

Advanced Computer Networks

Introduction

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Course goals

- Advanced topics in networking
 - cross-layer vision
 - advanced functionalities
 - design, management
- Organization
 - 36 h course, 18h networking lab
 - demos, exercises, questions, homework
 - slides are not exhaustive - you must take notes and ask questions!
- Your team
 - course: A. Duda, J-L. Richier, P. Laforgue
 - lab: M. Heusse, S. Viardot

Networking lab

- Important part of the course
 - perform required operations, write lab reports
 - cannot be repeated
 - grade < 8, you repeat your year!
- Goals
 - acquire practical knowledge
 - use Zebra as a router emulator
- Rooms D200 and D201:
 - 80 PCs with multiple network interfaces
 - network equipment: hubs, switches, routers
 - isolated from the rest of the network

Contents

- Introduction
 - network architectures
- Interconnection Layer 2
 - VLANs and bridges, spanning tree protocol
- Interconnection Layer 3
 - IPv6
 - Routing (RIP, OSPF, BGP)
- Congestion control
- Quality of service
- MPLS, multicast
- Mobility
- Network management

Course support

- Web site
 - `http://duda.imag.fr/3at`
- L. Toutain "Réseaux locaux et Internet", 3me édition, Hermes, 2003
- C. Huitema "Le routage dans l'Internet", Eyrolles, 1995.
- R. Perlman "Interconnexions : ponts et routeurs", Addison-Wesley, 1994.
- Gisèle Cizault "IPv6", O'Reilly 2001.

Overview

- Network architectures
 - protocol architectures
 - how entities cooperate?
 - interconnection structure
 - which entities are connected?
 - related protocols
 - how and where different functionalities are implemented?

Introduction:
network structure,
architecture and protocols

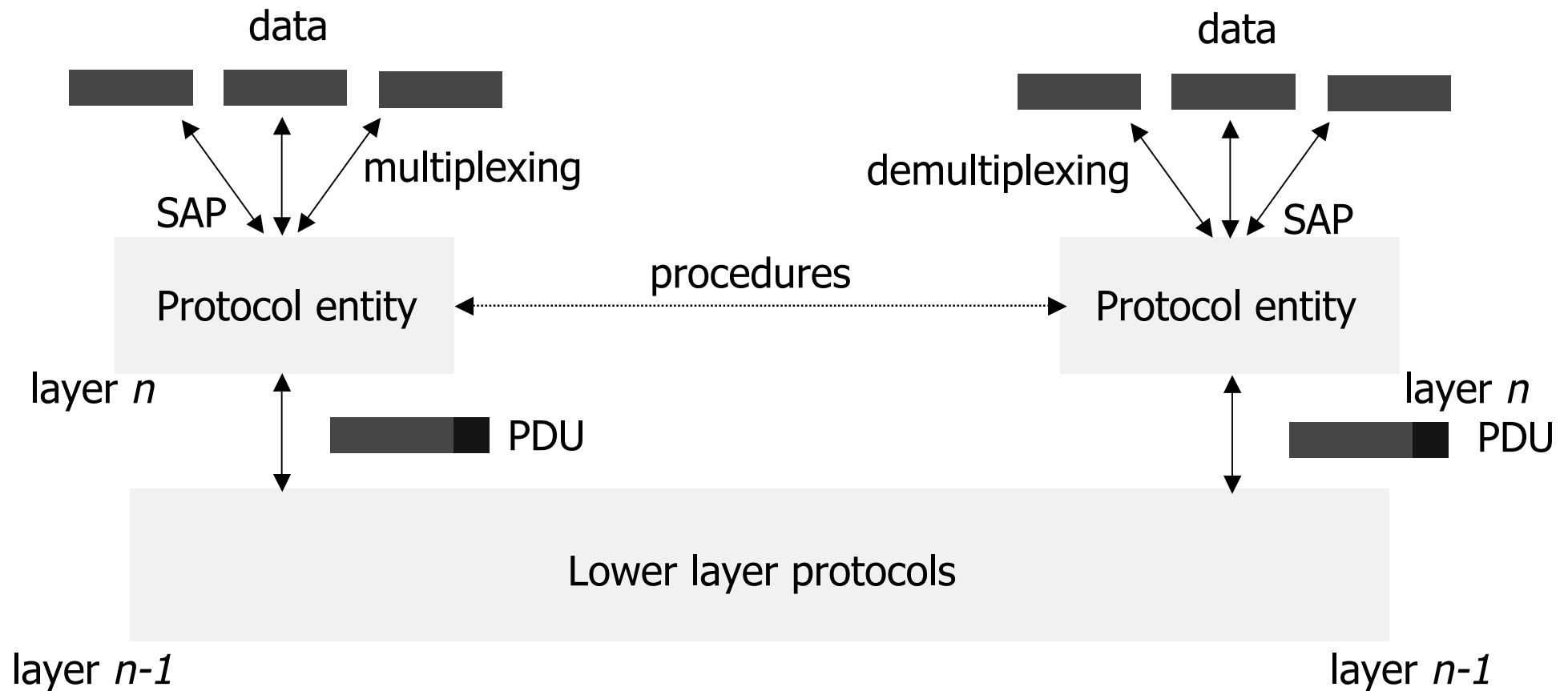
Layered Protocol Stack

- Managing complexity
 - a layer corresponds to an independent module (protocol entity)
- A layer supports
 - common data format - PDU (Protocol Data Unit)
 - rules of cooperation: peer-peer procedures
 - service interface: SAP (Service Access Point)

Protocol Architecture

- Protocol entity
 - provides a set of services, eg.
 - *connect, send*
 - data multiplexing/demultiplexing
 - construction/analysis of PDUs
 - execution of procedures
- Protocol unit (PDU)
 - header: control functions
 - opaque data
- Procedures
 - actions to perform protocol functions: eg. lost packet retransmission

Protocol architecture

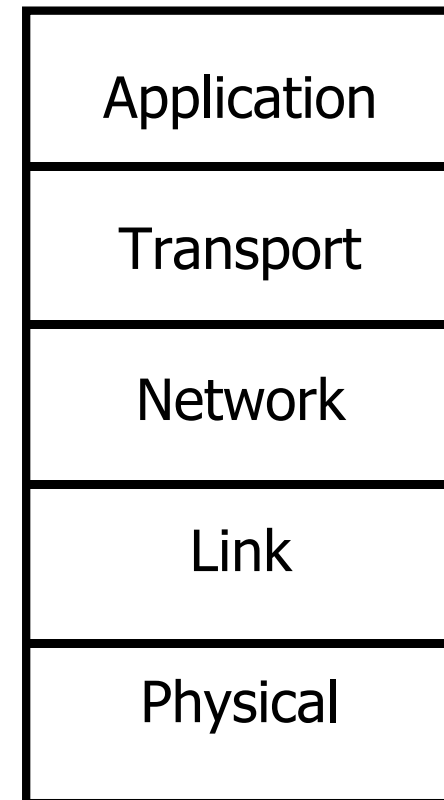


Internet design principles

- Cerf and Kahn's internetworking principles:
 - minimalism, autonomy - no internal changes required to interconnect networks
 - best effort service model
 - stateless routers
 - decentralized control
- define today's Internet architecture

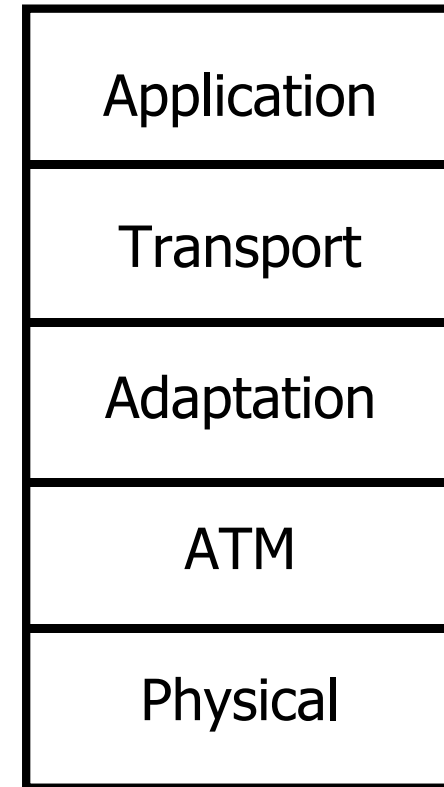
Internet protocol stack

- Application: supporting network applications
 - FTP, SMTP, HTTP, OSPF, RIP
- Transport: host-host data transfer
 - TCP, UDP
- Network: routing of datagrams from source to destination
 - IP
- Link: data transfer between neighboring network elements
 - PPP, Ethernet
- Physical: bits “on the wire”



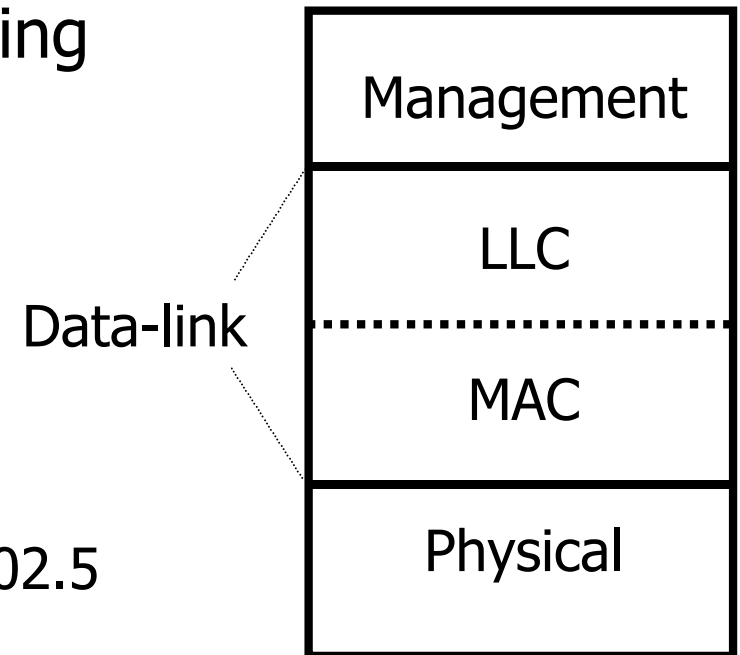
ATM protocol stack

- Application: native applications, other protocols
 - LAN Emulation, IP, Signaling
- Transport: host-host data transfer
 - SSCOP
- Adaptation: adapt the ATM layer to different types of applications
 - circuit emulation, real-time data
 - AAL5 suitable for IP traffic
- ATM: cell switching over virtual circuits
- Physical: bits "on the wire"



LAN stack

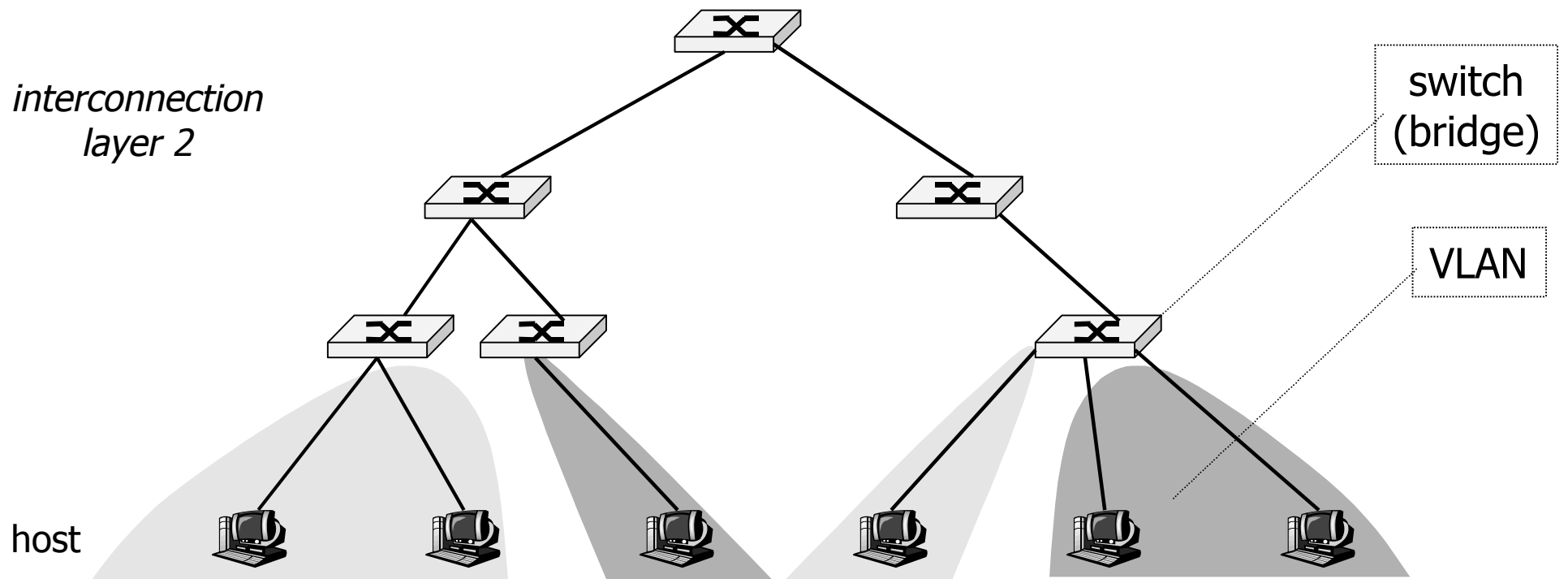
- Management: e.g. construct forwarding tables
 - SNAP: Spanning Tree protocol
- LLC: multiplex different protocols
 - IP, IPX, SNAP
- MAC: medium access
 - 802.3 (Ethernet), 802.4 (Token Ring), 802.5 (Token Bus), 802.11 (Wi-Fi)
- Physical: bits "on the wire"



Network architecture

- Logical structure
 - interconnected entities
- Protocol architecture
 - how entities cooperate
- Related protocols
 - different functionalities

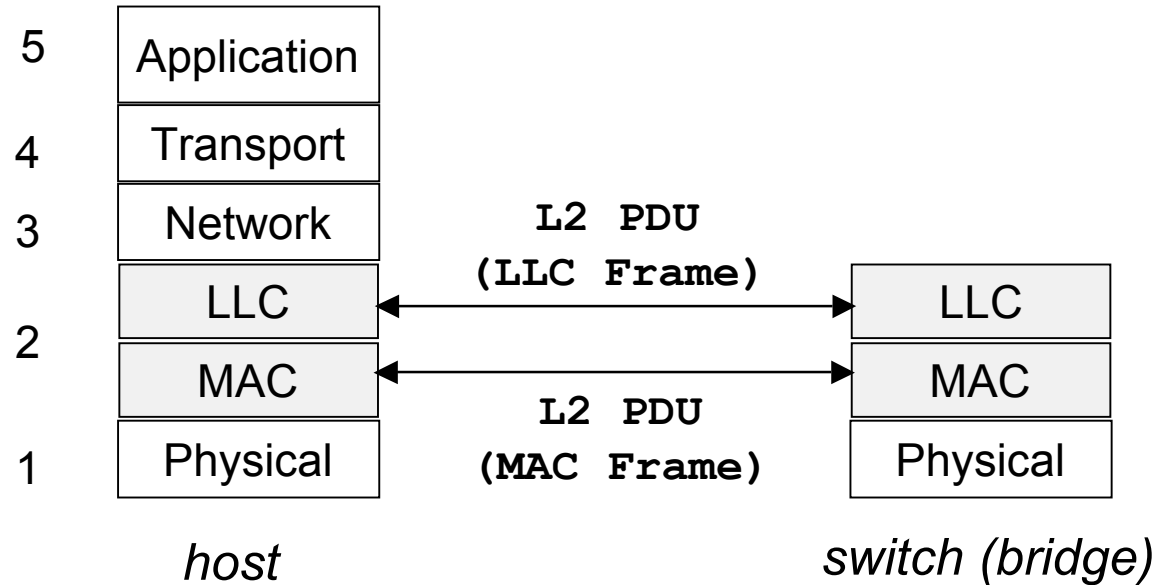
Interconnection structure - layer 2



Interconnection at layer 2

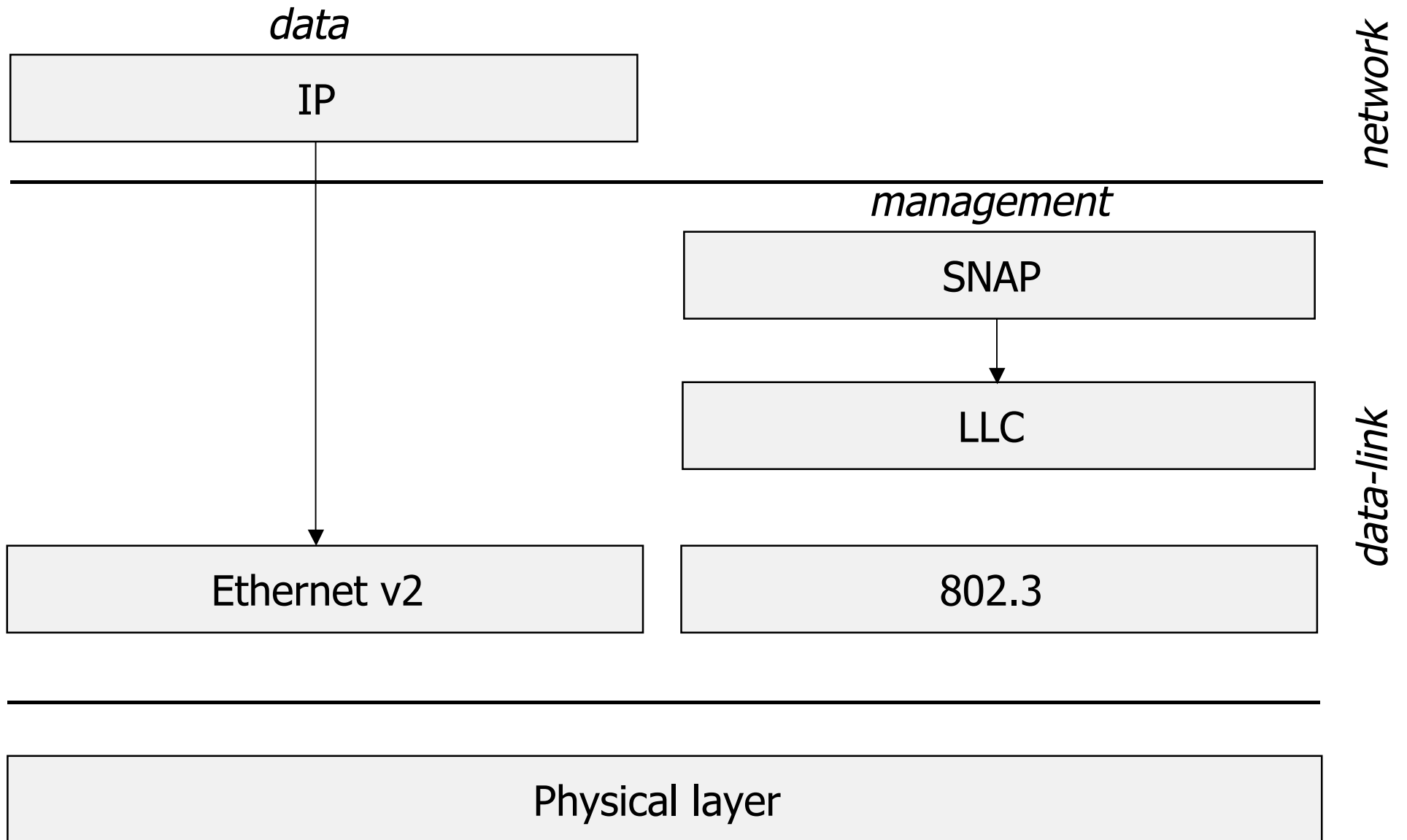
- Switches (bridges)
 - interconnect hosts
 - logically separate groups of hosts (VLANs)
 - managed by one entity
- Type of the network
 - broadcast
- Forwarding based on MAC address
 - flat address space
 - forwarding tables: one entry per host
 - works if no loops
 - careful management
 - Spanning Tree protocol
 - not scalable

Protocol architecture

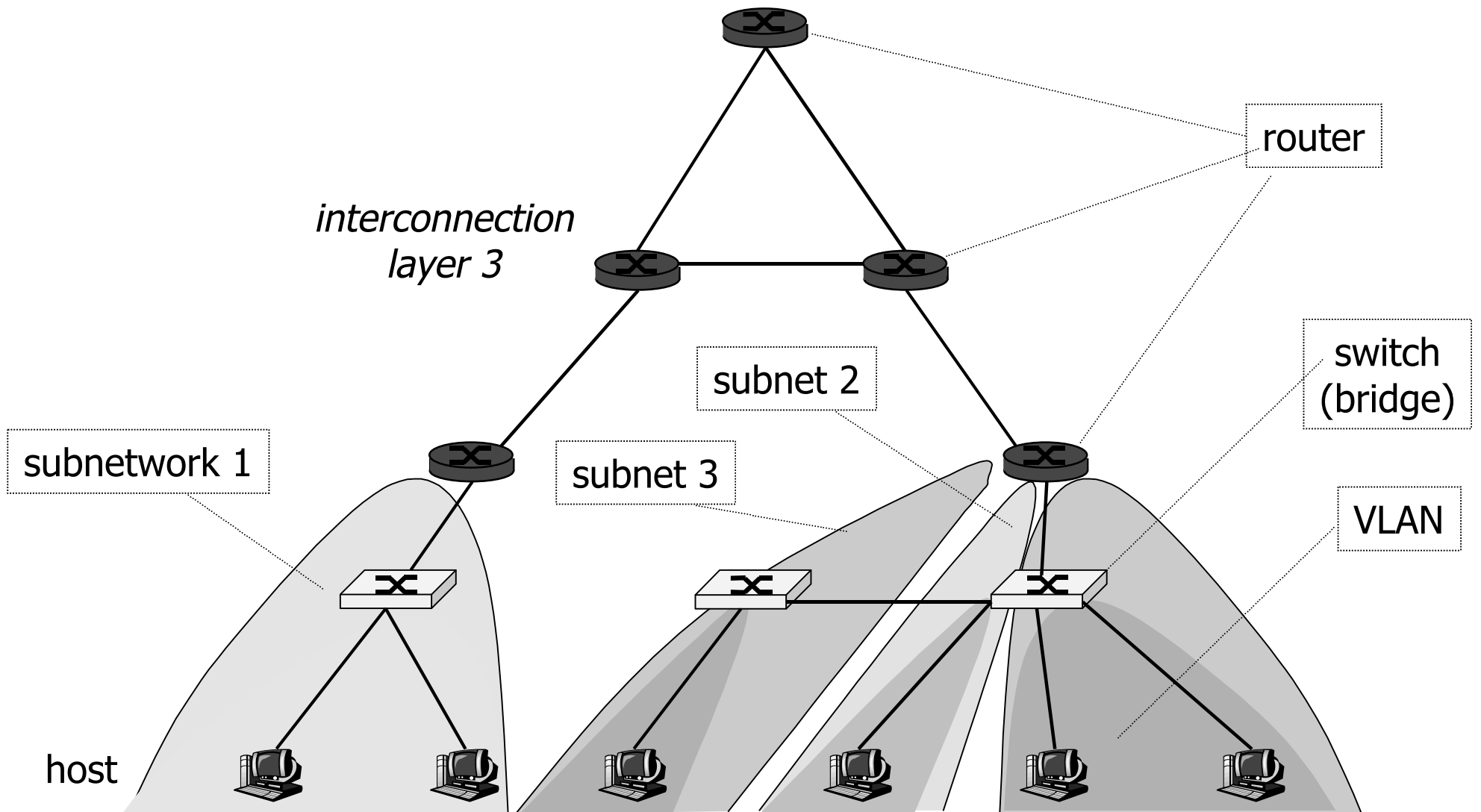


- Switches are layer 2 intermediate systems
- Transparent forwarding
- Management protocols (Spanning Tree, VLAN)

Protocols



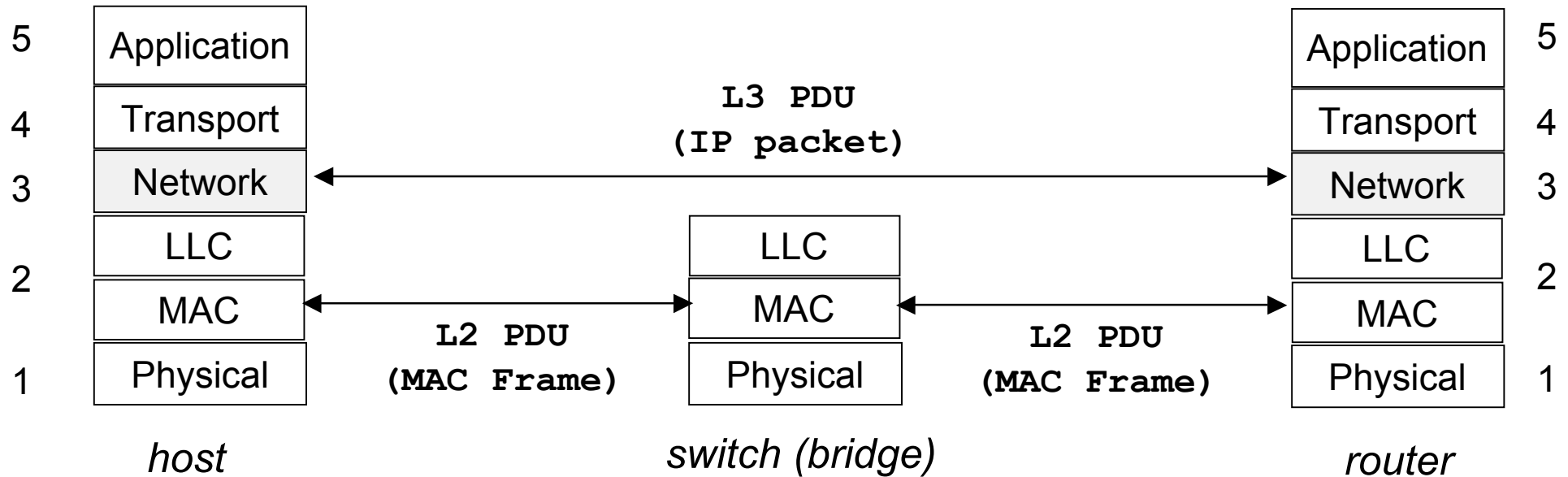
Interconnection structure - layer 3



Interconnection at layer 3

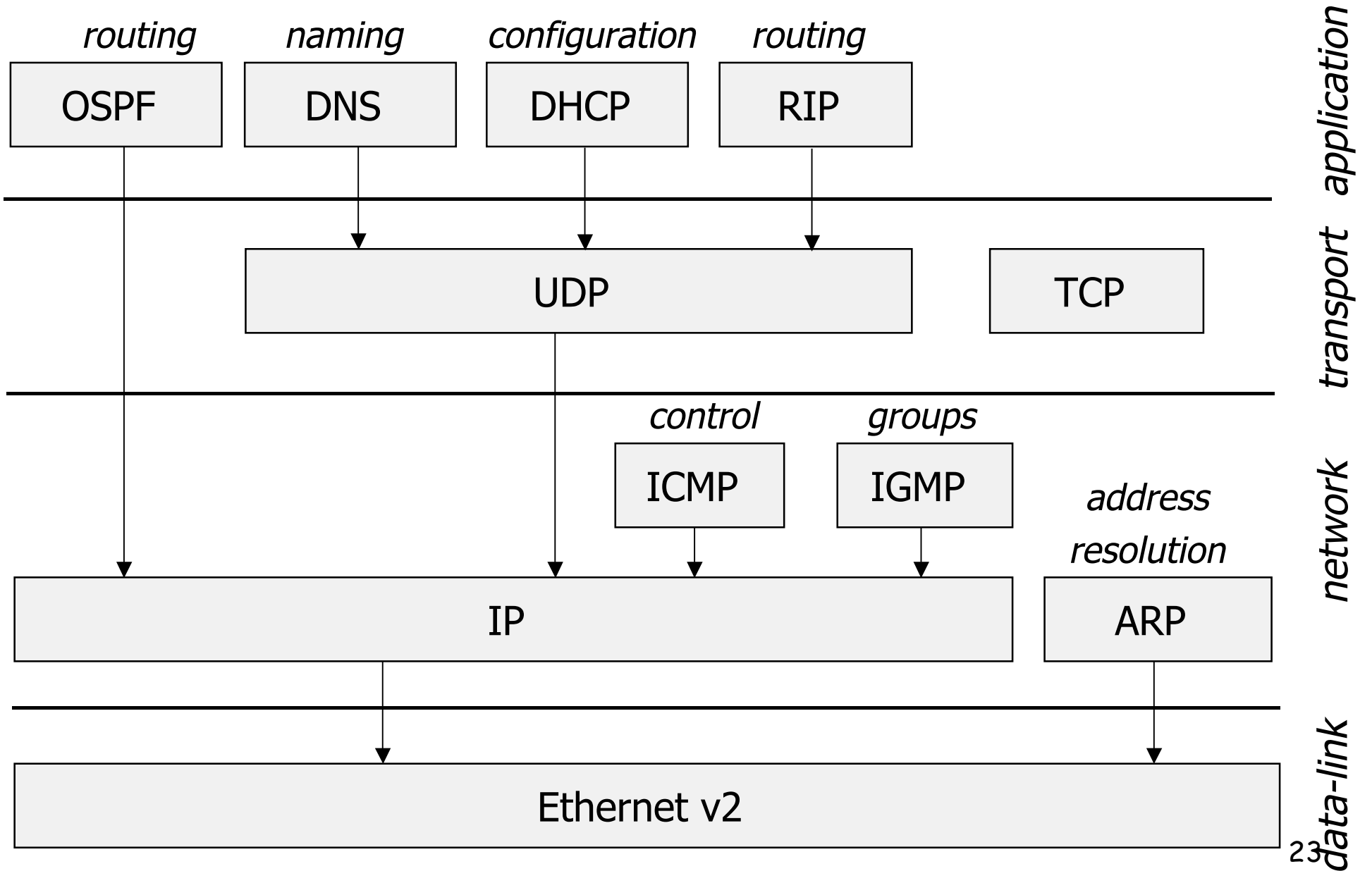
- Routers
 - interconnect subnetworks
 - logically separate groups of hosts
 - managed by one entity
- Forwarding based on IP address
 - structured address space
 - routing tables: aggregation of entries
 - works if no loops - routing protocols (IGP - Internal Routing Protocols)
 - scalable inside one administrative domain

Protocol architecture

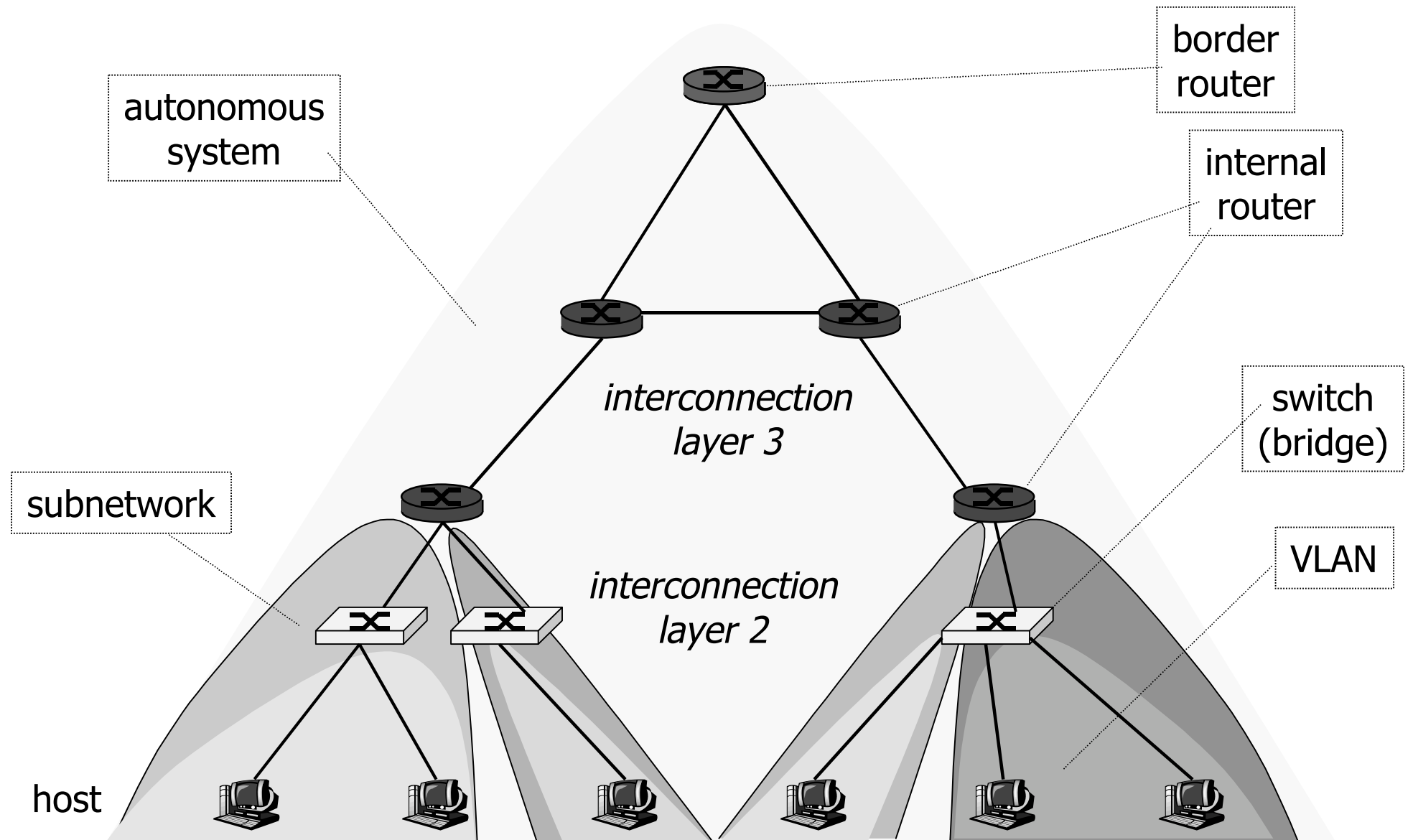


- Routers are layer 3 intermediate systems
- Explicit forwarding
 - host has to know the address of the first router
- Management protocols (control, routing, configuration)

Protocols



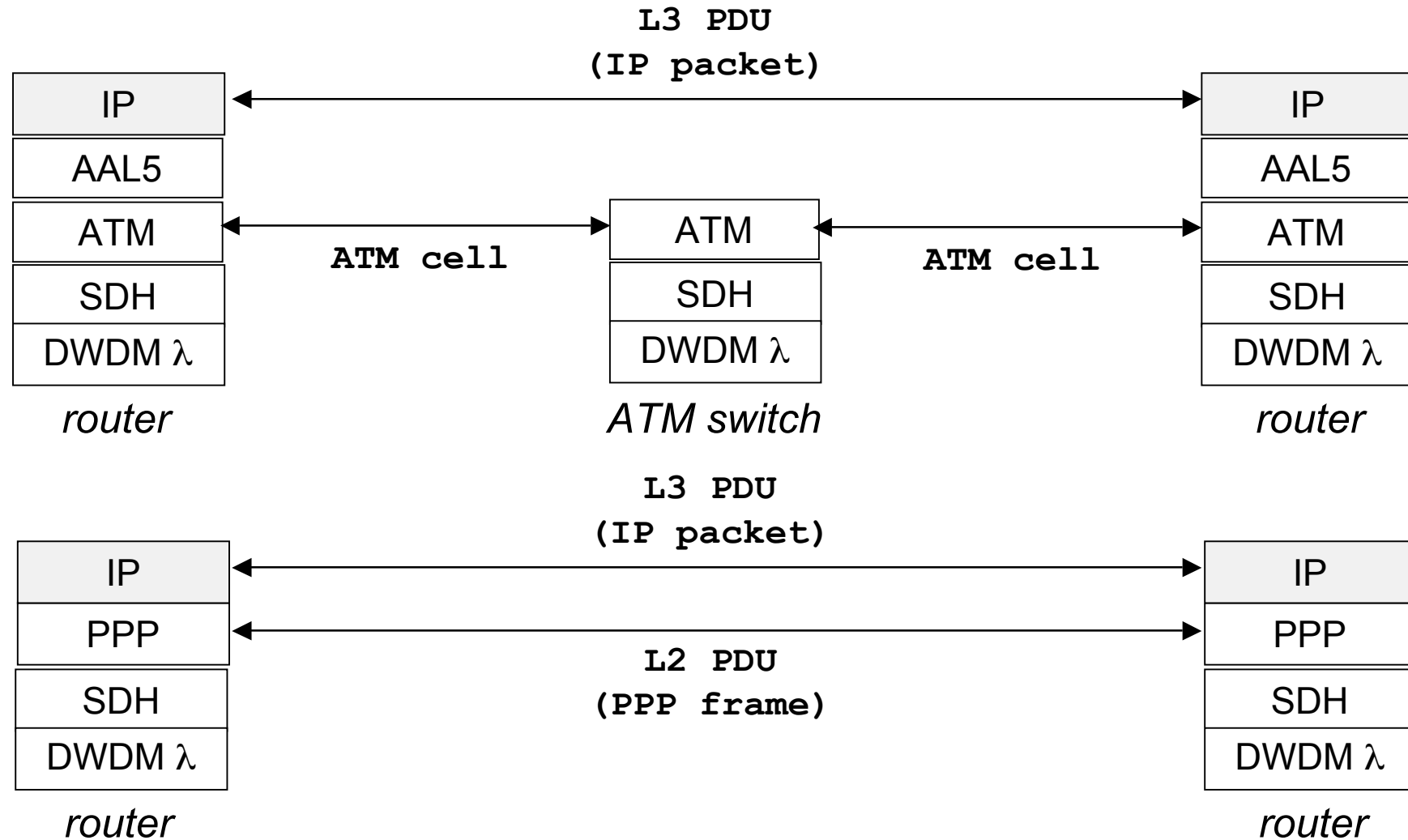
Autonomous systems



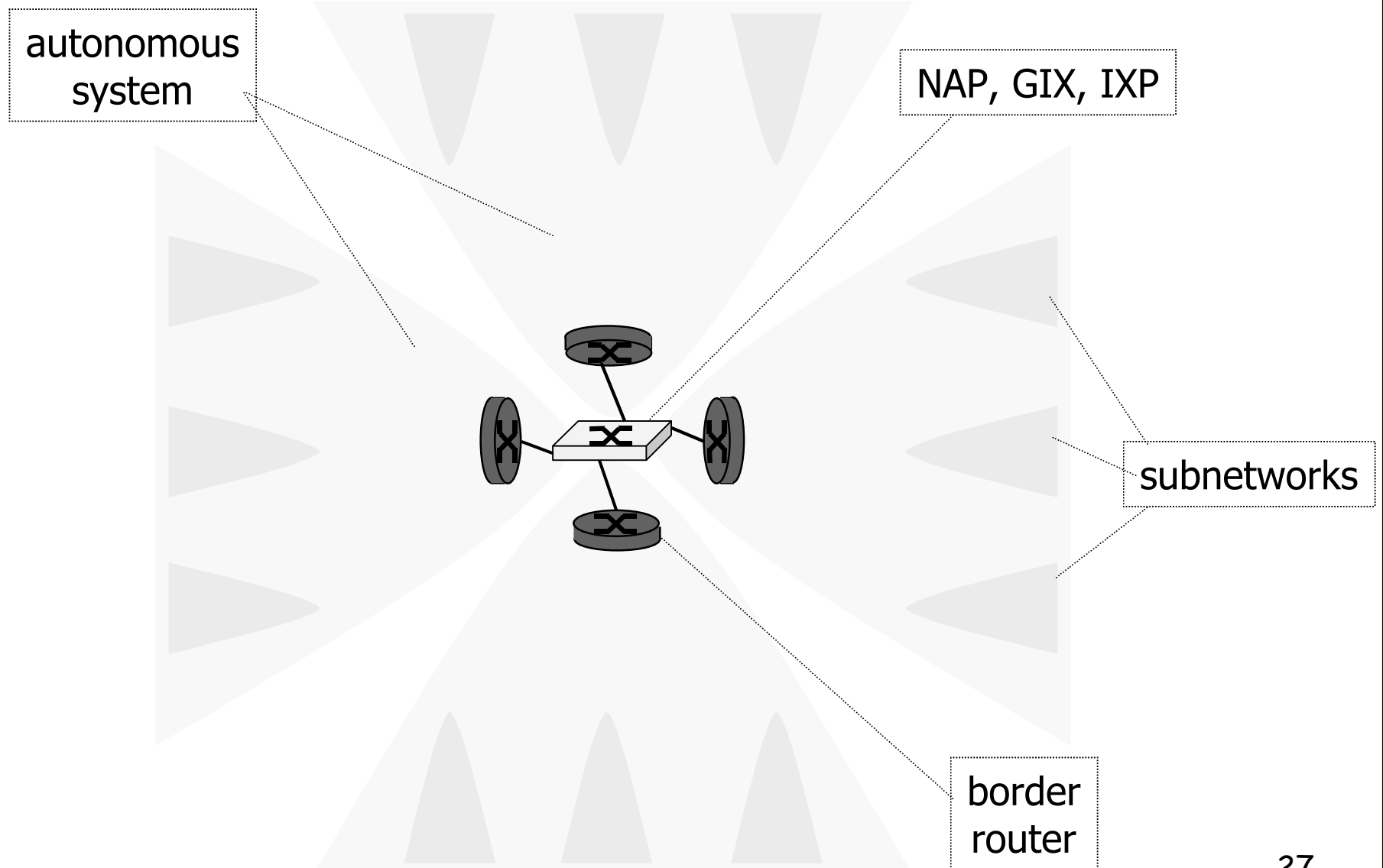
Long-haul links

- Fiber at physical layer (SONET/SDH)
 - Dense Wave Division Multiplexing (DWDM)
 - one color of the light λ
- Different technologies
 - ATM
 - Frame Relay
 - POS (Packet over SONET/SDH)
- Type of the network
 - NBMA (Non Broadcast Multiple Access) or point-to-point
- Complex protocol hierarchies
 - IP over ATM

Protocol architecture



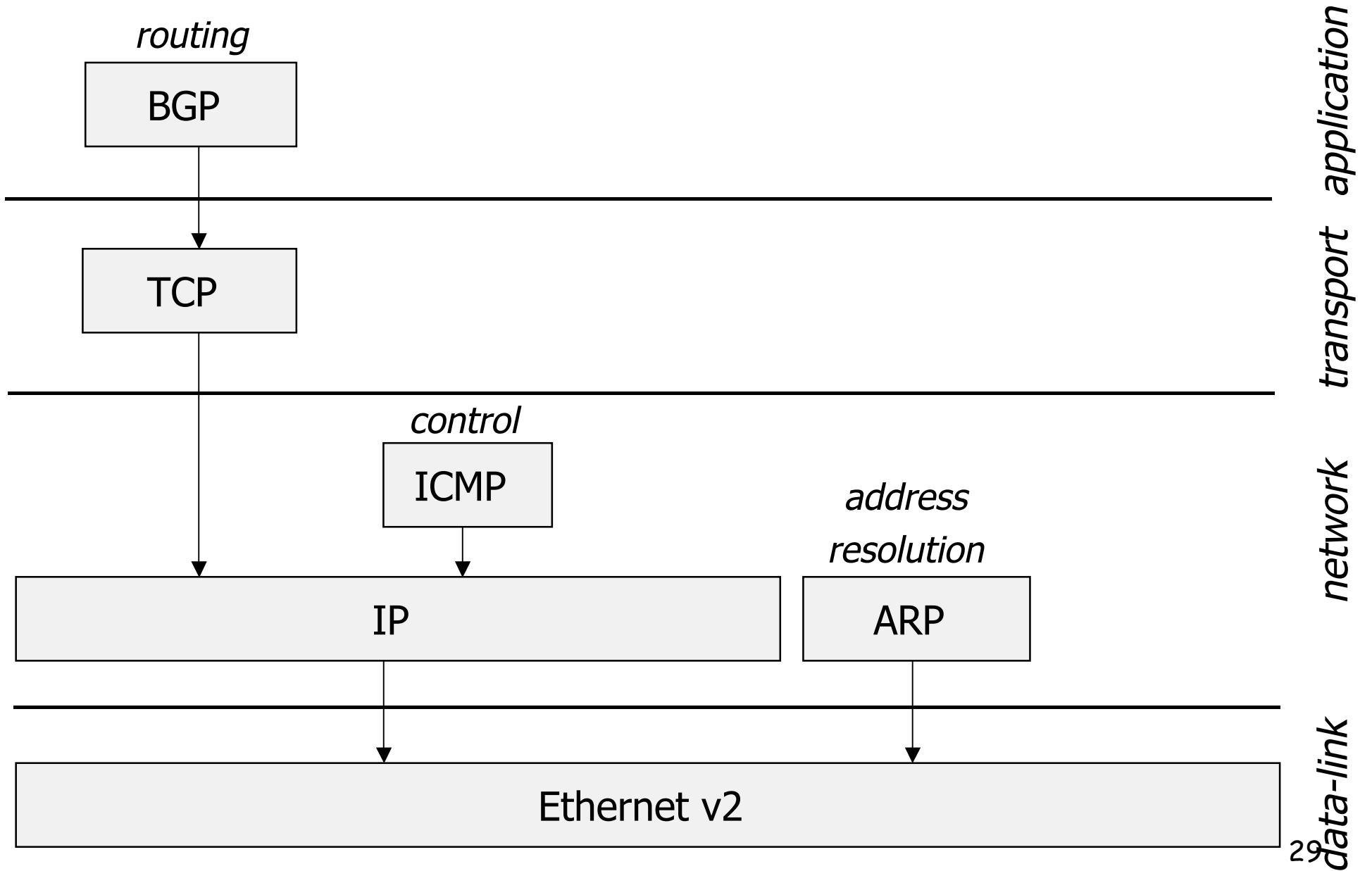
Internet



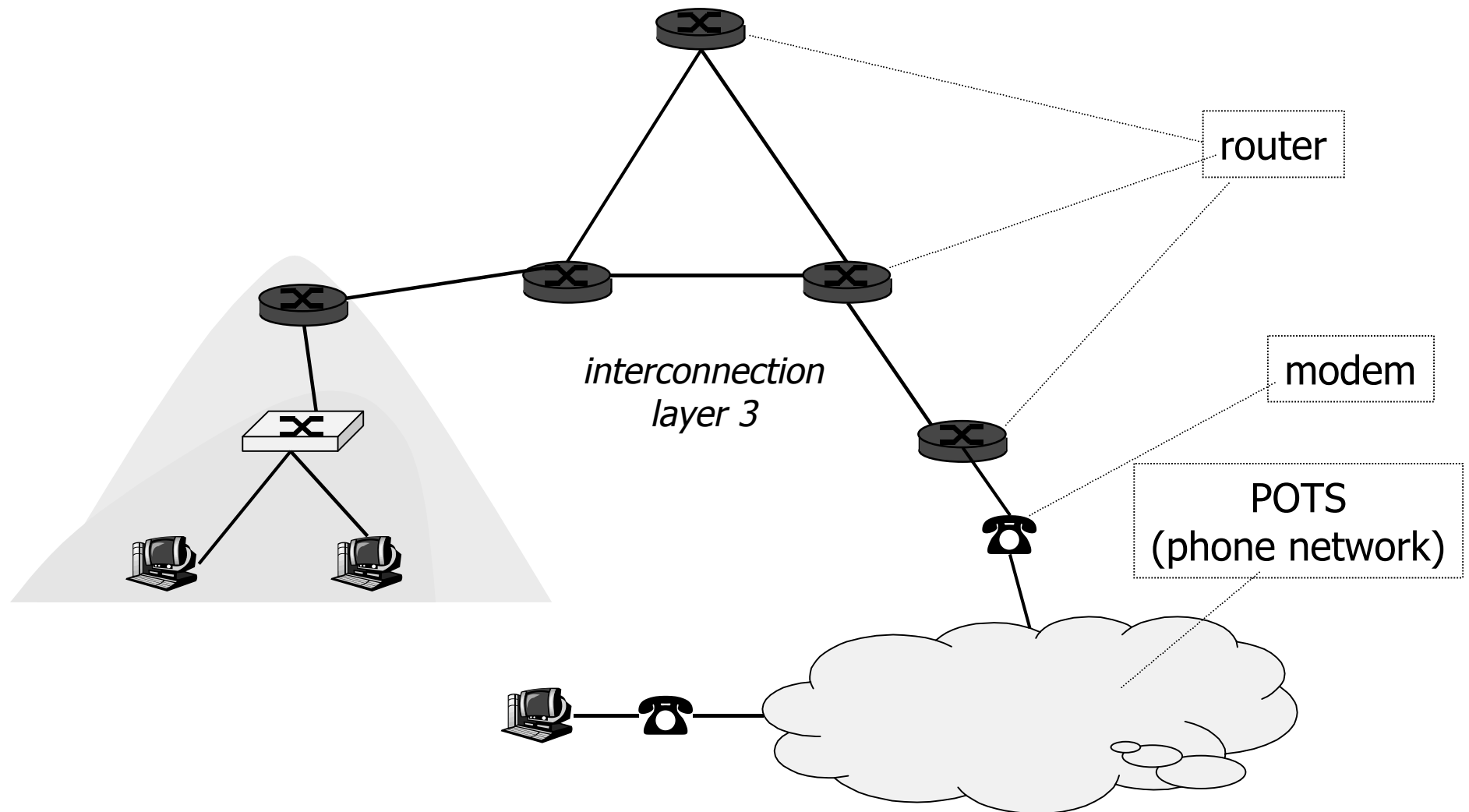
Interconnection of AS

- Border routers
 - interconnect AS
- NAP or GIX, or IXP
 - exchange of traffic - peering
- Route construction
 - based on the path through a series of AS
 - based on administrative policies
 - routing tables: aggregation of entries
 - works if no loops and at least one route - routing protocols (EGP - External Routing Protocols)

Protocols



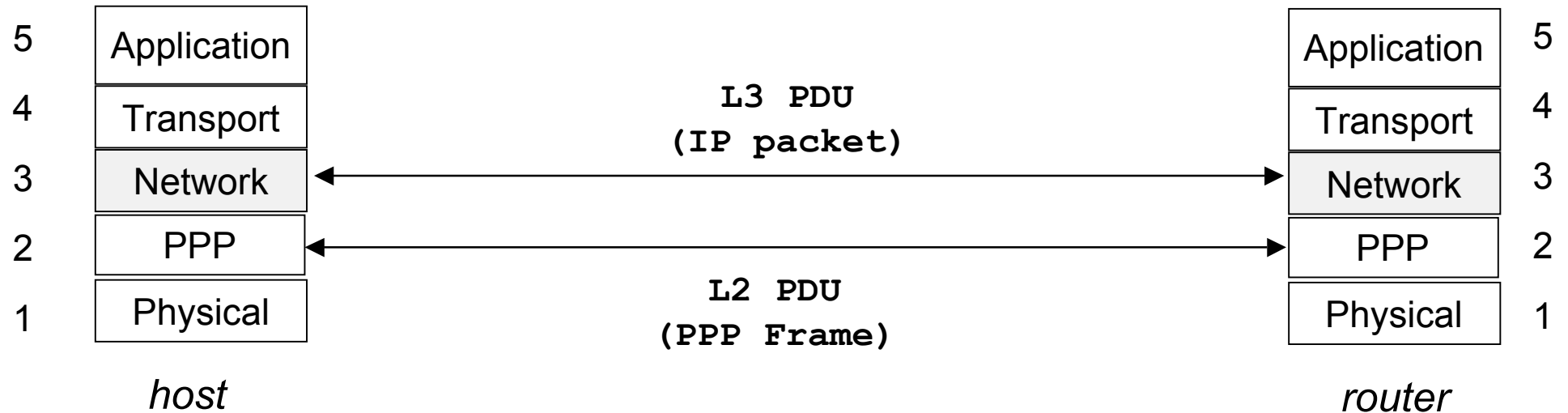
Residential access



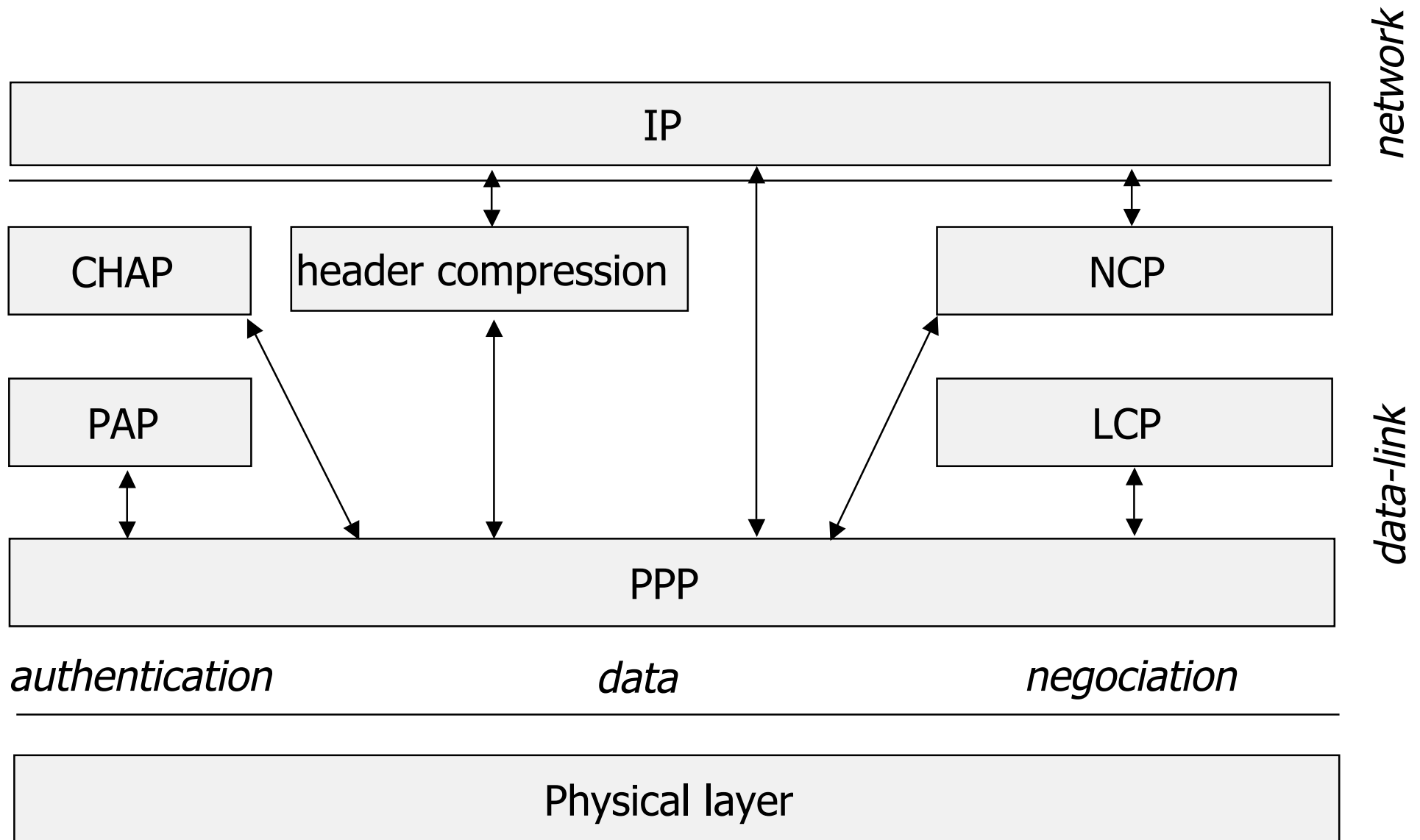
Residential access

- Modem
 - connects a host to the first router
- Point-to-point encapsulation (PPP)
 - activate a connection
 - authenticate the user
 - negotiate network address
 - multiplex different protocols (IP, IPX)

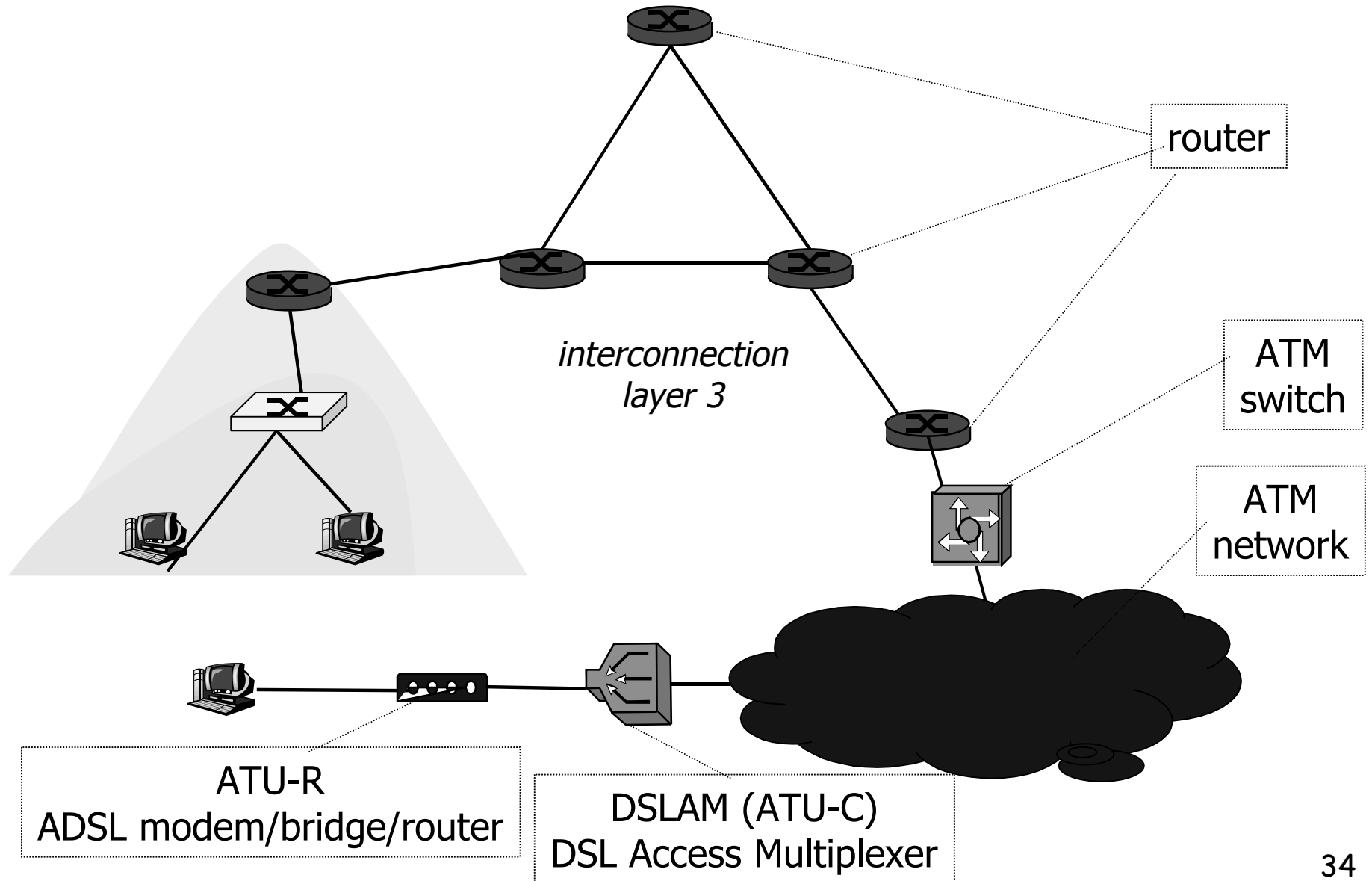
Protocol architecture



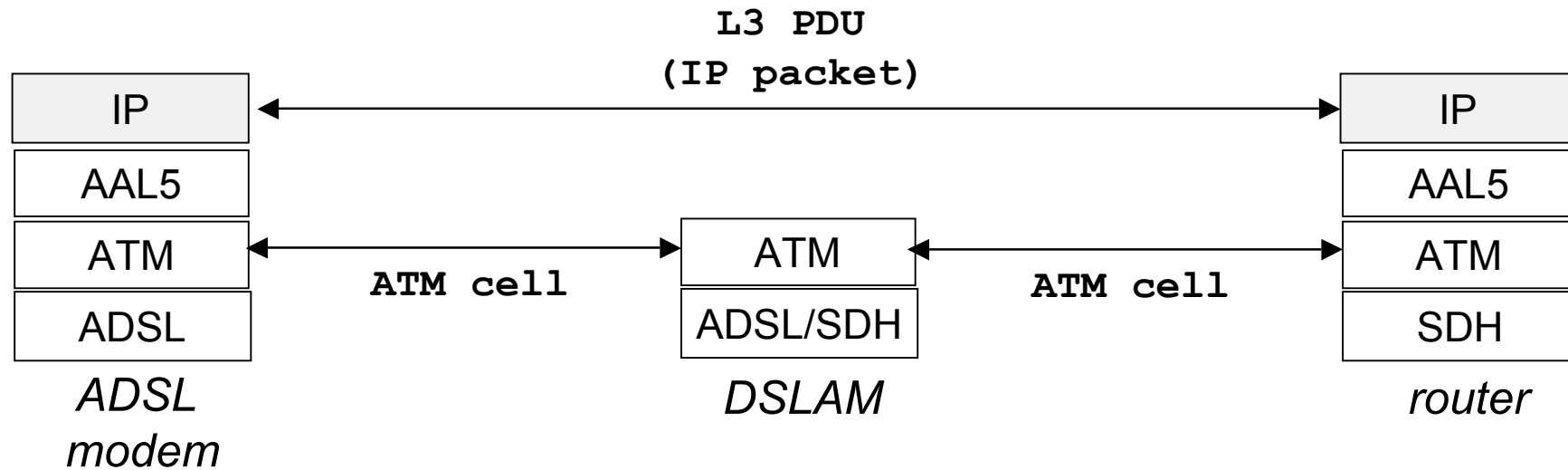
Protocols



Residential access

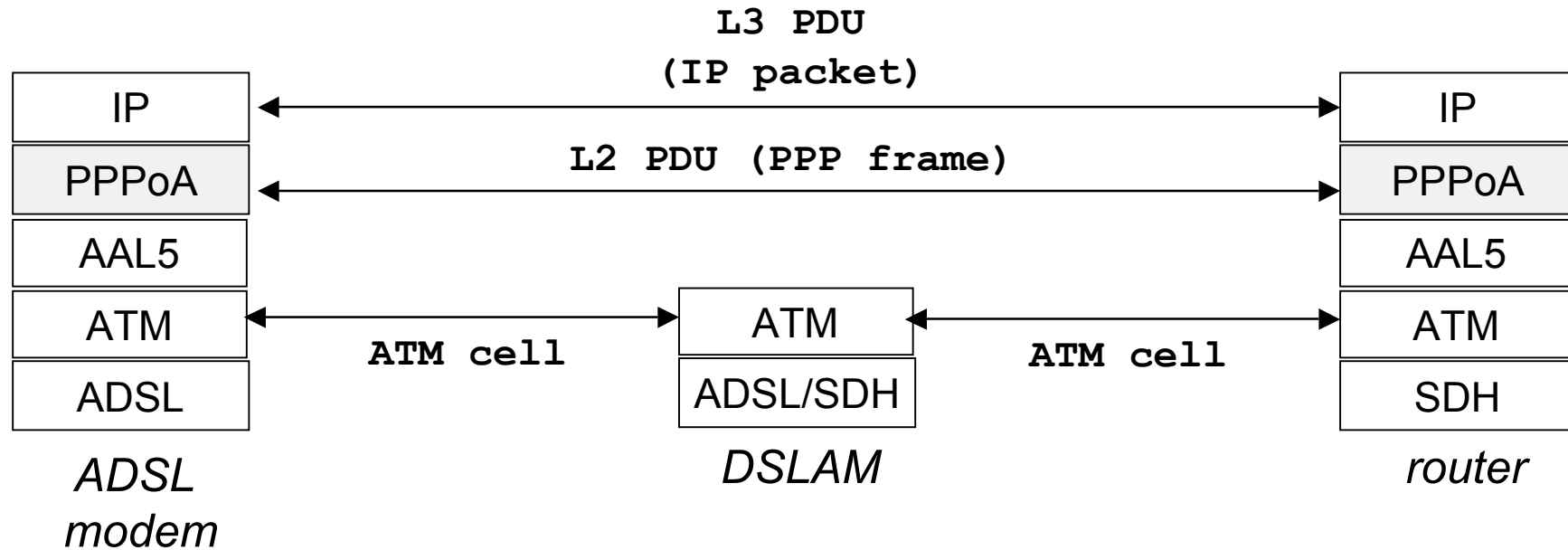


Protocol architecture



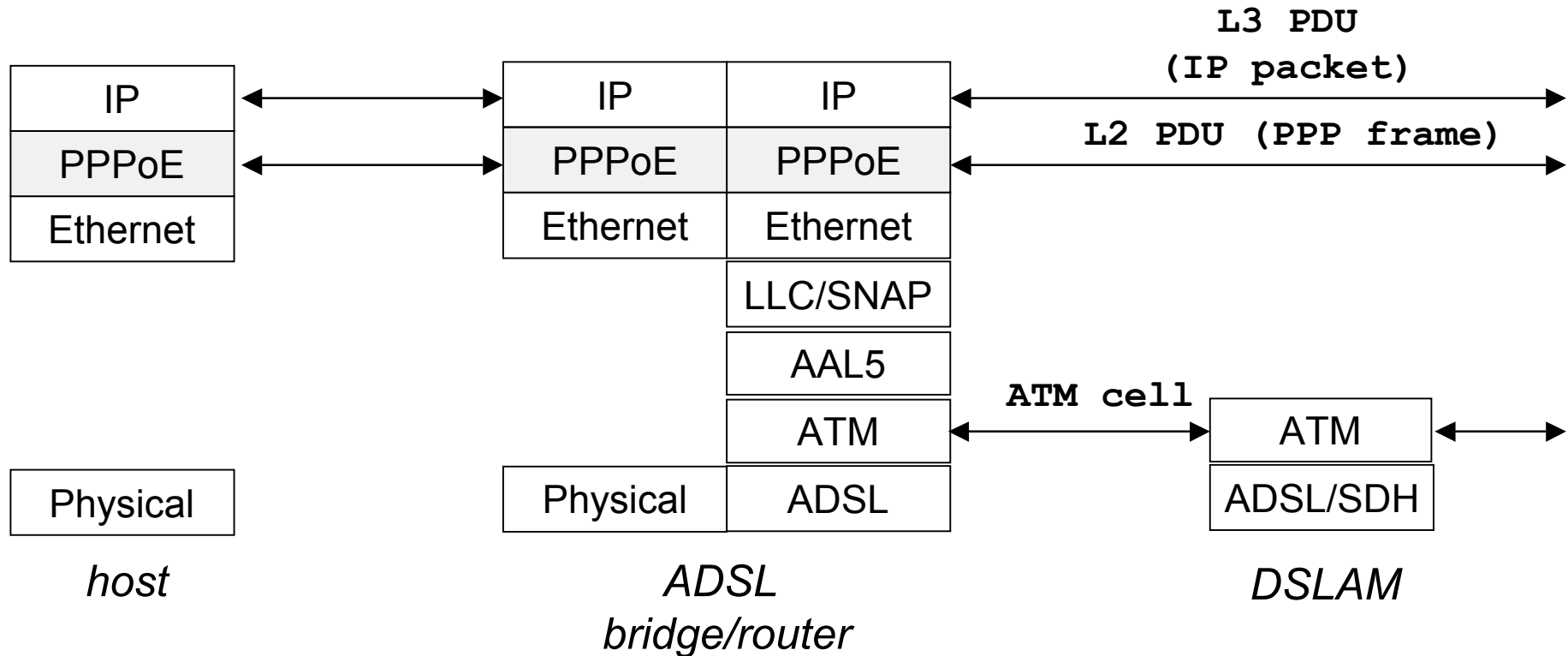
- IP over ATM
 - requires fixed IP address

Protocol architecture



- PPP over ATM (PPPoA)
 - multiple users share ADSL link

Protocol architecture



- PPP over Ethernet (PPPoE)
 - multiple users share ADSL link

Conclusion

- Complex architectures
 - other types of networks used as data links
- Internet
 - Rapid growth
 - scalability
 - No central control
 - coherent development
 - Three level hierarchy
 - host, subnetwork, autonomous system
 - manage complexity
 - Advances
 - larger address space - IPv6
 - performance - quality of service, e.g. DiffServ
 - security - Virtual Private Networks (VPN)