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
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

Protocol entity

SAP

data

multiplexing

PDU

procedures

layer n

Protocol entity

data
demultiplexing

SAP

PDU

layer n

Lower layer protocols

layer n-1
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”

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<th>Application</th>
<th>Transport</th>
<th>Adaptation</th>
<th>ATM</th>
<th>Physical</th>
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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”
Network architecture

- Logical structure
  - interconnected entities
- Protocol architecture
  - how entities cooperate
- Related protocols
  - different functionalities
Interconnection structure - layer 2

Interconnection layer 2

host

switch (bridge)

VLAN
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

- **data**
  - IP
    - Ethernet v2
      - LLC
      - SNAP
        - management
      - 802.3

- **network**

- **data-link**

- **Physical layer**
Interconnection structure - layer 3

subnet 1

subnet 2

subnet 3

host

interconnection layer 3

VLAN

switch (bridge)

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

- Autonomous system
- Subnetwork
- Host
- Interconnection layer 2
- Interconnection layer 3
- Border router
- Internal router
- Switch (bridge)
- VLAN
Long-haul links

- Fiber at physical layer (SONET/SDH)
  - Dense Wave Division Multiplexing (DWDM)
    - one color of the light $\lambda$
- 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

L3 PDU
(IP packet)

ATM switch

L3 PDU
(IP packet)

L2 PDU
(PPP frame)
Internet

autonomous system

NAP, GIX, IXP

subnetworks

border router
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

routing

BGP

TCP

control

ICMP

IP

address resolution

ARP

Ethernet v2
Residential access

- router
- modem
- interconnection layer 3
- POTS (phone network)
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

$host$

$L2$ PDU
(PPP Frame)

$L3$ PDU
(IP packet)

$router$
Protocols

PPP
  ^
  |
  V
NCP

LCP

header compression

CHAP

PAP

IP

network

data-link

authentication  data  negociation

Physical layer
Residential access

interconnection layer 3

router

ATM switch

ATM network

ATU-R
ADSL modem/bridge/router

DSLAM (ATU-C)
DSL Access Multiplexer

DSL Access Multiplexer
Protocol architecture

- IP over ATM
  - requires fixed IP address
- PPP over ATM (PPPoA)
  - multiple users share ADSL link
 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)