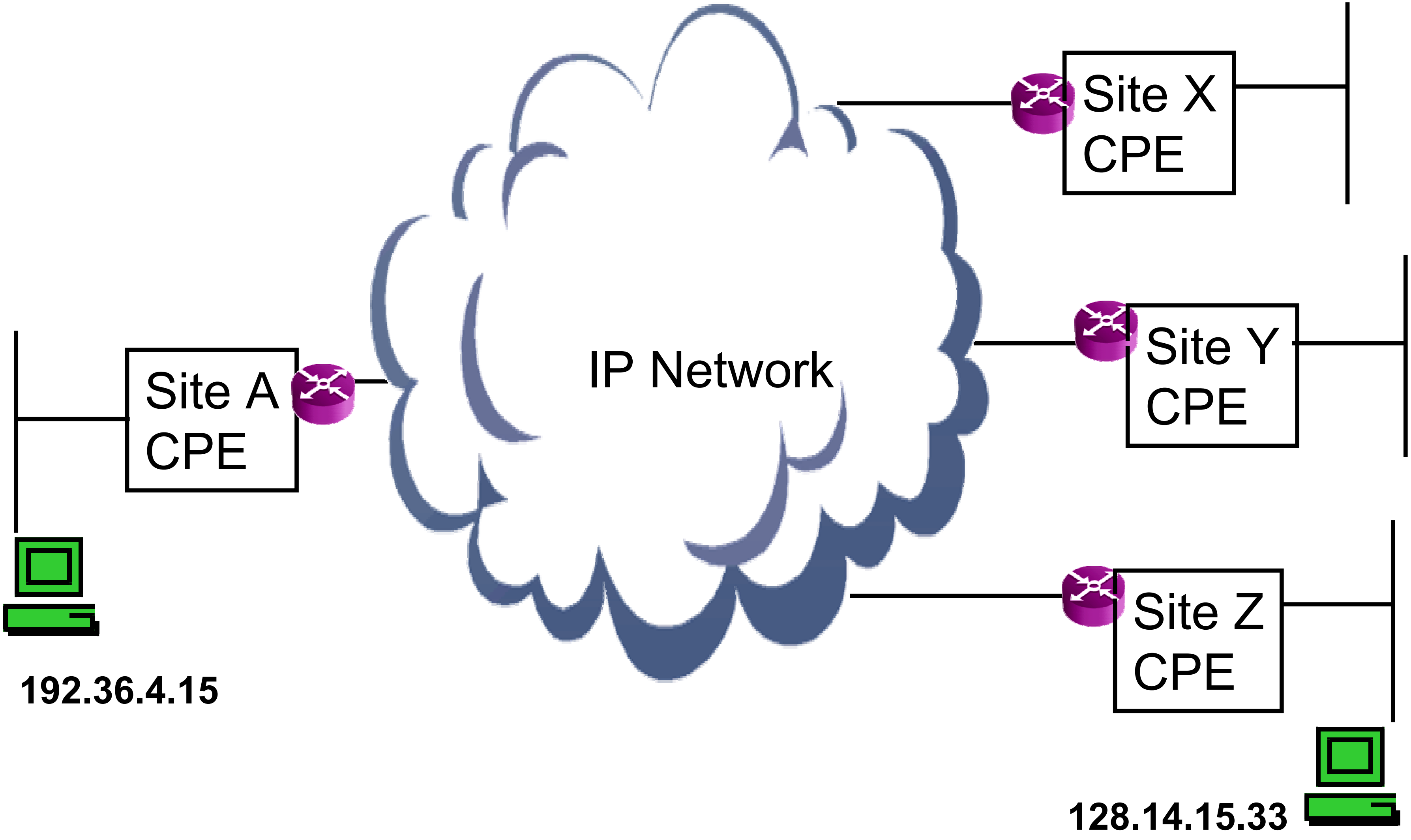
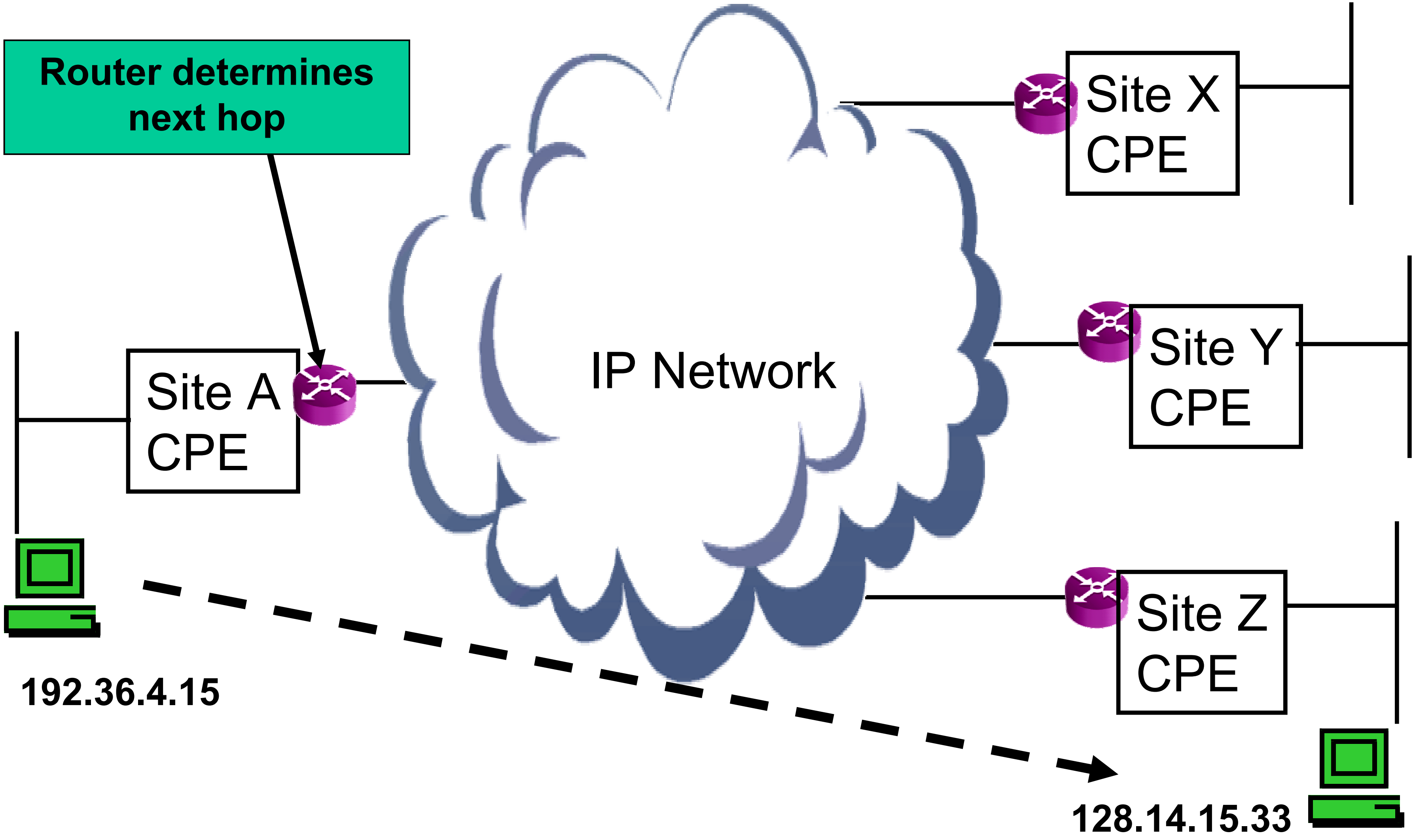
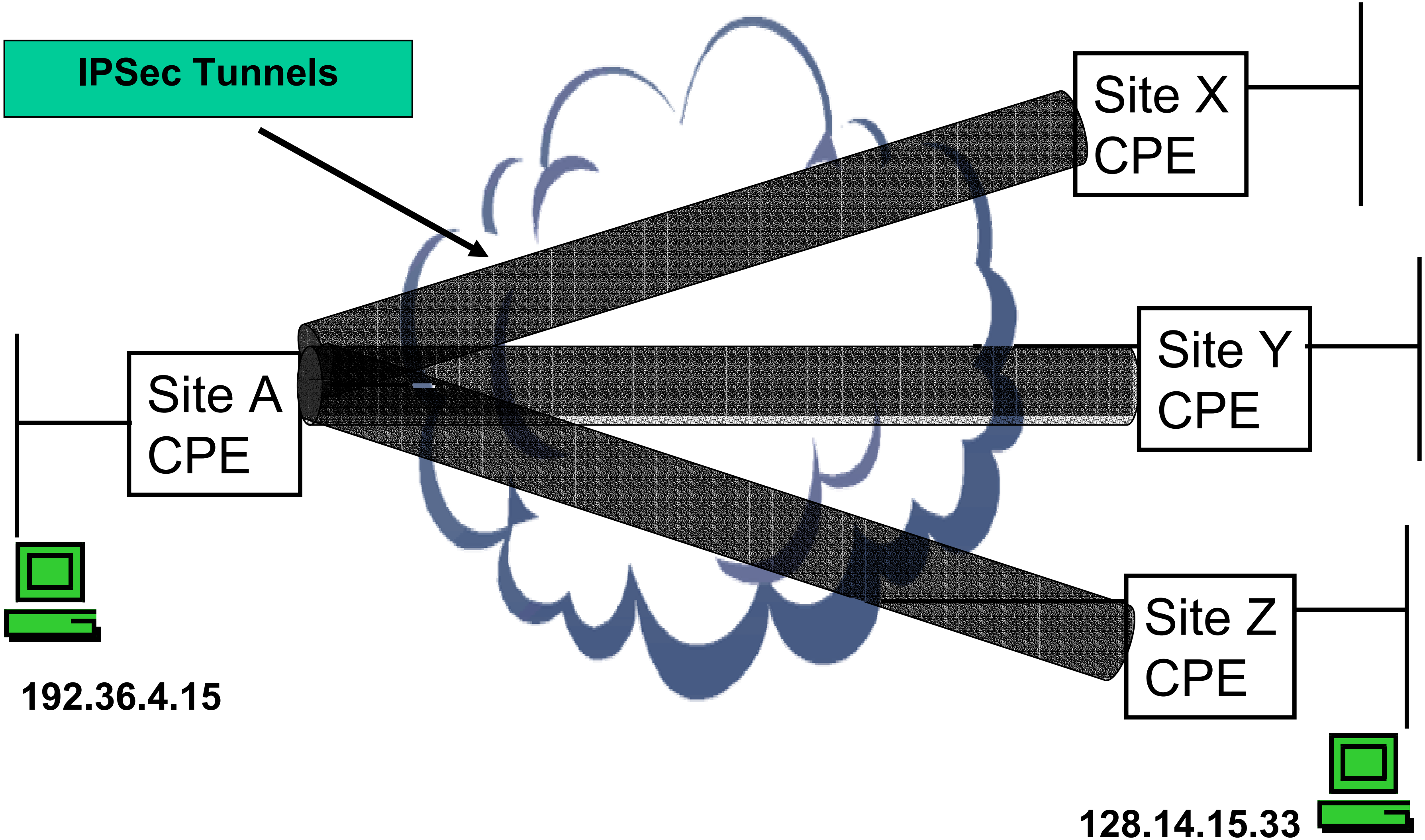
Typical Routing Environment



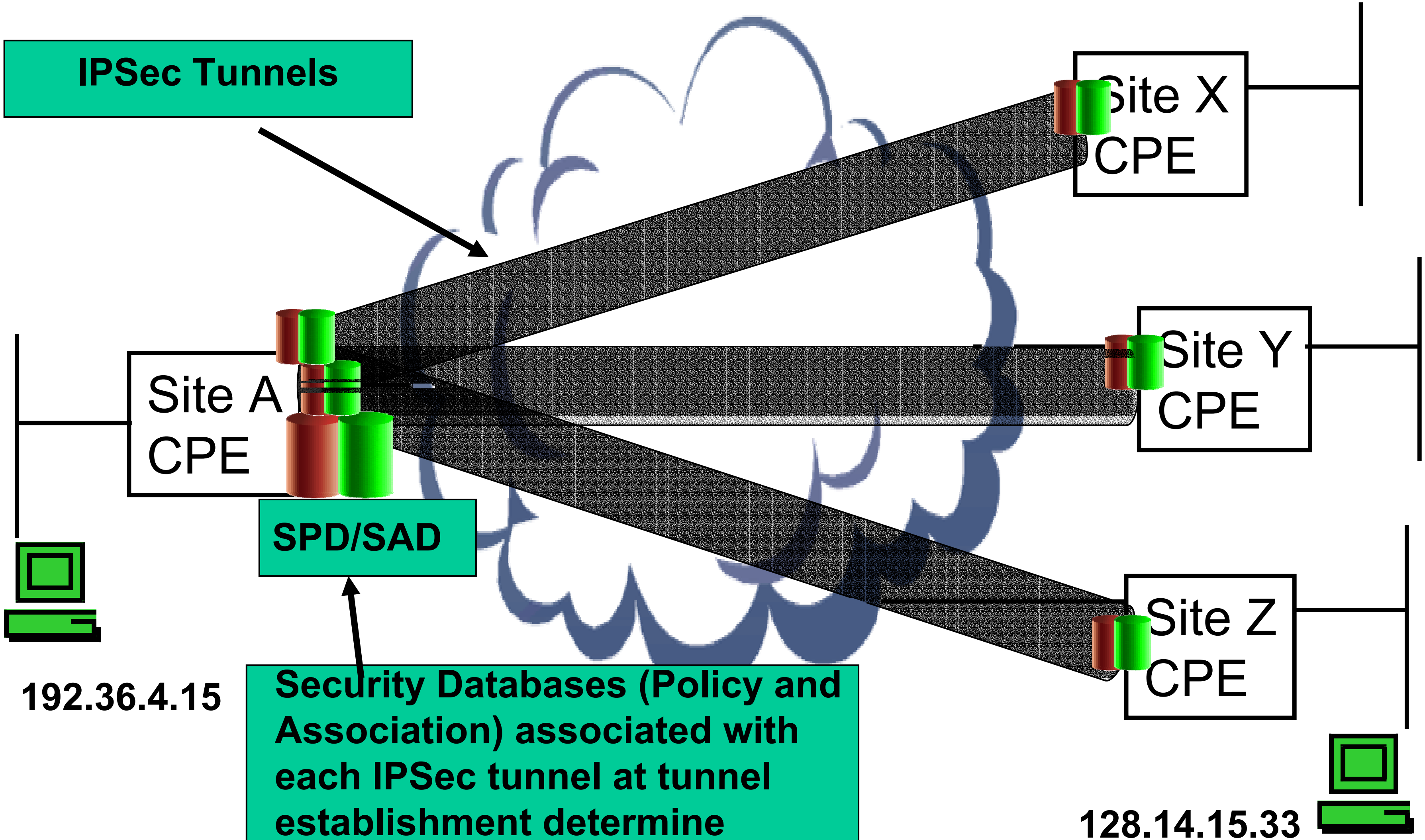
Typical Routing Environment



Typical IPSec VPN Environment

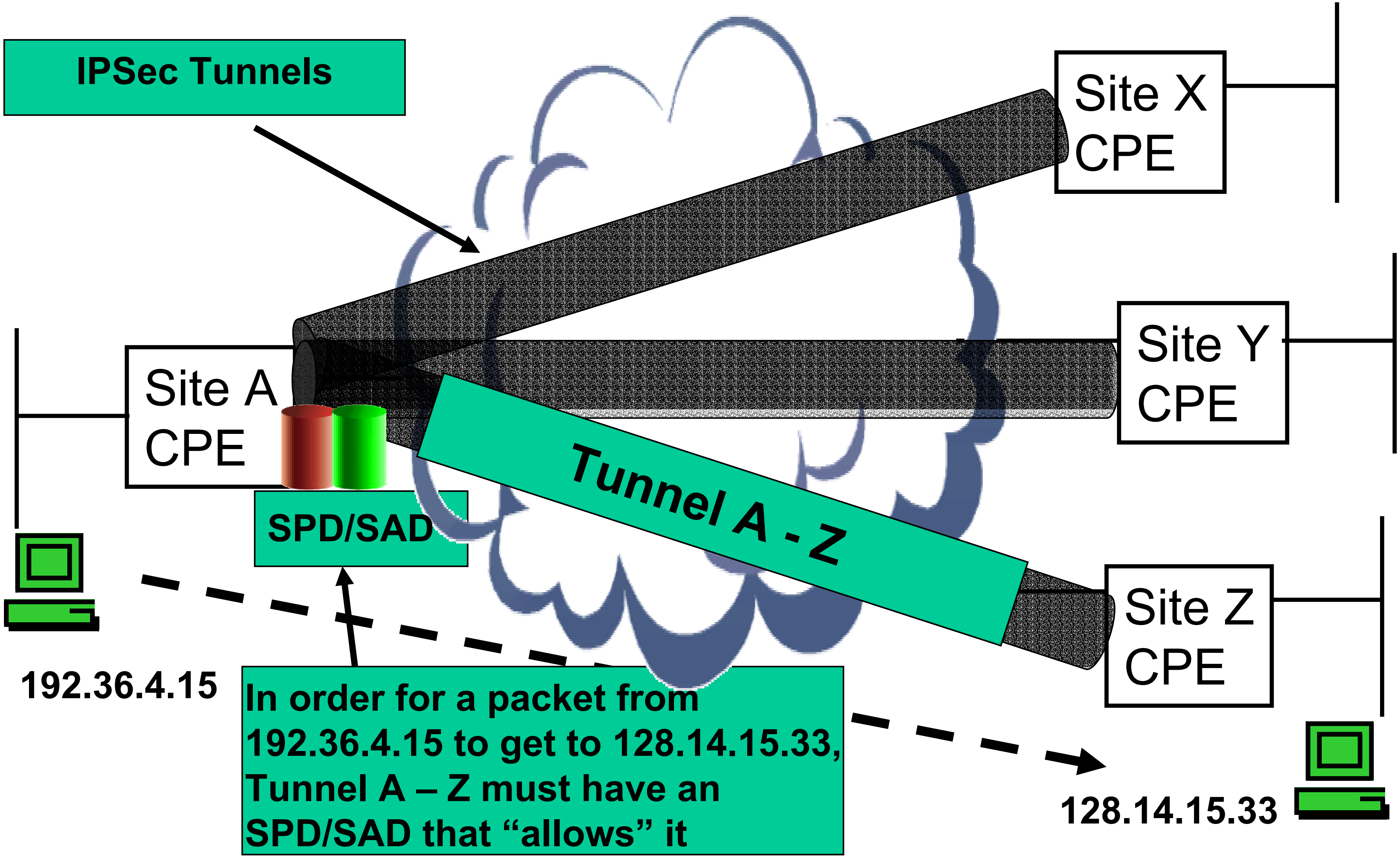


Typical IPSec VPN Environment



Security Databases (Policy and Association) associated with each IPSec tunnel at tunnel establishment determine "next hop"

Typical IPSec VPN Environment



IPSec Tunnels

Site X CPE

Site Y CPE

Site A CPE

SPD/SAD

Tunnel A - Z

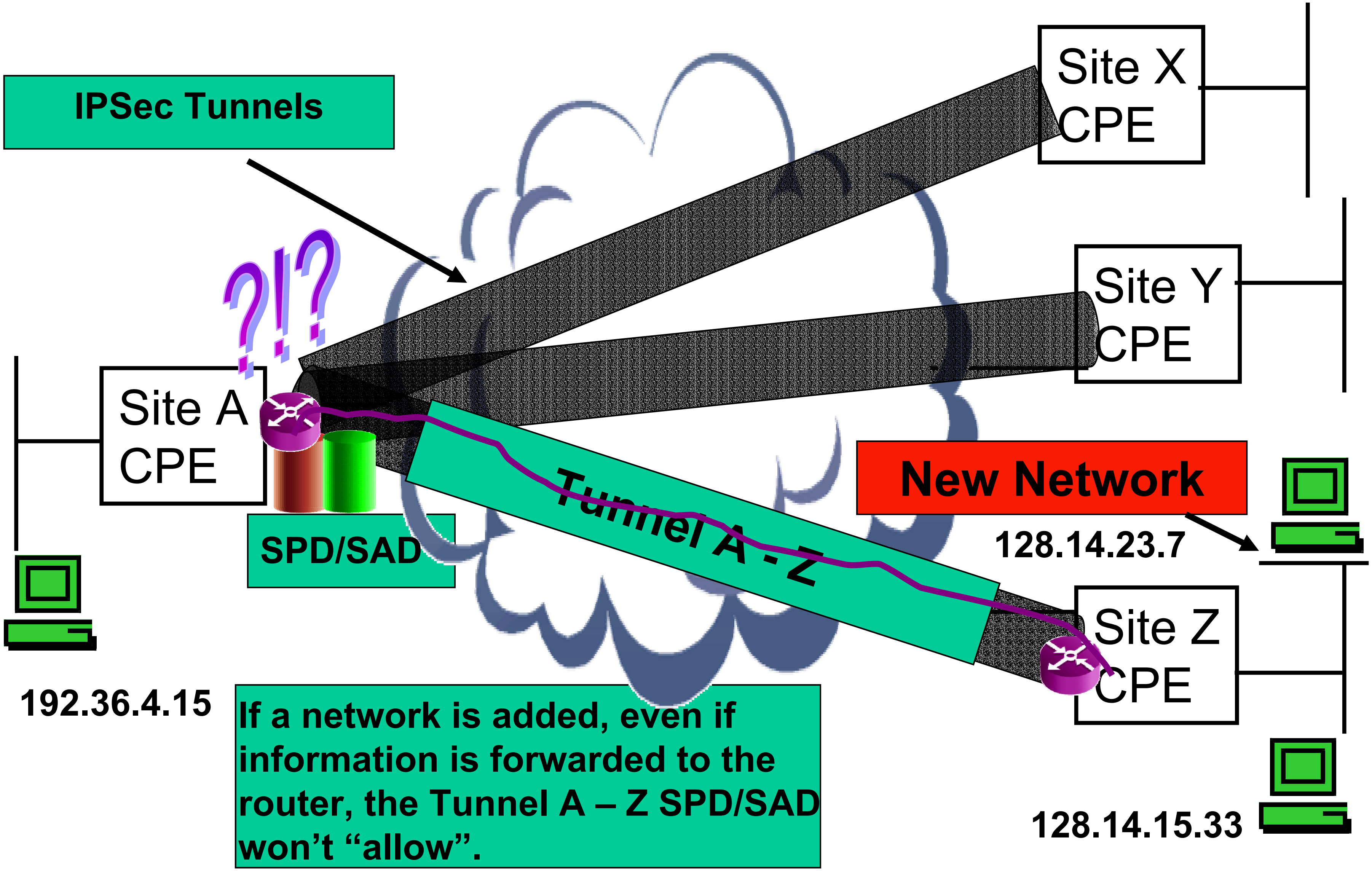
Site Z CPE

192.36.4.15

128.14.15.33

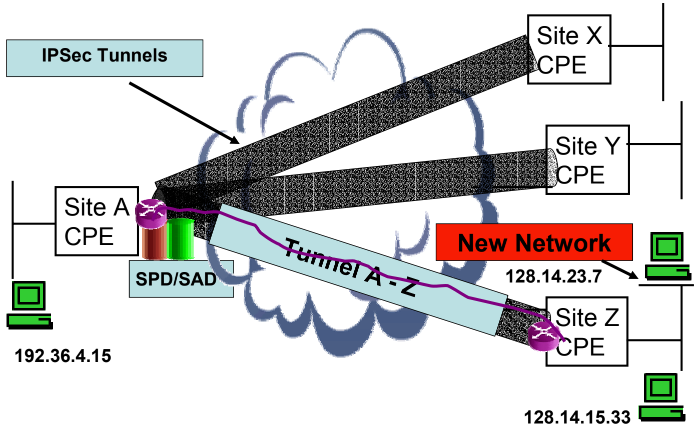
In order for a packet from 192.36.4.15 to get to 128.14.15.33, Tunnel A – Z must have an SPD/SAD that “allows” it

Typical IPSec VPN Environment



If a network is added, even if information is forwarded to the router, the Tunnel A – Z SPD/SAD won’t “allow”.

So: how do you do Dynamic Routing over IPSec tunnels?



- Rebuild IPsec SA for each routing change?

- Make a “Wild Card” SPD/SAD for the IPsec Tunnels?

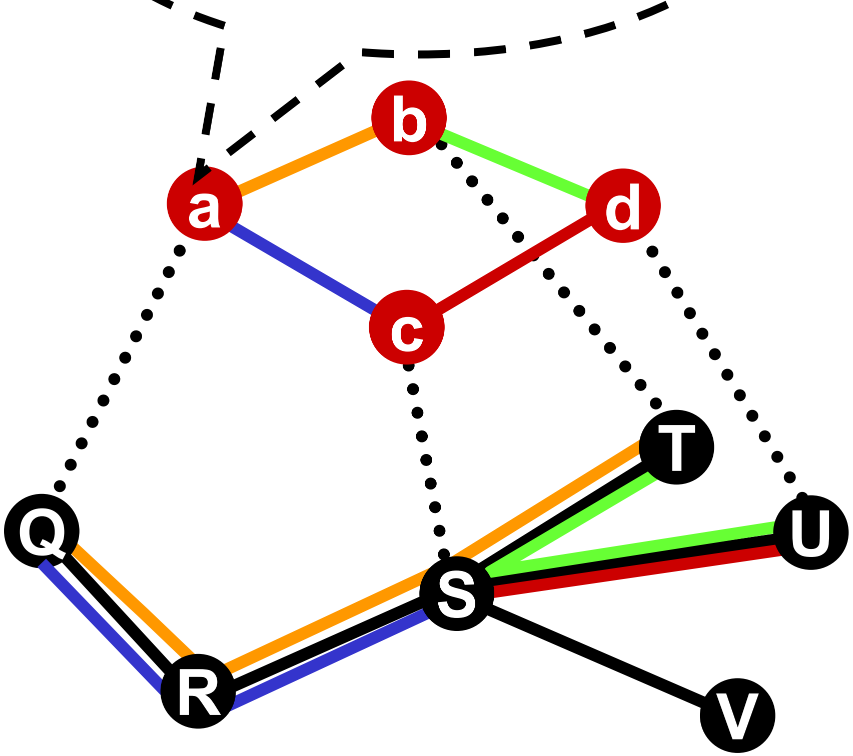
- Do the routing outside of IPsec?

- Current solutions incorporate the ideas of the last two points.

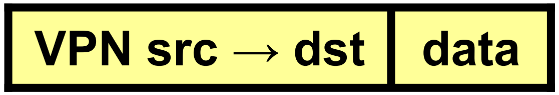
SA ≠ Interface

- tunnel SA = key, src, dst
- encapsulation: **interface operation**
- SAs not in IP forwarding table
- duplicate, separate forwarding mechanism

sel	key	src → dst
d	foo	Q → T
d	bar	Q → S

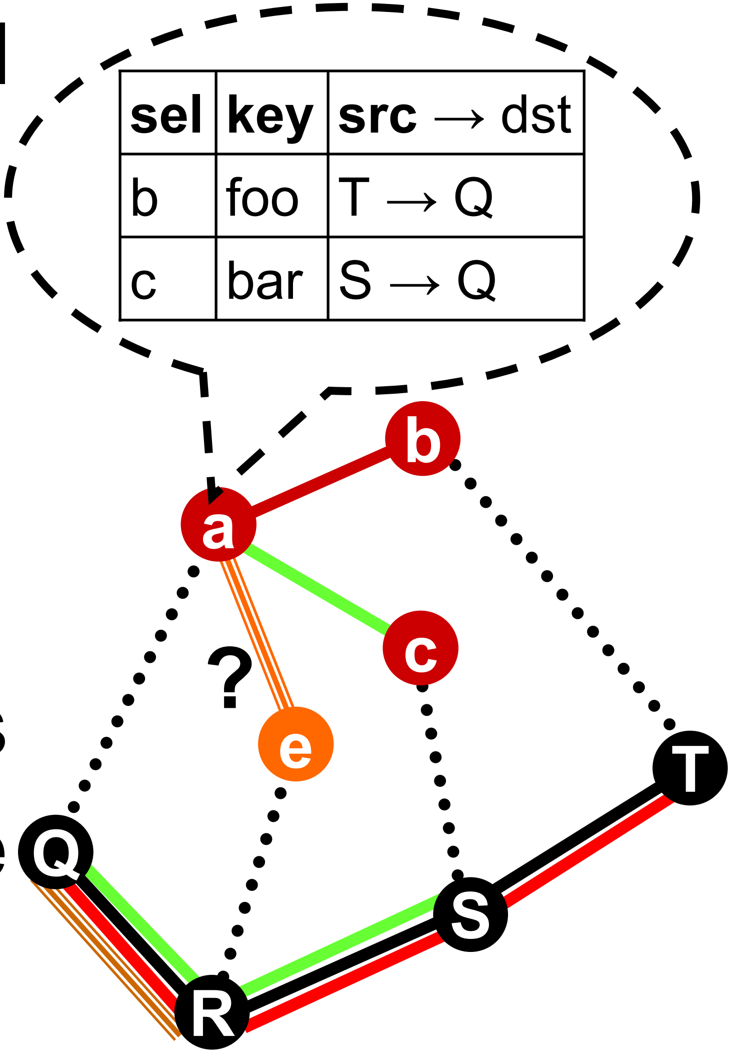


Source Address Selection

-  VPN src → dst data which source IP address?
- RFC 1122, section 3.3.4.3
  - uses notions of interface and route
- tunnel mode SA neither
- security implications!
  - replies in the clear
- result: special case for local traffic
  - must include in IPsec spec, bloat

Selectors and Routing

- selectors = tunnel firewall
- routing update →
  SA renegotiation
  - or valid traffic filtered
  - overhead, stabilization
  - couples routing + IPsec
- option: wildcard selectors
- selectors for tunnel mode less useful?



sel	key	src → dst
b	foo	T → Q
c	bar	S → Q

Routing Protocols via IPsec

- Tough when rtg protocol utilizes a L2 component
- OSPF – has multicast component used on broadcast networks, and NBMA
  - Solution: Use OSPF virtual links or pt-to-pt.
  - Must define neighbors. Good security anyway
- BGP – Works Great!
  - All peers pre-identified/pre-configured
  - All messages in IP. It's easy.
- RIP - L2 and IP level broadcast and can be carried w/o any trouble over the tunnel.
  - Gtwy on other side needs to act as a recipient of the RIP, and not just forward pkt into the internal network.
- ISIS – L2 component needed.

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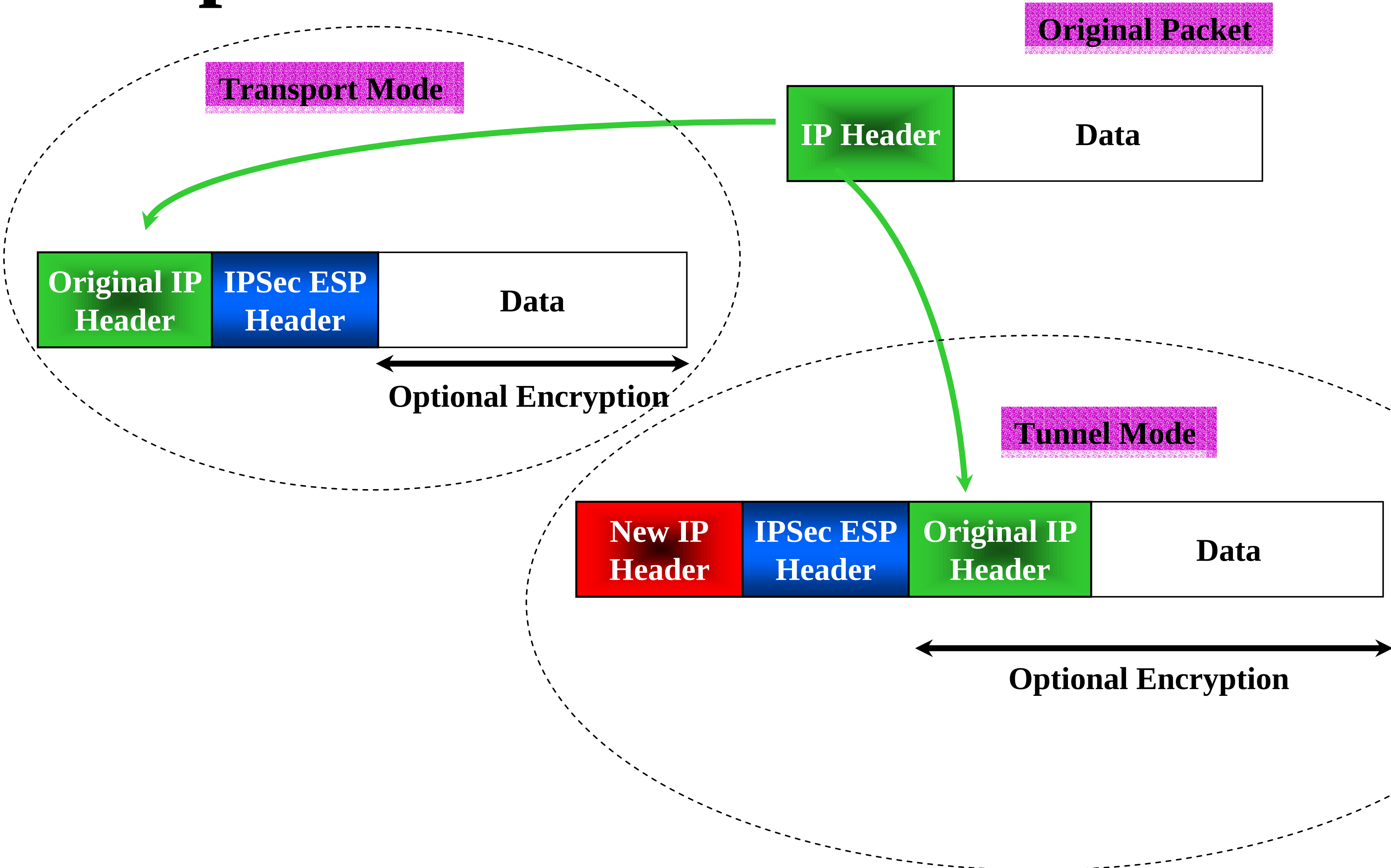
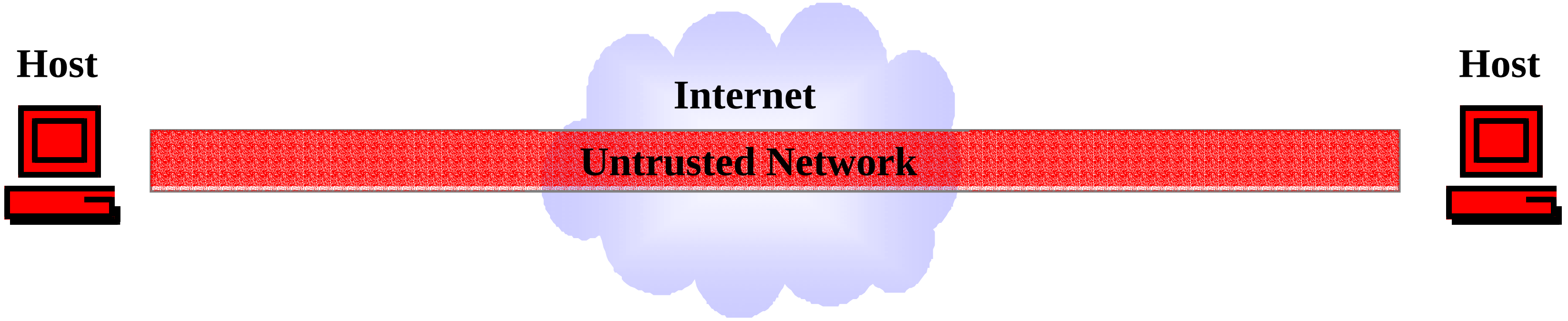
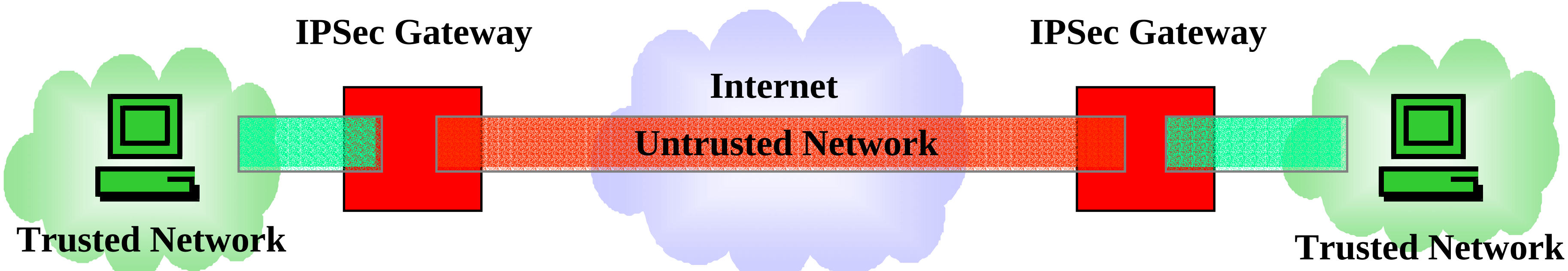
Two IPSec Modes: Transport and Tunnel Mode



Application of the IPsec modes



Can use **Transport (or Tunnel)** Mode between Hosts



Between Gateways: MUST hide IP addresses of trusted networks when traffic crosses the untrusted network.

- **Tunnel Mode…   OR**
- **IP encapsulation within Transport Mode**

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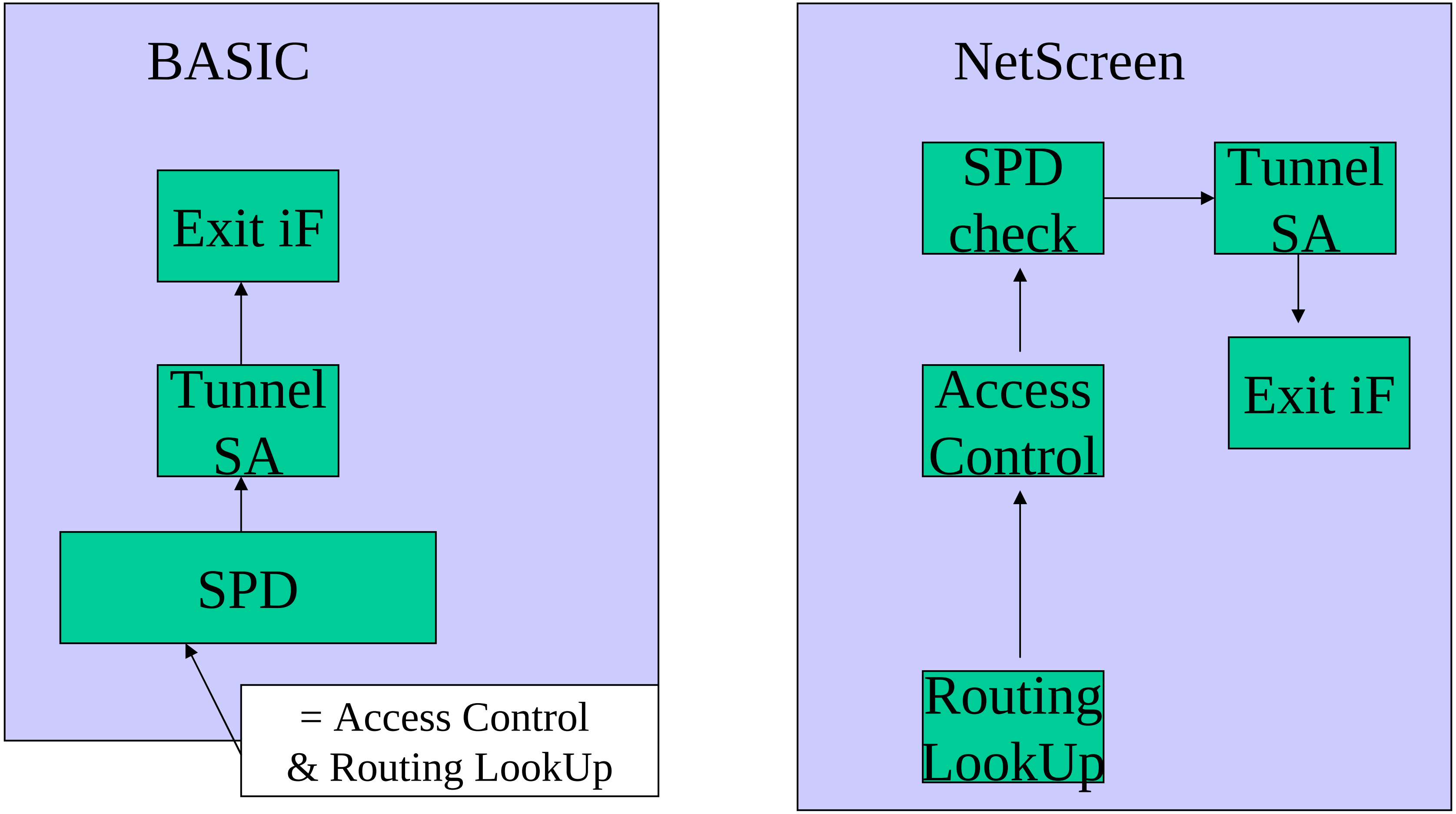
Implementations: NetScreen

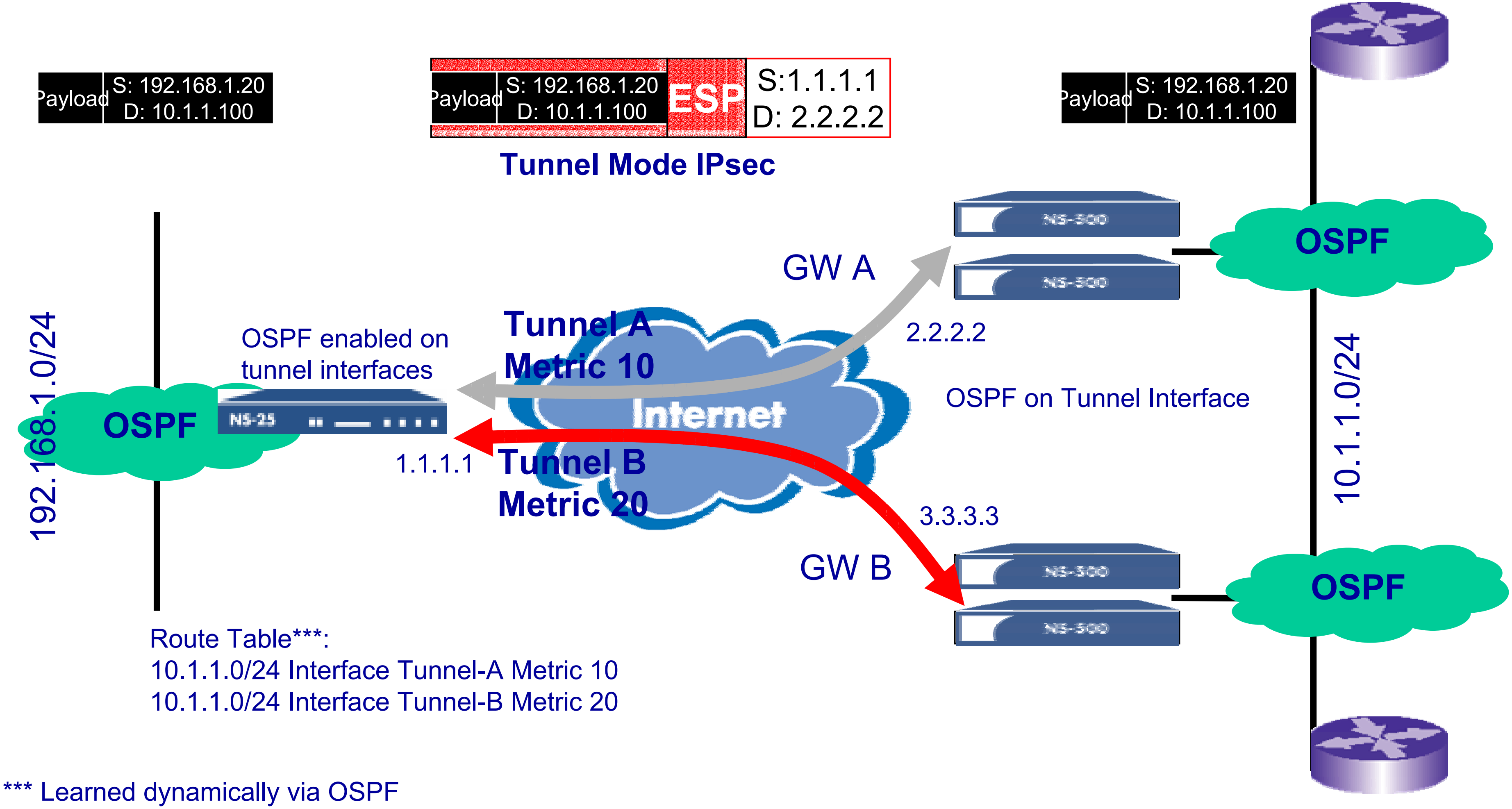
- How it works
  - Tunnel Mode using wild-card (0/0) Proxy-Ids
  - Remove Access control from tunnel decision
  - Explicitly separate Routing function from SPD function
  - Treat tunnel as routable interface (un- or numbered)
- Benefits
  - Less packet overhead
  - Works through NAT boundaries
  - Faster due to less encapsulation processes
- Drawbacks
  - Other side must support same method
  - IP traffic only

NetScreen – Functional Difference



NetScreen’s Solution

Tunnel Mode IPsec, Numbered or Unnumbered “Tunnel” Interfaces,
Route decision and access control separate from IPsec processing



Route Table***:
10.1.1.0/24 Interface Tunnel-A Metric 10
10.1.1.0/24 Interface Tunnel-B Metric 20

*** Learned dynamically via OSPF

Implementations: Nortel Networks Contivity

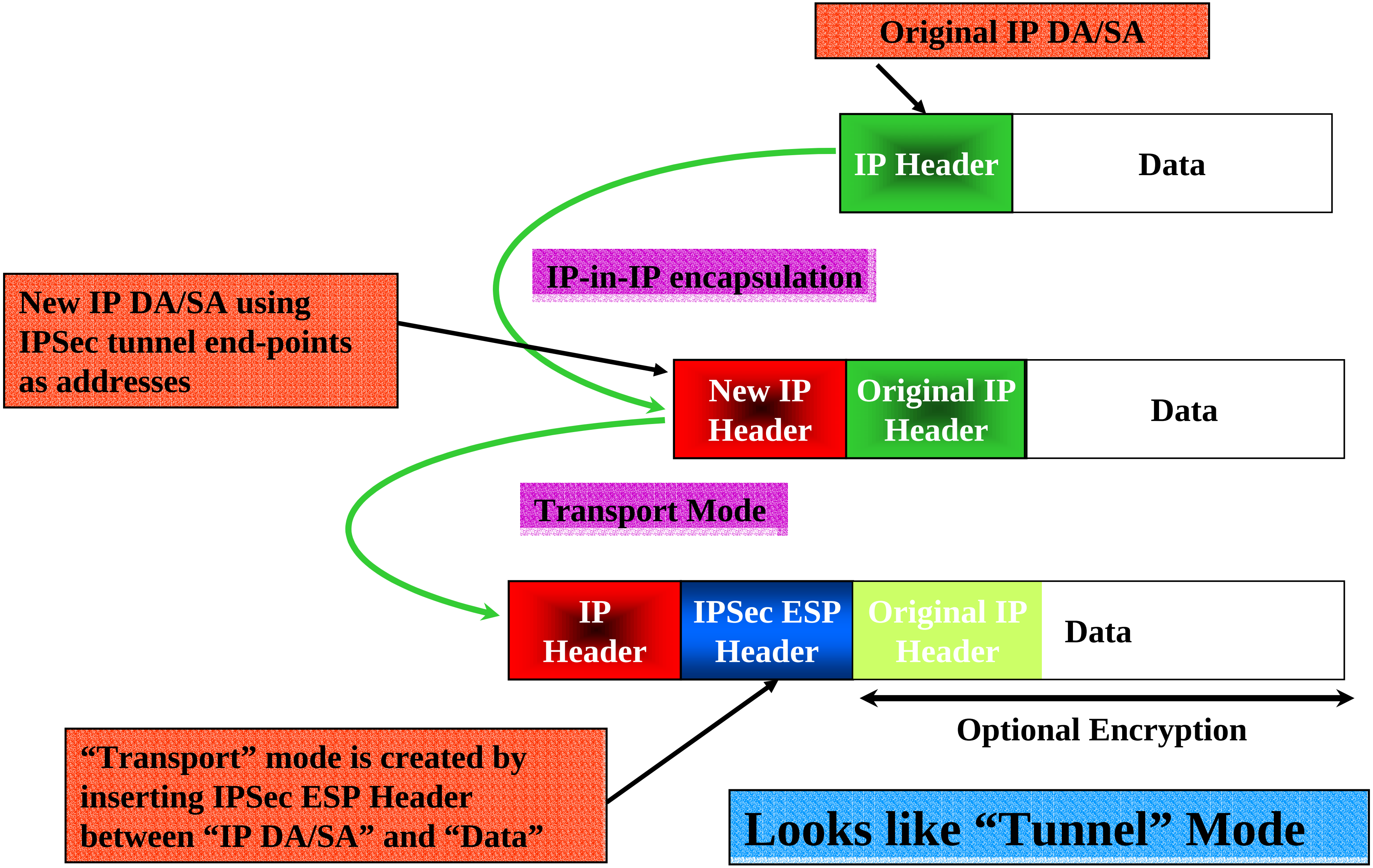
- How it works for dynamic routing*
  - Transport Mode IPsec Security Association is created, protecting IP-in-IP encapsulated traffic
  - IP-in-IP encapsulation assigns the tunnel endpoints based on routing table
  - Firewall, filtering, access control - applied outside IPsec
  - Contivity gateways see peers as next-hops for routing
- Benefits
  - Packets exactly same as Tunnel mode
  - Routing clearly separated from IPsec SPD processing; “Secure Routing Technology”
- Drawbacks
  - Other side must support same method

* IPsec Tunnel Mode is used with static routing

Transport mode + IP encapsulation

- Determine “next IPsec hop” of the packet, using any criteria the “routing engine” can handle:
  - route to destination (using dynamic information!)
  - protocol
  - port (socket)
  - even content analysis (URL, etc.)
- Construct new encapsulating IP header with source of own IPsec gateway address; destination of next IPsec hop
- Pass to IPsec process for TRANSPORT mode processing
- Resulting packet is equivalent to tunnel mode, but now it is routed using dynamic routing updates

Transport mode + IP encapsulation



"Transport" mode is created by inserting IPSec ESP Header between "IP DA/SA" and "Data"

Looks like "Tunnel" Mode

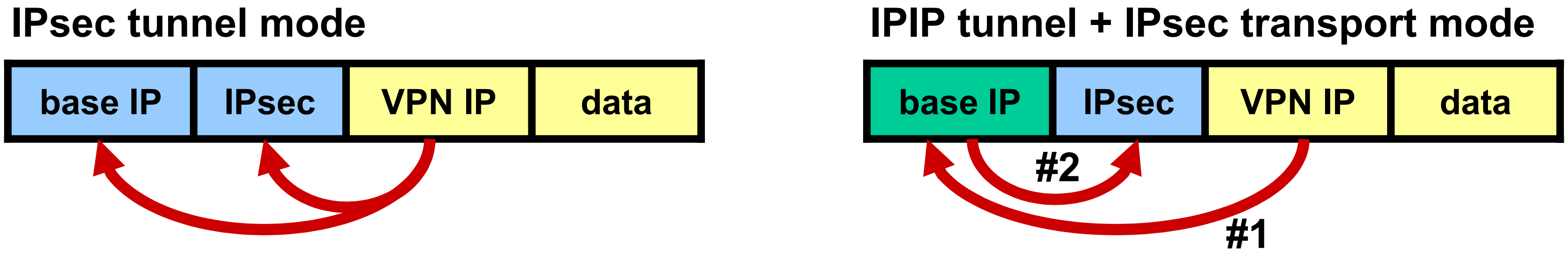
Implementations: ISI’s X-Bone and TetherNet

Subjective IPsec History

- goal: secure end-to-end IP
  - everybody will do transport mode
- tunnel mode: **stopgap**
  - wrap packets from legacy boxes
  - one-hop topologies
- then virtual networks come along

Proposed Solution

- kill tunnel mode, instead combine:
  - RFC 2003 IPIP tunnel (step #1)
  - IPsec transport mode (step #2)
- route VPN IP → encaps → IPsec base IP



- draft-touch-ipsec-vpn-05.txt

Benefits

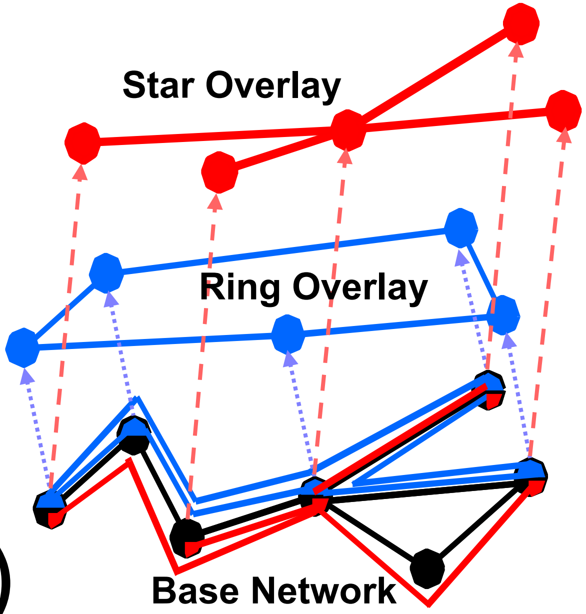
- IP tunnels: real interfaces with routes
  - explicit next hop
  - routing protocols and code just work
  - source address selection works
- simplifies spec
- decouples security from topology

Issues

- tunnel mode selectors more expressive
  - equivalent: policy routing + tunnel firewall
- IKE does 3 things:
  - key exchange → OK
  - tunnel management → factor out
  - policy negotiation → factor out
- NAT traversal
  - draft spec requires tunnel mode
  - equivalent: use UDP instead of IPIP

X-Bone

- parallel, secure, virtual Internets
  - IPv{4|6} with DNS, etc.
  - IPsec + dynamic routing
  - revisitation + recursion
  - web interface
- BSD, Linux (Cisco, Mac)
  - no OS changes: any IP app just works
- http://www.isi.edu/xbone/



TetherNet

- true Internet behind NATs and firewalls
  - IPv{4|6}
  - multicast
  - fwd/rev DNS
  - traffic shaping
  - 802.11b AP
  - secure: IPsec for traffic, X.509 for user auth
  - web interface configuration
- http://www.isi.edu/tethernet/

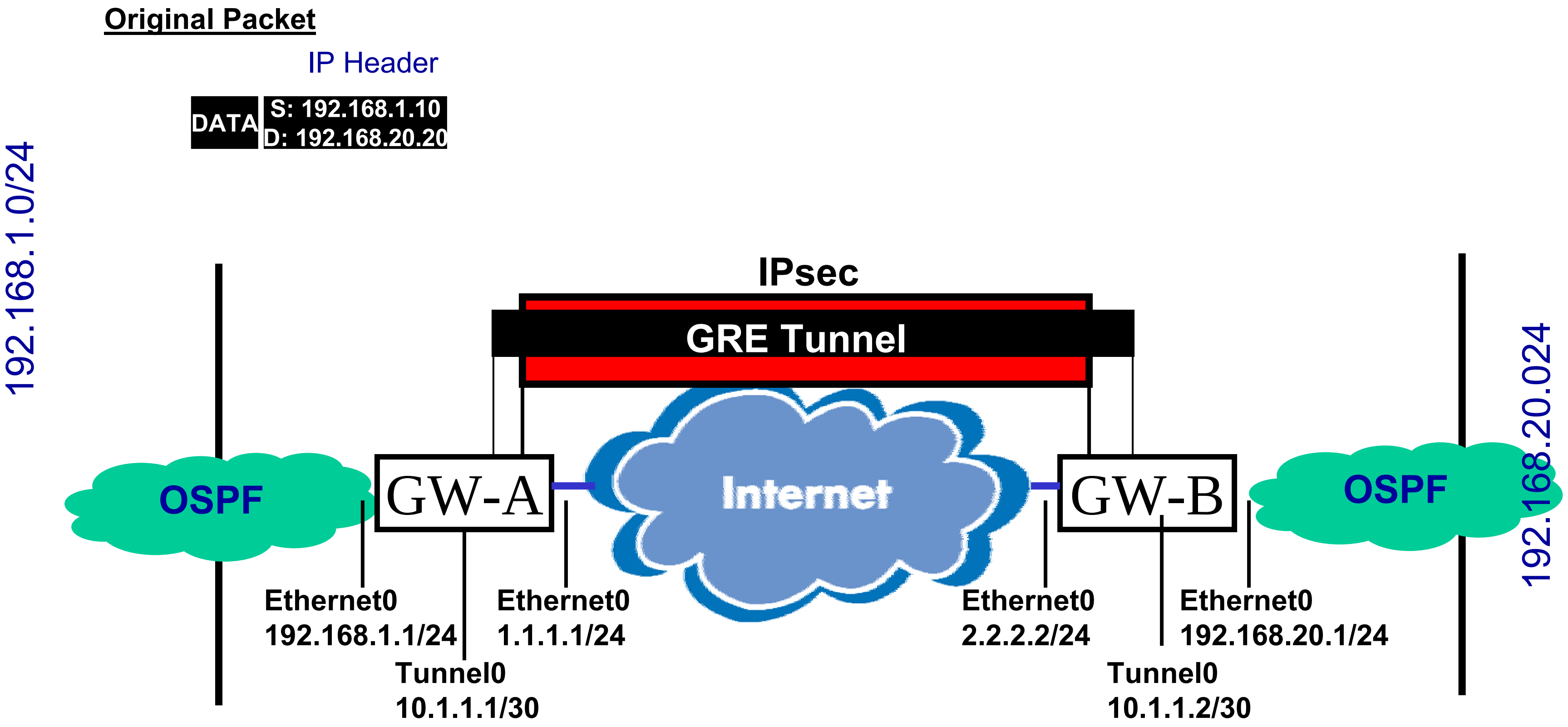
Implementations: GRE-in-IPsec

- How it works
  - Creates virtual routing interface via Generic Routing Encapsulation (GRE), also called a tunnel interface
  - Makes SPD <Local GRE interface, Remote GRE Interface, GRE protocol type>
    - any traffic can pass in the IPsec tunnel w/o changing SPD
    - NEEDS ACCESS CONTROL ON GRE
  - Tunnel or Transport (more efficient) Mode

"S" = Source; "D" = Destination

GRE-in-IPsec

Transport Mode



Original Packet

IP Header

DATA

S: 192.168.1.10
D: 192.168.20.20

192.168.1.0/24

192.168.20.024

IPsec

GRE Tunnel

OSPF

GW-A

Internet

GW-B

OSPF

Ethernet0
192.168.1.1/24

Tunnel0
10.1.1.1/30

Ethernet0
1.1.1.1/24

Ethernet0
2.2.2.2/24

Tunnel0
10.1.1.2/30

Ethernet0
192.168.20.1/24

“S” = Source; “D” = Destination

GRE-in-IPsec

Transport Mode

Original Packet

IP Header

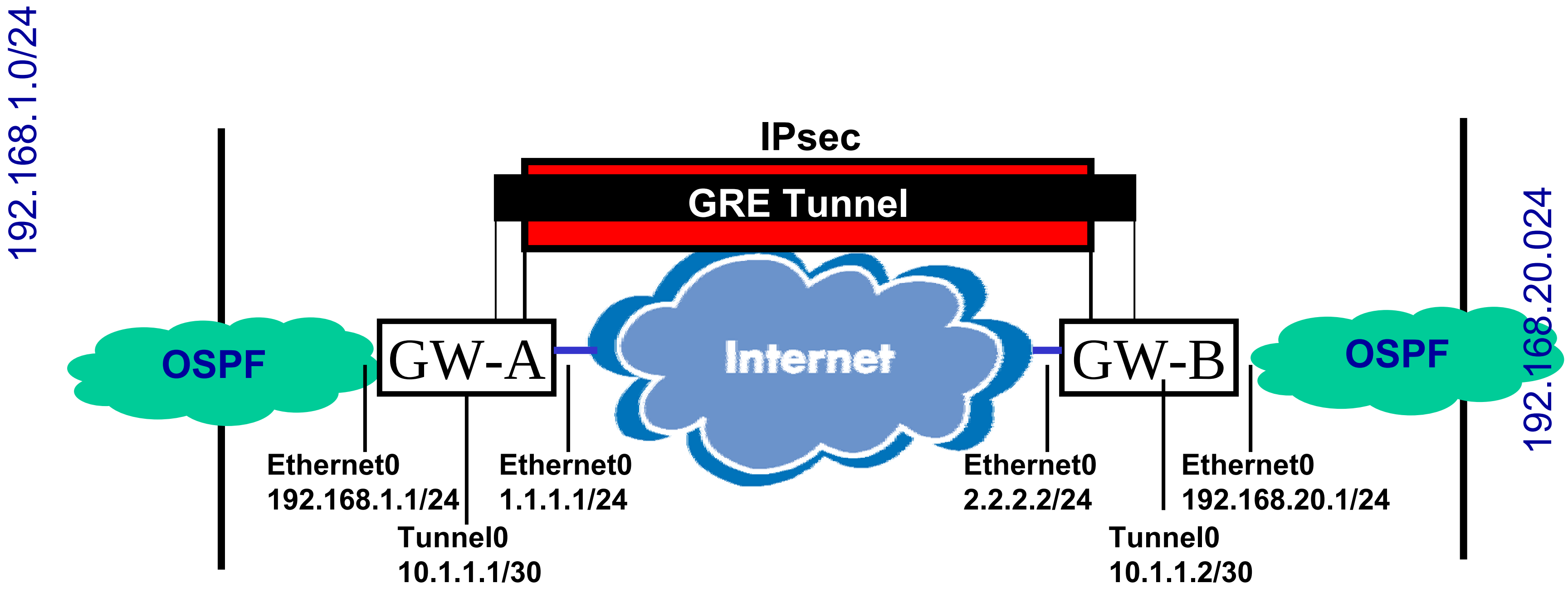
DATA | S: 192.168.1.10
D: 192.168.20.20

GRE header +
New IP Header

GRE Process

DATA | S: 192.168.1.10
D: 192.168.20.20 | GRE | S:1.1.1.1
D: 2.2.2.2

GRE Encapsulates original IP Header and Data with a GRE header, and appends a New IP Header



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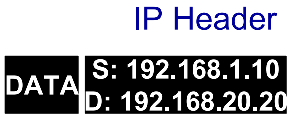
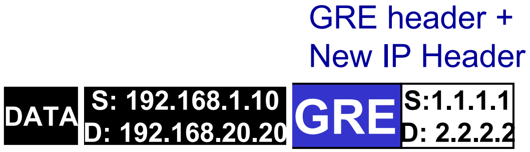
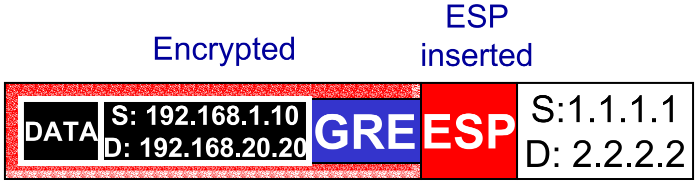


GRE Process

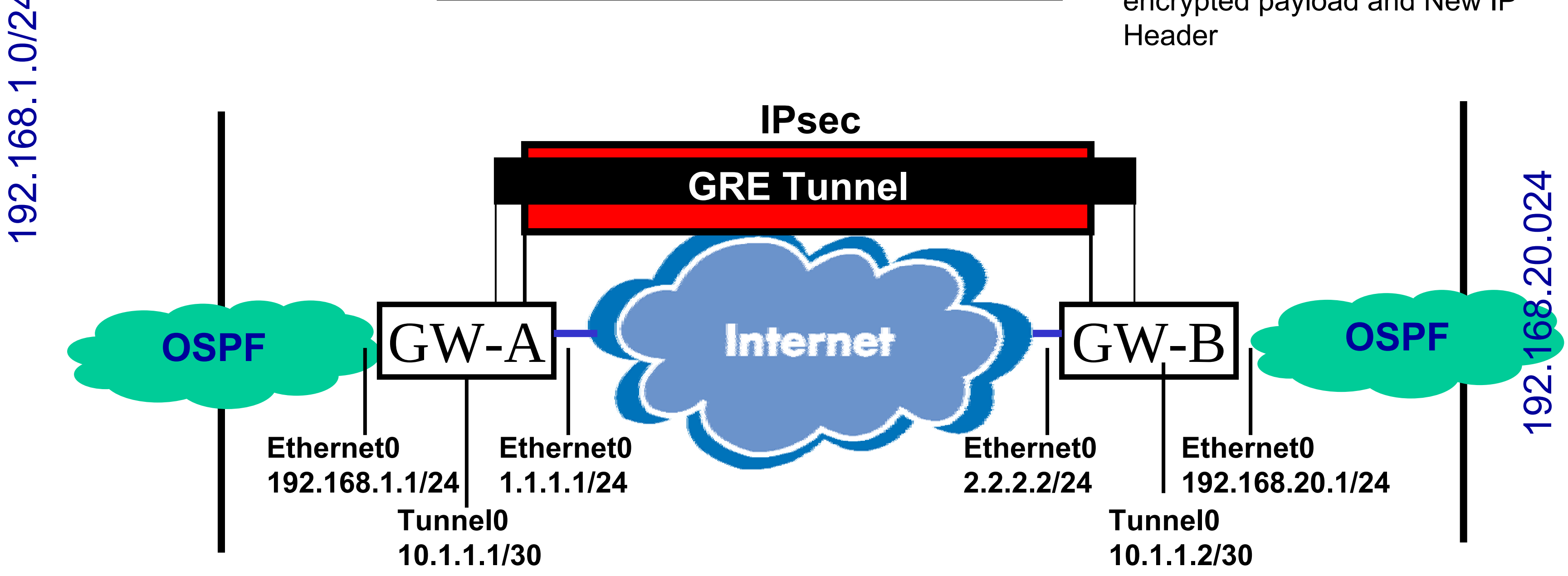


GRE Encapsulates original IP Header and Data with a GRE header, and appends a New IP Header

IPsec Process



IPsec Transport Mode Encrypts entire original packet + GRE header, and inserts the ESP header between encrypted payload and New IP Header



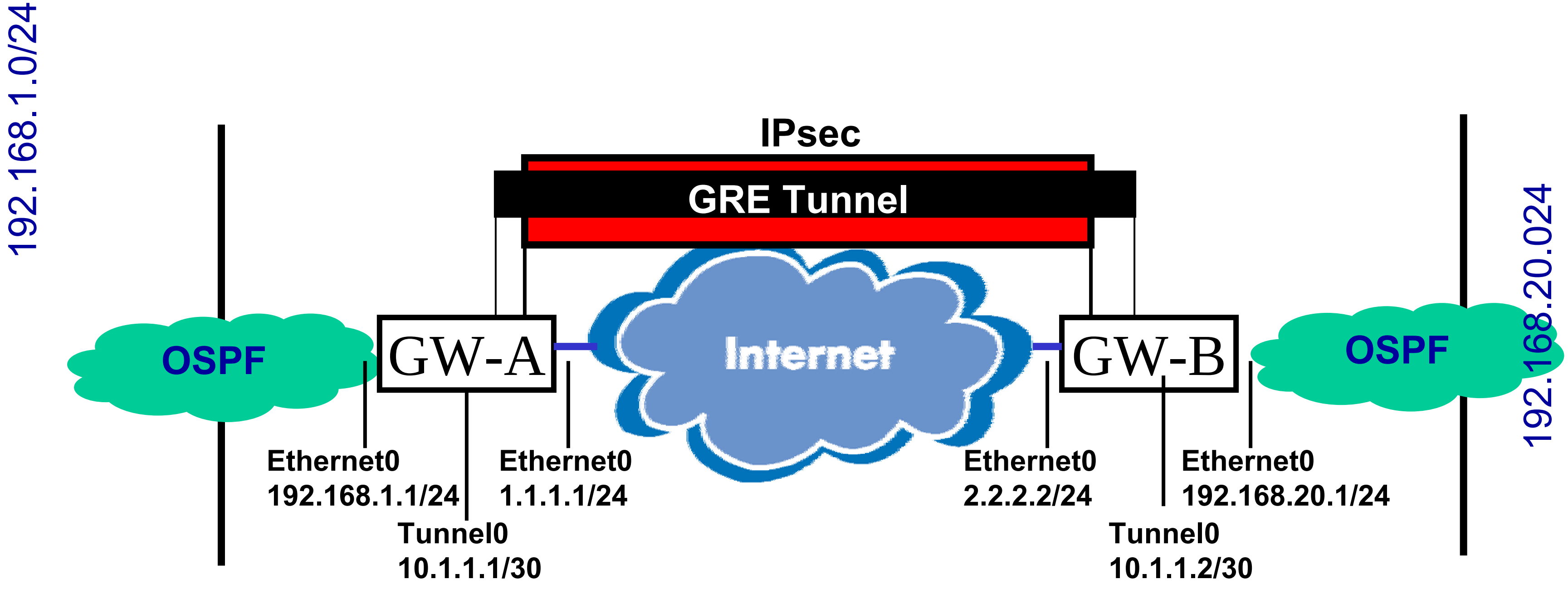
"S" = Source; "D" = Destination

GRE-in-IPsec

Transport Mode

Routing Statements:

Sent between Tunnel0's in GRE with original IP Header of S=10.1.1.1, D=10.1.1.2



GRE Pro’s & Con’s

- Benefits
  - Carry non-IP traffic (only method for IS-IS)
  - Tunnel or Transport mode
- Drawbacks
  - Additional encapsulation, > overhead
    - 4 bytes for Transport
    - 20 bytes for Tunnel
  - Performance hit
    - another encapsulation to process
    - Fragmentation – offset by lowering MTU on GRE interface

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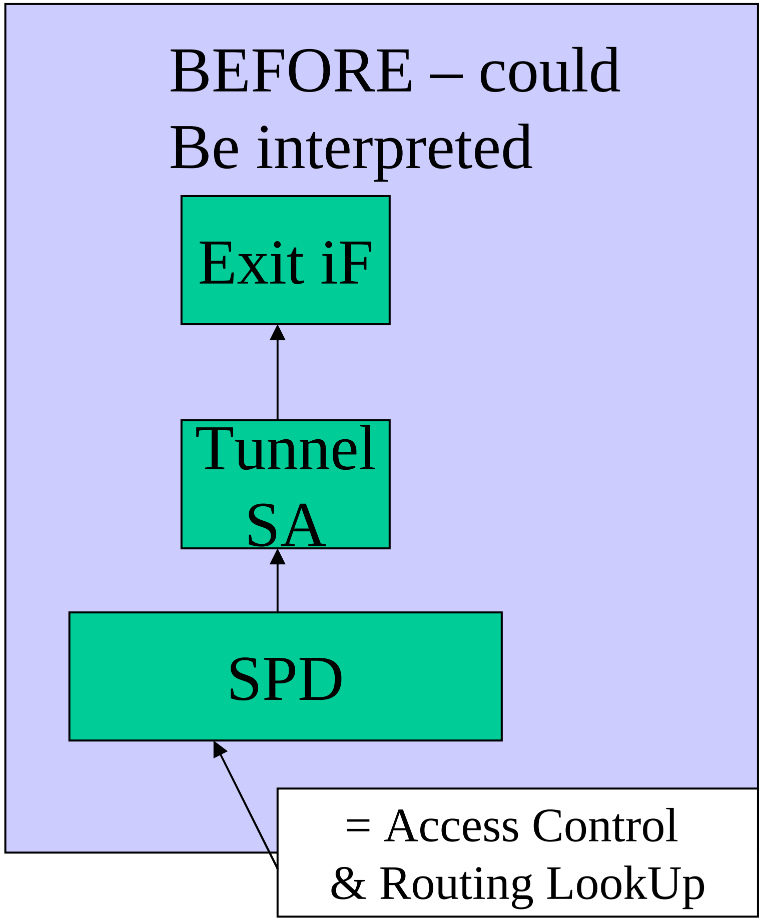
Changes in ESP (2401bis)

- ESP SPD lookup. Traffic Selectors in the SPD are only used to drop or permit traffic, but not used for a routing decision. Routing function exists outside of IPsec.



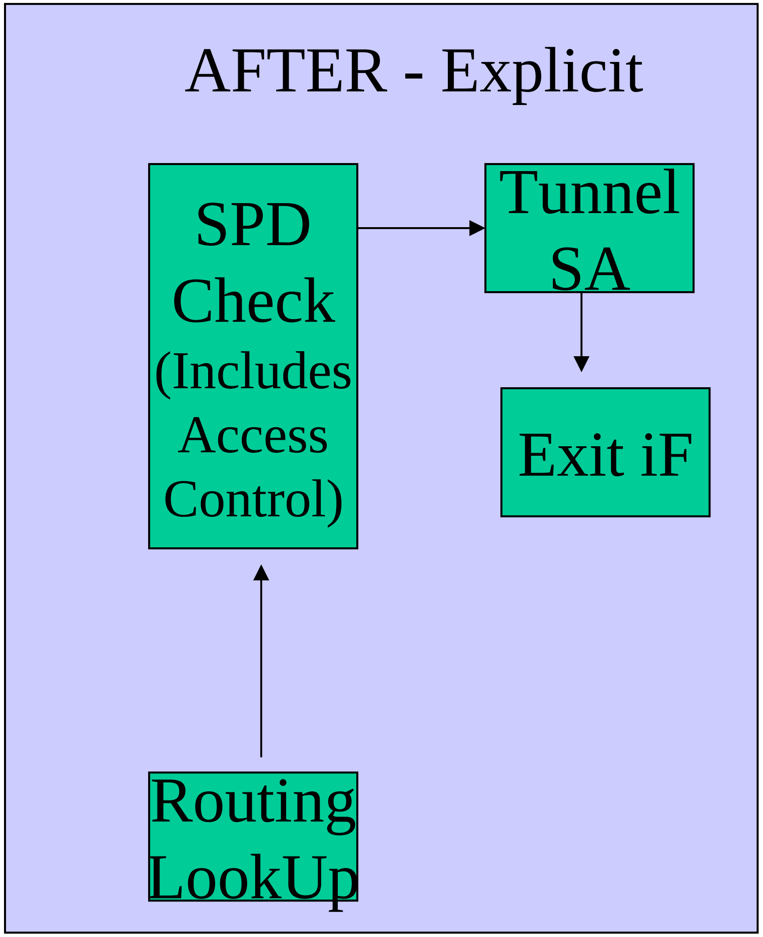
BEFORE – could
Be interpreted

Exit iF

Tunnel SA

SPD

= Access Control
& Routing LookUp



AFTER - Explicit

SPD Check (Includes Access Control)

Tunnel SA

Exit iF

Routing LookUp

IETF - Dynamic Routing in IPsec

- Draft-knight-ppvpn-ipsec-dynroute-02.txt
- (http://www.ietf.org/internet-drafts/ *)
- Gives the gory details of using transport mode with IP-in-IP encapsulation for dynamic routing
- Describes transport of routing protocols within IPsec

Following IETF Activities

- Mailing lists and archives of Working Groups
  - IPSEC
    - General Discussion: ipsec@lists.tislabs.com
    - To Subscribe: ipsec-request@lists.tislabs.com
    - Archive: ftp://ftp.tis.com/pub/lists/ipsec
  - PPVPN (Provider Provisioned VPN)
    - General Discussion: ppvpn@nortelnetworks.com
    - To Subscribe: lyris@nortelnetworks.com
    - In Body: (UN)SUBSCRIBE ppvpn in message body
    - Archive: http://standards.nortelnetworks.com/ppvpn/index.htm
- Reading the drafts and RFCs
  - http://www.ietf.org/ID.html
  - http://www.ietf.org/rfc.html

Thank You!