CHAPTER-7

Internet Protocol (IP) and IP Addressing

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What is IP……?

- IP stands for Internet Protocol
- IP specifies the format of packets, also called datagrams, and the addressing scheme.
- Most networks combine IP with a higher-level protocol called Transmission Control Protocol (TCP), which establishes a virtual connection between a destination and a source.

What is IP cont'd…

- IP by itself is something like the postal system.
- It allows you to address a package and drop it in the system, but there's no direct link between you and the recipient.
- TCP/IP, on the other hand, establishes a connection between two hosts so that they can send messages back and forth for a period of time.

Purpose.....

- Provide a standard means of communication between devices
- Can't communicate if speaking two different languages

Therefore we have a concept called "Protocol"

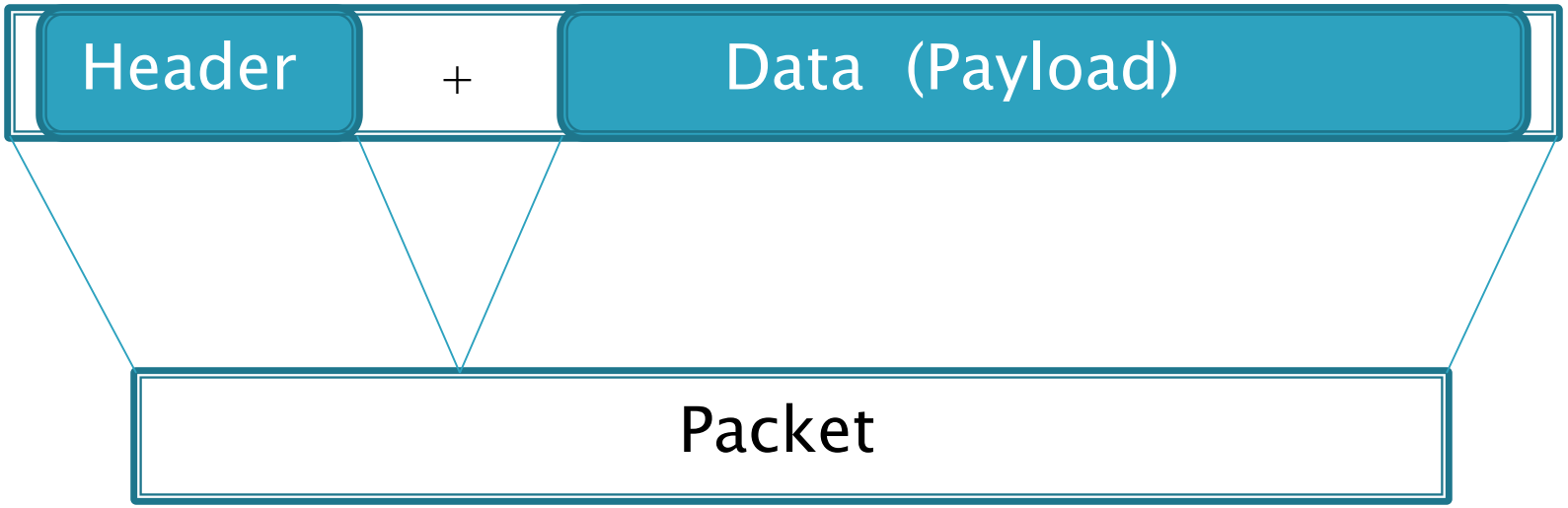
What is Protocol…

- Rules and conventions explaining how something must be done
- Used to describe how devices can communicate
- Protocol also defines the format of Data i.e. : being exchanged.

If we both utilize the same protocol then you know how to format data so I will understand it and I know how to format data so you will understand it

Construction of Datagrams….

- Each #datagram has two components
  - Header
  - Payload



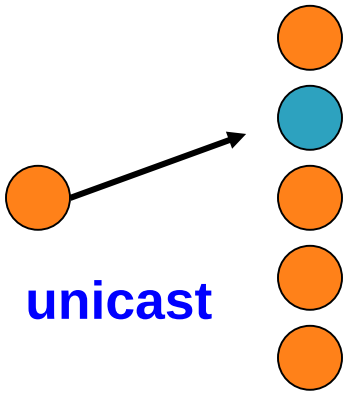
IP Service

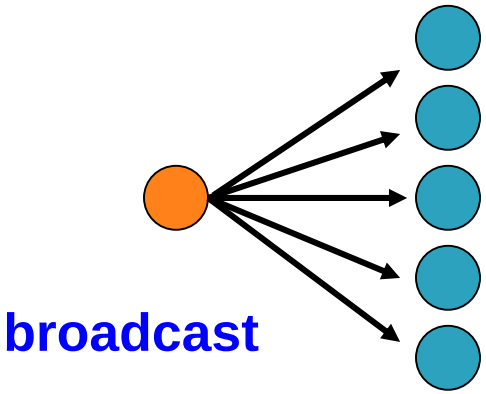
- Delivery service of IP is minimal.

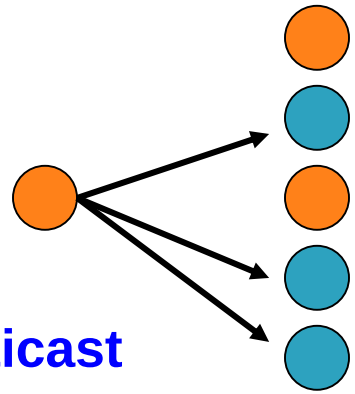
- IP provides an unreliable connectionless best effort service
  - Unreliable : IP doesn't make an attempt to recover lost packets
  - Connectionless : Each packet is handled independently
- IP doesn't make guarantees on the service (No throughput , No delay guarantee…)

IP Service (Cont.…)

- IP supports the following services
  - One-to-one (unicast)
  - One-to-all (broadcast)
  - One-to-several (multicast)

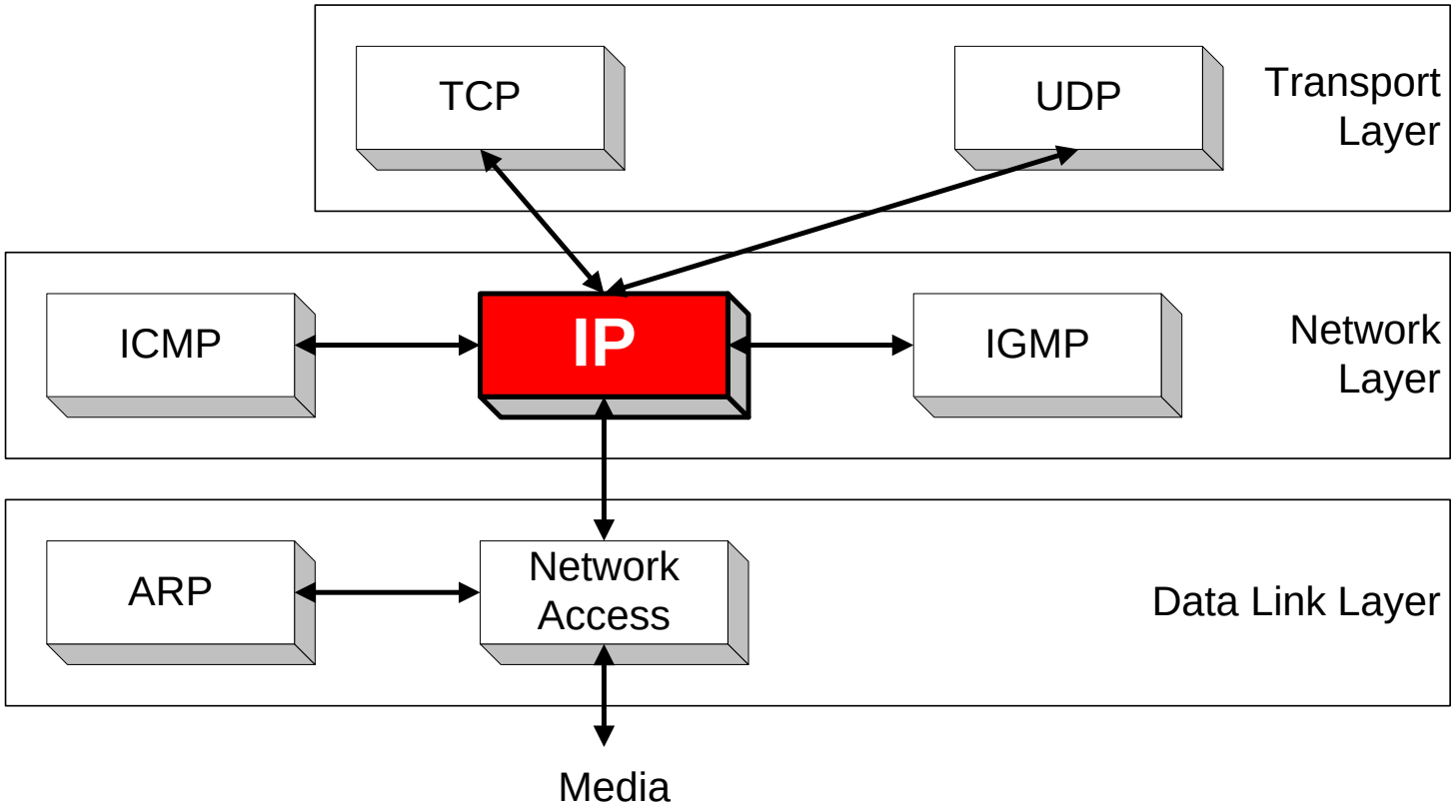






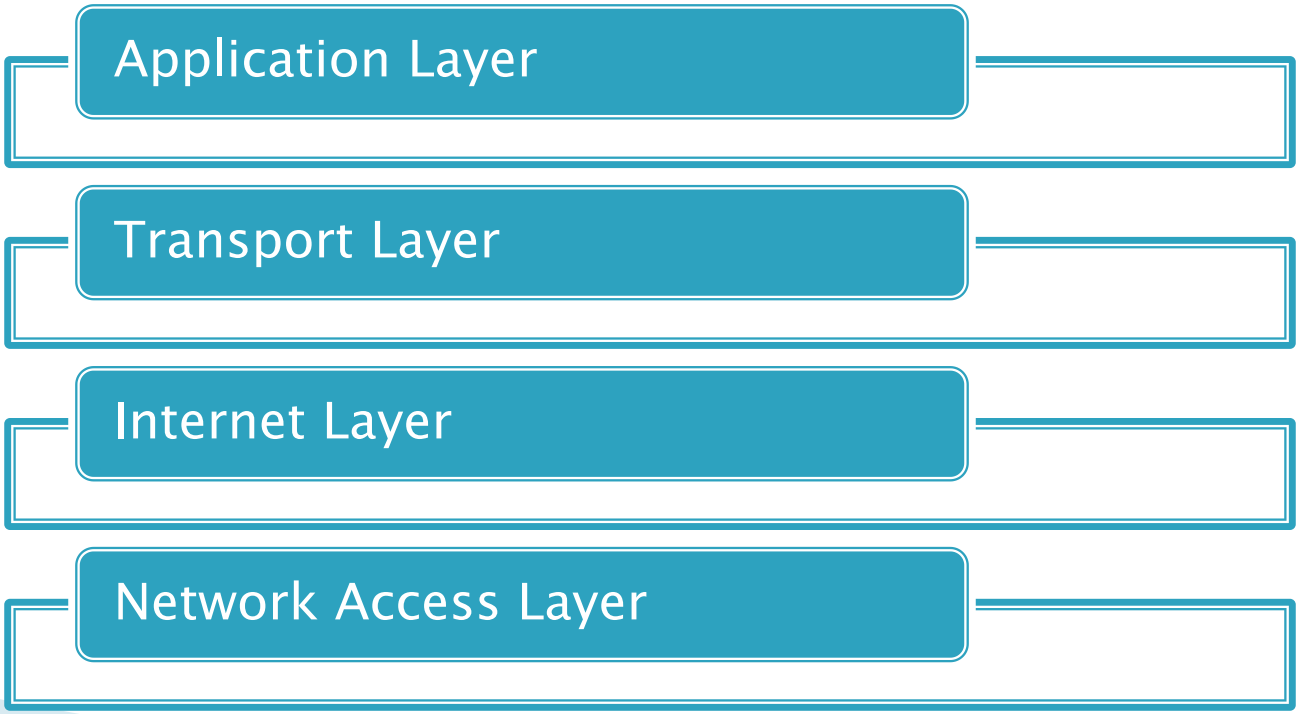
Orientation of Internet Protocol

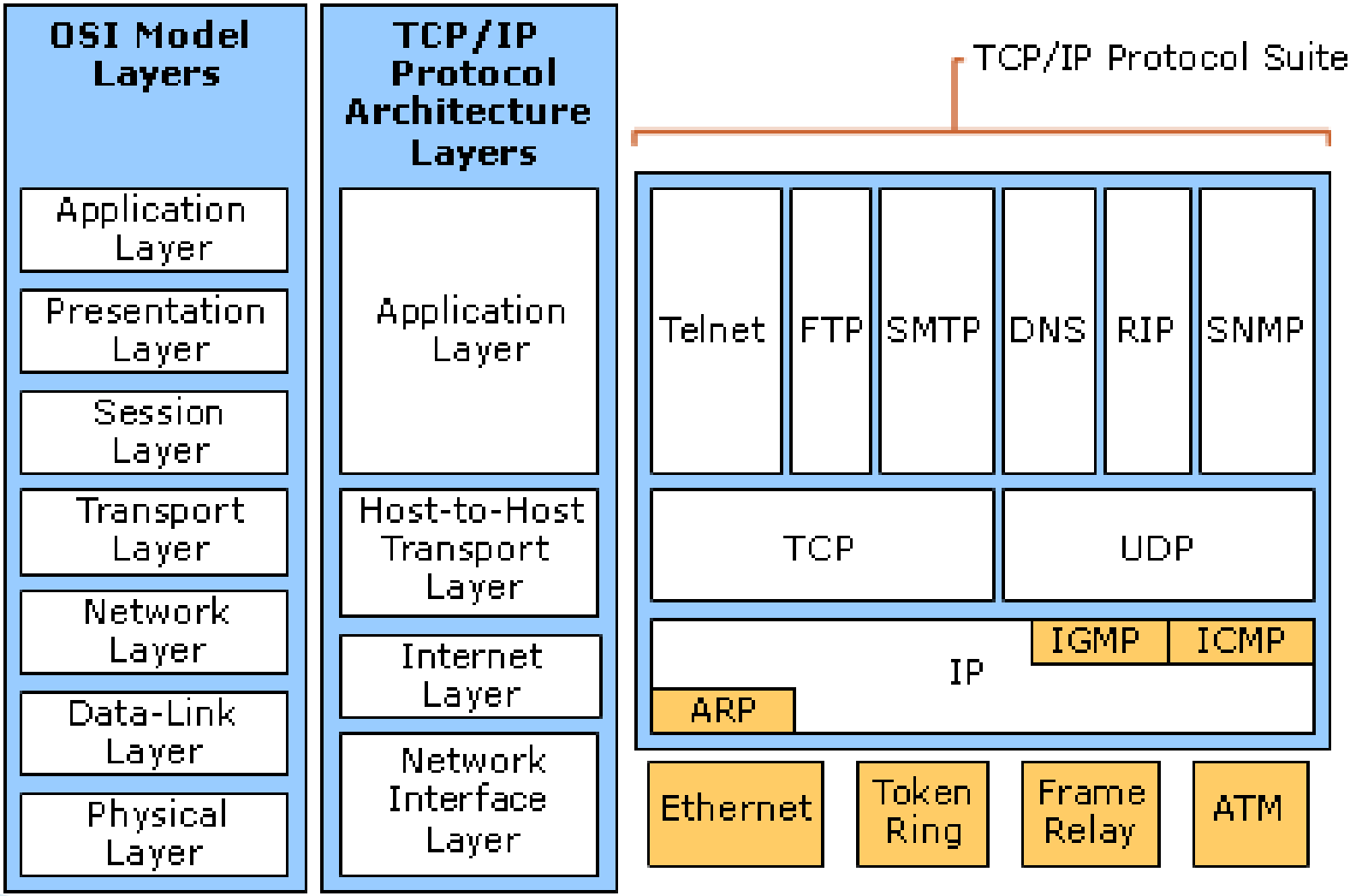
- IP is a Network Layer Protocol



TCP/IP Model

- Because TCP/IP was developed earlier than the OSI 7 layer model, it doesn't have 7 layers but only 4 layers.




OSI Model Layers
Application Layer
Presentation Layer
Session Layer
Transport Layer
Network Layer
Data-Link Layer
Physical Layer
TCP/IP Protocol Architecture Layers
Application Layer
Host-to-Host Transport Layer
Internet Layer
Network Interface Layer
TCP/IP Protocol Suite
Telnet
FTP
SMTP
DNS
RIP
SNMP
TCP
UDP
IGMP
ICMP
IP
ARP
Ethernet
Token Ring
Frame Relay
ATM

Application Layer.....

- Application layer protocols defined the rules when implementing specific network applications.

- Examples :
  - FTP – (File Transfer Protocol)
  - Telnet – (Remote Terminal Protocol)
  - SMTP – (Simple Mail Transfer Protocol)
  - HTTP – (Hyper Text Transfer Protocol)

Transport Layer…

- End to End data transfer……
- Examples :
  - TCP (Transmission Control Protocol)
    - Connection oriented (connection established before data exchanged)
    - Reliable delivery of data
  - UDP (User Datagram Protocol)
    - Connectionless service
    - Delivery is not guaranteed (unreliable)

Internet Layer……

- Internet layer protocols define the rules of how to find the routers for a packet to the destination.
- It only gives best effort delivery. (packets can be delayed, corrupted, lost or out of order)
- Examples :
  - IP – Internet Protocol (Provide packet delivery)
  - ARP – Address Resolution Protocol (Defined the procedure of network address / mac address translation(mapping))
  - ICMP – Internet Control Message Protocol (Defined the procedure of error message transfer)

Network Access Layer….

- Also known as Network Interface Layer…
- At which data is transmitted and received across the physical network.
  - Mostly in hardware
  - A well known example is Ethernet
- Examples :
  - Ethernet
  - Token Ring
  - Frame Relay
  - ATM (Asynchronous Transfer Mode)

MAC to IP Address Comparison

- MAC address
  - Identifies a specific NIC in a computer on a network
  - Each MAC address is unique
  - TCP/IP networks can use MAC addresses in communication
- Network devices cannot efficiently route traffic using MAC addresses because they:
  - Are not grouped logically
  - Cannot be modified
  - Do not give information about physical or logical network configuration

MAC to IP Address Comparison (continued)

- **IP addressing**
  - Devised for use on large networks
- IP addresses have a hierarchical structure and do provide logical groupings
  - IP address identifies both a network and a host

ARP(Address Resolution Protocol)

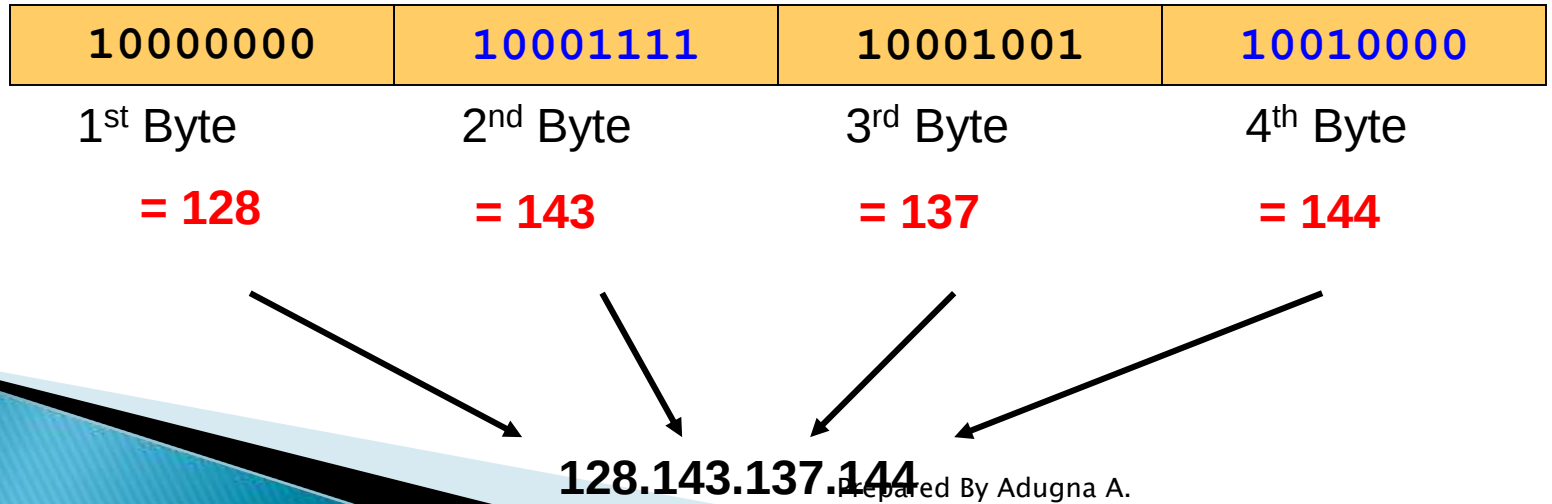
- When any device wishes to send data to another target device, it must :
- First determine the MAC address of that target given its IP address.
- These IP-to-MAC address mappings are derived from an ARP cache maintained on each device.
- If the MAC address of a given IP address does not appear in a device's cache, that device cannot direct messages to that target until it obtains a new mapping.
- In this case the sender sends an ARP request broadcast message on the local subnet.
- The host with the given IP address sends an ARP reply in response to the broadcast, allowing the initiating device to update its cache and proceed to deliver messages directly to the target.

IP Address

- What is an IP address…?
  - An IP address is a unique global address for a network interface

– Is a **32 bit long** identifier(IPV4)

– Encodes a network number (**network prefix**) and a **host number**



IP Addressing

- There are two IP addressing scheme:
  - 1. Class-full
  - 2. Classless

- In classful addressing the address space is
  - divided into 5 classes:
    - ***A, B, C, D, and E.***

Address space rule

The address space in a protocol That uses N-bits to define an Address is:

$$2^N$$

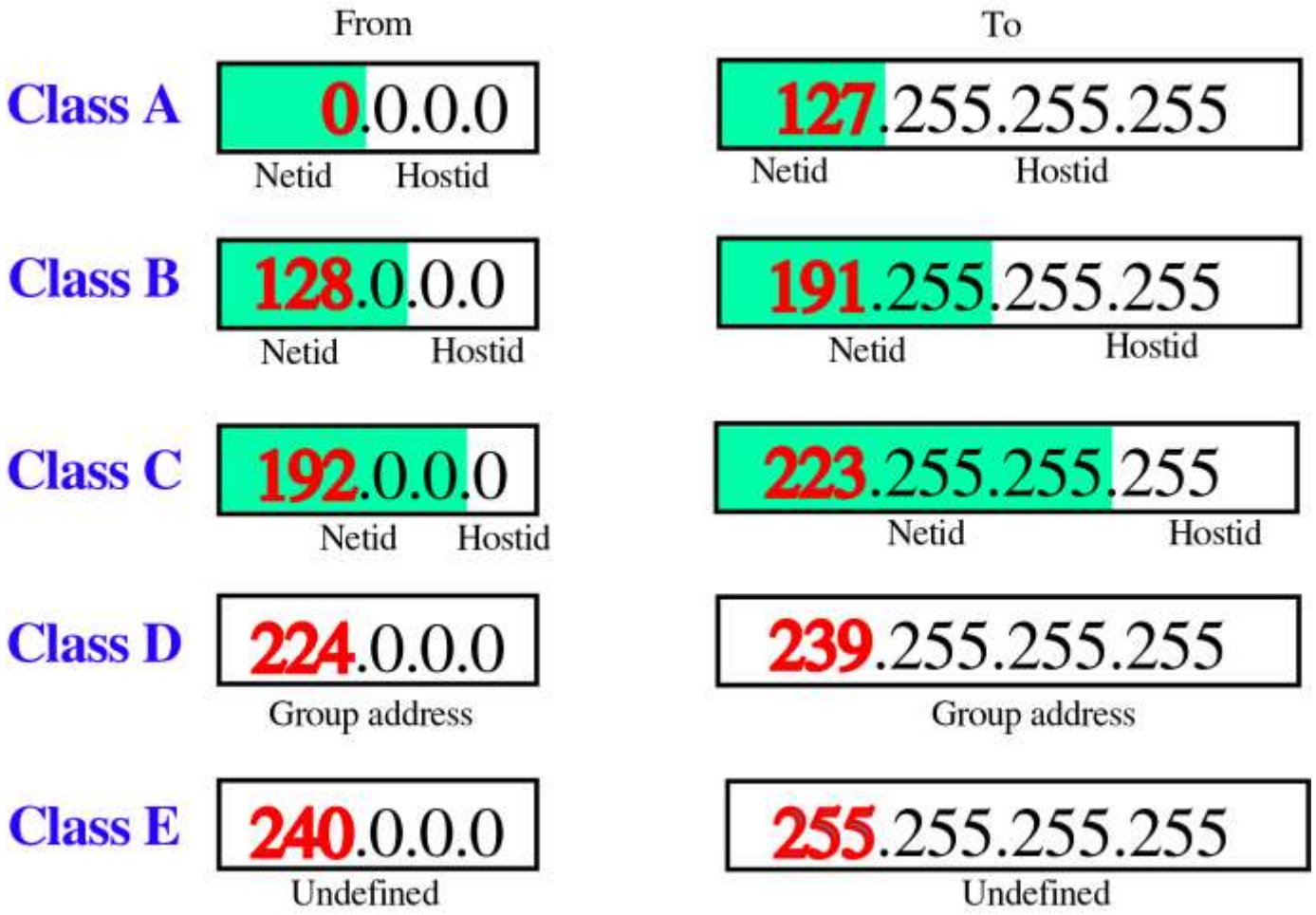
The address space of IPv4 is

$$2^{32}$$

or

4,294,967,296.

Class Ranges of Addresses



Class A

- Class A addresses are assigned to networks with a very large number of hosts
- Reserved for governments and large corporations throughout the world
- Each Class A address supports 16,777,214 hosts
- The high-order bit(MSB) in a class A address is always set to zero.
- The next seven bits (completing the first octet) complete the network ID.
- The remaining 24 bits represent the host ID.

Class B

- Class B addresses are assigned to large- and medium-sized companies
- Each Class B address supports 65,534 hosts
- The two high-order bits in a class B address are always set to binary 1 0.
- The next 14 bits complete the network ID.
- The remaining 16 bits represent the host ID.

Class C

- Class C addresses are used for small networks.
  - Addresses are assigned to groups that do not meet the qualifications to obtain Class A or B addresses
  - supports 254 hosts
- The three high-order bits in a class C address are always set to binary 1 1 0.
- The next 21 bits complete the network ID.
- The remaining 8 bits represent the host ID.

Class D & E

- **Class D** addresses are reserved for IP multicast addresses.
  - Also known as multicast addresses
  - **Multicasting** is the sending of a stream of data (usually audio and video) to multiple computers simultaneously
    - The four high-order bits in a class D address are always set to binary 1 1 1 0.
    - The remaining bits are for the address that interested hosts recognize.
- **Class E** addresses are reserved for research, testing, and experimentation
  - The high-order bits in a class E address are set to 1111.
  - The Class E range starts where Class D leaves off

Application of IP Address

- Each Network is assigned a network address & every device on the network is assigned a host address.
- There are only 2 specific rules that govern the value of the address.

Non-usable addresses

- Address cannot be designated by all zeros or all ones.
- These are special addresses that are reserved for special purposes.

Example

- All 1's in the network ID are reserved for use as an IP broadcast address.

Special Addresses

Special IP Addresses			
Network Address	*Host Address*	*Description*	*Example*
0's	0's	Default Cisco Route	0.0.0.0
0's	Host Address	Local Network Hosts	0.0.0.115
1's	1's	Broadcast to Local Network	255.255.255.255
Network Address	1's	Broadcast to Network Address	192.21.12.255
127	Anything	Loopback Testing	127.0.0.1

Class A

- The 1st bit, which are always 0, designate the address as a Class A address
- There are 128 Class A(2^7) Network Addresses(the first MSB is used to refer the class)

- Addresses with all zeros and ones aren't used.
- 126(2^7 –2) Class A Networks are available.
- Each of this network can support 2^{24} – 2 or 16,777,214 hosts.

Class B IP Addresses

- The 1st 2 bit, which are always 10, designate the address as a Class B address & 14 bits are used to designate the Network.
- Using our formula, $(2^{14} - 2)$, there can be 16,382 Class B Networks & each Network can have $(2^{16} - 2)$ Hosts, or 65,534 Hosts.

Class C

- The 1st 3 bits of all class C addresses are set to 110, leaving 21 bits for the Network address, which means there can be 2,097,150 ($2^{21} - 2$) Class C Networks.

- But it can support only 254 ($2^8 - 2$) Hosts per Network.

Summary of Usable Addresses

Characteristics of the IP Address Classes						
Class	Address Range	Identify Bits (binary value)	Bits in Network ID	Number of Networks	Bits in Host ID	Number of Hosts/ Network
A	0 ~ 127	1 (0)	7	126	24	16,777,214
B	128~191	2 (10)	14	16,382	16	5,534
C	192~223	3 (110)	21	2,097,150	8	254

Address Class	First Network ID	Last Network ID
Class A	1.0.0.0	126.0.0.0
Class B	128.0.0.0	191.255.0.0
Class C	192.0.0.0	223.255.255.0

IP Address	1st Octet Range	Usable Network and Host IDs
Class A (N.H.H.H)	1-126	Networks : 2^8-2 and Hosts= 2^24-2
Class B (N.N.H.H)	128-191	Networks : 2^16-2 and Hosts= 2^16-2
Class C (N.N.N.H)	191-223	Networks : 2^24-2 and Hosts= 2^8-2

Private IP Range

- Private IP Addresses:
  - Many companies use private IP addresses for their internal networks
    - Will not be routable on the Internet

Class	Private
A	10.x.x.x (10.0.0–10.255.255.255)
B	127.16.x.x (127.16.0.0–127.16.255.255)
C	192.168.x.x(192.168.0.0–192.168.255.255)

Classless IP addressing

- Part –2

Netid and Hostid

- In classful addressing, an IP address in class A, B, or C is divided into netid and hostid.
- These parts are of varying lengths, depending on the class of the address.
- In class A, one byte defines the netid and three bytes define the hostid.
- In class B, two bytes define the netid and two bytes define the hosfid.
- In class C, three bytes define the netid and one byte defines the hostid.

Mask

- Although the length of the netid and hostid (in bits) is predetermined in classful addressing, we can also use a mask (also called the default mask)
- The masks for classes A, B, and C are shown below
- The mask can help us to find the netid and the hostid. define the netid.
- CIDR(Classless Interdomain Routing) notation also applicable

Class	*Binary*	*Dotted-Decimal*	*CIDR*
A	11111111 00000000 00000000 00000000	255.0.0.0	/8
B	11111111 11111111 00000000 00000000	255.255.0.0	/16
C	11111111 11111111 11111111 00000000	255.255.255.0	/24

Address Depletion

- The imperfection in classful addressing scheme combined with the fast growth of the Internet led to the near depletion of the available addresses.
- Yet the number of devices on the Internet is much less than the 2^{32} address space.
- We have run out of class A and B addresses, and a class C block is too small for most midsize organizations.
- One solution that has alleviated the problem is the idea of classless addressing.

Classless Addressing

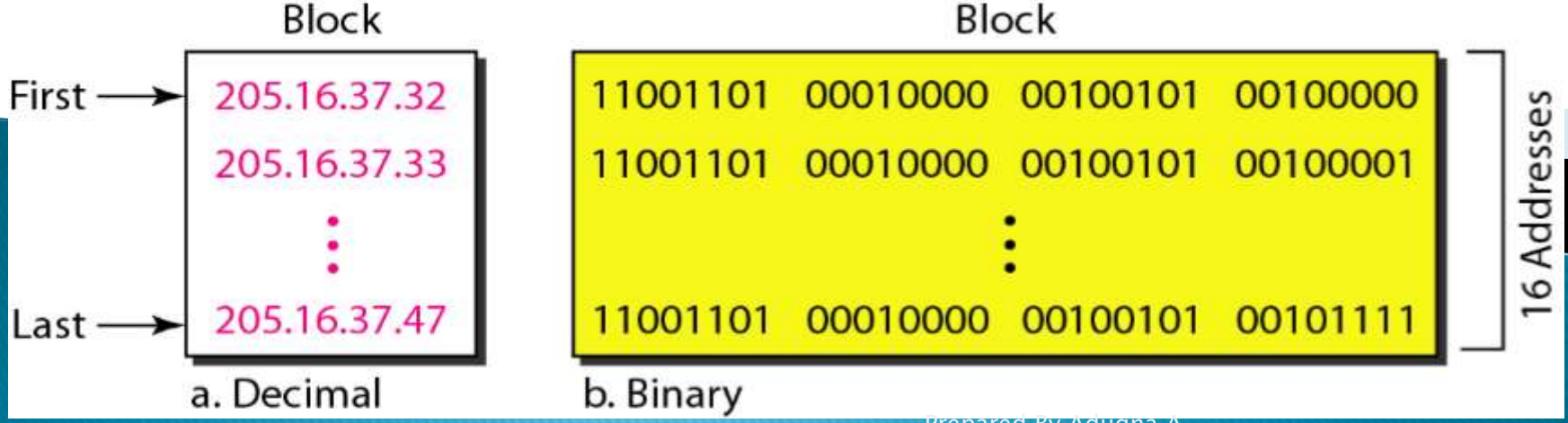
- To overcome address depletion and give more organizations access to the Internet.
- In this scheme, there are no classes, but the addresses are still granted in blocks.

Address Blocks

- In classless addressing, when an entity, small or large, needs to be connected to the Internet, it is granted a block (range) of addresses.
- The size of the block (the number of addresses) varies based on the size of the entity.
- For example, a household may be given only two addresses; a large organization may be given thousands of addresses.
- An ISP, as the Internet service provider, may be given thousands or hundreds of thousands based on the number of customers it may serve.

Restriction

- To simplify the **handling of addresses**, the Internet authorities impose three restrictions on classless address blocks:
  1. The addresses in a block must be contiguous, one after another.
  2. The number of addresses in a block must be a power of 2 (1, 2, 4, 8 ....).
  3. The first address must be evenly divisible by the number of addresses.



- The above figure shows a block of addresses granted to a small business that needs 16 addresses.
- We can see that the restrictions are applied to this block.
  - The addresses are contiguous.
  - The number of addresses is a power of 2 ($16 = 2^4$)
  - First address is divisible by 16.

Classless addressing Mask

- As we discussed before, a mask is a 32-bit number in which the n leftmost bits are 1s and the 32 - n rightmost bits are 0s.
- However, in classless addressing the mask for a block can take any value from 0 to 32. It is very convenient to give just the value of n preceded by a slash (CIDR - Classless Interdomain Routing notation).
- The address and the/n notation completely define the whole block (the first address, the last address, and the number of addresses).

Network Addressing

- IP addresses identify both the network and the host
  - The division between the two is not specific to a certain number of octets
- **Subnet mask**
  - Indicates how much of the IP address represents the network or subnet
- Standard (default) subnet masks:
  - Class A subnet mask is 255.0.0.0
  - Class B subnet mask is 255.255.0.0
  - Class C subnet mask is 255.255.255.0

Subdividing IP Classes

- Reasons for subnetting
  - To match the physical layout of the organization
  - To match the administrative structure of the organization
  - To plan for future growth
  - To reduce network traffic

Subnet Mask….

- Subnet masks are frequently expressed in dotted decimal notation.
- Subnet mask is not an IP address.
- Each host on a TCP/IP network requires a subnet mask even on a single segment network.

Address Class	Bits for Subnet Mask	Subnet Mask
Class A	11111111 00000000 00000000 00000000	255.0.0.0
Class B	11111111 11111111 00000000 00000000	255.255.0.0
Class C	11111111 11111111 11111111 00000000	255.255.255.0

Journey to IP Versions…

- IPV(1-3) : were not formally assigned.
- IPV4 : TCP/IP , 32bit IP address currently used.
- IPV5 : Internet Stream Protocol (SP)
  - Experimental Protocol
  - Never Introduced for public use.
- IPV6 : Designed to replace IPV4 , 128bit IP address

Features of IPV4…

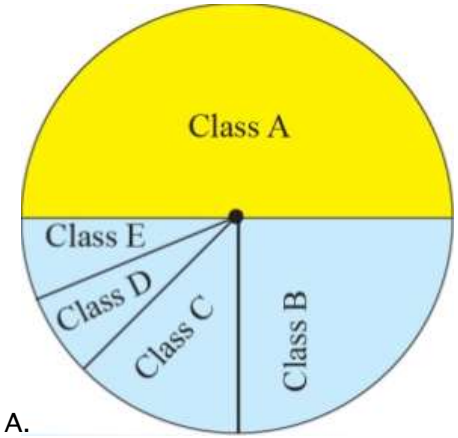
- Connectionless protocol and best effort based.
- Simplicity
  - It is simpler and easy to remember
  - Require less memory
- Familiarity
  - Millions of devices are already knowing it
  - Existing infrastructure already support it

Benefits of IPV4….

- Widely support
- Shorter & Sweeter (header)
- Support of all Operating Systems
- All commonly used protocols are supported

Shortcoming of IPV4….

- IPV4 specification didn't identify any security mechanism.
- Millions of class A addresses are wasted.
- Many class B addresses also wasted.
- Not so many organizations are so small to have a class C block.
- Class E addresses were reserved for future purposes.

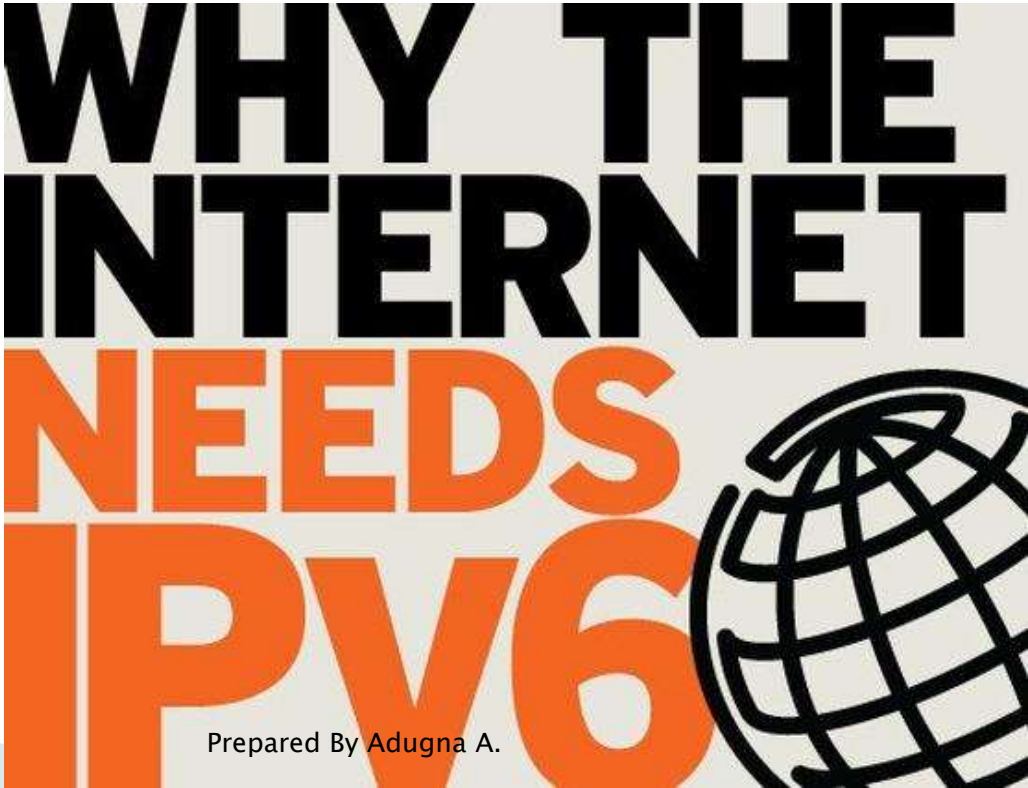


IPV4 Supporting Devices..

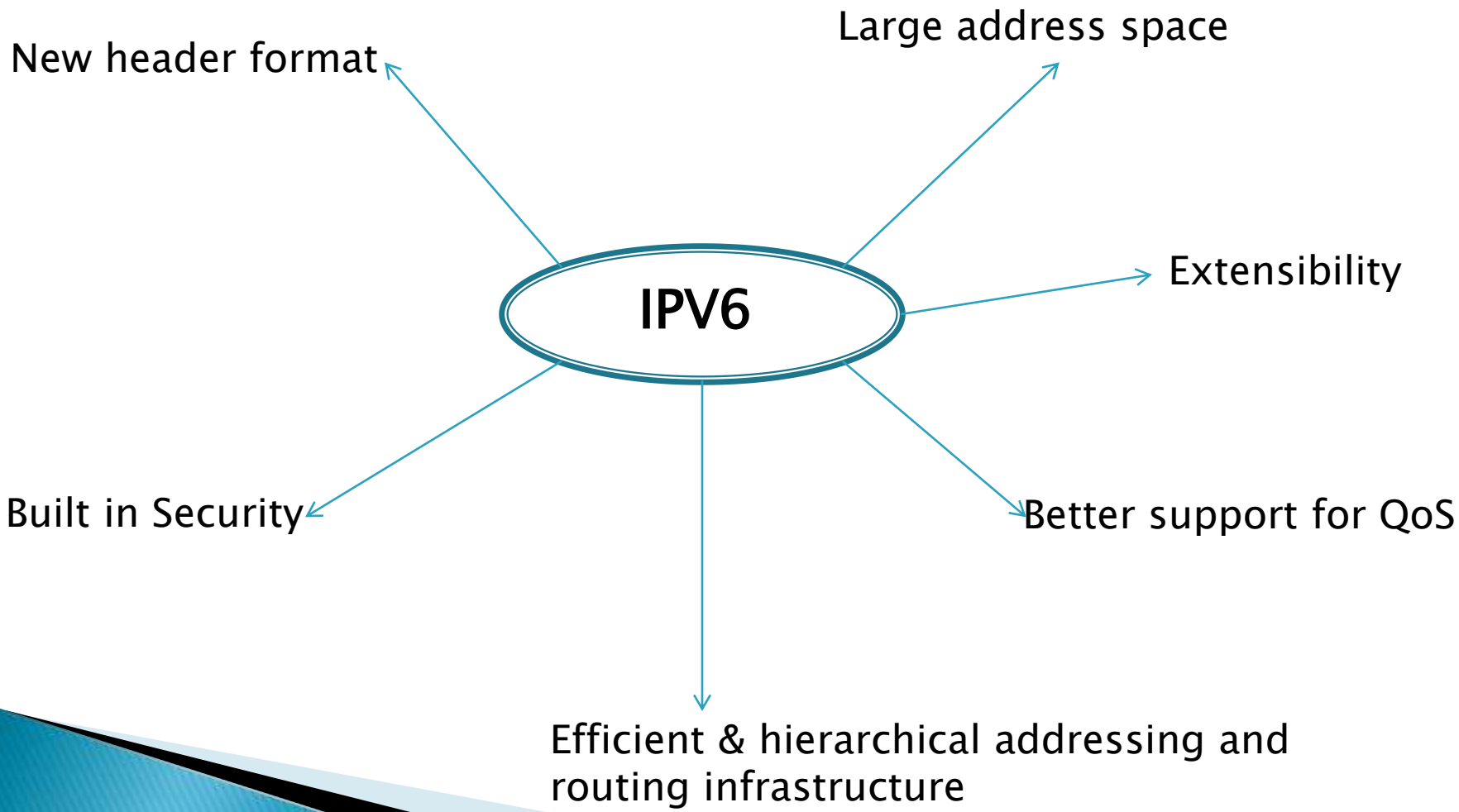
- PCs
- Servers
- Modems
- Routers
- Printers
- Cameras
- Smart Phones
- Tablets & Gaming Systems
- Just about anything else connecting to the Internet

Why IPV6…..?

IPV6 provides a platform on new internet functionality that will be needed in the immediate future and provide flexibility for future growth and expansion.



Benefits of IPV6…..



IP Based Technologies..

- Internet
- VoIP
- IP – TV
- IP–VPN
- Wireless Mobile Technology
- Internet Broadcasting
- Multihoming

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