IPv6

Internet Technologies and Applications

Contents

- Summary of IPv6 core features
- Auto-configuration
- IPv4-IPv6 transition techniques
- IPv6 networks today

Motivation

- Current version of TCP/IP
  - Worked well for over 25 years!
  - Design is flexible and powerful
  - Has adapted to:
    - New computer and communication technologies
    - New applications
    - Increases in size and load
- Most significant problem with IPv4
  - Address space limitation
  - How long can we last with 2^{32} (4 billion) addresses?
    - Limitations due to address classes
    - Extended lifetime due to private addresses and NAT
      - Not every computer has a public IP address
    - Initial estimates in 1990's were: 2005 to 2010
    - Current estimates: 2020 to 2025

IPv6

- RFC 2460 released in 1998
  - Designed in early and mid 1990's
- Major new features
  - Larger addresses
  - Extended address hierarchy: ISPs can assign blocks of address to customers
  - Flexible header format: a base format plus options
  - Improved options: easy to include any combination of options
  - Provision for protocol extension: easy to adapt for new options and features
  - Support for autoconfiguration: computers can assign local address automatically
  - Support for resource allocation: includes support for DiffServ

IPv6 Addresses

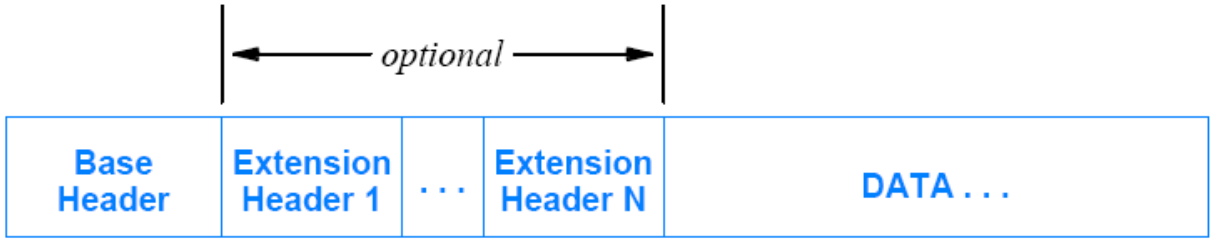
- 128-bit address
  - 3 x 10^{38} – which is 10^{24} addresses for every square metre of Earth's surface!
- Like IPv4, there is a network portion and host portion
- Notation
  - 8 x 4 hexadecimal numbers
  - 68E6:8C64:FFFF:FFFF:0000:1180:096A:FFFF
  - And many abbreviated forms …
    - E.g. compress zeros
- Proposed address spaces
  - Includes backward compatible option for IPv4 addresses
    - E.g. 80 0 bits, 16 bits (0 or FFFF), then IPv4 address

IPv6 Address Space

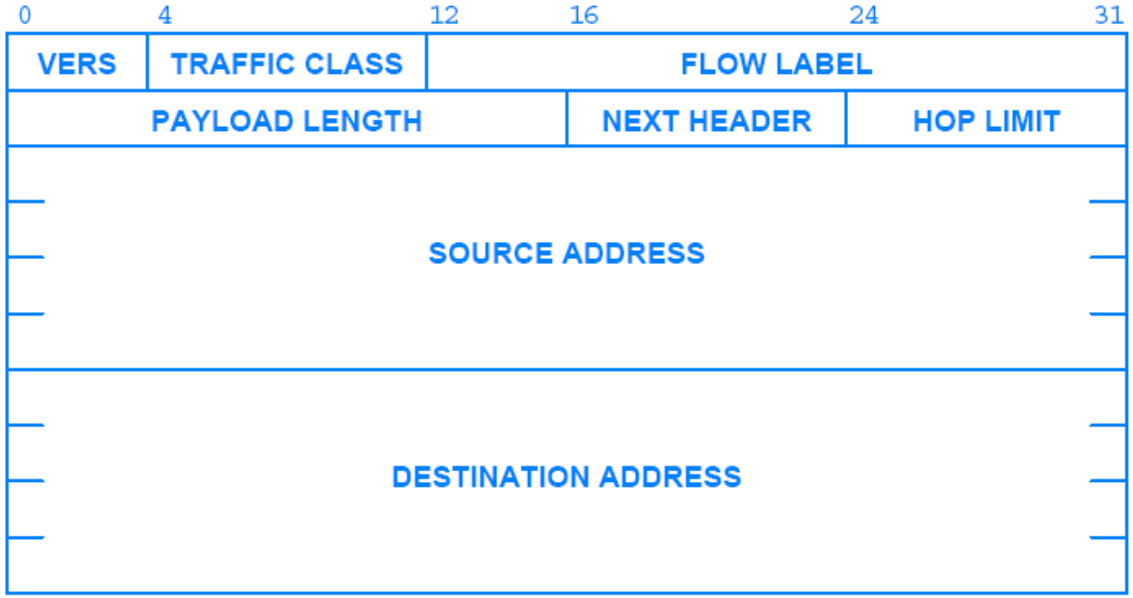
Binary Prefix	Type Of Address	Part Of Address Space
0000 0000	Reserved (IPv4 compatibility)	1/256
0000 0001	Unassigned	1/256
0000 001	NSAP Addresses	1/128
0000 01	Unassigned	1/64
0000 1	Unassigned	1/32
0001	Unassigned	1/16
001	Global Unicast	1/8
010	Unassigned	1/8
011	Unassigned	1/8
100	Unassigned	1/8
101	Unassigned	1/8
110	Unassigned	1/8
1110	Unassigned	1/16
1111 0	Unassigned	1/32
1111 10	Unassigned	1/64
1111 110	Unassigned	1/128
1111 1110 0	Unassigned	1/512
1111 1110 10	Link-Local Unicast Addresses	1/1024
1111 1110 11	IANA - Reserved	1/1024
1111 1111	Multicast Addresses	1/256

IPv6 Datagrams

- General format:



- Base header is required; also multiple optional headers allowed



IPv6 Datagrams

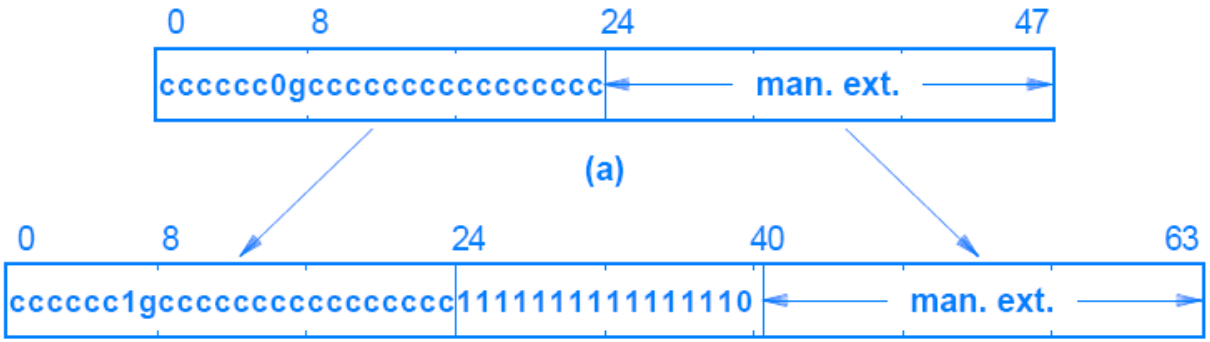
- Extension Headers:
  - Each extension header has a “Next Header” field which says what is the type of next header
  - Examples:
    - Fragmentation
    - Routing
    - Security
    - Hop-by-hop options
    - …

Link Local Addresses

- Used for computers within a single network
- A router will never forward a datagram from a link-local address outside of the network
- Useful for configuration of the network and in isolated networks (e.g. peer-to-peer wireless network)
- First 10 bits of address are:
  - 1111 1110 10

Autoconfiguration in IPv6

- IPv6 supports serverless or stateless autoconfiguration
  - Do not need a DHCP server to configure computers IP address
  - Relies on:
    - Link local addresses
    - Embedded interface identifiers
- Embedded interface identifiers
  - Example: 48-bit IEEE MAC address (e.g. your network card address)
    - Split into company identifier (c) and manufacturers extensions
  - In IPv6 becomes 64-bit identifier



Autoconfiguration in IPv6

1. Host generates IPv6 link-local address from:
   - Link-local prefix (1111 1110 10), 54 zeros and 64 bit embedded interface identifier
2. Checks whether the generated address is unique on the network
   - Performs Duplicate Address Detection
     - Send *Neighbour solicitation* to local network with source of 0 and destination of the generated address
     - If someone responds (that is, they already have the generated address) then not unique, and try another address or do manual configuration
     - If no response after timeout, then assume its unique
3. Host sends a *router solicitation* to see if a router is on the network
4. Router may respond wit *router advertisement* which includes information for the host
   - E.g. Router may send global prefix, so host can change from link-local address to global IPv6 address

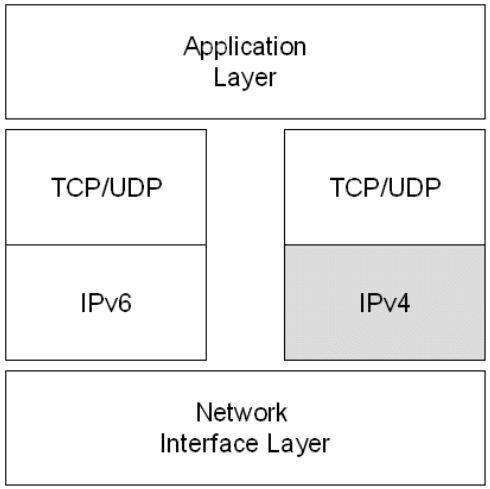
- Also options of using random identifiers for link-local addresses rather than 48-bit MAC address (useful for privacy)

Transition from IPv4 to IPv6

- IPv4 and IPv6 are incompatible
- How do we upgrade our networks in a practical way?
- The aim:
  - IPv4 hosts can be upgraded at any time
  - New hosts, using IPv6, can be added at any time
  - Existing IPv4 hosts, with IPv6 installed, can continue to use IPv4 address
  - Little preparation require to upgrade IPv4 to IPv6 hosts
- The solutions:
  - Dual stack
  - IPv6 over IPv4 Tunnelling

Transition with Dual Stack

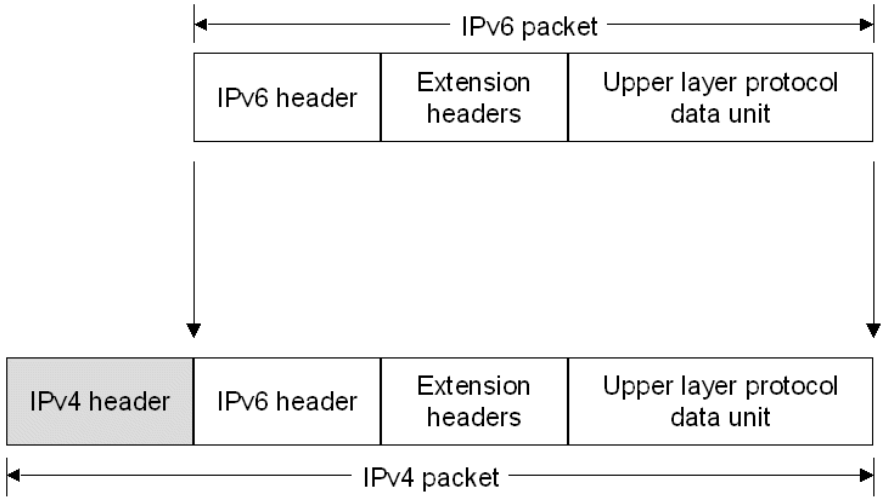
- Implement both IPv4 and IPv6



- Allows nodes to communicate with both IPv4 and IPv6 nodes easily
- Makes the implementation and management more complex
- Usually makes use of tunnelling or protocol translation
  - E.g. the IPv6 stack may still use tunnelling over IPv4

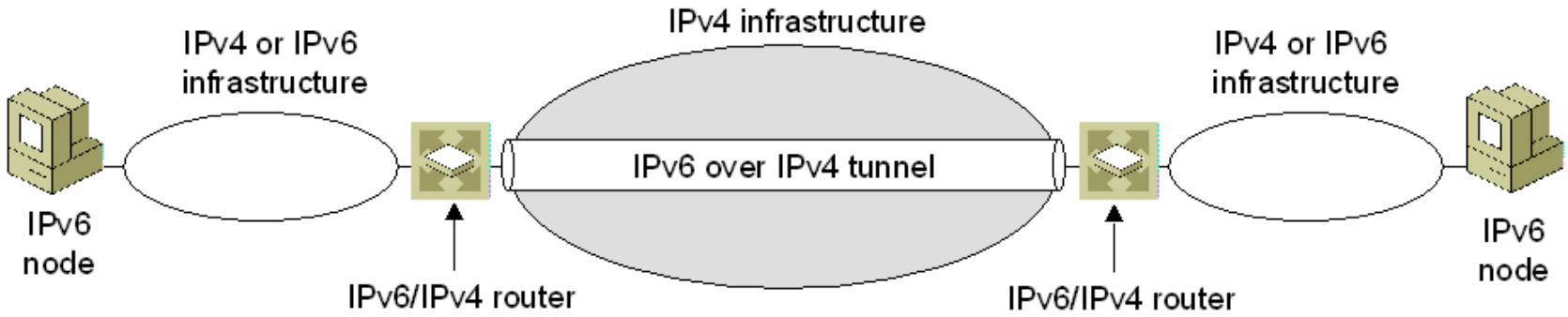
Transition with Tunnelling

- IPv6 datagrams are tunnelled inside IPv4 datagrams

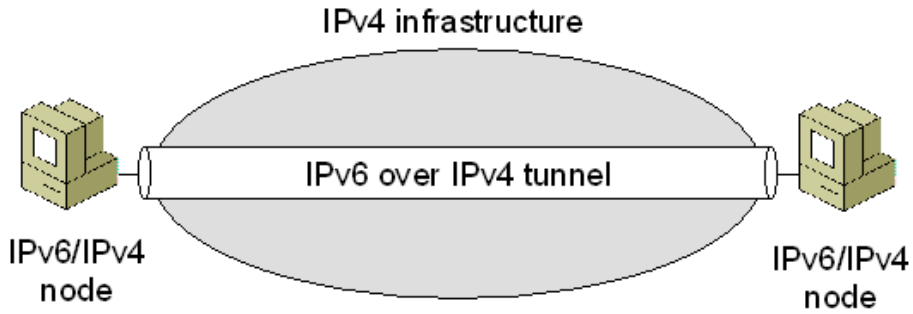


Transition with Tunnelling

- Router to Router

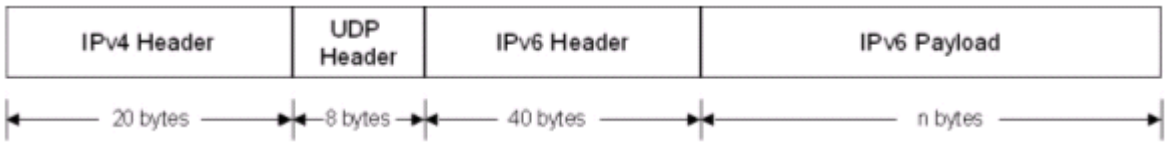


- Host to Host

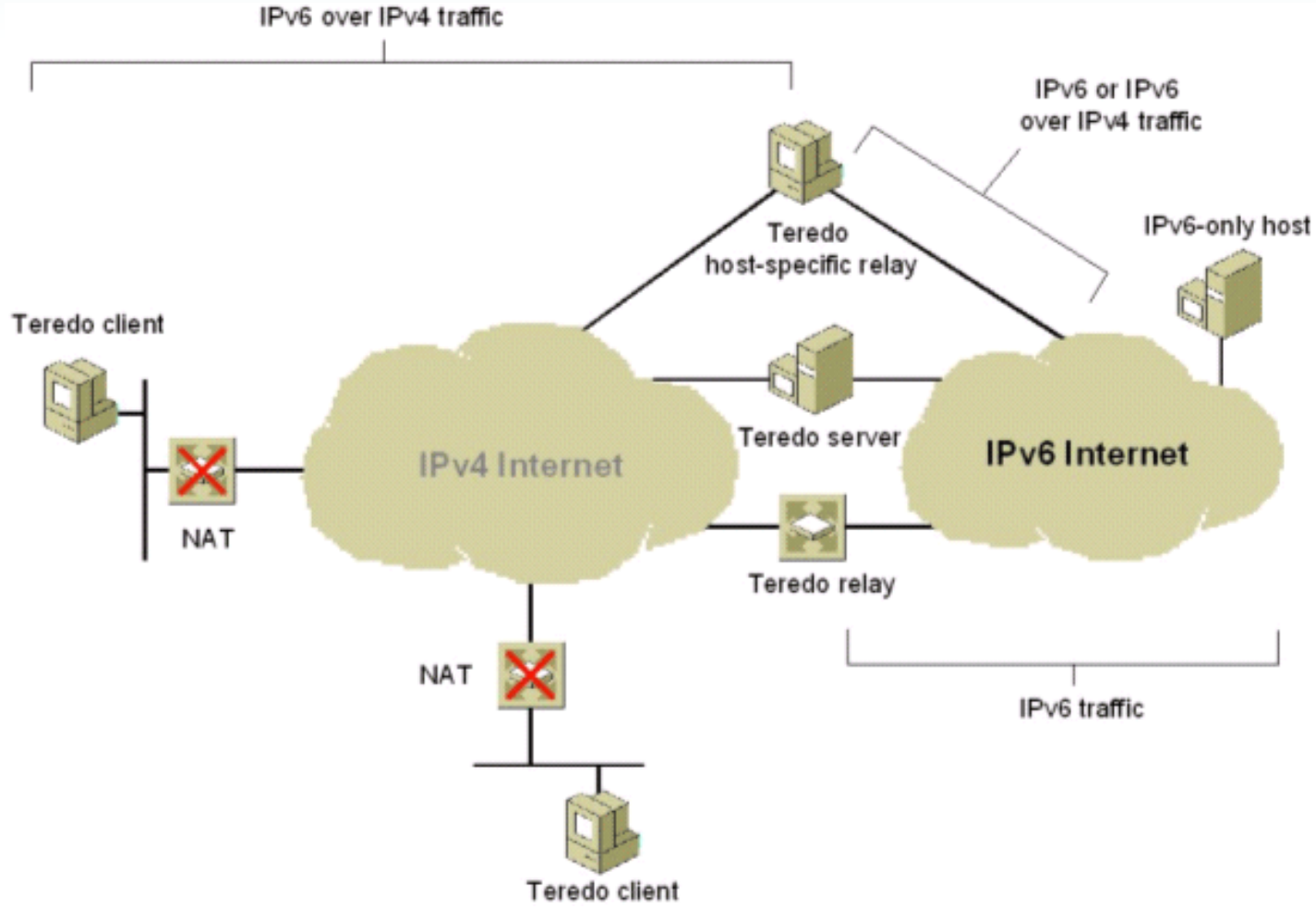


6to4 and Teredo Tunnelling

- 6to4 Tunnelling
  - Automatic setup of tunnels and address mapping
  - Carries IPv6 datagrams in IPv4 datagrams
  - Requires 6to4 routers to create tunnel endpoints
  - Good solution for medium and large networks
- Teredo Tunnelling
  - Tunnel endpoints created host to host
  - Suitable for small/home office using NAT
    - NATs often don't handle IPv4 datagrams with header 41 (i.e. IPv6)
  - IPv6 datagram carried in UDP packet in IPv4 datagram
    - UDP is easier to traverse the NAT
  - Teredo is used in Microsoft Windows XP and Vista



Teredo Tunnelling

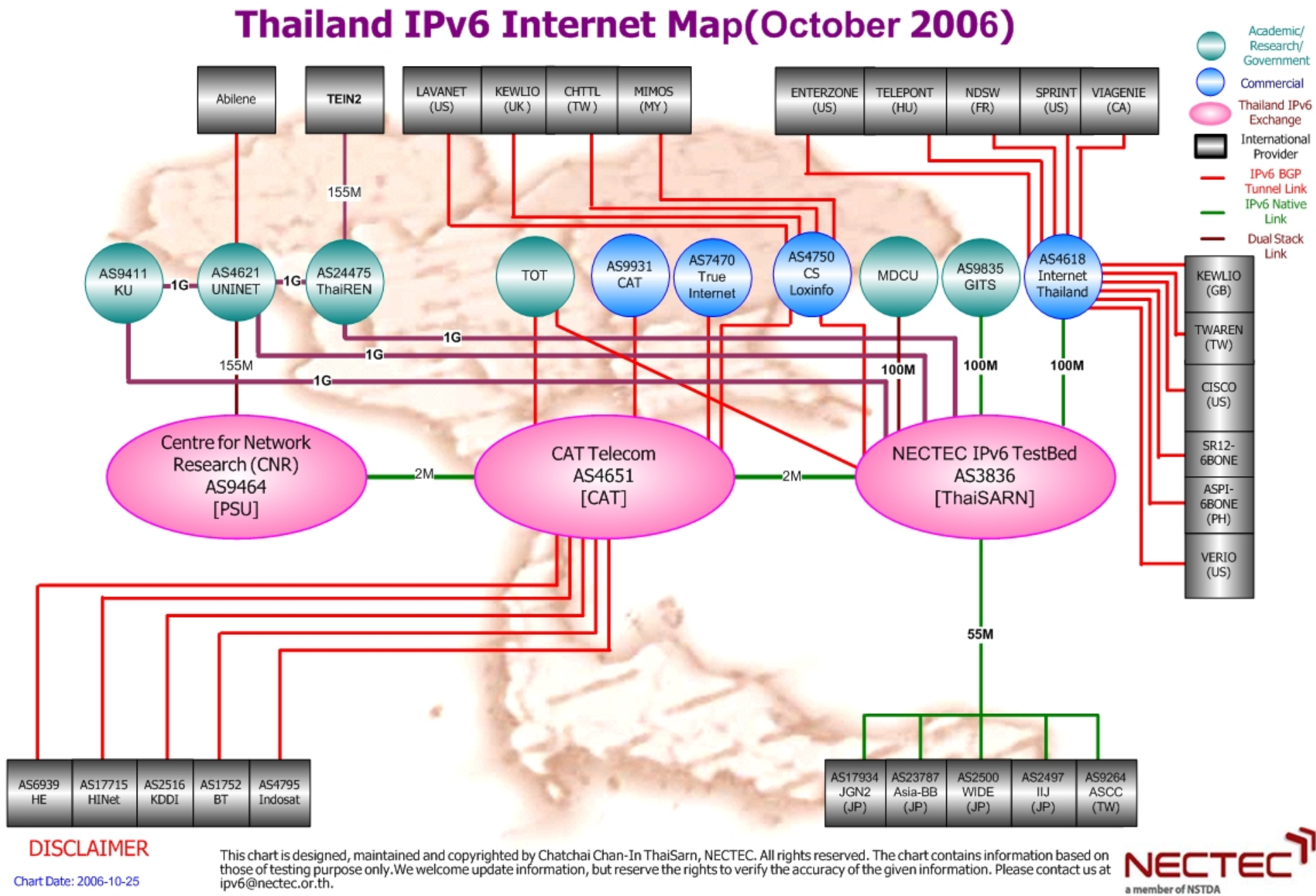


Issues with IPv6

- Is the upgrade needed?
  - The address space problem still exists, but NATs have extended the lifetime of IPv4 address by 15-20 years
- What additional features does IPv6 offer?
  - Autoconfiguration, in-built security, mobility, QoS
  - But these are all possible in IPv4 now (as options)
- How to do the transition?
  - There are well known techniques being used and successfully demonstrated

IPv6 Networks

- 6Bone
  - Experimental IPv6 deployment that finished in 2006 (ran for 10 years)
- Now most countries/organisations have experimental and operational IPv6 networks
- IPv6 Implementations
  - Most commercial routers support IPv6
  - Most current operating systems support IPv6
    - Windows XP/Vista, various Linux and BSD OS's, MAC, …
- What is holding IPv6 back?
  - Larger support from ISPs, training and management about IPv6, what is the need to switch?



DISCLAIMER

Chart Date: 2006-10-25

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