RDIS (N-ISDN)

- Rede digital fim-a-fim
- Baseada na comutação de canais a 64Kbps
- Limitada a 2.048 Mbps
- Acessos Básicos (2B+D)
  - 2 x 64Kbps + 16Kbps
  - 192Kbps (144Kbps + 48Kbps sync)

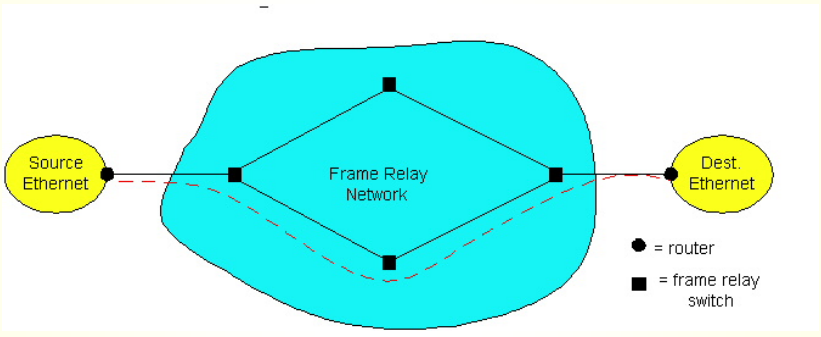
RDIS (ISDN)

- Acessos Primários
  - 30 x 64Kbps + 64 Kbps (1968Kbps + 64Kbps sync)
  - Interfaces H0, H1, n x B + m x H0
- Canais de “alta” velocidade
  - H0 : 384Kbps (5 x H0 + D)
  - H12 : 1920Kbps (H12 + D)

RDIS Banda Larga (B-ISDN)

- Rede Digital (utilização genérica)
  - Banda Larga (150Mbps ~ 620Mbps)
- Ligações
  - Comutadas, Permanentes, Semi-Permanentes
  - Ponto-a-Ponto, Ponto-Multiponto
- Suporta
  - Comutação de Circuito
  - Comutação de Pacotes

FRAME RELAY



FRAME RELAY

- "Herdeiro" do X.25.
- O X.25 era caracterizado por:
  - Comutação de pacotes
  - Pacotes de controlo *inband*
  - Multiplexagem de Circuitos Virtuais
  - Controlo de fluxo e de erros, tanto a Nível 2 como a Nível 3
  - Elevada probabilidade de erros nos *links* (tecnologia analógica)

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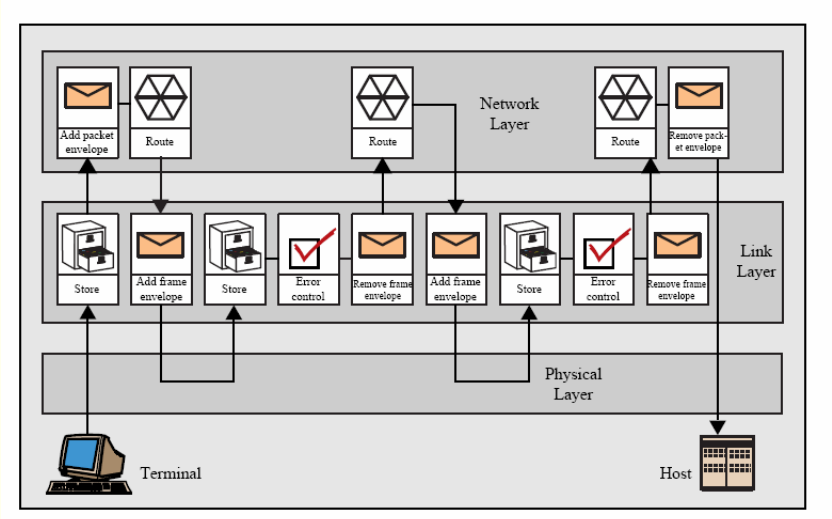
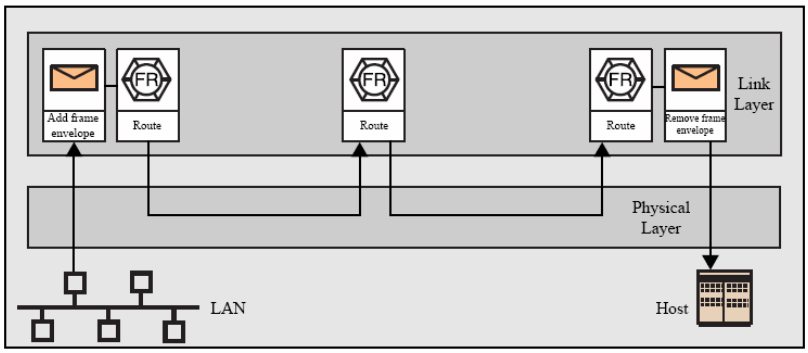


(a) Packet switching



(b) Frame relay

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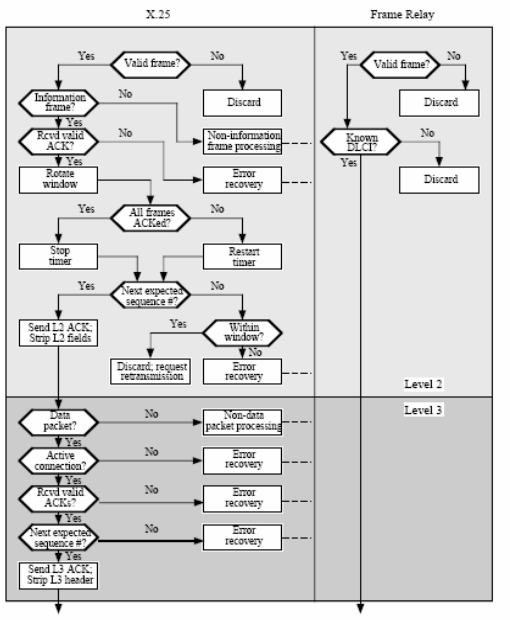

Figure 12.6 Simplified Model of X.25 and Frame Relay Processing

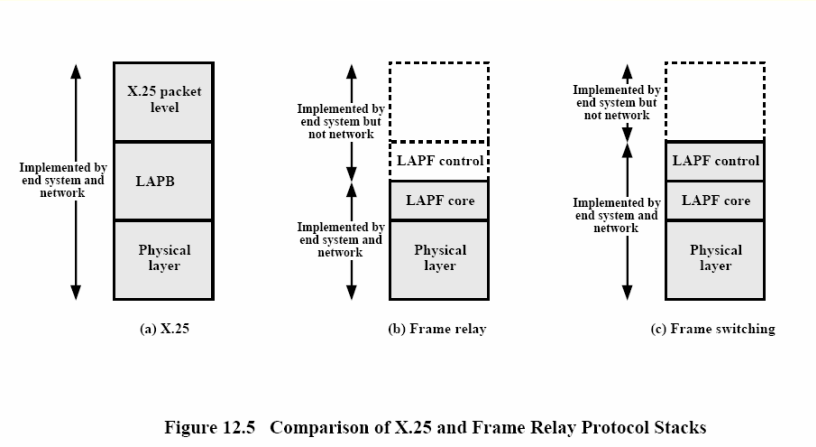

Figure 12.5 Comparison of X.25 and Frame Relay Protocol Stacks

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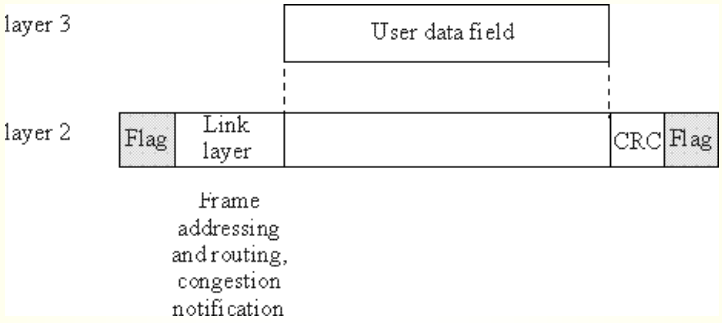
FRAME RELAY (LAPF)

- Link Access Procedure for Frame-Mode
  - Identifica *frames* (delimitados p/ flags HDLC)
  - Detecta (não corrige) erros de transmissão (FCS – Frame Check Sequence)
  - Verifica correcção/integridade de *frames*
  - Multiplexagem (Mux/desMux) de *frames* pertencentes a diferentes ligações virtuais
  - Mecanismos de controlo de congestão

FRAME RELAY

- Sinalização de controlo *out-of-band* (ligação lógica separada)
- Multiplexagem e comutação apenas a Nível 2
- Eliminação de controlo de fluxo *hop-a-hop*
- Controlo de fluxo e de erros apenas fim-a-fim
- Baixa probabilidade de erros nos *links* (tecnologia digital)

FRAME RELAY: Encapsulamento



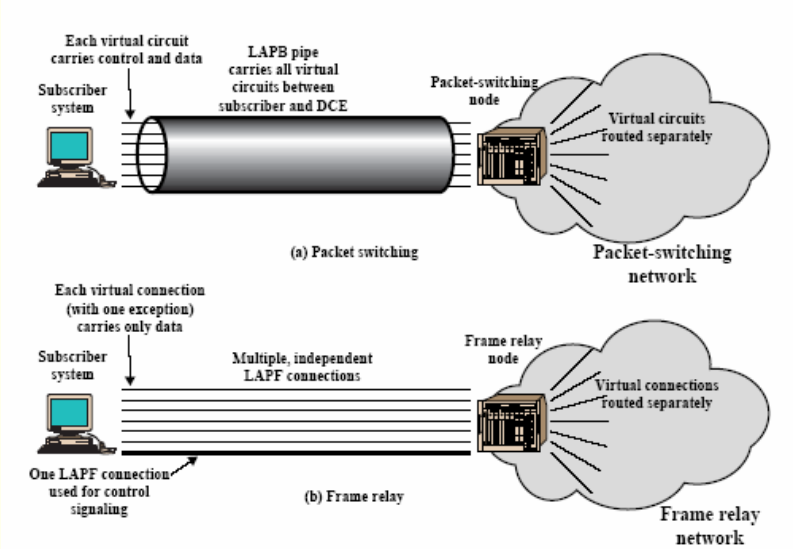


Figure 12.7 Virtual Circuits and Frame Relay Virtual Connections

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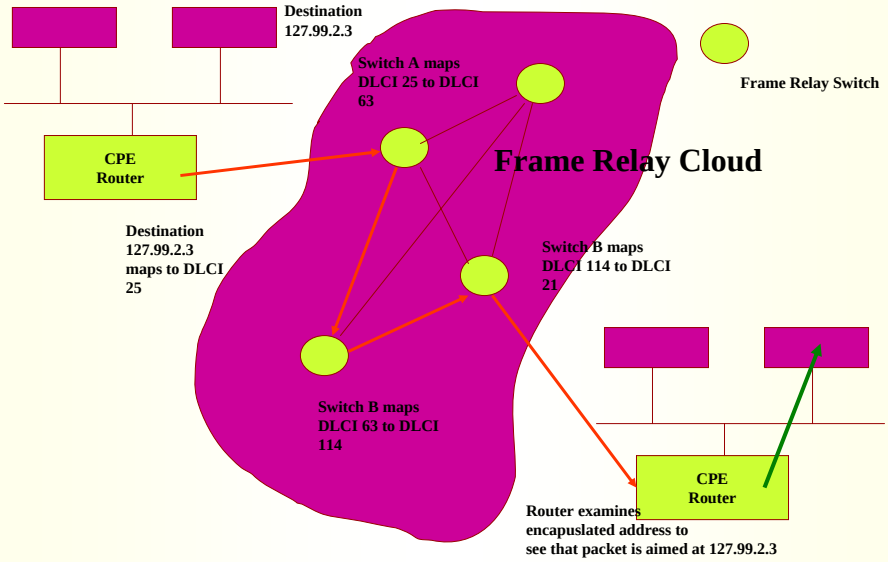
DLCI and FR Routing



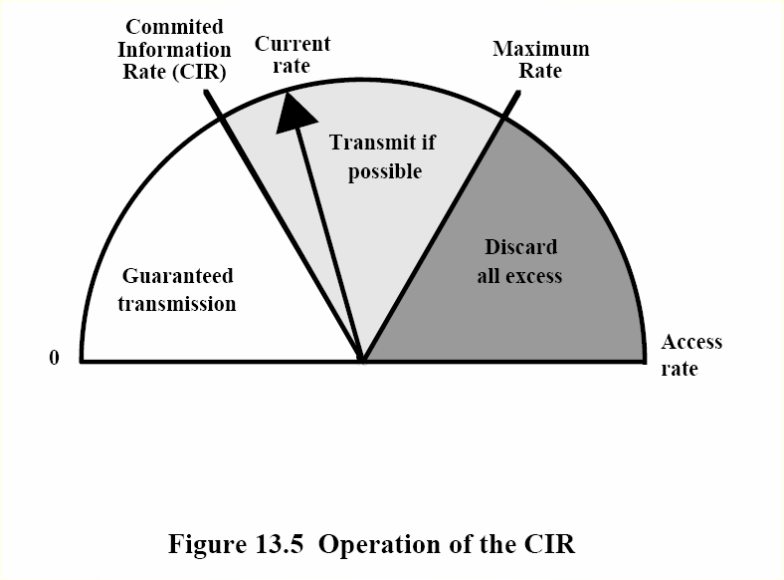
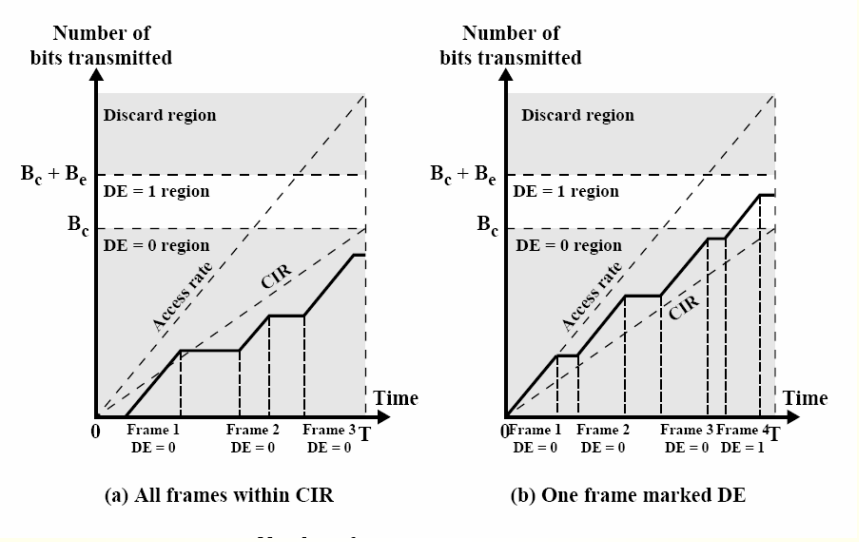


Figure 13.5 Operation of the CIR

FRAME RELAY: QoS e Gestão de Tráfego

- **CIR** (Committed Information Rate):
  Taxa (em bps) que a rede, em condições de funcionamento normal, *"garante"* (deve) aceitar
- Commited Burst Size (Bc):
  Máximo que a rede **aceita** (mas não garante!) transmitir, em condições de funcionamento normal
- Excess Burst Size (Be):
  Excesso máximo que a rede **tenta** transmitir



(a) All frames within CIR

(b) One frame marked DE

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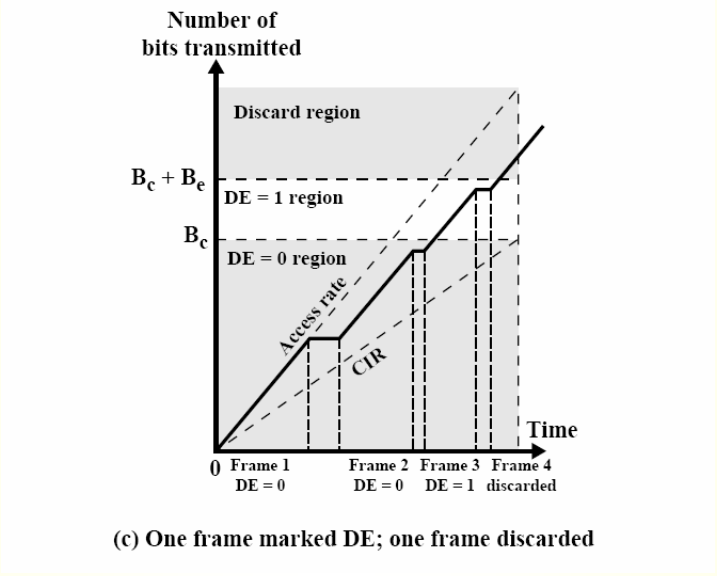


(c) One frame marked DE; one frame discarded

FRAME RELAY: Controlo de Congestão

- Bits para Controlo de Congestão
  - BECN - Backward Explicit Congestion Notification (Notificação dirigida à origem)
  - FECN - Forward Explicit Congestion Notification (Notificação dirigida ao destino)
  - DE - Discard Eligible
- Mensagens de gestão (via DLCI 1007): Consolidated Link Layer Management (CLLM)
- Notificação implícita (detecção nível superior)

Controlo de Congestão via FECN/BECN

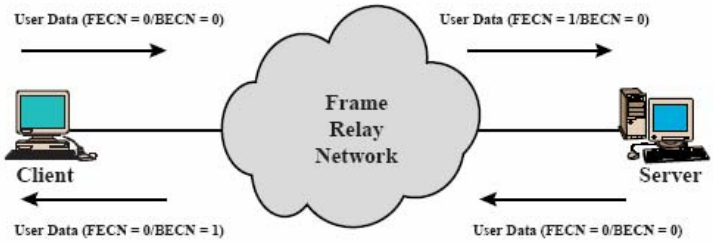


Figure 13.8 Example of Use of FECN/BECN Bits
(mild congestion in the direction of server)

FRAME RELAY: QoS e Gestão de Tráfego

- **CIR** (Committed Information Rate):
  Taxa (em bps) que a rede, em condições de funcionamento normal, *"garante"* (deve) aceitar
- Commited Burst Size (Bc):
  Máximo que a rede **aceita** (mas não garante!) transmitir, em condições de funcionamento normal
- Excess Burst Size (Be):
  Excesso máximo que a rede **tenta** transmitir

ATM

- Slides (fonte "Computer Networking:…"):
  - Capítulo-5c-ATM.ppt

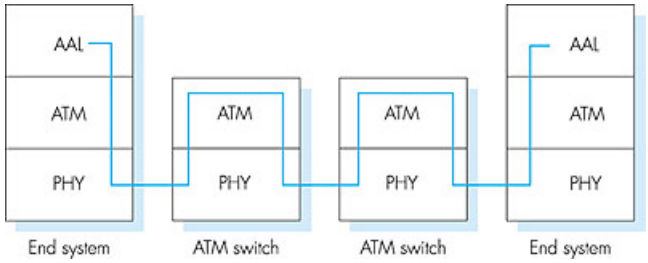
  -

  - *Computer Networking: A Top-Down Approach Featuring the Internet*; James F. Kurose & Keith W. Ross

Asynchronous Transfer Mode: ATM

- **1980s/1990's standard for high-speed** (155Mbps to 622 Mbps and higher) *Broadband Integrated Service Digital Network* architecture
- Goal: *integrated, end-end transport of carry voice, video, data*
  - meeting timing/QoS requirements of voice, video (versus Internet best-effort model)
  - "next generation" telephony: technical roots in telephone world
  - packet-switching (fixed length packets, called "cells") using virtual circuits

ATM architecture

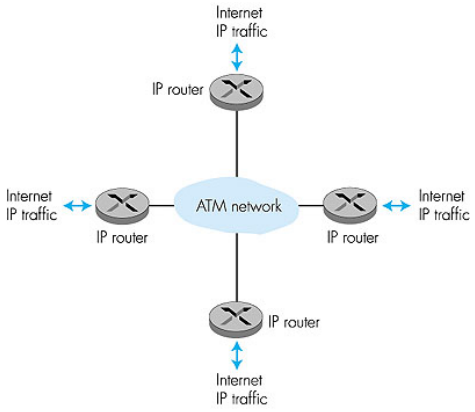


- **adaptation layer: only at edge of ATM network**
  - data segmentation/reassembly
  - roughly analagous to Internet transport layer
- ATM layer: "network" layer
  - cell switching, routing
- physical layer

ATM: network or link layer?

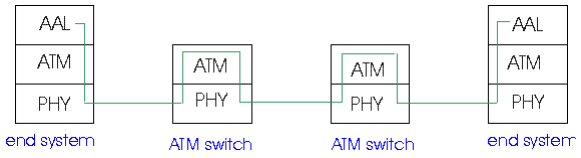
Vision: end-to-end transport: "ATM from desktop to desktop"
- ATM *is* a network technology

Reality: used to connect IP backbone routers
- "IP over ATM"
- ATM as switched link layer, connecting IP routers



ATM Adaptation Layer (AAL)

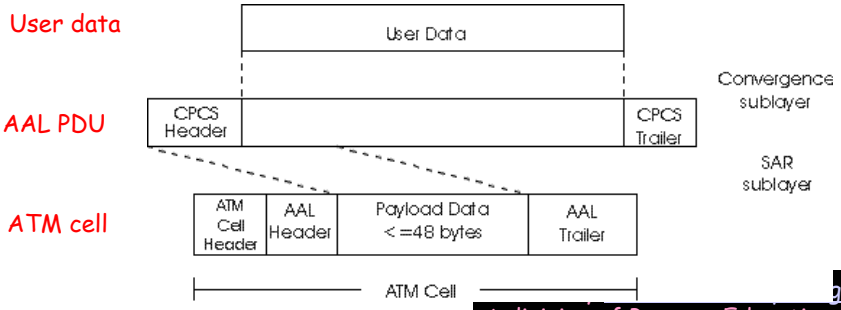
- ATM **Adaptation Layer** (AAL): "adapts" upper layers (IP or native ATM applications) to ATM layer below
- AAL present **only in end systems**, not in switches
- AAL layer segment (header/trailer fields, data) fragmented across multiple ATM cells
  - analogy: TCP segment in many IP packets



ATM Adaption Layer (AAL) [more]

Different versions of AAL layers, depending on ATM service class:

- AAL1: for CBR (Constant Bit Rate) services, e.g. circuit emulation
- AAL2: for VBR (Variable Bit Rate) services, e.g., MPEG video
- AAL5: for data (eg, IP datagrams)



AAL5 - Simple And Efficient AL (SEAL)

- **AAL5**: **low overhead** AAL used to carry IP datagrams
  - 4 byte cyclic redundancy check
  - PAD ensures payload multiple of 48bytes
  - large AAL5 data unit to be fragmented into 48-byte ATM cells

CPCS-PDU payload	PAD	Length	CRC
0-65535	0-47	2	4

ATM Layer

Service: transport cells across ATM network

- analagous to IP network layer
- very different services than IP network layer

Network Architecture	Service Model	Guarantees ?				Congestion feedback
		Bandwidth	Loss	Order	Timing	
Internet	best effort	none	no	no	no	no (inferred via loss)
ATM	CBR	constant rate	yes	yes	yes	no congestion
ATM	VBR	guaranteed rate	yes	yes	yes	no congestion
ATM	ABR	guaranteed minimum	no	yes	no	yes
ATM	UBR	none	no	yes	no	no

ATM Layer: Virtual Circuits

- VC transport: cells carried on VC from source to dest
  - call setup, teardown for each call *before* data can flow
  - each packet carries VC identifier (not destination ID)
  - *every* switch on source-dest path maintain "state" for each passing connection
  - link,switch resources (bandwidth, buffers) may be *allocated* to VC: to get circuit-like perf.
- Permanent VCs (PVCs)
  - long lasting connections
  - typically: "permanent" route between to IP routers
- Switched VCs (SVC):
  - dynamically set up on per-call basis

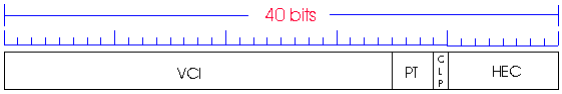
ATM VCs

- Advantages of ATM VC approach:
  - QoS performance guarantee for connection mapped to VC (bandwidth, delay, delay jitter)
- Drawbacks of ATM VC approach:
  - Inefficient support of datagram traffic
  - one PVC between each source/dest pair) does not scale (N*2 connections needed)
  - SVC introduces call setup latency, processing overhead for short lived connections

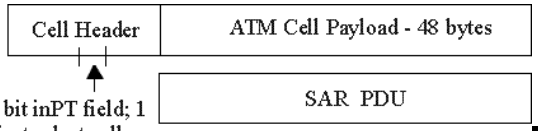
ATM Layer: ATM cell

- 5-byte ATM cell header
- 48-byte payload
  - Why?: small payload -> short cell-creation delay for digitized voice
  - halfway between 32 and 64 (compromise!)

Cell header



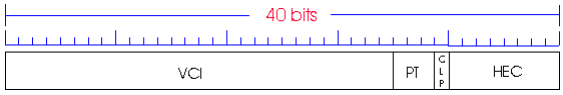
Cell format



3rd bit inPT field; 1 indicates last cell (AAL-Indicate bit)

ATM cell header

- **VCI:** virtual channel ID
  - will *change* from link to link thru net
- **PT:** Payload type (e.g. RM cell versus data cell)
- **CLP:** Cell Loss Priority bit
  - CLP = 1 implies low priority cell, can be discarded if congestion
- **HEC:** Header Error Checksum
  - cyclic redundancy check



ATM Physical Layer (more)

Two pieces (sublayers) of physical layer:

- Transmission Convergence Sublayer (TCS): adapts ATM layer above to PMD sublayer below
- Physical Medium Dependent: depends on physical medium being used

TCS Functions:

- Header **checksum** generation: 8 bits CRC
- Cell **delineation**
- With "unstructured" PMD sublayer, transmission of **idle cells** when no data cells to send

ATM Physical Layer

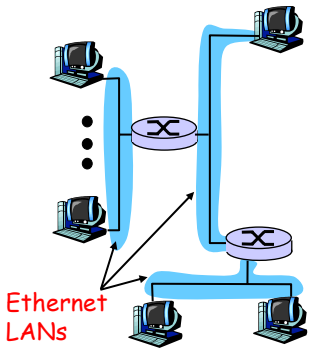
Physical Medium Dependent (PMD) sublayer

- **SONET/SDH**: transmission frame structure (like a container carrying bits);
  - bit synchronization;
  - bandwidth partitions (TDM);
  - several speeds: OC1 = 51.84 Mbps; OC3 = 155.52 Mbps; OC12 = 622.08 Mbps
- **TI/T3**: transmission frame structure (old telephone hierarchy): 1.5 Mbps/ 45 Mbps
- **EI/E3**: Hierarquia Europeia: 2 Mbps/ 34 Mbps
- **unstructured**: just cells (busy/idle)

IP-Over-ATM

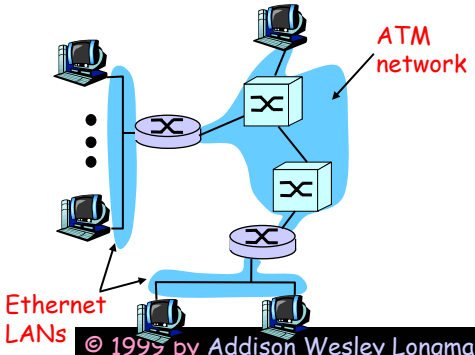
Classic IP only

- 3 "networks" (e.g., LAN segments)
- MAC (802.3) and IP addresses



IP over ATM

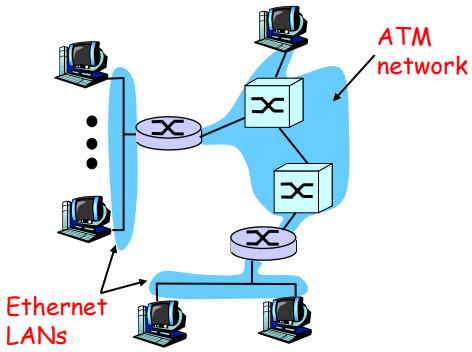
- replace "network" (e.g., LAN segment) with ATM network
- ATM addresses, IP addresses



IP-Over-ATM

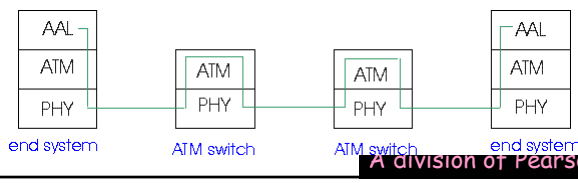
Issues:

- IP datagrams into ATM AAL5 PDUs
- from IP addresses to ATM addresses
  - just like IP addresses to 802.3 MAC addresses!



Datagram Journey in IP-over-ATM Network

- at Source Host:
  - IP layer finds mapping between IP, ATM dest address (using ARP)
  - passes datagram to AAL5
  - AAL5 encapsulates data, segments to cells, passes to ATM layer
- ATM network: moves cell along VC to destination
- at Destination Host:
  - AAL5 reassembles cells into original datagram
  - if CRC OK, datgram is passed to IP



ARP in ATM Nets

- ATM network needs destination ATM address
  - just like Ethernet needs destination Ethernet address
- IP/ATM address translation done by ATM ARP (Address Resolution Protocol)
  - ARP server in ATM network performs broadcast of ATM ARP translation request to all connected ATM devices
  - hosts can register their ATM addresses with server to avoid lookup

ATM

- Exemplo para análise

- Exemplo na Univ. Minho

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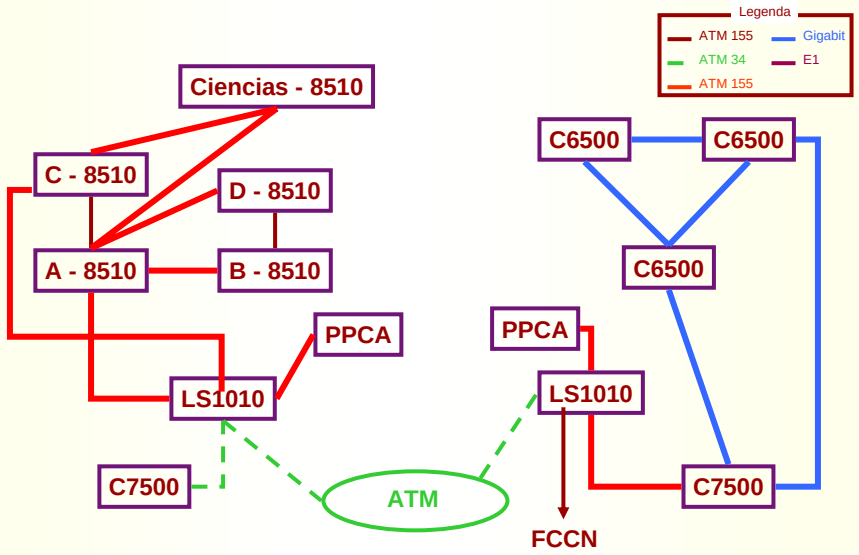
Univ. Minho – Situação Actual



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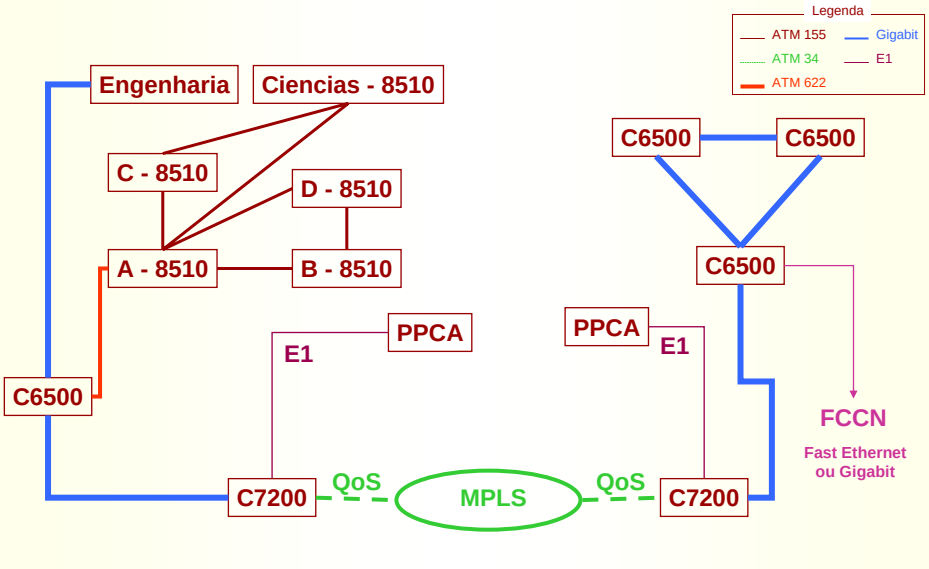
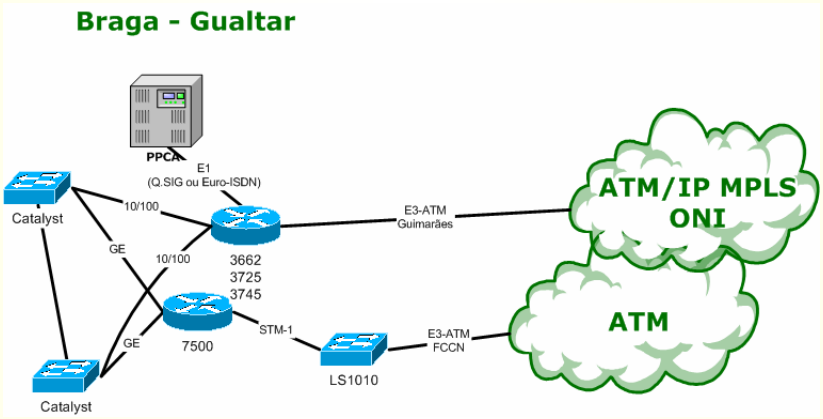
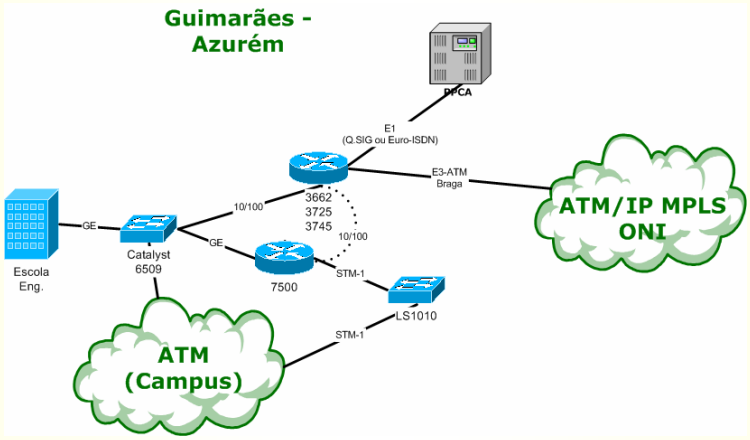
Univ. Minho – Evolução prevista



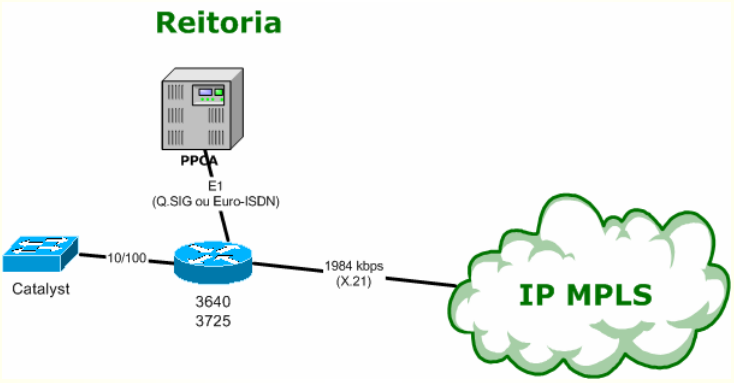
UM – Gualtar



UM - Azurém



Largo Paço


Reitoria
PPCA
E1
(Q.SIG ou Euro-ISDN)
10/100
Catalyst
3640
3725
1984 kbps
(X.21)
IP MPLS