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
  - lab: M. Heusse, S. Viardot

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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 equipement: hubs, switches, routers
  - isolated from the rest of the network

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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

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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.

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Overview

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

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Introduction: network structure, architecture and protocols

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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)

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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

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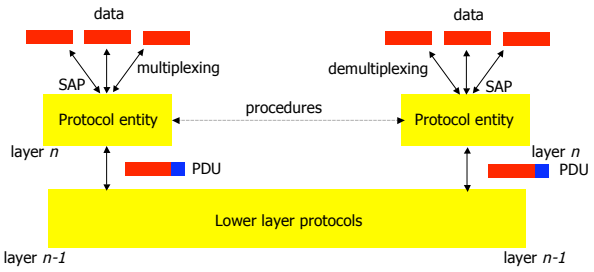
Protocol architecture



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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

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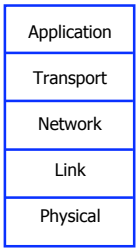
Internet protocol stack

- 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"



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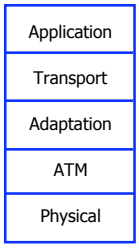
ATM protocol stack

- 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"



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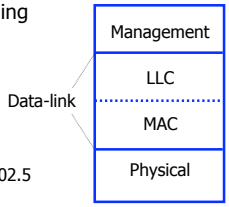
LAN stack

- 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"



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Network architecture

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

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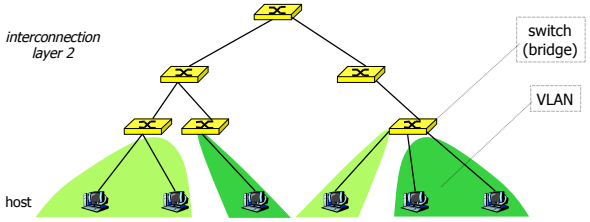
Interconnection structure - layer 2



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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

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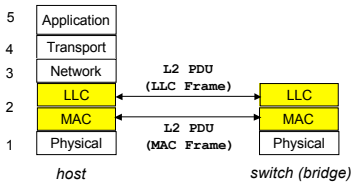
Protocol architecture



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

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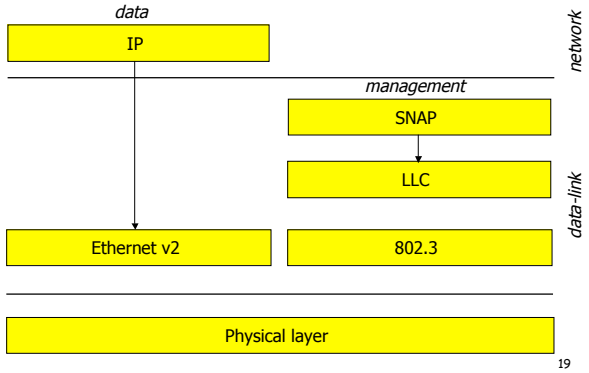
Protocols



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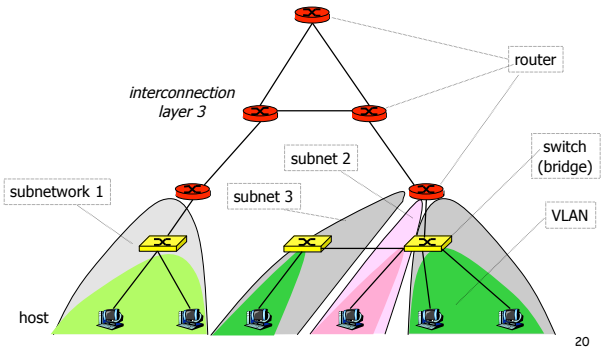
Interconnection structure - layer 3



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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

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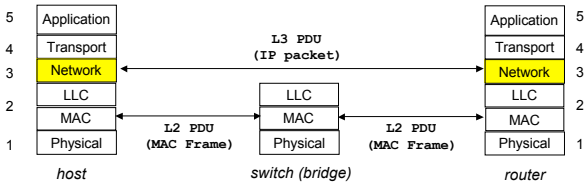
Protocol architecture



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

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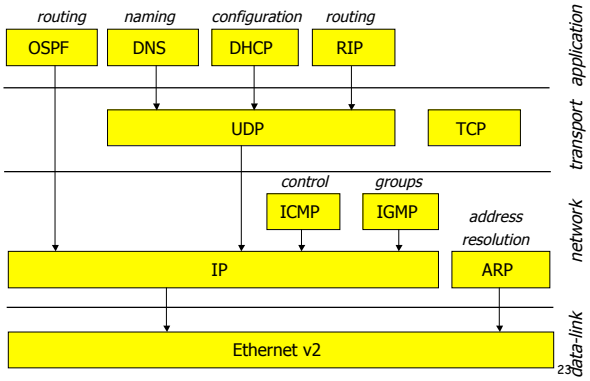
Protocols



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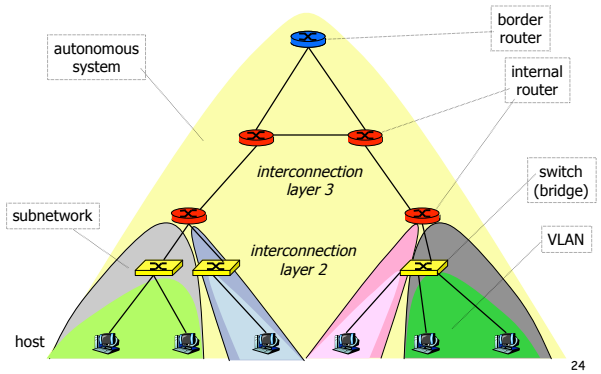
Autonomous systems



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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

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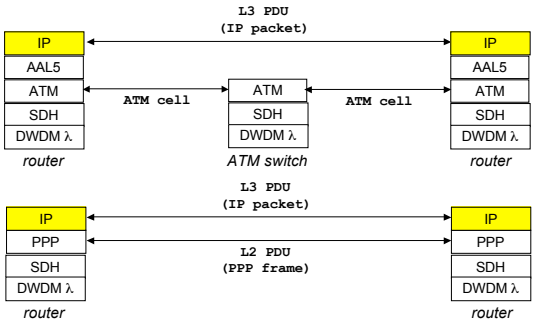
Protocol architecture



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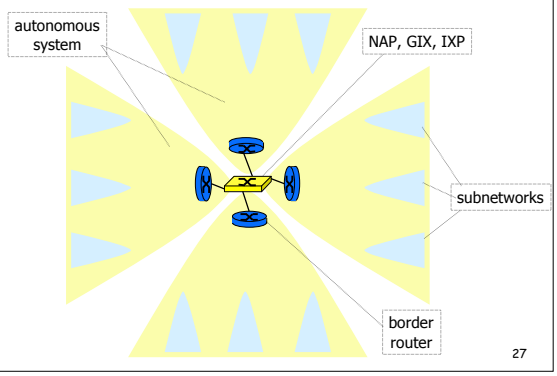
Internet



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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)

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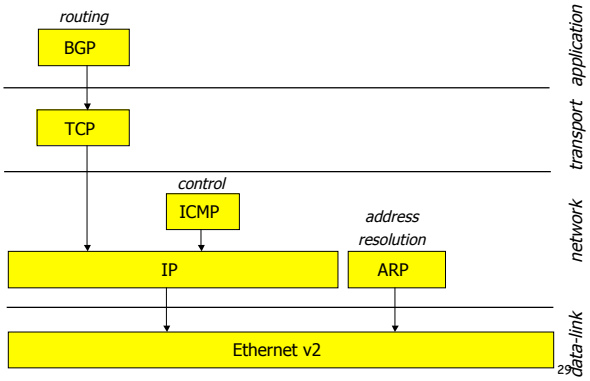
Protocols



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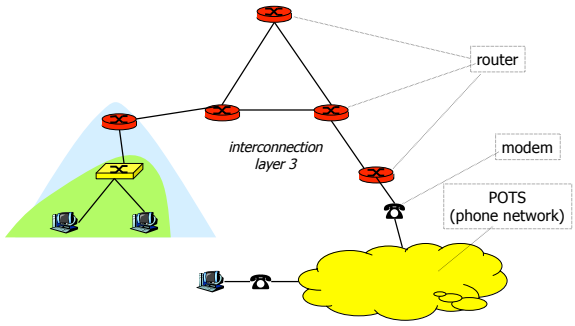
Residential access



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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)

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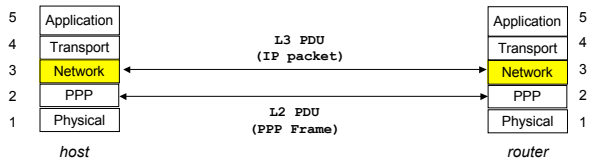
Protocol architecture



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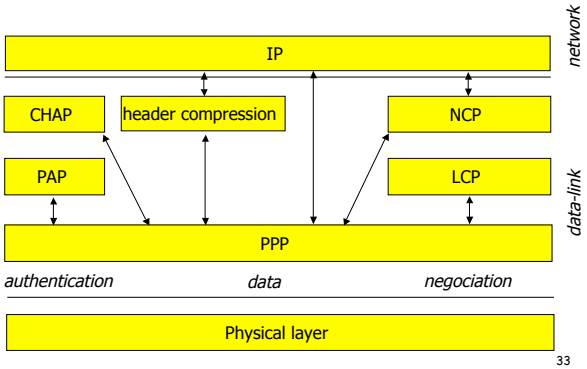
Protocols



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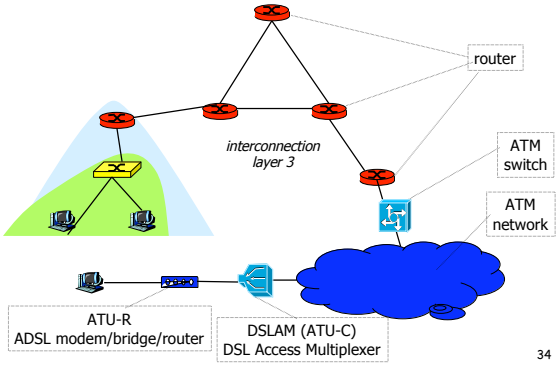
Residential access



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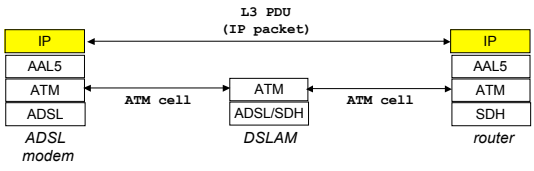
Protocol architecture



- IP over ATM
  - requires fixed IP address

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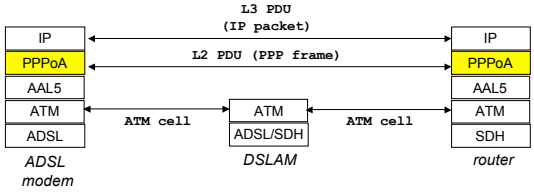
Protocol architecture



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

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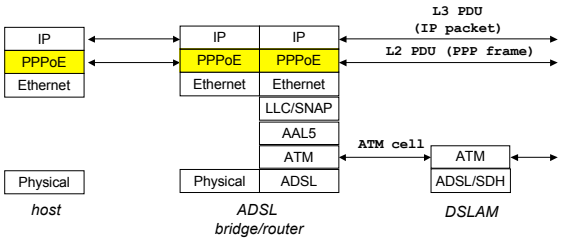
Protocol architecture



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

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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)

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