Computer Networks 1
(Mạng Máy Tính 1)

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Lecture 7: Network Layer in the Internet

Reference:

Chapter 5 - "*Computer Networks*",
Andrew S. Tanenbaum, 4th Edition, Prentice Hall, 2003.

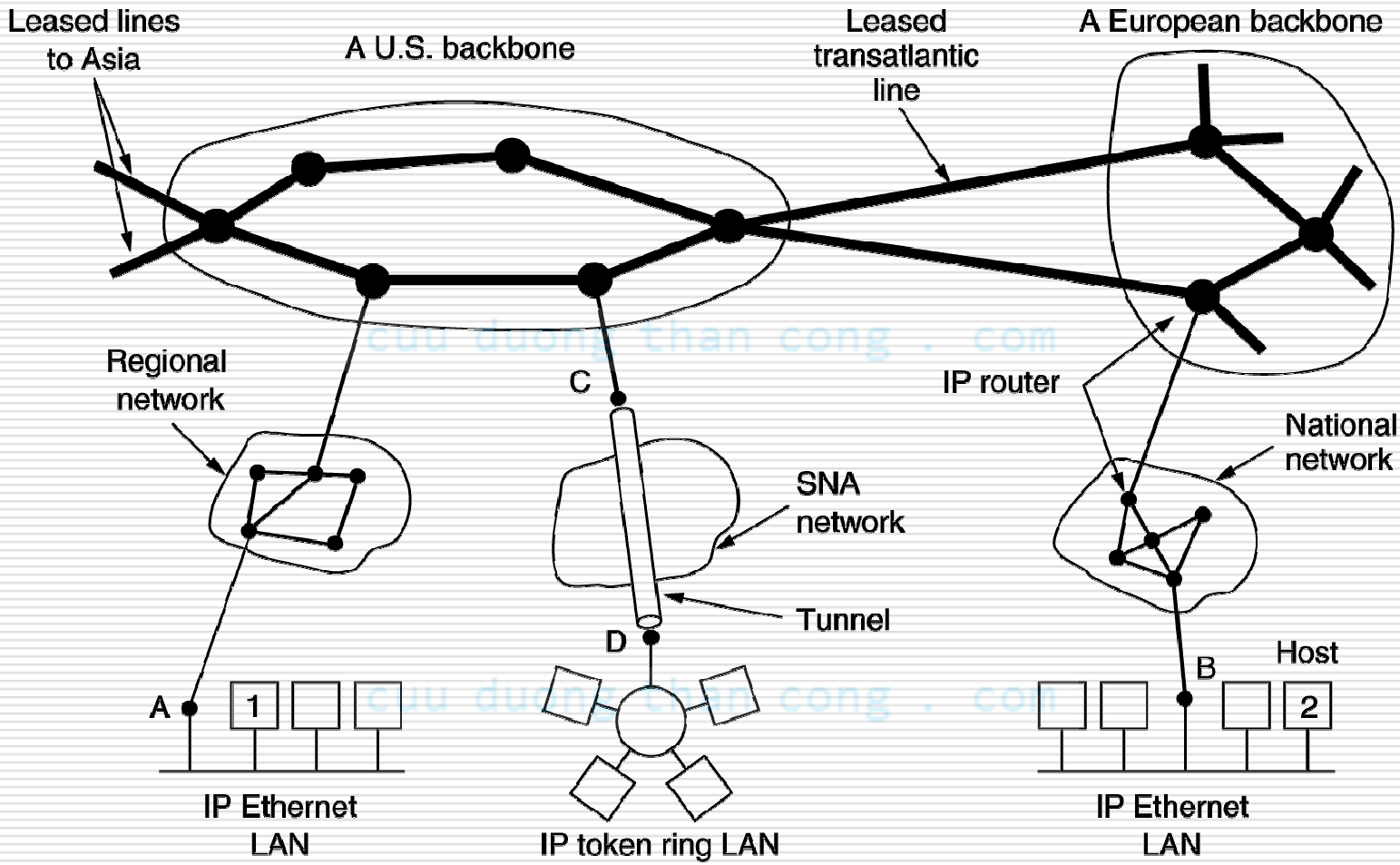
The Network Layer in the Internet

- The IP Protocol
- IP Addresses
- Internet Control Protocols
- OSPF – The Interior Gateway Routing Protocol
- BGP – The Exterior Gateway Routing Protocol
- IPv6

Design Principles for Internet

- Make sure it works.
- Keep it simple.
- Make clear choices.
- Exploit modularity.
- Expect heterogeneity.
- Avoid static options and parameters.
- Look for a good design; it need not be perfect.
- Be strict when sending and tolerant when receiving.
- Think about scalability.
- Consider performance and cost.

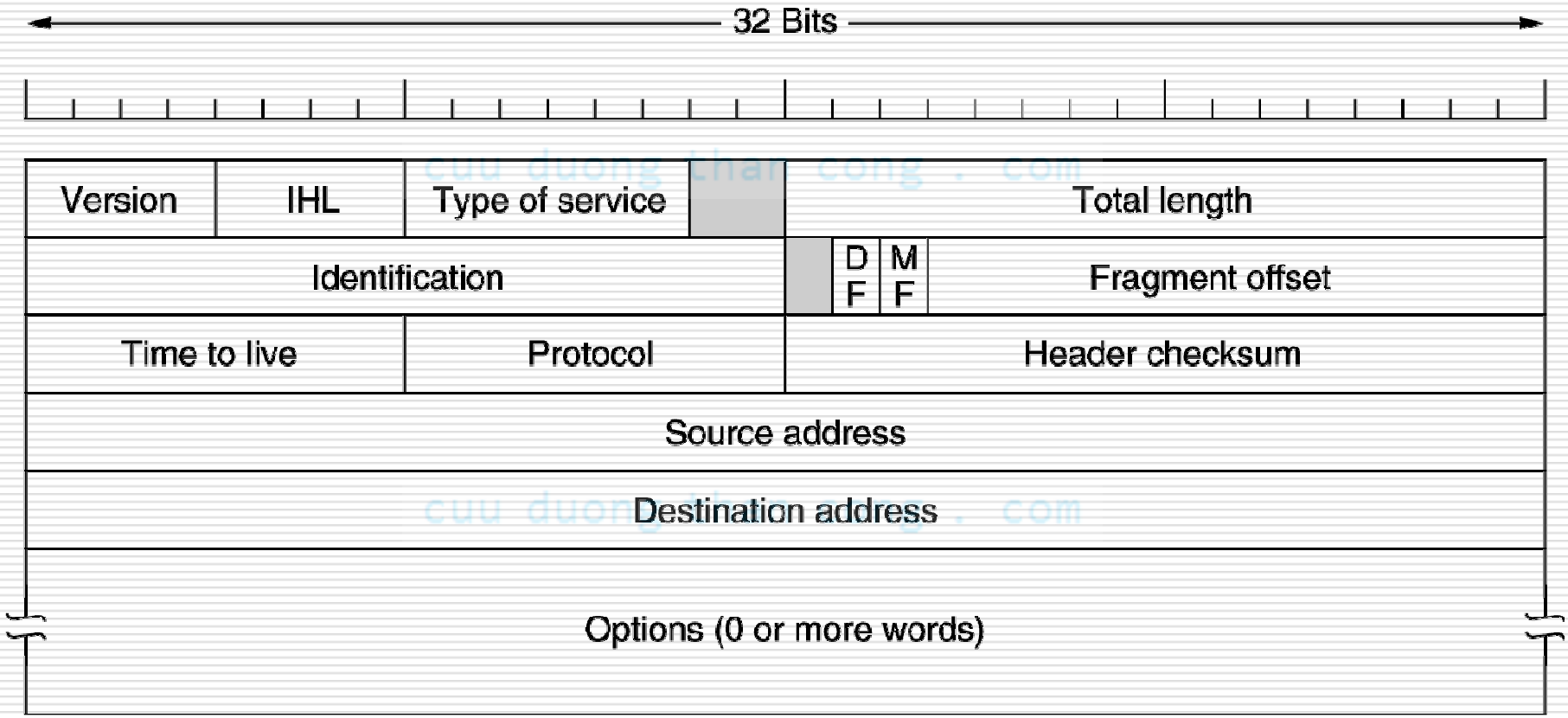
Collection of Subnetworks



The Internet is an interconnected collection of many networks.

The IP Protocol

The IPv4 (Internet Protocol) header.



The IP Header

- *Version*: version of the protocol used
- *IHL*: header length (number of 32-bit words)
- *Type of service*: combination of reliability and speed, commonly ignored by routers
- *Total length*: length of the datagram
- *Identification*: to identify a fragment within a datagram
- *DF*: don't fragment, tell the routers not to fragment
- *MF*: more fragments
- *Time-to-live*: a time counter to limit the message lifetime
- *Header checksum*: of the header only
- *Source and destination addresses*: address of the source and destination of the datagram

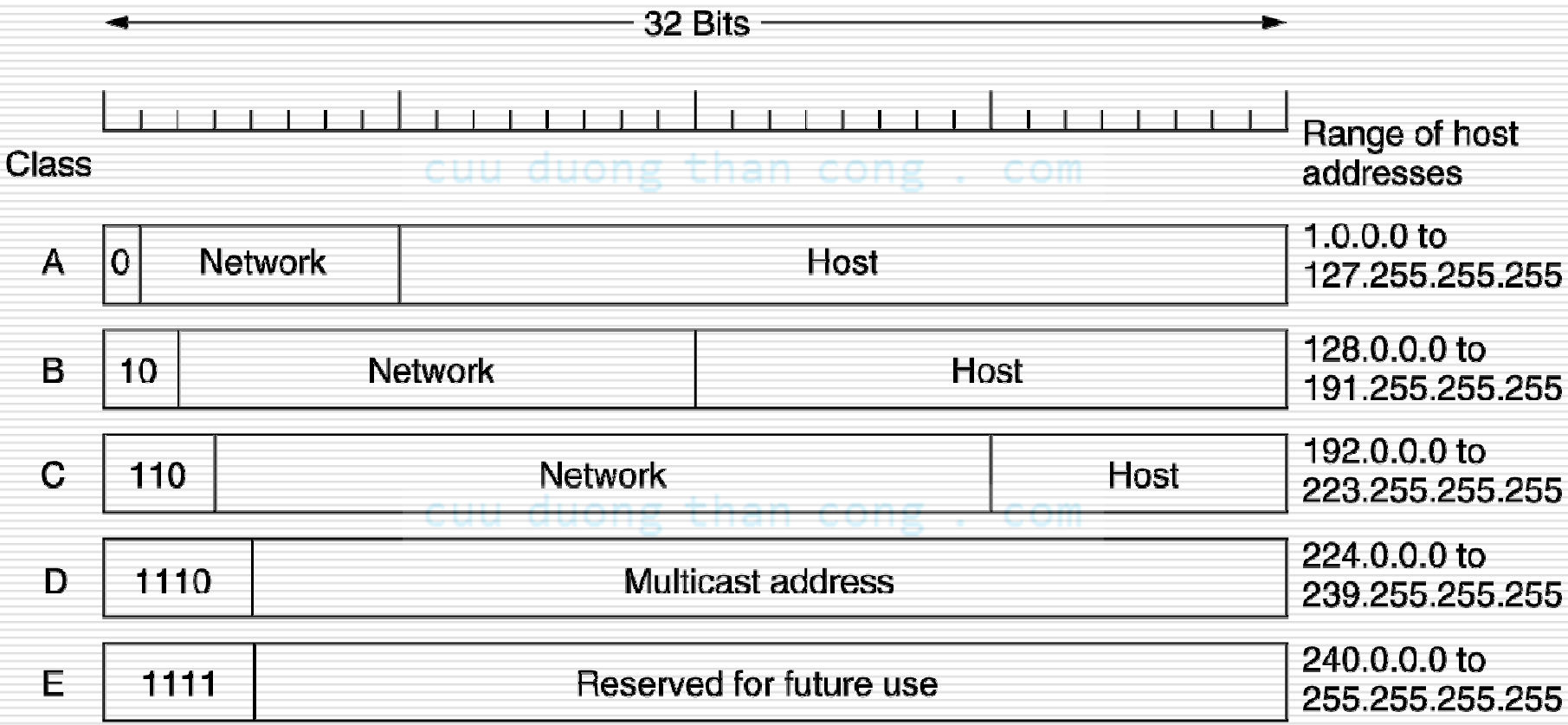
IP Options

Some of the IP options.

Option	Description
Security	Specifies how secret the datagram is
Strict source routing	Gives the complete path to be followed
Loose source routing	Gives a list of routers not to be missed
Record route	Makes each router append its IP address
Timestamp	Makes each router append its address and timestamp

IP Addresses

IP address formats.

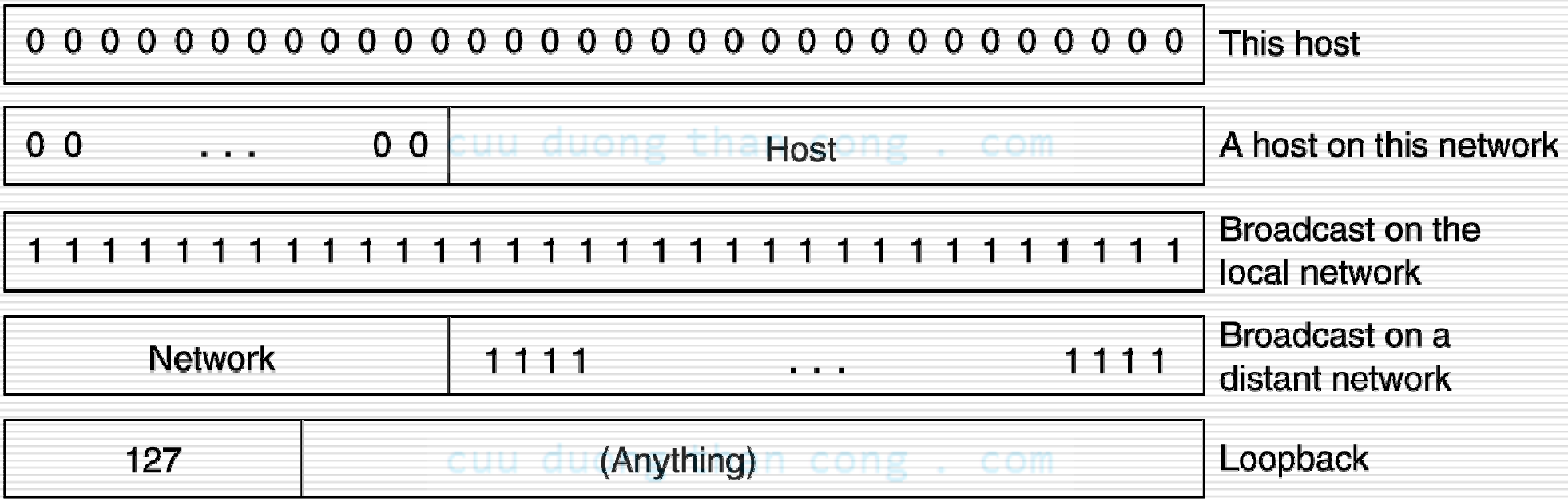


IP Address Classes

- Class A: 128 networks, 16 mil hosts each
- Class B: 16.384 networks, 64K hosts each
- Class C: 2 mil networks, 256 hosts each
- Class D: for multicast
- Class E: Reserved

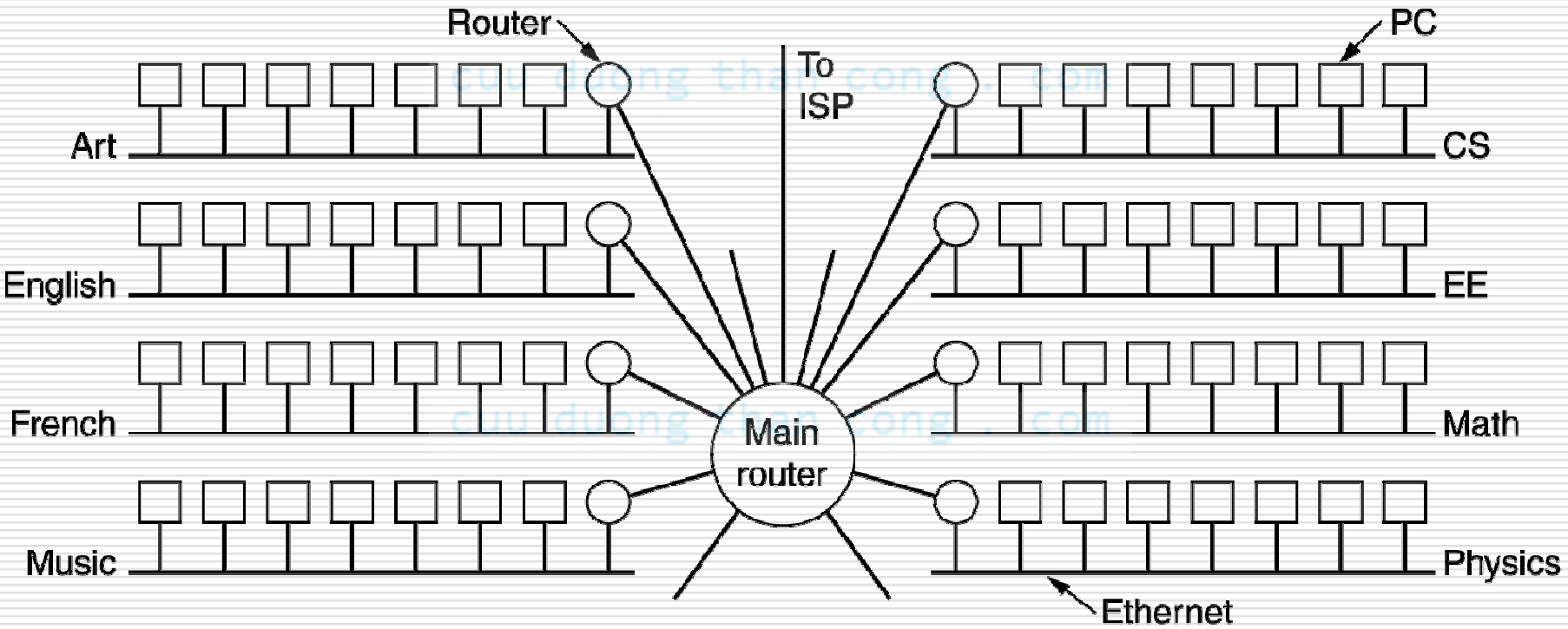
IP Addresses (2)

Special IP addresses.



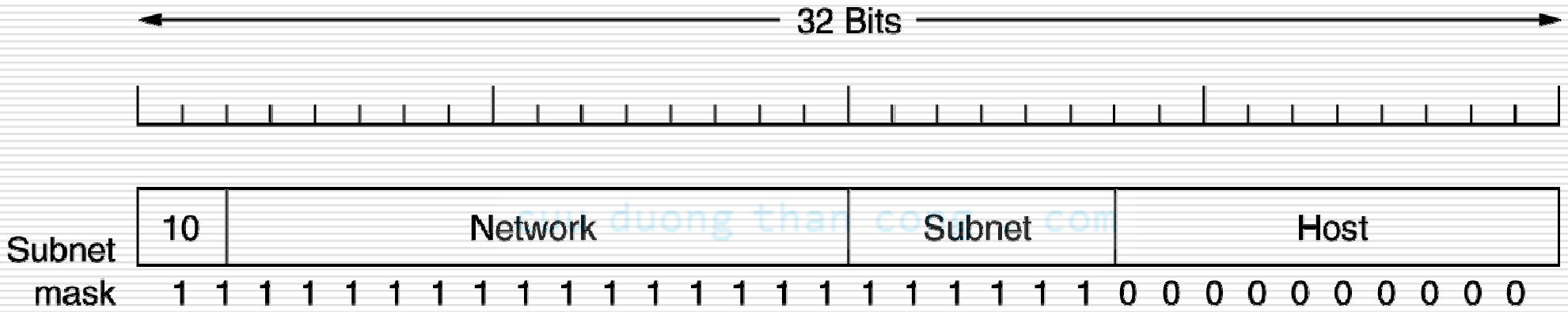
Subnets

A campus network consisting of LANs for various departments.



Subnet and Subnet Mask

- Some bits of the host are used to create subnet number
- Subnet masks are used to indicate the splits between network, subnet number and host number



A class B network subnetted into 64 subnets (6 bits).

Routing with Subnetting

- Routing to destination to an outside network is done as usual
- Routing table adds more entries for routing within the network
  - (this-network, subnet, 0): to route message to another subnet
  - (this-network, this-subnet, host): to route message to a host within this-subnet

CDR – Classless InterDomain Routing

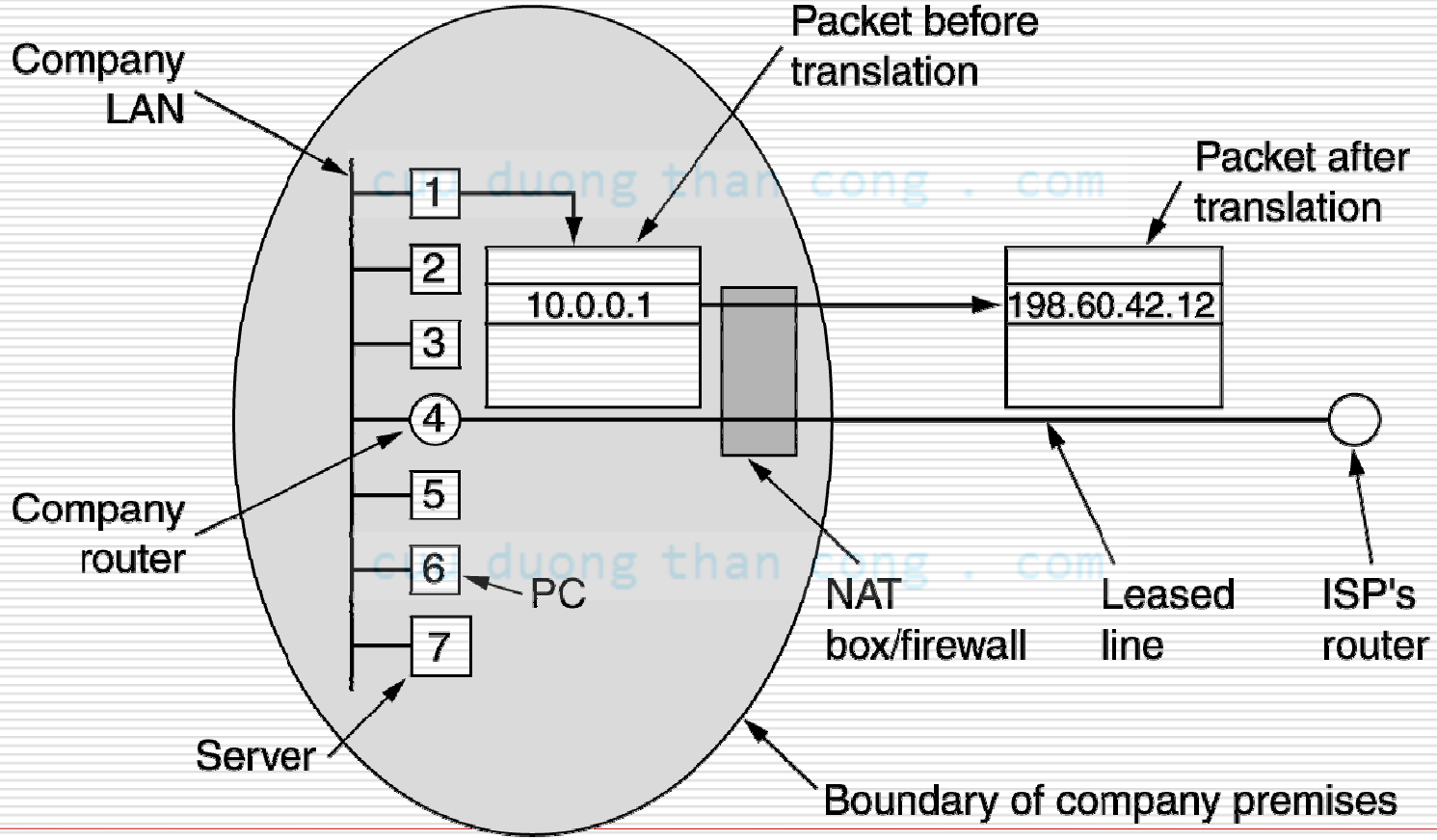
- Allocate IP addresses in variable size block without regard to classes
- If a site needs, it is provided with a block of addresses
- Routing process is more complicated

A set of IP address assignments.

University	First address	Last address	How many	Written as
Cambridge	194.24.0.0	194.24.7.255	2048	194.24.0.0/21
Edinburgh	194.24.8.0	194.24.11.255	1024	194.24.8.0/22
(Available)	194.24.12.0	194.24.15.255	1024	194.24.12/22
Oxford	194.24.16.0	194.24.31.255	4096	194.24.16.0/20

NAT – Network Address Translation

Placement and operation of a NAT box.



NAT – Network Address Translation (2)

- Use TCP or UDP header (source port field) of a message to keep track of its outgoing connection
- A mapping table is used at the NAT box to keep track of the private IP + port the NAT index
- In coming message address is reversed back to original private IP and source port using the index

Internet Control Message Protocol

- Used when unexpected events occurred in the network, also used to test the network

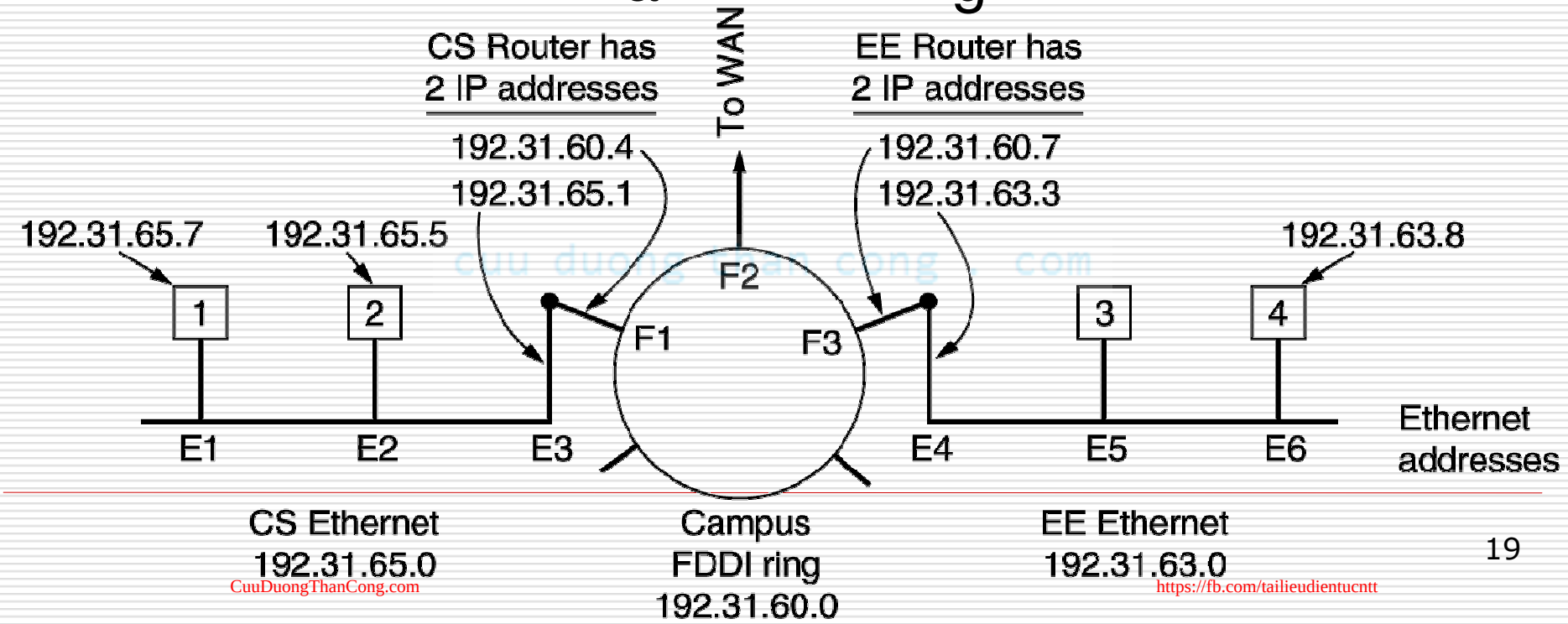
The principal ICMP message types.

Message type	Description
Destination unreachable	Packet could not be delivered
Time exceeded	Time to live field hit 0
Parameter problem	Invalid header field
Source quench	Choke packet
Redirect	Teach a router about geography
Echo request	Ask a machine if it is alive
Echo reply	Yes, I am alive
Timestamp request	Same as Echo request, but with timestamp
Timestamp reply	Same as Echo reply, but with timestamp

ARP– The Address Resolution Protocol

- Used to map an IP addresses to data link layer addresses, e.g. Ethernet addresses

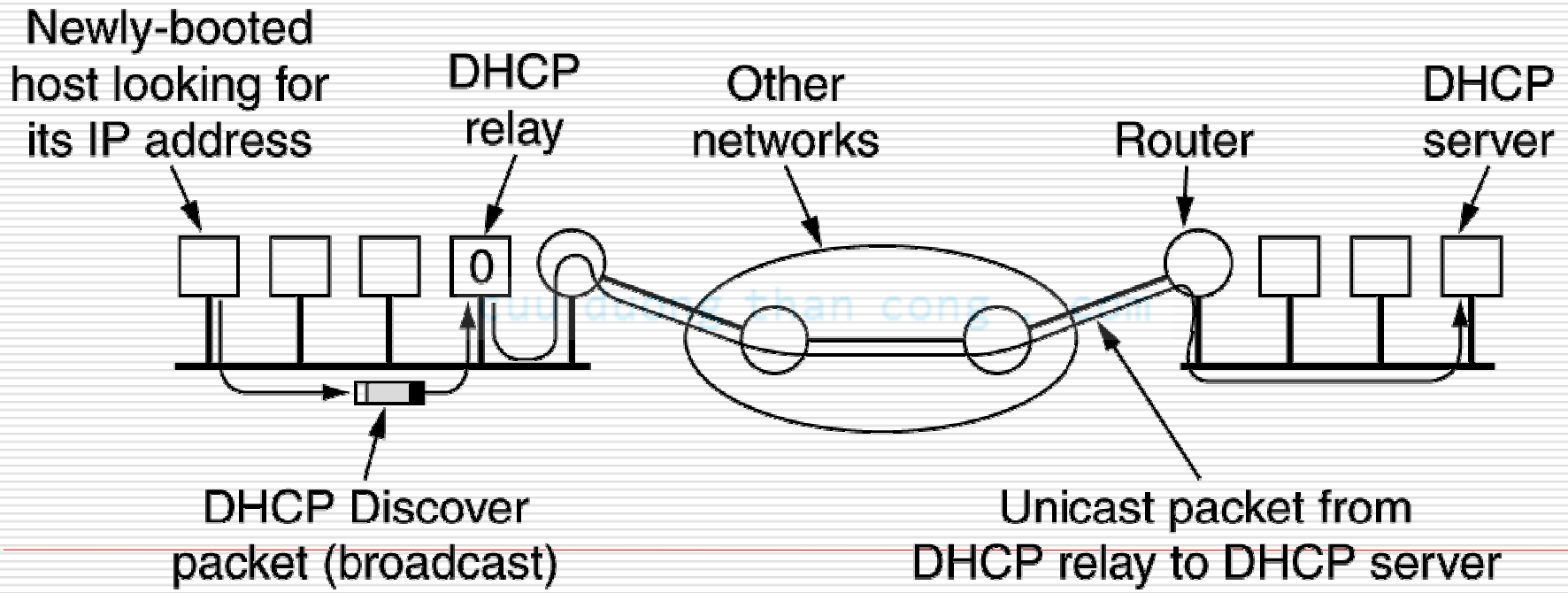
Three interconnected /24 networks: two Ethernets and an FDDI ring.



Dynamic Host Configuration Protocol – DHCP

- A replacement for RARP (Reverse ARP) and BOOTP (Bootstrap protocol)

Operation of DHCP.

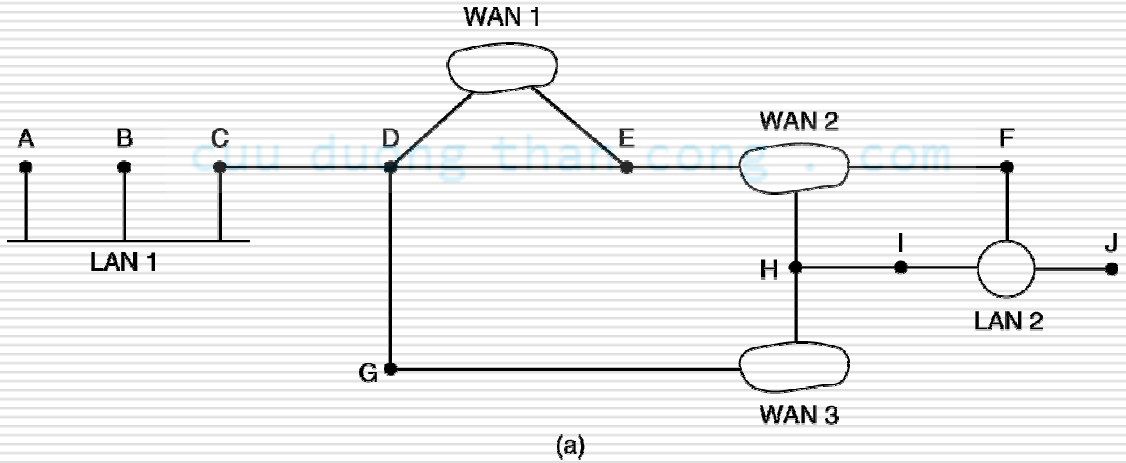


OSPF – Open Shortest Path First
The Interior Gateway Routing Protocol

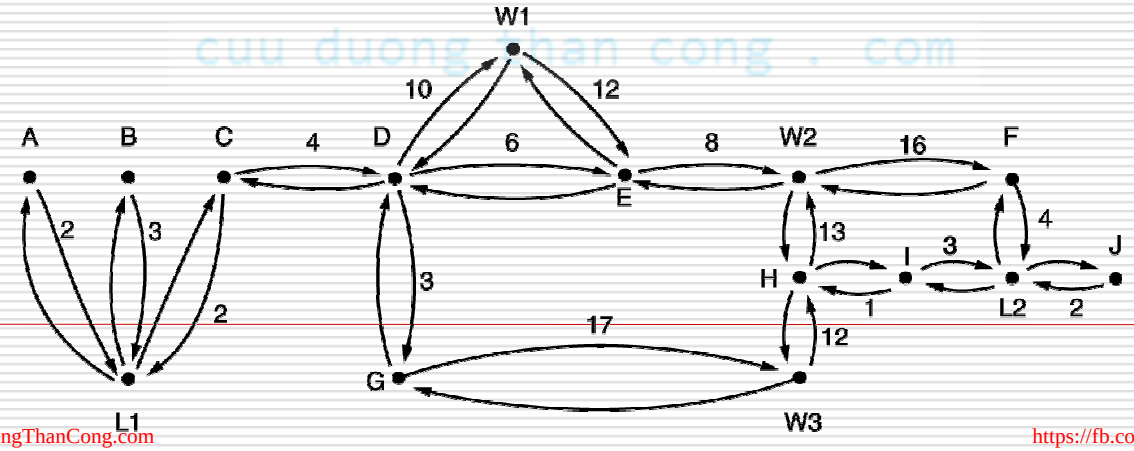
- To replace RIP (distance vector protocol) when the networks getting bigger
- Similar to Link State Routing Protocol
- Requirements:
  - Open
  - Support variety of distance metrics
  - Dynamic
  - Support service based routing
  - Do load balancing
  - Support hierarchical systems
  - Security

OSPF (1)

(a) An autonomous system. (b) A graph representation of (a).



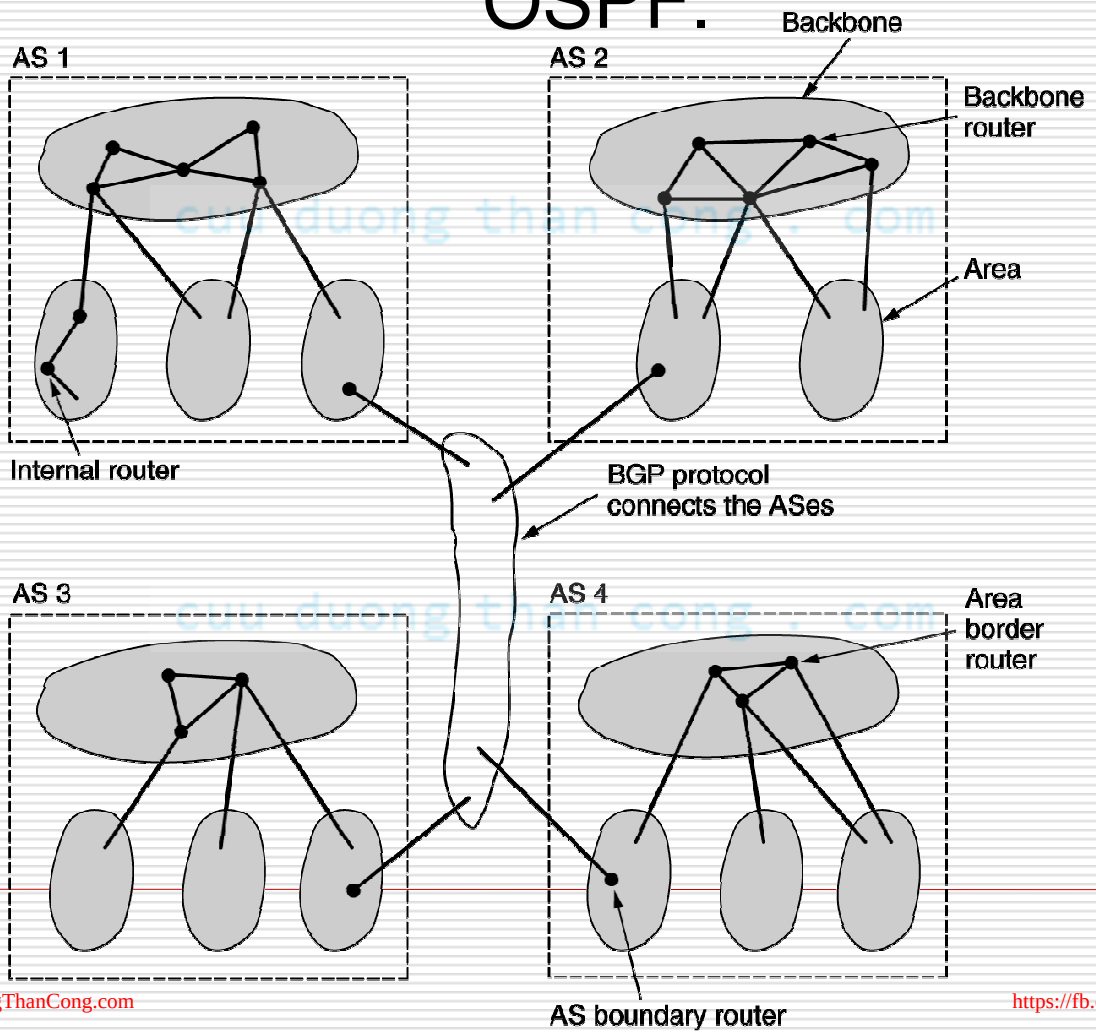
(a)



(b)

OSPF (2)

The relation between ASes, backbones, and areas in OSPF.



OSPF (3)

The five types of OSPF messages.

Message type	Description
Hello	Used to discover who the neighbors are
Link state update	Provides the sender's costs to its neighbors
Link state ack	Acknowledges link state update
Database description	Announces which updates the sender has
Link state request	Requests information from the partner

BGP – Border Gateway Protocol
The Exterior Gateway Routing Protocol

- For routing messages between Autonomous Systems
- Often constrained by:
  - Politics
  - Security
  - Economic considerations
- Routers are configured with policies

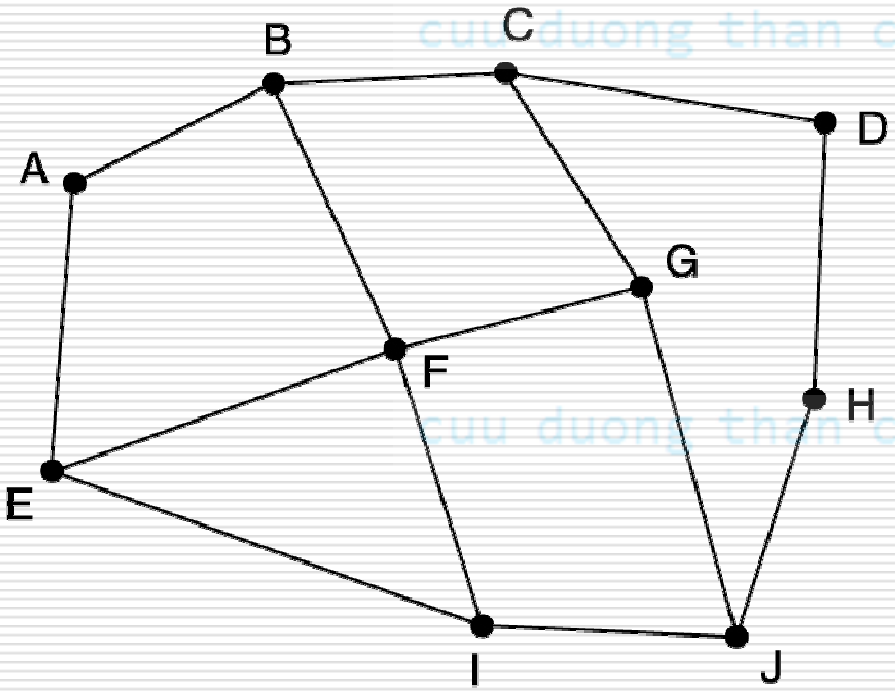
BGP (1)

- Fundamentally a distance vector protocol
- Networks are grouped into 3 categories
  - Stub networks: one connection to BGP graph
  - Multiconnected networks: multiconnection to BGP graph, possibly handle third party traffic
  - Transit networks: e.g. backbone, willing to handle third party messages

BGP (2)

(a) A set of BGP routers.

(b) Information sent to F.



Information F receives from its neighbors about D

From B: "I use BCD"
From G: "I use GCD"
From I: "I use IFGCD"
From E: "I use EFGCD"

(a) (b)

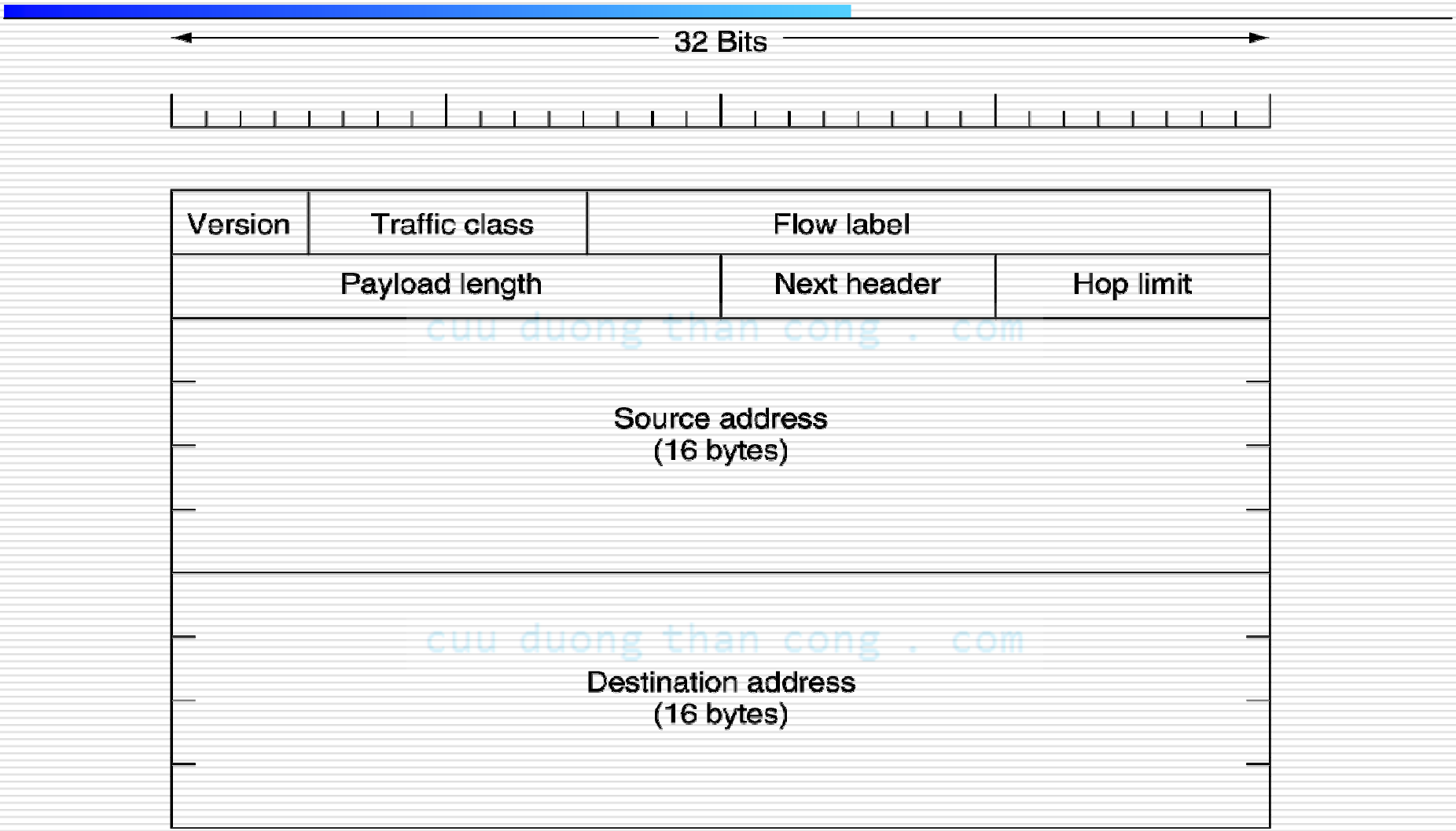
IPv6

- IPv4 address is going to be exhausted in the very near future
- IPv6 is introduced to cop with increasing demand for IP address

IPv6 Design Goals

- Support billions of hosts, even with inefficient address space allocation.
- Reduce the size of the routing tables.
- Simplify the protocol, to allow routers to process packets faster.
- Provide better security (authentication and privacy) than current IP.
- Pay more attention to type of service, particularly for real-time data.
- Aid multicasting by allowing scopes to be specified.
- Make it possible for a host to roam without changing its address.
- Allow the protocol to evolve in the future.
- Permit the old and new protocols to coexist for years.

The Main IPv6 Header



IPv6 Address

- 16 byte length address
- Consists of eight groups of 4 hex digits with colon between groups
  - 8000:0000:0000:0000:0123:4567:89AB:CDEF
- Leading zero can be ommited
- One or more groups of 16 zero bits can be replace by a pair of colons:
  - 8000::123:4567:89AB:CDEF
- IPv4 addresses can be written as a pair of colons and old dotted decimal number:
  - ::192.31.20.46