Advanced Lecture on Internet Infrastructure
1. The Principle of the Internet

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Structure of Lecture

- 2nd Quater
  - Advanced Lecture on Internet Infrastructure
    - Physical, Datalink and Network Layers
- 4th Quater
  - Advanced Lecture on Internet Applications
    - Transport and Application Layers

Purpose of the Lectures

- Understand the Pinciple of the Internet and Knowhow of Internet Style Protocol Design
  - The end to end principle (rfc1958)
    - principle of global connectivity
    - principle of scalability
- We are in Protocol Era
  - Protocols designed for various applications
  - APIs are of secondary importance

Reference Articles for Lecture

- RFC (Request for Comments)
- 「本当のインターネットをめざして」、情報処理学会誌、全36回（1999年4月号〜2002年3月号）
- 「インターネットの真実」、週間東洋経済（2001年1月より2002年4月まで連載）
- Slides used in the Previous Fiscal Year (Japanese version not updated since 2018)
  - ftp://chacha.hpcl.titech.ac.jp/2019/infra*.ppt

Topics for the 2nd Quarter (1)

- 1. Principle of the Internet: End to end principle, CATENET model
- 2. Physical Layer: Access Network, Backbone Network, Optical Fiber, ADSL, Radio Wave
- 3. Datalink Layer: Ethernet, ATM, PPP, IOG
- 4. Internetworking Layer: IPv4, ARP

Topics for the 2nd Quarter (2)

- 5. Internetworking Layer: IPv6, ND
- 6. Internetworking Layer: IP security
- 7. Internetworking Layer: NAT, DHCP & AUTOCONF
- 8. Routing: IGP, Policy, IX, Multihoming, Mobility

Topics for the 2nd Quarter (3)

- 9. Routing: Traffic Engineering, ROLC, MPLS (skipped, last year)

- 10. Routing: Multicast, Impossibility of Route Aggregation

- 11. Bandwidth & Delay Guarantee: Guaranteed Service, DiffServe.

- 12. Ultra High Speed Routers, Optical Routers

- 13~?. Auxiliary Topics

Evaluation Method

- Interim and Final Report

- Attendance is not Checked, but, ...

- Questions or Comments are Mandated

  - In the quarter, questions or comments with technical content must be made at least twice during lecture (may be in Japanese)

  - Good questions and comments will be awarded with points

  - Declare your name and student ID, if you make questions or comments

Evaluation with Zoom (draft)

- questions/comments should be asked/made by verbal interruption
  - raising hand by zoom is hard to be noticed unless dedicated chair is assigned
  - don't hesitate to interrupt my talk
- name/ID and points are declared and given through chat

What is Protocol?

- Procedure to communicate over networks

BTW, What is the Internet?

- Not e-mail
  - seriously thought so 20 years ago
- Not web, either
  - many still misunderstand so
- Is not applications
- The Internet is a network directly connecting terminals based on the principle of the Internet using IP (Internet Protocol)

End to End Principle Disintermediated Networking

- Implement things by terminals (end) not by the network
  - network equipment has only single function (to connect terminals) and is high speed
- Implement things by directly involved terminals without involving other terminals
  - scalable (no load concentration)
  - highly reliable (system works if only terminals are working and can communicate each other over some route)

What is not the Internet (1)
e-mail

- UUNET (JUNET) was not the Internet
- Communication System for Personal Computers was not the Internet
- E-mail is an application works on the Internet
  - also works on other (phone) networks
- In the past, (oversea) e-mail was charged
  - some mail on mobile phone is still charged
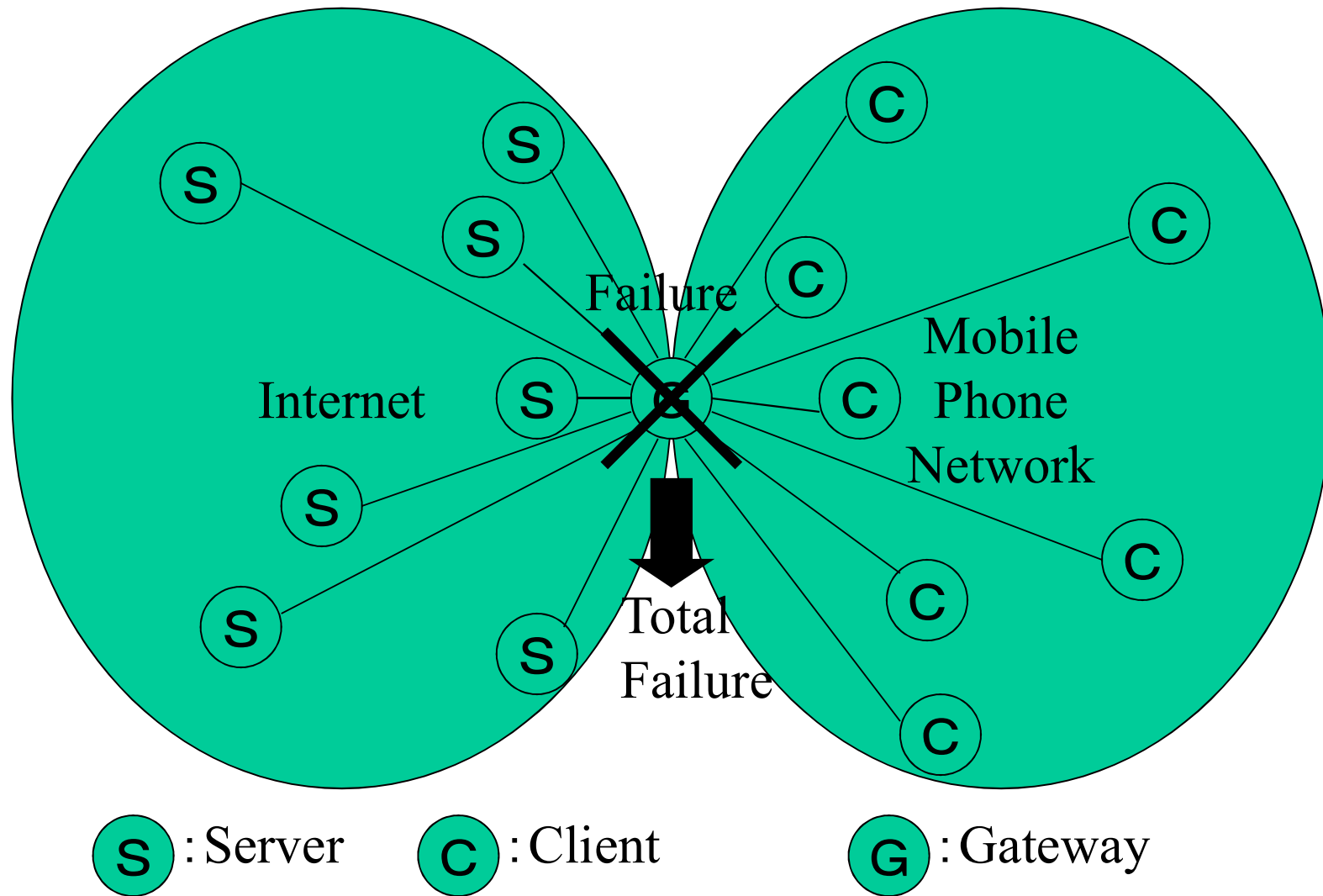
What is not the Internet (2) Web

- Web is not the Internet
  - though Microsoft makes it obscure
- Web, too, is an application works on the Internet
  - also works on other networks
  - web browsing from mobile phone network is, in principle, charged
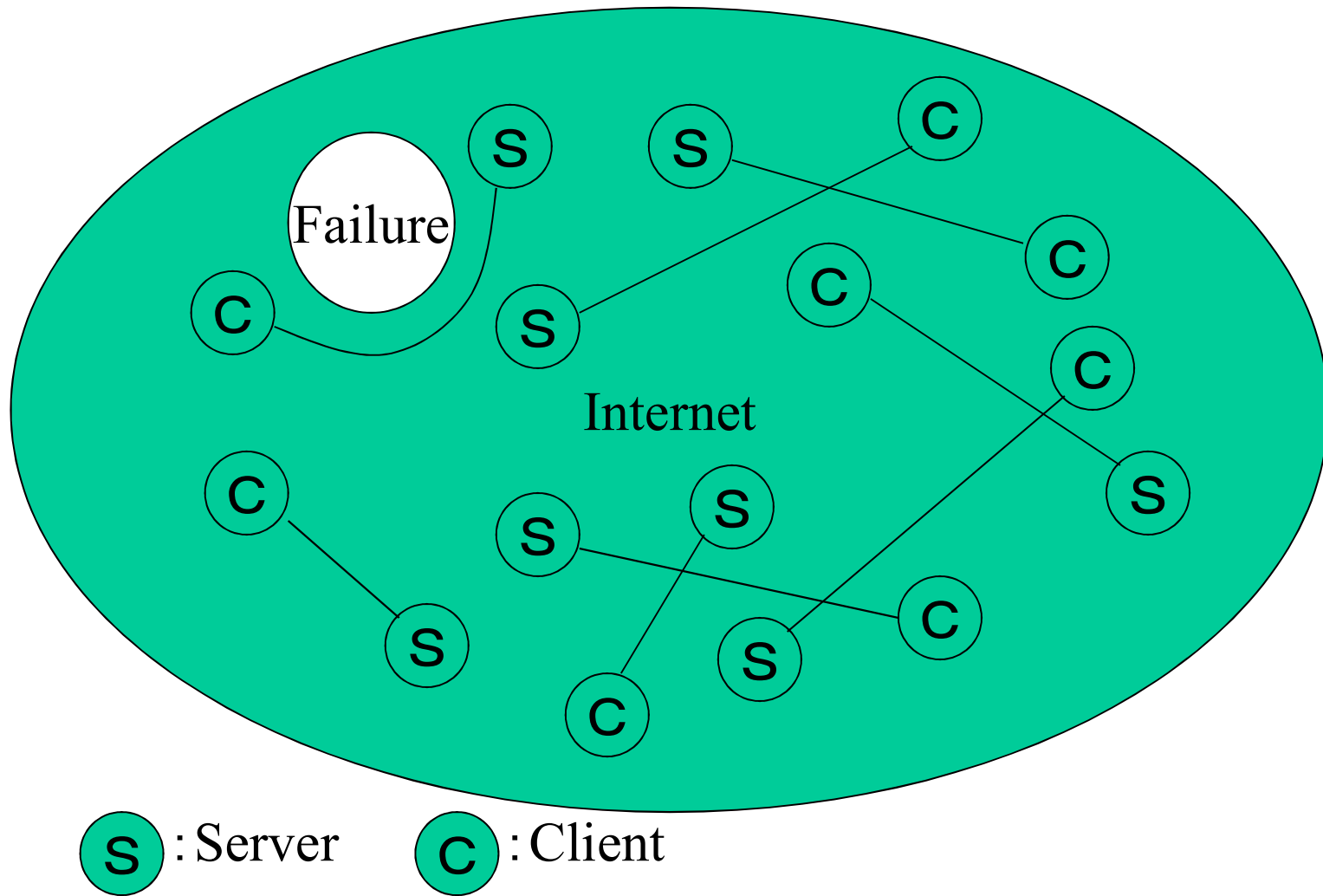   - mobile phone network is not the Internet, of course
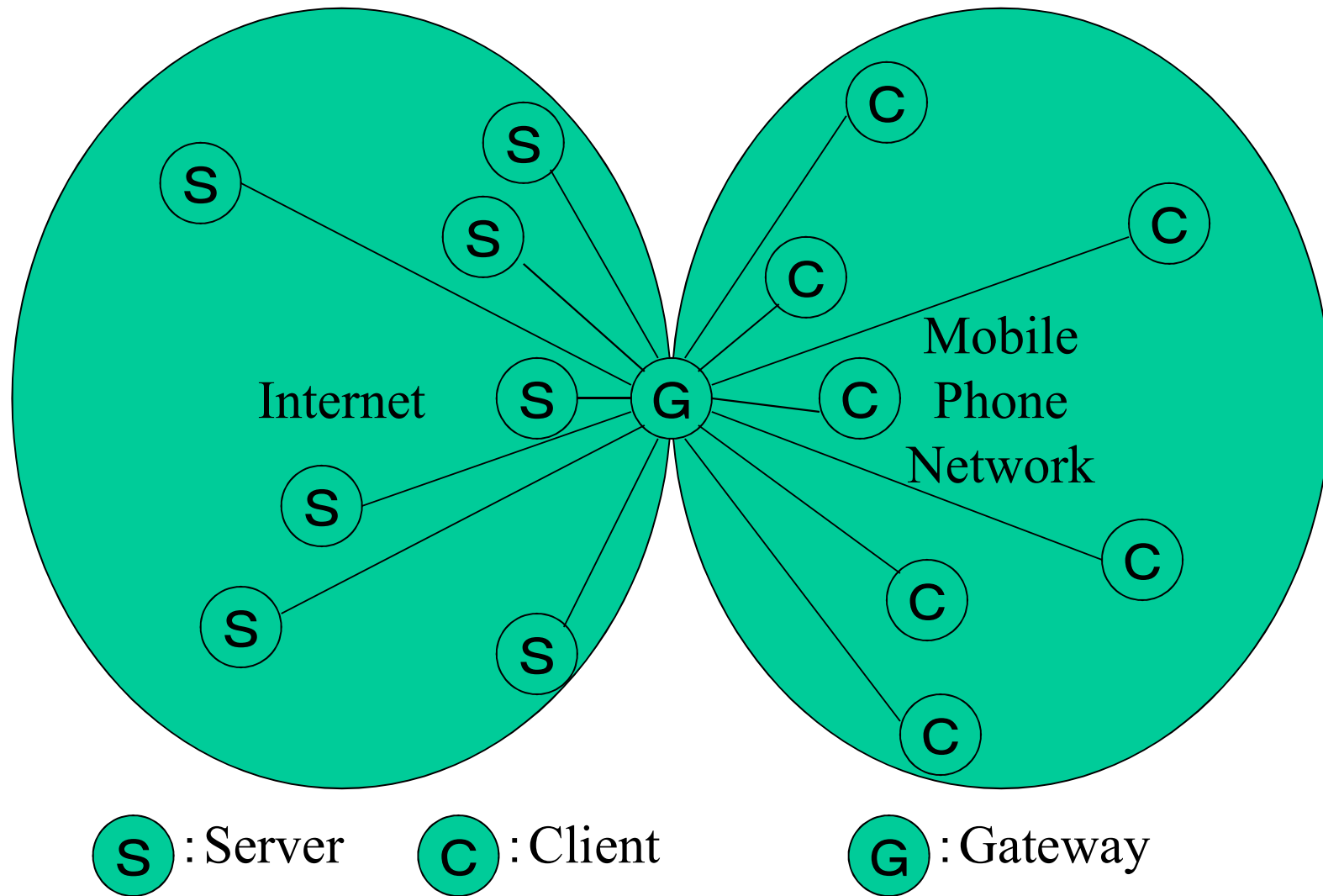
S : Server   C : Client   G : Gateway

Web Browsing from Mobile Phone Network
Servers and clients are separated and communicate through the gateway

S : Server   C : Client   G : Gateway

Web Browsing from Mobile Phone Network
Servers and clients are separated and communicate through the gateway

S : Server   C : Client

Internet

Servers and clients are mixed and communicate with shortest pathes

What is not the Internet (3) Phone

- Phone is not phone network
- Phone is an application works on phone networks
  - also works on other networks
  - phone over the Internet is free of charge
- Phone, today, is a promotion tool to sell Internet services
  - no need to support phone network
  - mobile phone is to sell mobile Internet services

What is not the Internet (4) Phone Network

- Phone is not phone network
- Phone is an application works on phone networks
  - also works on other networks
  - phone over the Internet is free of charge
- We don't need phone networks
  - neither are mobile phone networks
  - phone numbers are not necessary, either
    - IP addresses! (though alternatives may exist)

Networks

- Physical Distribution Networks
  - postal service, parcel services, convenience stores

- Information Communication Networks
  - Publishing Network (Book, News Paper, CD, Movie)
  - Financial Network
  - Phone Network
  - Broadcast Network
  - the Internet

Internet Disintermediate ICN

- Price Destruction of ICN
  - Publishing, financial, phone and broadcast networks will disappear
  - IC cost of the society decreased
    - ISP business itself is not profitable
- Publishing, financial, phone and broadcast services will:
  - remain, but, on the Internet
  - social activities increase

Publishing Network

- Mass Distribution of Same Information
- Delay of the Distribution may be Tolerated
- Protected by Copyright Act
- The First Victim of the Internet
  - Collapsing

Financial Network

- Manage Transfer of Money
- Partly, Phisical Distribution Network, but, today, mostly ICN
- Security!!!
  - Not that there is no accident
 - Who will pay the loss on accidents

Phone Network

- Network for Realtime Voice Transfer
  - Allocate bandwidth for voice transfer
  - Minimize (guarantee) delay for voice transfer
- Dedicated line service may be Offerred
  - but, primary service is voice transfer
- Slow and Expensive
- Was Protected as National Company
  - Leberated by Telecommunication Business Act
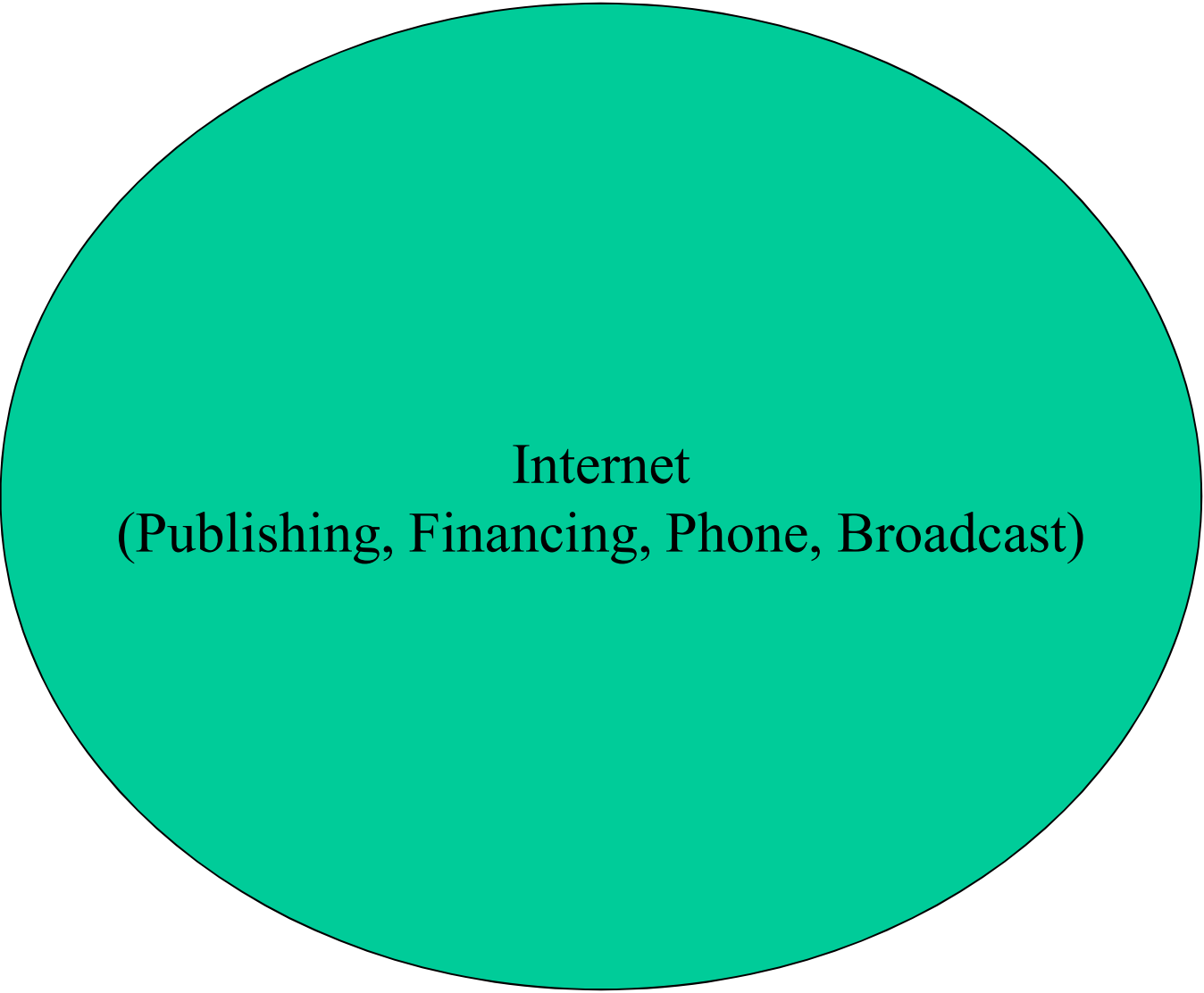
Broadcast Network

- Network to Transfer Voice/Image to Many in Realtime
  - Allocate bandwidth for the transfer
  - Minimize delay
- Wide Area One to Many Communication over Radio Waves
  - Broadcast/Multicast
- Protected by Broadcast Act

Integration of Broadcast and Telecommunication

- Viewed from Phone Network
  - one to many transfer over phone network
    - integration of broadcast network to phone network (BISDN)
- Viewed from Broadcast Network
  - receive feedback through phone network
  - one to one communication over radio wave possible?
    - integration of phone network to broadcast network
- Viewed from the Internet?

Broadcast
Networ

Phone
Network

Broadcast
Network
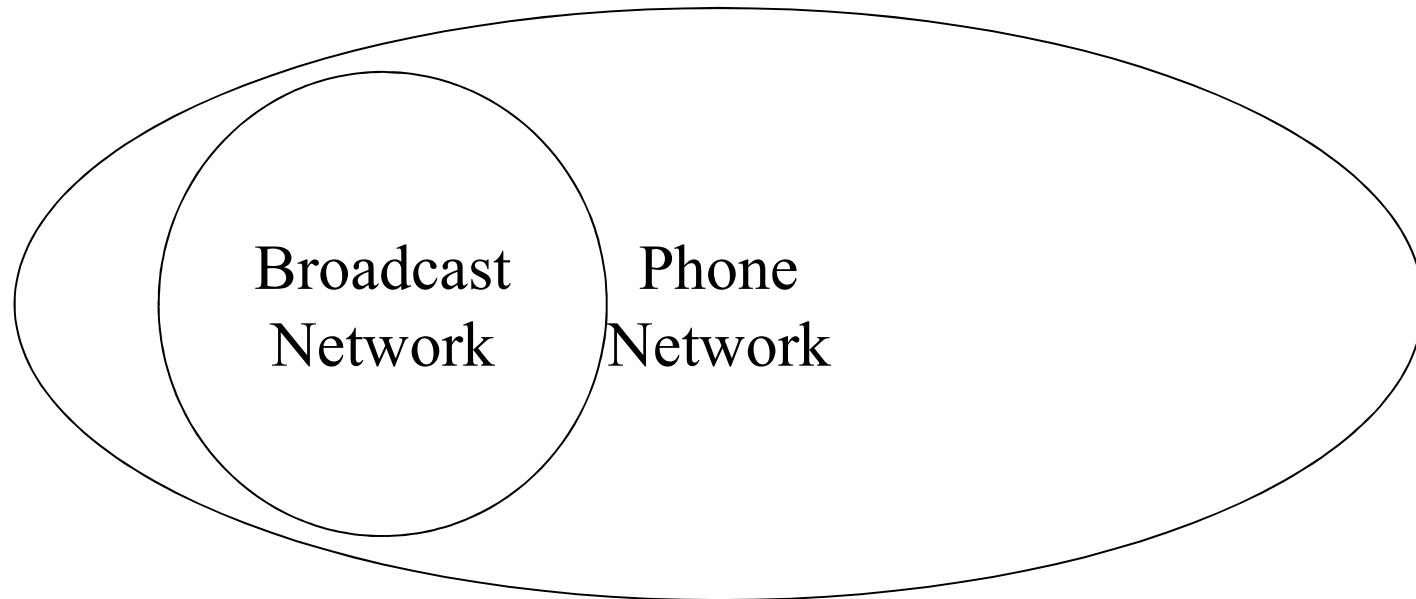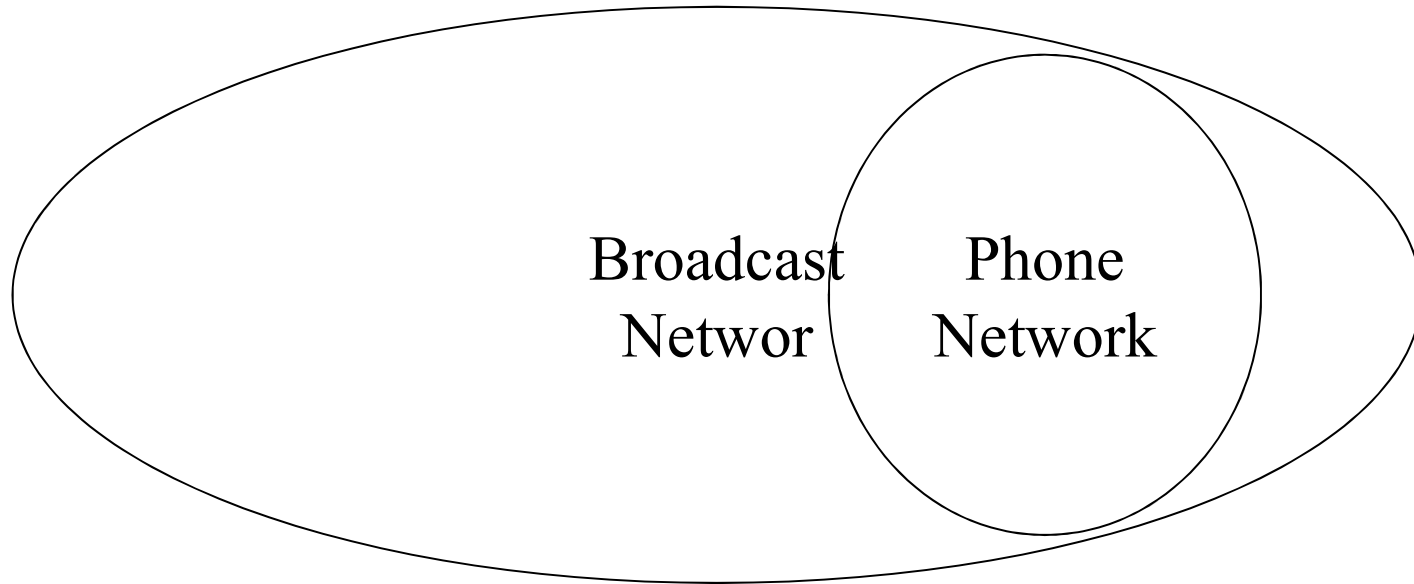
Phone
Network

Two Visions on "Integration of Broadcast and Telecommnication

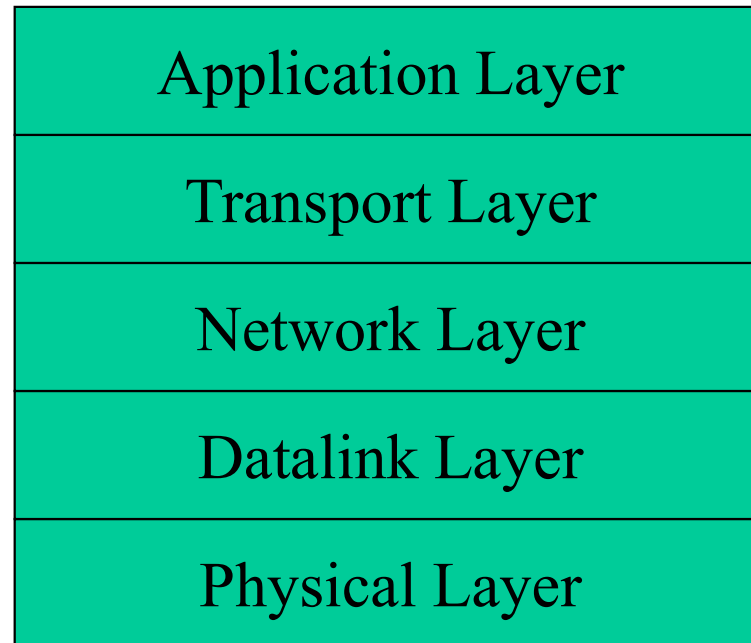Internet
(Publishing, Financing, Phone, Broadcast)

Integration of IC Services by the Internet

Layering of Protocols

- Have Layers based on Level of Abstraction
  - 7 layer model of OSI (Open Systems Interconnection) by ISO/ITU-T
  - 5 layer model of the Internet
- Corresponds to Subroutines (Structuring) in Programming

Application Layer	Layer 7
Presentation Layer	Layer 6
Session Layer	Layer 5
Transport Layer	Layer 4
Network Layer	Layer 3
Datalink Layer	Layer 2
Physical Layer	Layer 1

Layering Structure of OSI

Application Layer
Transport Layer
Network Layer
Datalink Layer
Physical Layer

Layering Structure of the Internet

Physical Layer

- Map Physical Phenomena and Information
  - Voltage high/low <-> 0/1
  - Light on/off <-> 0/1
  - Amplitude and Phase <-> 0/1/.../63
- Multiple Similar Physical Layers may be <u>Integrated</u> (Repeaters)
- Corresponds to Control Firmware in Peripheral Devices in

Datalink Layer

- Joint between Network and Physical Layers
- If Physical Layer have more than 2 devices
  - distinction between them is necessary
- Multiple Dissimilar Physical Layers may be <u>Integrated</u>
  - Local Relays (Bridges)
- Corresponds to Device Drivers in Programming
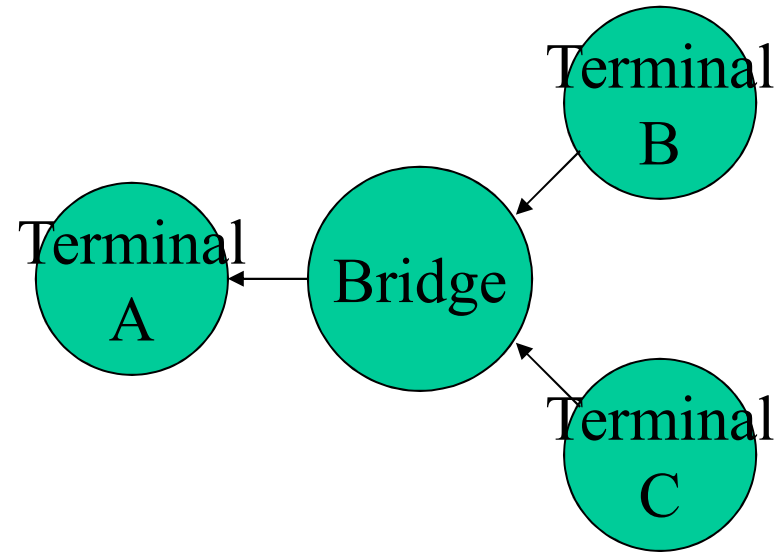
Network Layer
Internetworking Layer

- <u>Integrate</u> Many Datalink Layers to form a Global Network

- Global Relaying (Routers, Gateways)

- Corresponds to File Manager and Inter-process Commnication in Programming

# Which Layer Should be Used for the "Integration"

- Any of the 3 Layers
  - but, is wasteful to do so everywhere
- Clean to do it only at one Layer
  - Internetworking layer MUST Integrate
  - Not necessary at datalink layer
    - simplify datalink layer
  - Waste bandwidth at physical layer
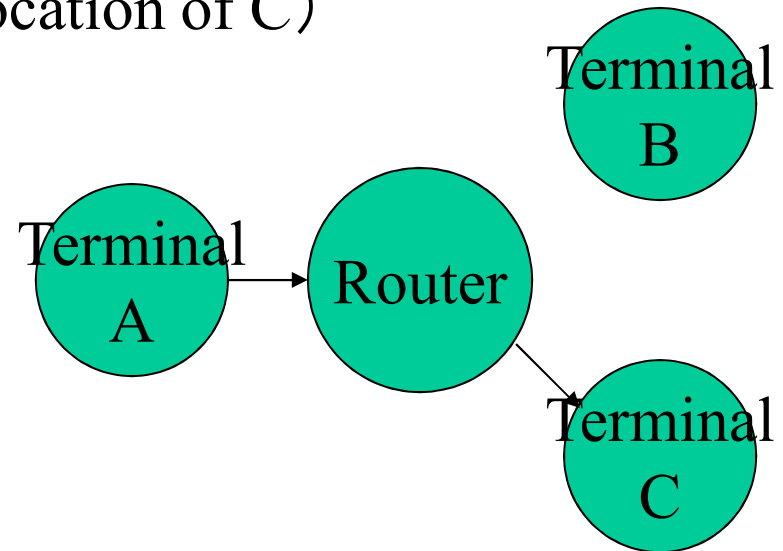   - Many terminals share single physical phenomena
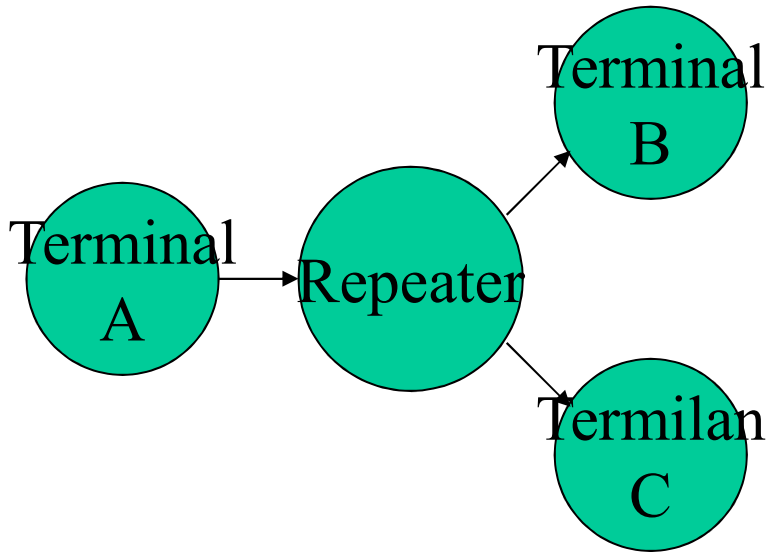
(a) Integration at L1

(b) Integration at L2 (Remember location of C)
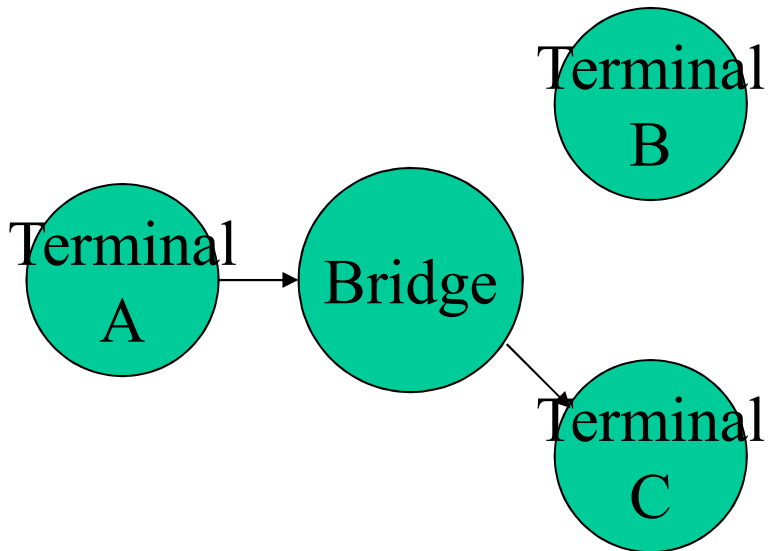
(c) Integration at L2 (remembering C)

(d) Integration at L3

Relaying Behavior at each Layer (Packet from A to C)

Interworking

- Integration of Networks
  - above the Network Layer
- Contradiction
- The End to End Principle requires direct communication between Terminals
  - Interworking impossible on the Internet
  - A single network should covers the entire world
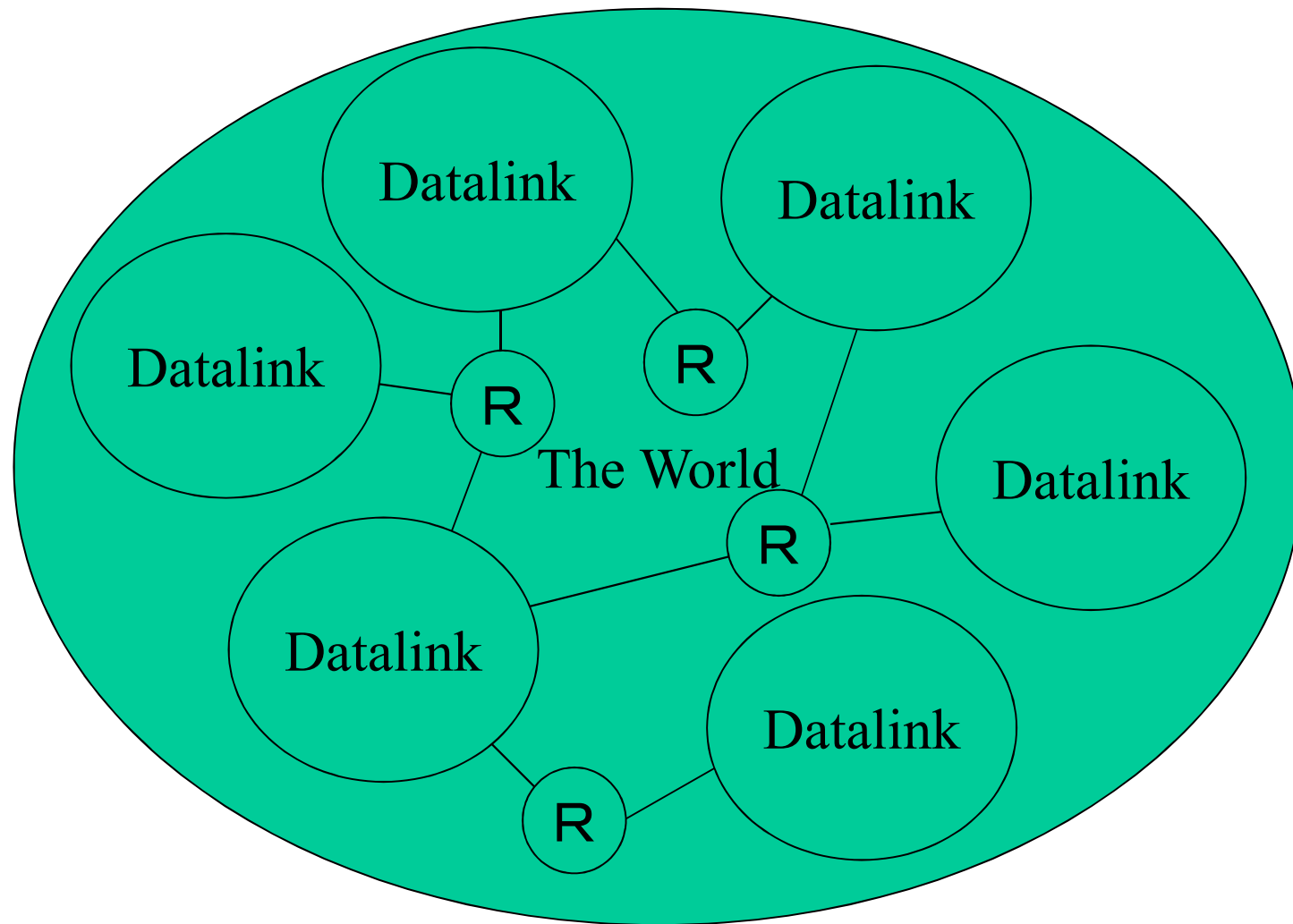 - Easier than specifing various interworking mechanisms almost at random

Network and Datalink

Network

Network

Network
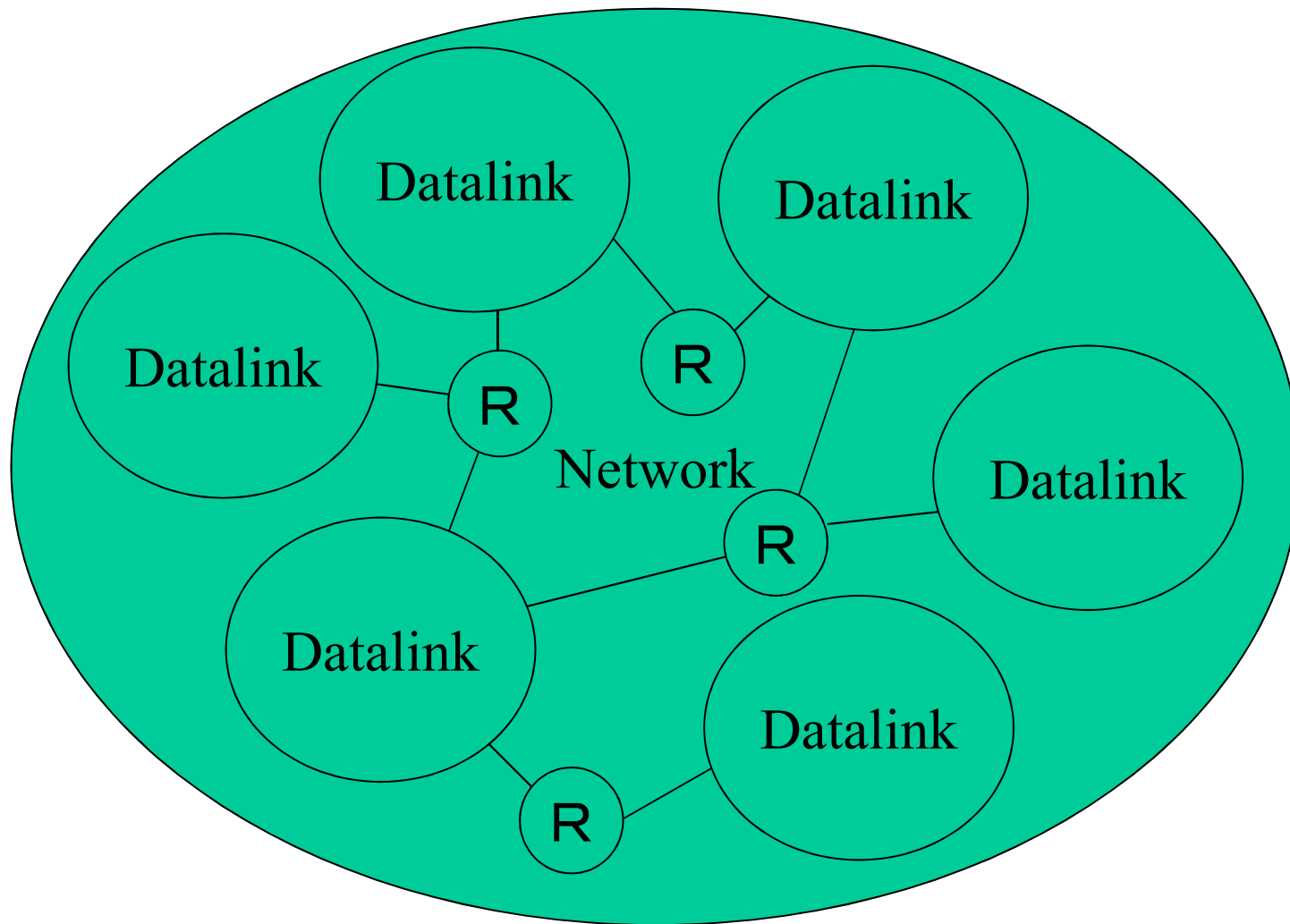
The world

Network

Network
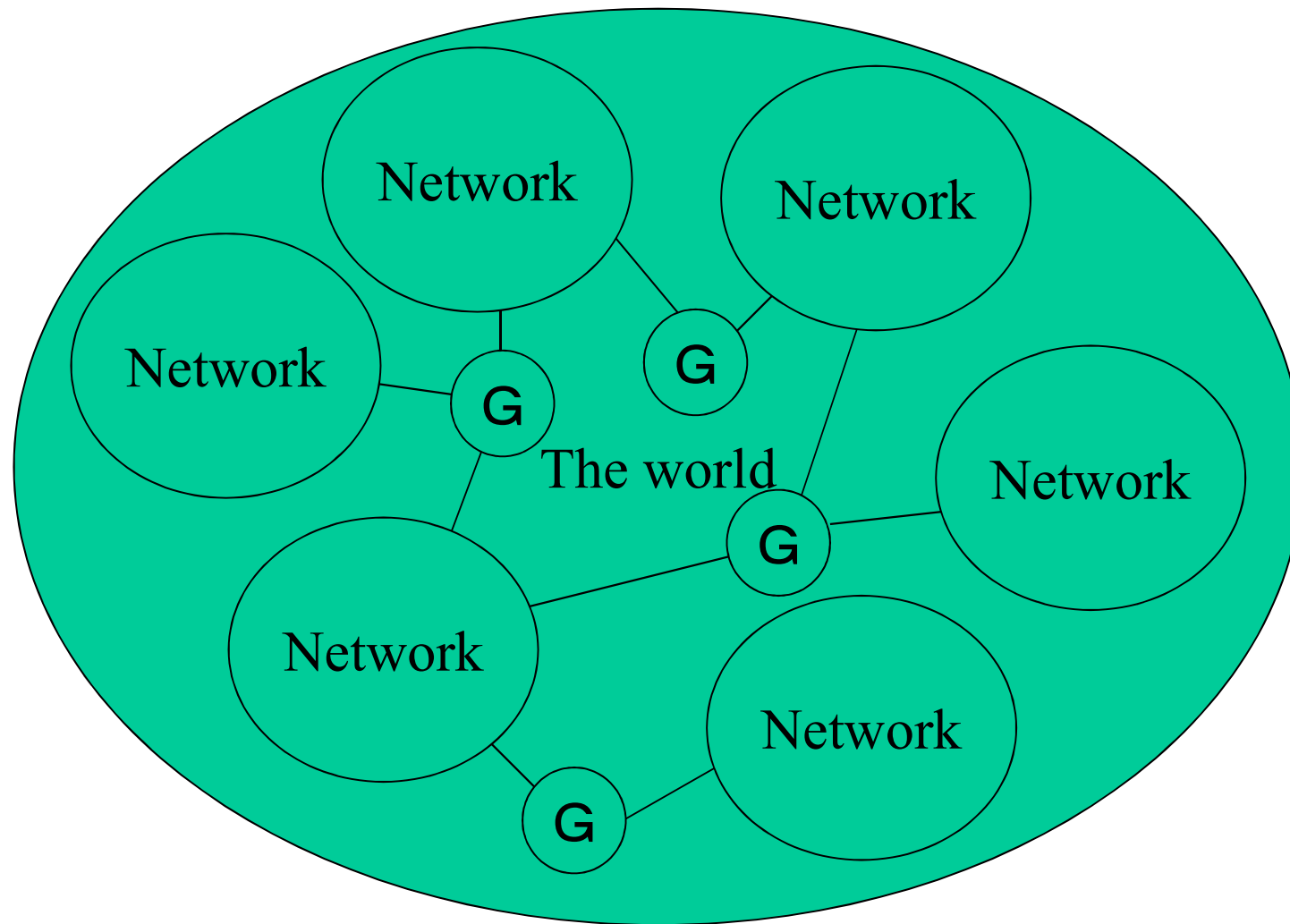
Network

Network

G : Interworking Unit

The World and Networks

The World and the Internet

Transport Layer

- Network Layer Identify Terminals
- Transport Layer Identify Communications
  - Multiple communications may exists between a pair of terminals
    - different communication is processed by different process
    - may require different bandwidth etc.
      - unimportant in the current best effort Internet
- Corresponds to Process Manager in Programming

Sesssion, Presentation and Application Layers

- Corresponds to Internal Structure of each Process in Programming

- Corresponds to Internal Structure of each Process in Terminals

- Without Interworking, there is no Point to have 3 Layers
  - Layering of the Internet has the Application Layer only

Transport and Application Layers

- With Best Effort Network, Distinction is within Each Terminal

- Assigning Packets of Each Communication to Corresponding Process is Transport

- Further Distinctions is not Meaningful
  - Protocols shared by many applications (e.g. TCP (assure reliability and manage bandwidth)) are, traditionally, classified as Transport

Layering of the Internet

- Physical and Application Layers are Essential

- The Internetworking Layer does as Much Things as Possible

- Datalink and Transport Layers should Avoid to do Thing

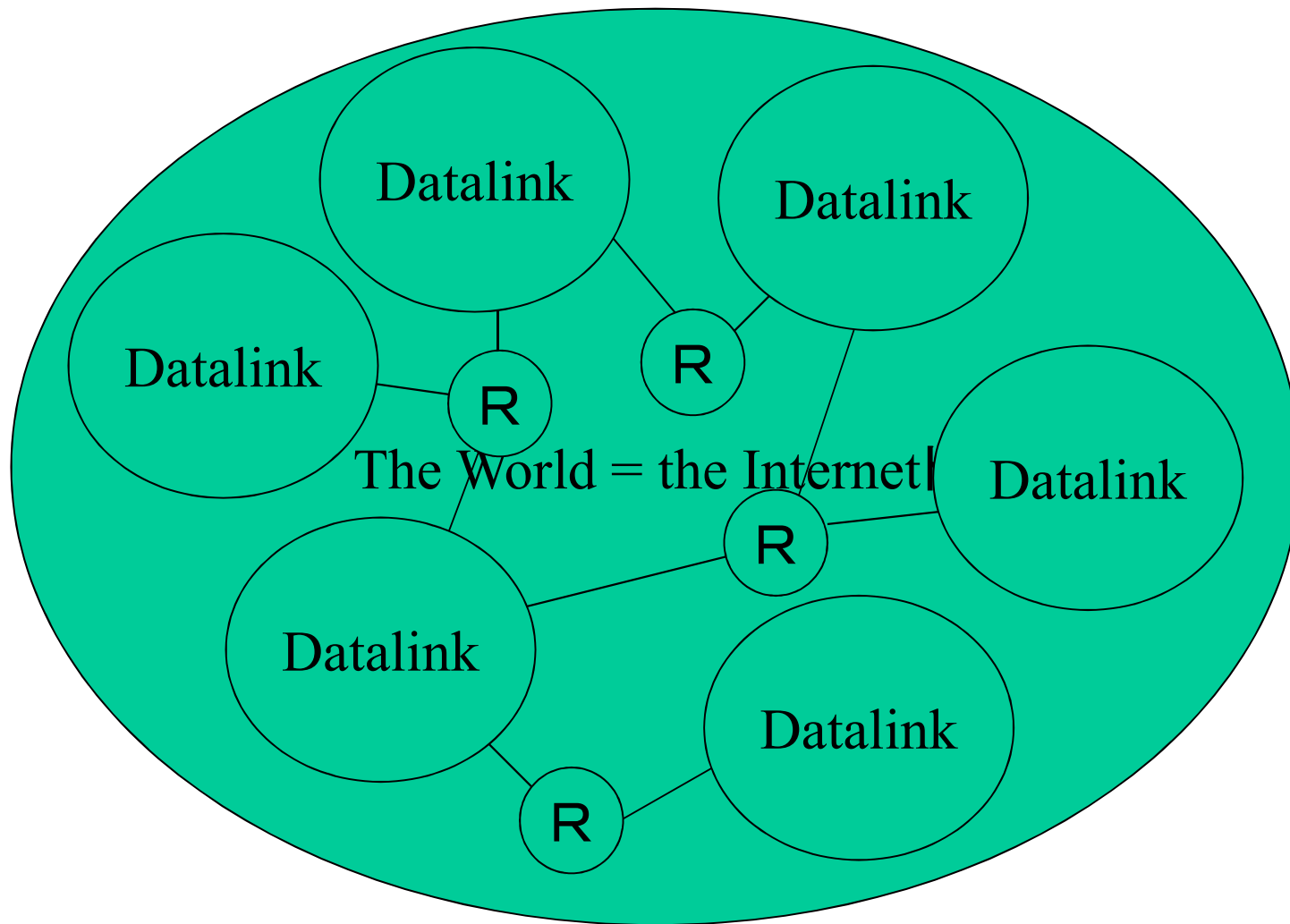| Application Layer |
| Transport Layer |
| Internetworking Layer |
| Datalink Layer |
| Physical Layer |
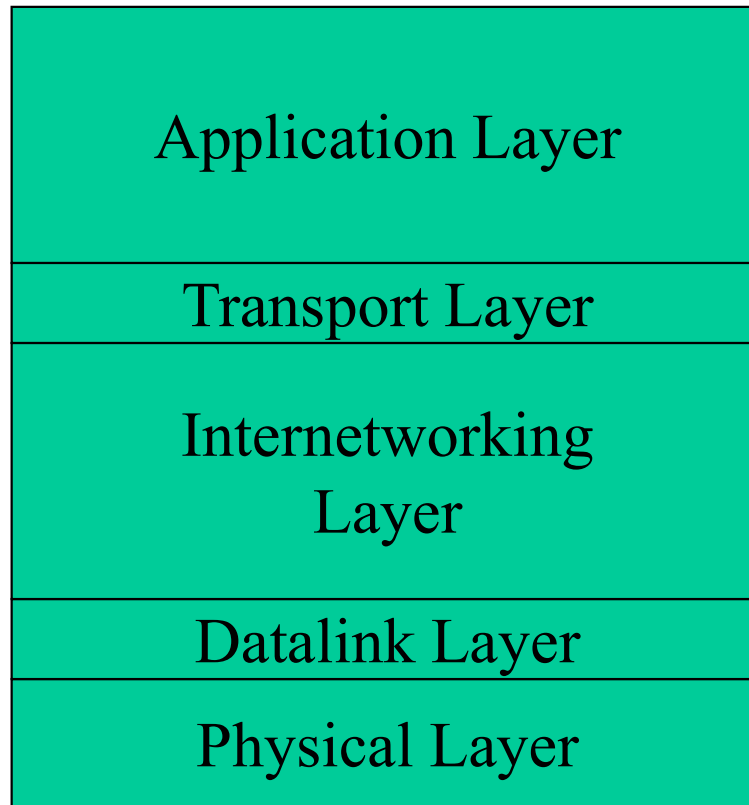
Here is the Essence of the Internet

Layering Structure of the Internet

Structure of the Internet

- CATENET Model
  - Many small (w.r.t. # of devices) datalinks interconnected by IP (Internet Protocol) routers

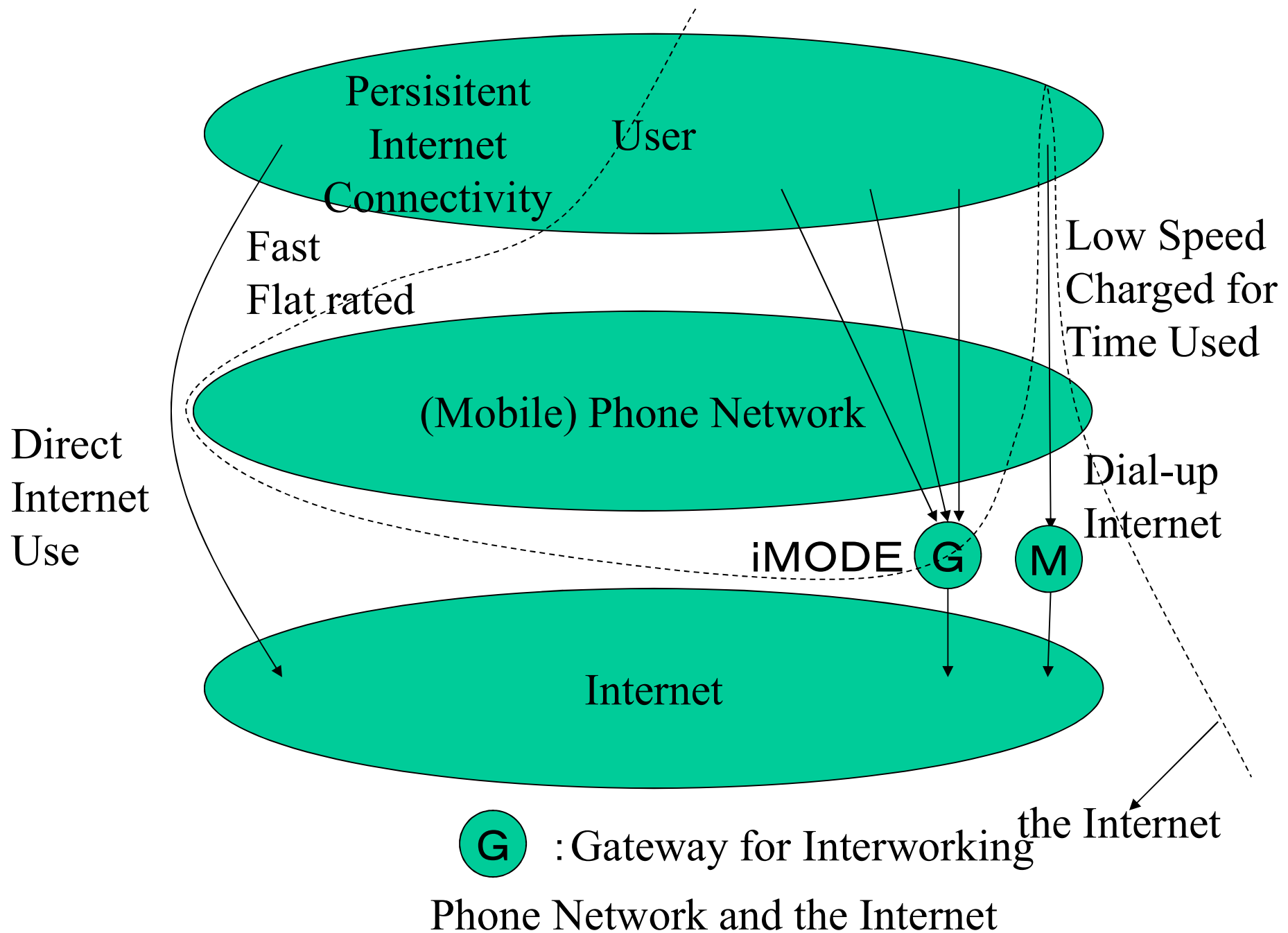The World = the Internet

R : Router

CATENET Model

The Internet and Structure of Networks

- ## Example of Internet
  - Dial-up Internet
- ## Example of non Internet
  - i-mode
    - IP, but, relaying at transport layer
  - Legacy NAT
    - IP, but, addresses etc. are modified, which is not visible to terminals
      - Interworking at the transport layer and above

Persisitent
Internet
Connectivity

User

Fast
Flat rated

Low Speed
Charged for
Time Used

(Mobile) Phone Network

Direct
Internet
Use

Dial-up
Internet

iMODE G   M

Internet

the Internet

G : Gateway for Interworking
Phone Network and the Internet

the World

IP Network

IP Network

IP Network

N

N

IP Network

N
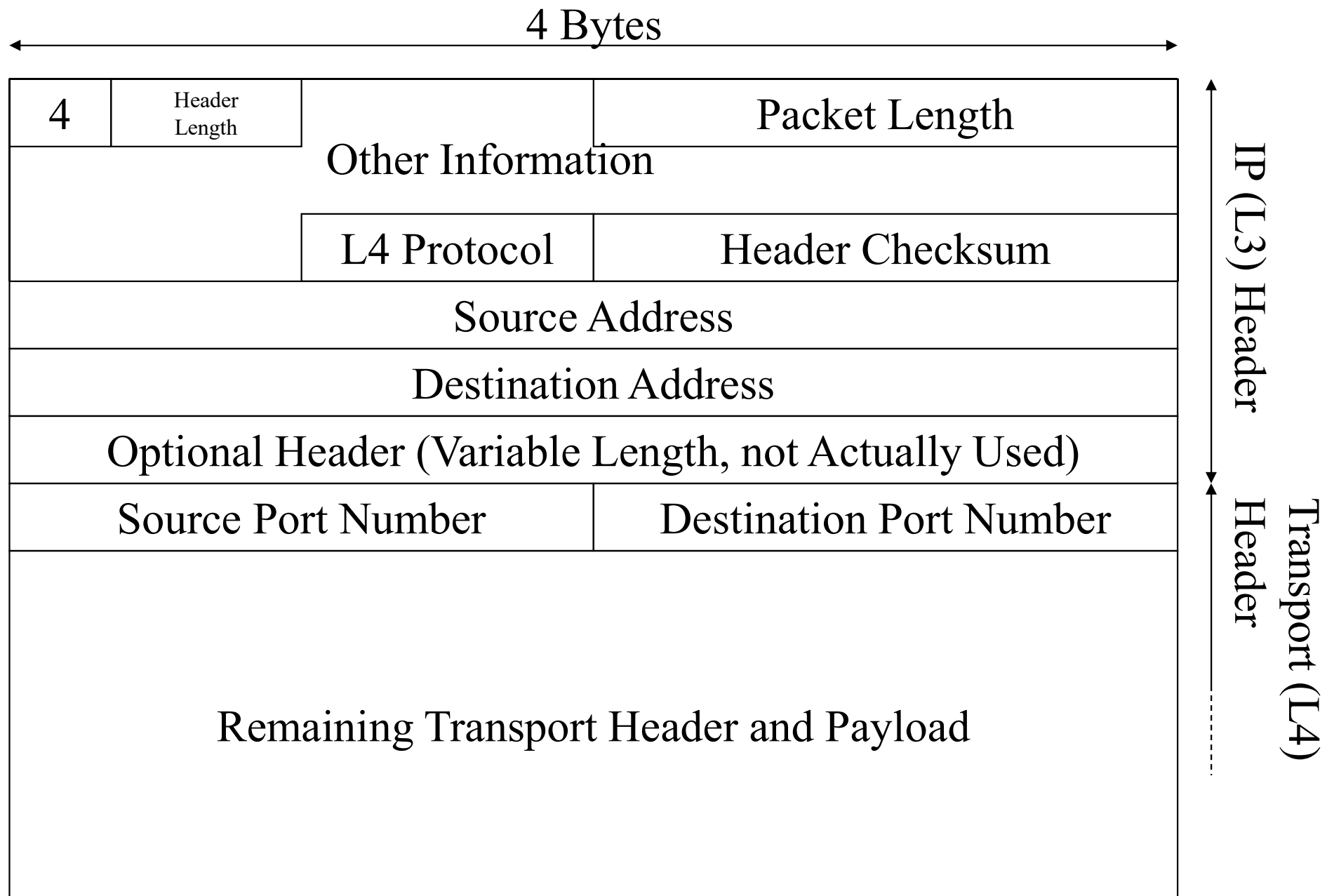
the Internet

N
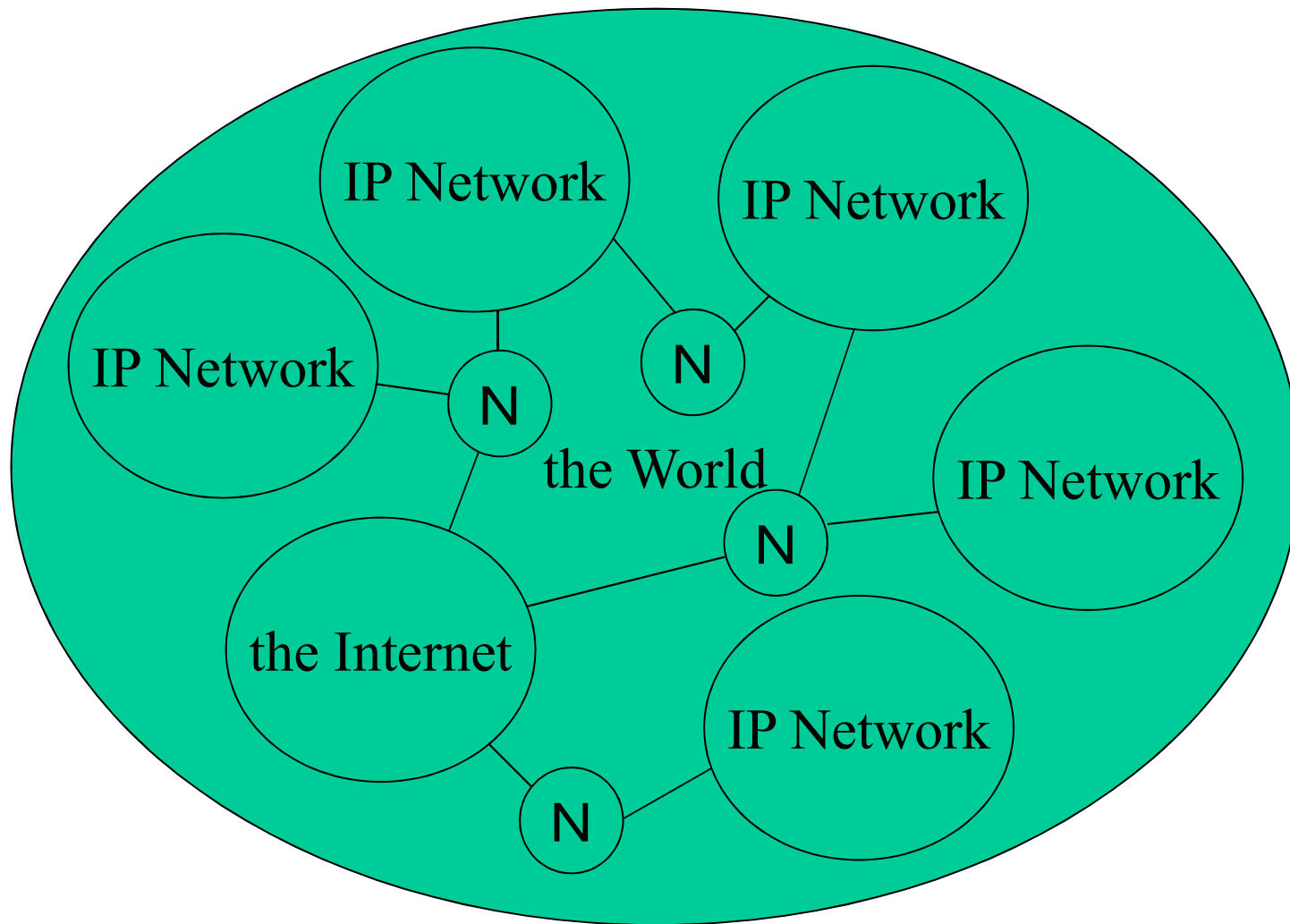
IP Network

N :NAT Device

NAT and the Internet

Data Format of the Internet

- Data are Assembled to Form Packets
- Each Packet has its Own Destination
  - datagram, not virtual circuit
- With IPv4, 20B Internetworking Layer Header is Attached
- In Addition to a Transport Layer Header

4 Bytes			
4	Header Length	Packet Length	
Other Information			
	L4 Protocol	Header Checksum	
Source Address			
Destination Address			
Optional Header (Variable Length, not Actually Used)			
Source Port Number		Destination Port Number	
Remaining Transport Header and Payload			

IP (L3) Header

Transport (L4) Header

Format of IPv4 Packets

Reason Why Optional OP Header is not (can not be) Used

- Options Processed by Routers
  - Router Processing become Complex
    - routers become slower
    - routers may crash
  - Is processing by routers necessary at all?
    - according to the end to end principle, options are harmful and useless

- Options not Processed by Routers
  - Options at or above the transport layer

Wrap-up

- The End to End Principle is the Fundamental Principle of the Internet
- Interworking is against the End to End Principle
  - global connectivity principle derived
  - 7 layer model is meaningless
- Optional IP Headers are against the End to End Principle