L26 - Frame-Relay

Frame Relay

Principles, Standards, LAPF
Traffic Management

Agenda

- Overview and Principles
- Standards
- Frame Relay User Plane
- Traffic Management

What is Frame Relay?

- **packet switching technology**
  - based on store-and-forward of packets
  - connection oriented
- **interface definition between user and network equipment**
  - FR-DTE (e.g. router) <–> FR-DCE (frame relay switch)
  - UNI (User to Network Interface)
- **wide area network service**
  - based on virtual circuit technique
- **operation within FR network cloud**
  - switch to switch communication not standardized
  - vendor specific implementation

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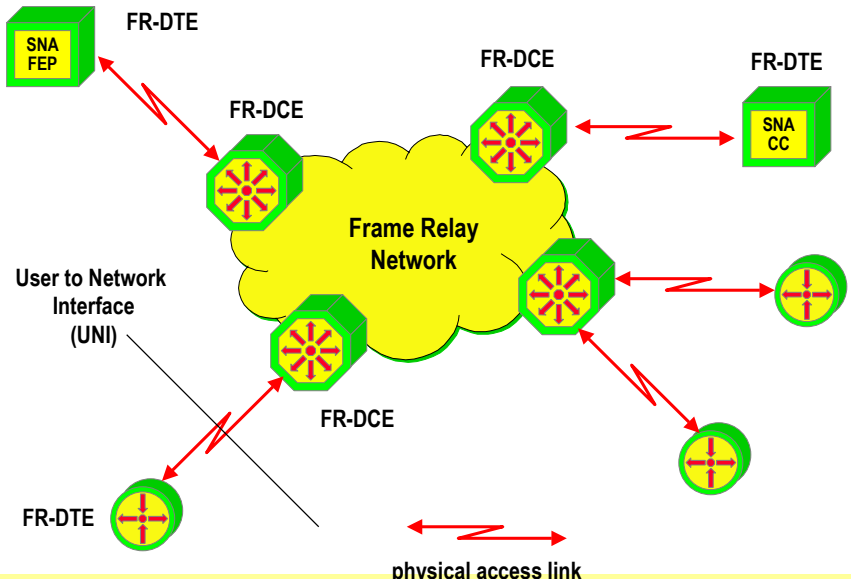
Frame Relay Basic Topology



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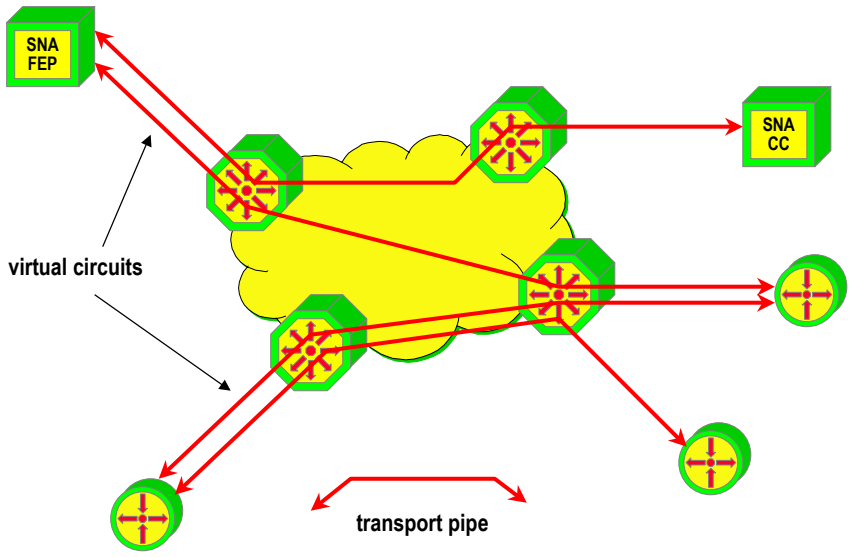
Frame Relay Virtual Circuits

- **virtual circuit technique used**
  - for statistically multiplexing many logical data conversations over a single physical transmission link
- **end systems (FR-DTE) use virtual circuits for delivering data to the FR network and vice versa**
- **virtual circuits appear to end systems as transparent transport pipes (logical point-to-point connections)**

Frame Relay Virtual Circuits



Frame Relay DLCI

- **virtual circuits (VCs) are identified using DLCI numbers**
  - data link connection identifier (DLCI), locally significant
- **some implementations support global addressing**
  - still locally significant
  - but number of user ports limited
- **two kinds of virtual circuits**
  - permanent virtual circuits (PVC) established in advance by service provider
  - switched virtual circuits (SVC) established on demand by user through signaling procedure

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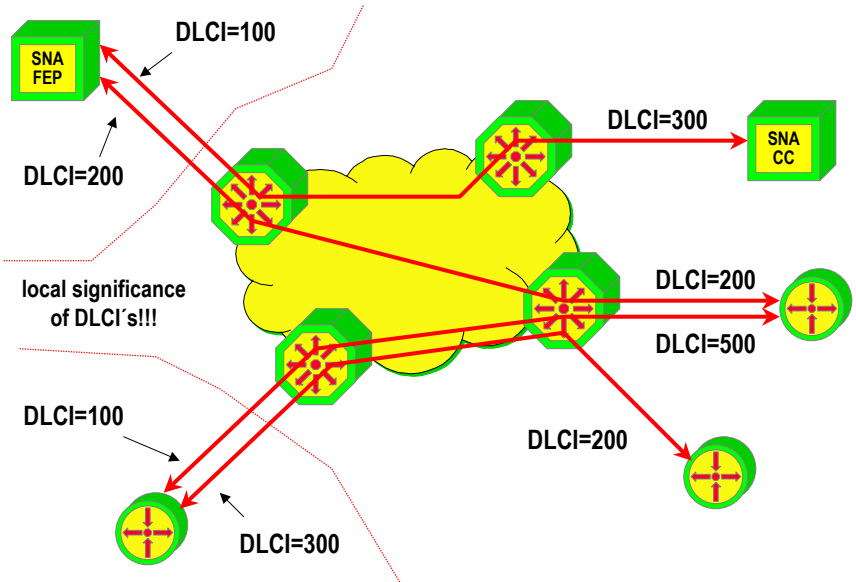
Data Link Connection Identifier (DLCI)



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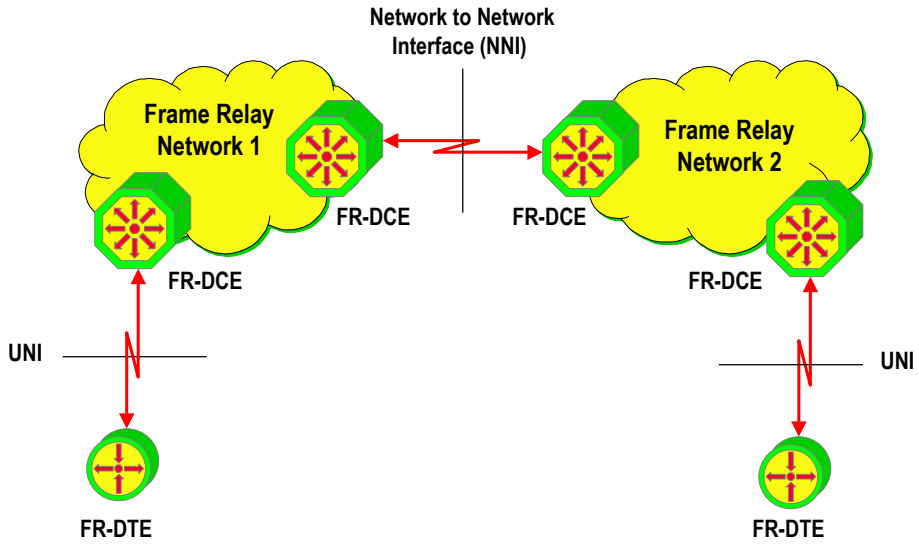
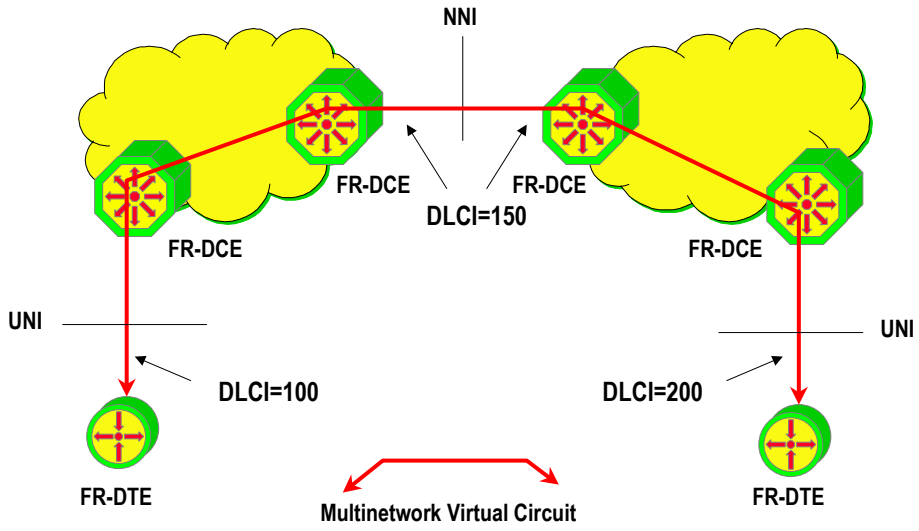
Frame Relay Interconnections

- **sometimes it is necessary to connect frame relay networks together**
  - e.g. private frame relay network of a company to a public frame relay service
  - communication between frame relay switches (FR-DCE to FR-DCE) must be implemented
- **this requirement is handled by an additional interface specification:**
  - NNI (Network to Network Interface)
- **communication between FR-DTEs connected to different frame relay networks**
  - uses sequence of VC´s (multinetwork VC)

Frame Relay Complex Topology



Virtual Circuits over NNI



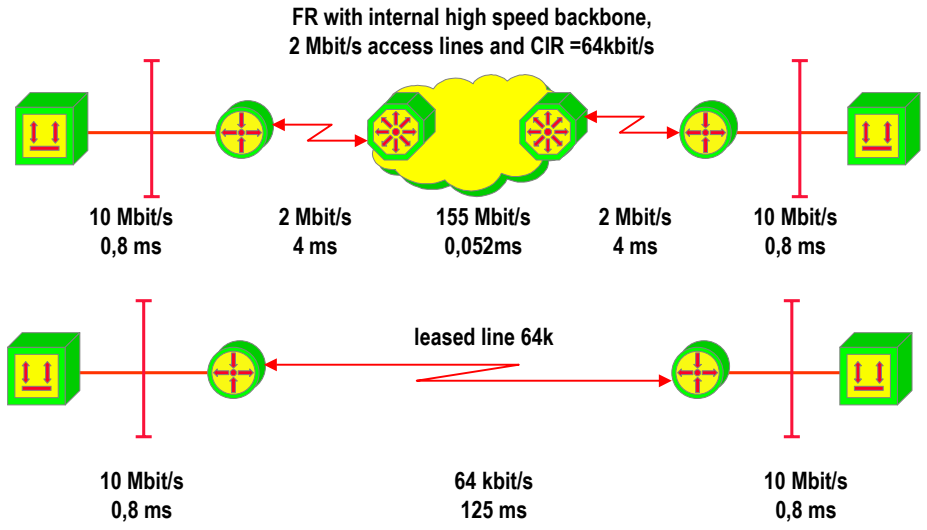
Frame Relay versus X.25

- **protocols like X.25 have been developed for low quality, low speed lines**
  - use error recovery and flow control on layer 2 and 3
- **those protocols are an overkill for high speed lines providing very low error rates**
- **frame relay has been designed to overcome these problems**
  - use only part of layer 2
  - error recovery moved to the end system
  - congestion control instead of flow control
  - therefore simpler link operation and hence higher speed and throughput then X.25 is possible

Why Frame Relay?

- **statistical multiplexing fits better to bursty LAN to LAN communication than dedicated leased line**
- **high speed of access line and trunk lines within the network tries to guarantee a low transit delay**
  - but cost of frame relay service will be less than cost of leased line with same access bit rate
- **frame relay packet switching is faster than X.25 packet switching, migration to higher speed is possible**
  - X.25 up to 2 Mbit/s
  - Frame Relay up to 45 Mbit/s with same technology

Delay Aspects for 1000 Bytes



When Frame Relay?

- **if communication behavior between end systems can be mapped to frame relay service parameters (CIR, Bc, Be)**
- **if communication is bursty (typically LAN-LAN)**
- **if low delay is necessary (interactive applications)**
- **if a single physical link should be used reaching many different locations**
  - alternative: many point-to-point leased lines (cost !!!)
- **if physical lines (trunks and access!!!) have very low bit error rate**

Roots of Frame Relay

- **originally defined by ITU-T as a network service within ISDN**
  - I.122 specifies the framework for additional packet mode bearer services, one of these services is frame relay
  - initial requirement was for ISDN primary rate access
- **frame relay is based upon ISDN data link layer procedures for the D channel**
  - D channel is used for ISDN signaling and ISDN data transfer in packet switching mode
  - I.440/I.441 ISDN user-network interface data link layer
  - Q.920/Q.921 link access procedures on the D channel (LAPD)

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Frame Relay Standardization

- ITU-T (former CCITT)
  - frame relay as packet transfer mode within ISDN
- ANSI
  - US standardization for ISDN
- Frame Relay Forum (FRF)
  - founded by Gang of Four (GOF; Cisco, Dec, Northern Telecom, Stratacom)
  - goal of GOF: promotion of acceptance and implementation of frame relay based on international standards
  - FRF implementations agreements

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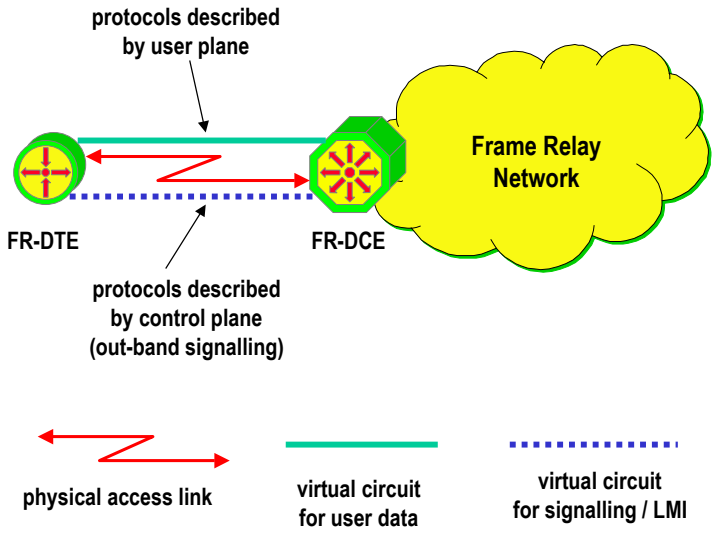
Control Plane <-> User Plane



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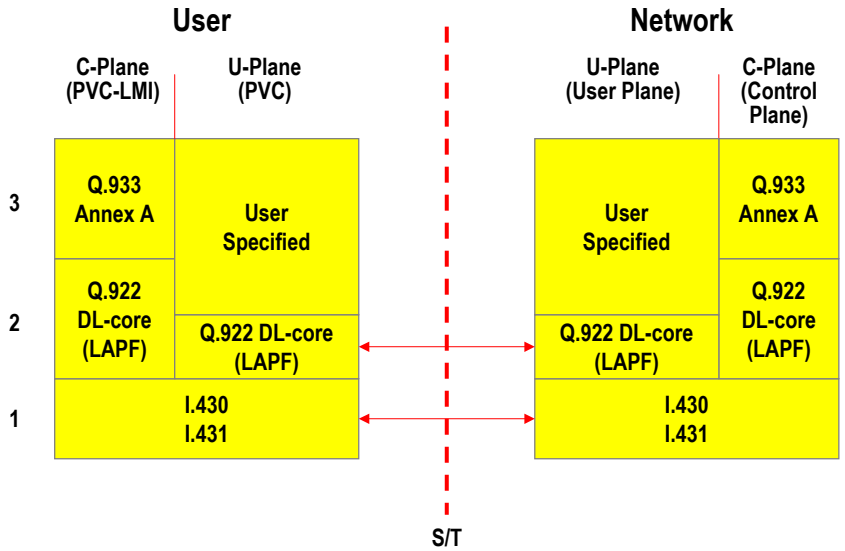
ITU-T Frame Relay Protocol Architecture



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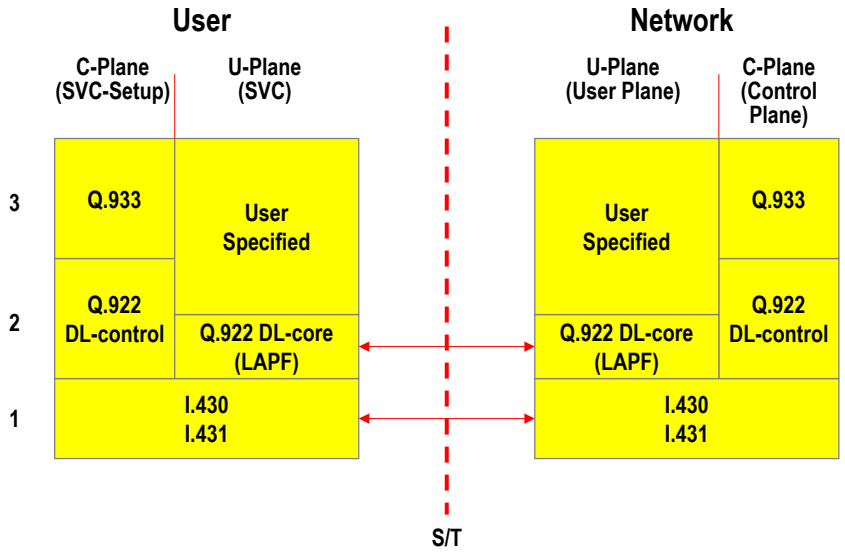
ITU-T Frame Relay Protocol Architecture



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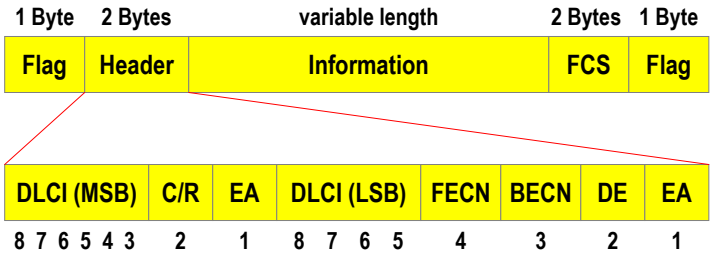
Frame Relay Layer 1

- **physical layer (1) options defined in FRF.1:**
  - ANSI T1.403 (DS1, 1.544 Mbps)
  - ITU-T V.35
  - ITU-T G.703 (2.048 Mbps)
  - ITU-T G.704 (E1, 2.048 Mbps)
  - ITU-T X.21
  - ANSI/EIA/TIA 613 A 1993 High Speed Serial Interface (HSSI, 53 Mbps)
  - ANSI T1.107a (DS3, 44.736 Mbps)
  - ITU G.703 (E3, 34.368 Mbps)
  - ITU V.36/V.37 congestion control
- **other specifications in original ISDN standards**

Frame Relay Layer 2

- **data link layer (2) defined in Q.922 Annex A (LAPF) or T1.618 specifies**
  - frame alignment and delimiting (HDLC Flag)
  - zero bit insertion and extraction (bit stuffing)
  - error detection but no correction
  - verification that frame fulfill minimum size, maximum agreed size, integral number of octets
  - frame multiplexing/demultiplexing using an address field (DLCI number)
  - congestion control
- **all remaining upper layers are transparent to the frame relay user plane**

Frame Format (Q.922 Annex A, T1.618)



DLCI	Data Link Connection Identifier	FECN	Forward Explicit Congestion Notification
C/R	Command/Response Bit	BECN	Backward Explicit Congestion Notification
EA	Address Extension Bits	DE	Discard Eligibility

Frame Format

- **DLCI address**
  - uniquely identifies a virtual circuit through the network to a specific destination
  - in most cases 10 bit length (value range 0 - 1023)
  - could be expanded with additional octets using EA bits
  - FRF, GOF specifies only two octets DLCI address
- **DLCI reserved values (10 bit DLCI)**
  - for signaling, management and future aspects
    - 0 -15
    - 992 - 1023 (ANSI, ITU-T, FRF)
    - 1008 - 1023 (GOF)

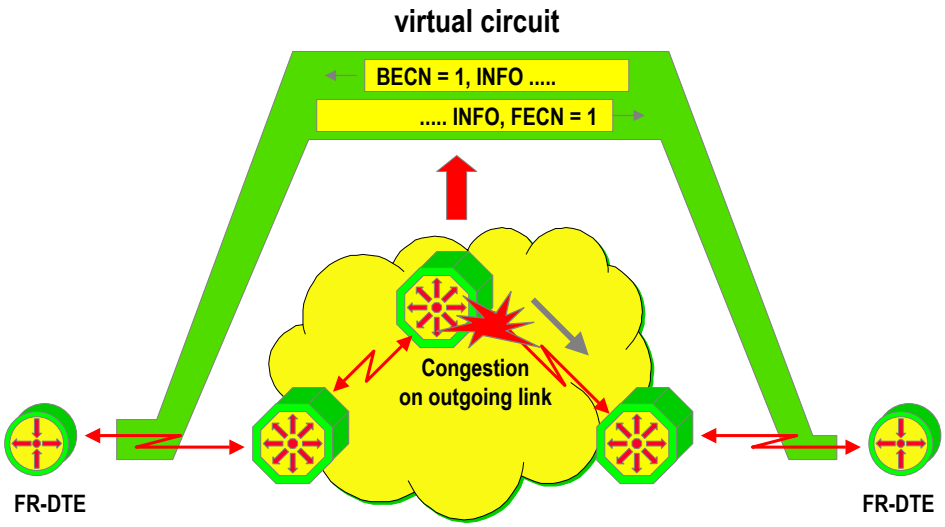
Frame Format

- **EA Extended Address indicator**
  - first and middle DLCI address octets are indicated by EA=0
  - last address octet is indicated by EA=1
  - second address octet always contains FECN, BECN, DE
- **C/R (Command/Response) generally not used**
  - passed transparently across the frame relay network
- **Information field**
  - number of octets can be between 1 - 8192
  - FRF defines 1600 bytes as default maximum size
  - note: FCS with CRC-16 supports frame lengths up to 4096 bytes only

Frame Format

- **Forward Explicit Congestion Notification (FECN)**
  - may be set by a frame relay network to notify the user that congestion was experienced for traffic in the direction of the frame carrying FECN indication
- **Backward Explicit Congestion Notification (BECN)**
  - may be set by a frame relay network to notify the user that congestion was experienced by traffic in the opposite direction of the frame carrying BECN indication

FECN/BECN



Frame Format

- **DE Discard Eligibility**
  - only relevant in congestion situations
  - may be set by the user or the network to indicate that this frame should be discarded in preference to other frames (without the DE bit set) in case of congestion
- **possible DE use**
  - user has a traffic contract with service provider
  - user can signal, if frames are within traffic contract (DE=0) or not (DE=1)
  - user can map time critical traffic to DE=0, best-effort traffic to DE=1
  - network can mark frames which are outside the contract but which are still tried to deliver

FR Data Link Layer Service

- **LAPF/T1.618 does not provide any error recovery or flow control procedures**
- **although frame relay is connection oriented**
  - only a best effort service is offered to end systems
- **only delivering frames in sequence is offered to end systems**
  - basic transport service
- **principle rule:**
  - a frame relay network tries to guarantee delivering frames which are inside the traffic contract with high probability

FR Data Link Layer Service

- **if a frame error is detected by a frame relay switch**
  - the corresponding frame will be discarded
- **if a congestion situation is experienced by a frame relay switch (buffer overflow)**
  - frames will be discarded
- **error recovery must be done by end systems**
  - end systems must detect missing frames using their own higher layer sequence numbers
  - discarded frames must be retransmitted by end systems

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Frame Relay Facts

- frame relay eliminates several functions of the OSI data link layer
  - one of the functions of this layer is flow control
  - but network still must deal with congestion
- in theory users can forward as much data into the network as physical access speed allows
- without any kind of traffic control
  - the network could be flooded if all users forwarding data simultaneously
  - congestion would cause frames to be discarded
  - discarded frames will cause retransmission by end systems and maybe increase congestion

Frame Relay Facts

- **remember**
  - frame relay depends on statistical multiplexing
  - service provider offering a less expensive service (compared to leased lines) rely that not all users need the access line capacity (or a fraction of this capacity) all the time
- **prerequisite for any kind of traffic control is a traffic contract between user and network provider**

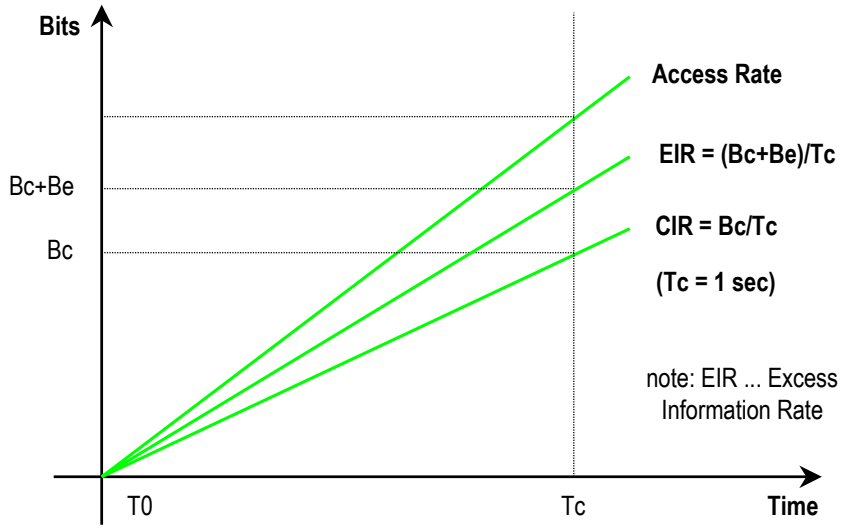
Traffic Contract Parameters

- **Access Rate (AR)**
  - physical data rate of the user access link (in bit/s)
- **Measurement Interval (Tc)**
  - time interval over which rates and burst sizes are measured
- **Committed Burst Size (Bc)**
  - maximum amount of bits that a network agrees to transfer under normal operating conditions over time Tc

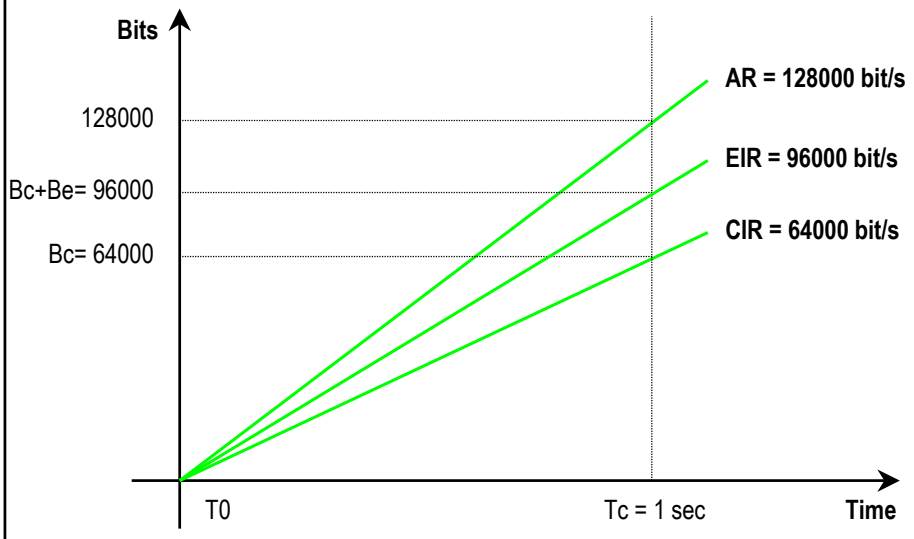
Traffic Contract Parameters

- **Committed Information Rate (CIR)**
  - maximum rate in bit/s at which network transfers data under normal conditions (CIR = Bc/Tc; Tc = 1 sec)
- **Excess Burst Size (Be)**
  - maximum amount of uncommitted data bits that a network will attempt to deliver over measurement interval Tc
- **Excess Information Rate (EIR)**
  - maximum rate in bit/s at which network tries to deliver (EIR = Bc+Be/Tc; Tc = 1 sec)

Relationship between Parameters



Parameter Example 1



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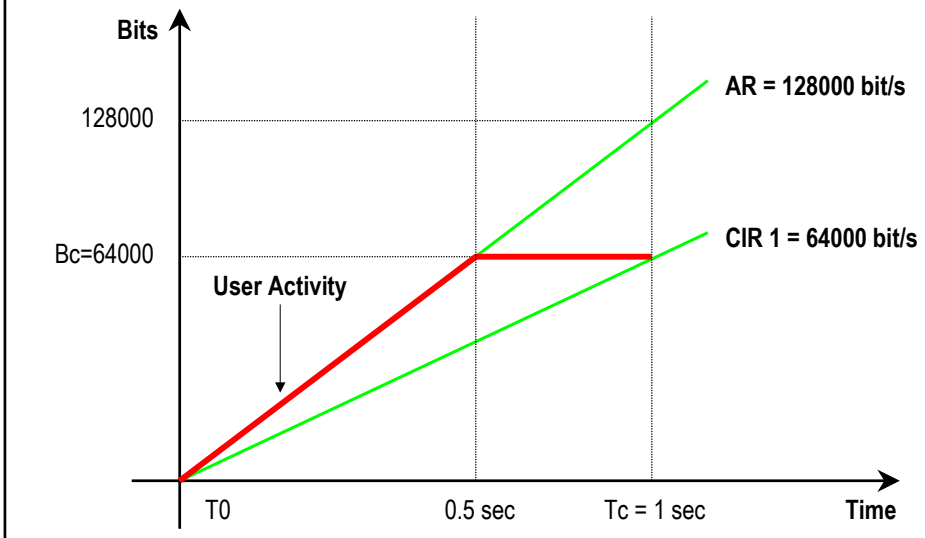
Possible Frame Relay Usage (CIR 1)



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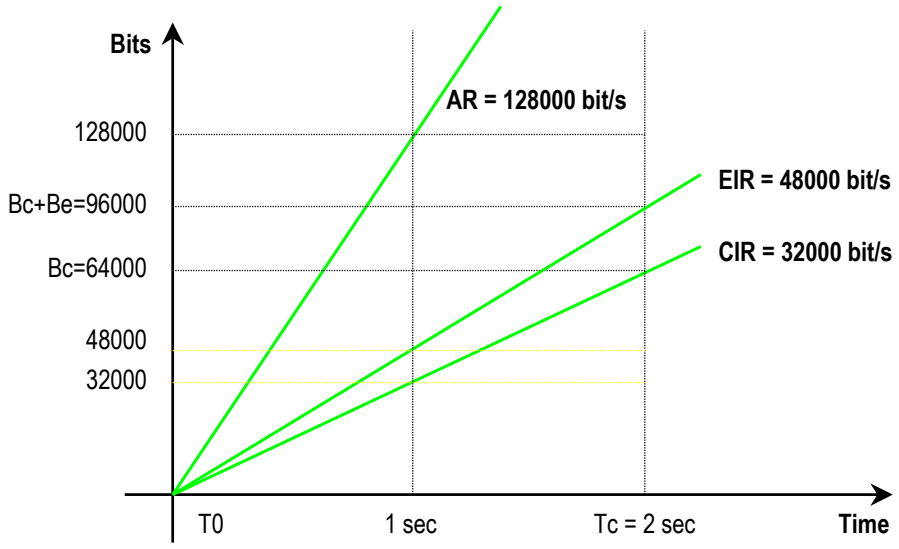
Parameter Example 2



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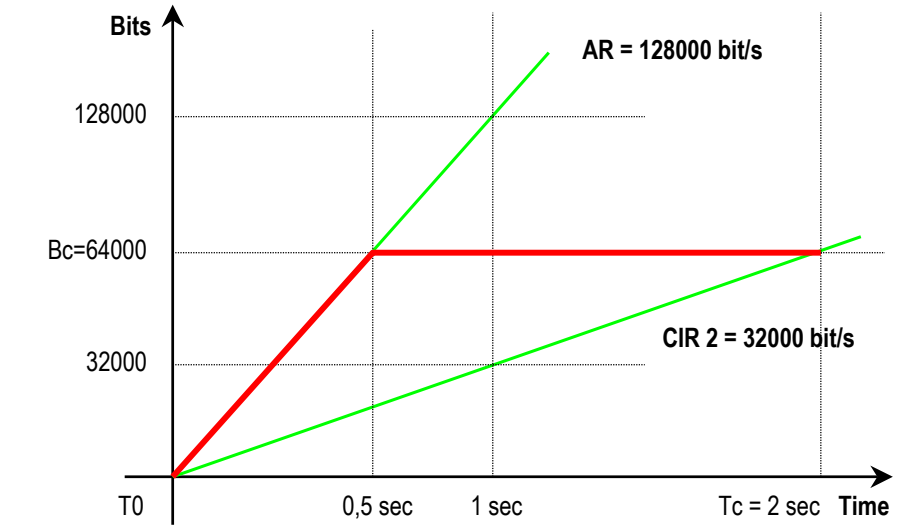
Possible Frame Relay Usage (CIR 2)



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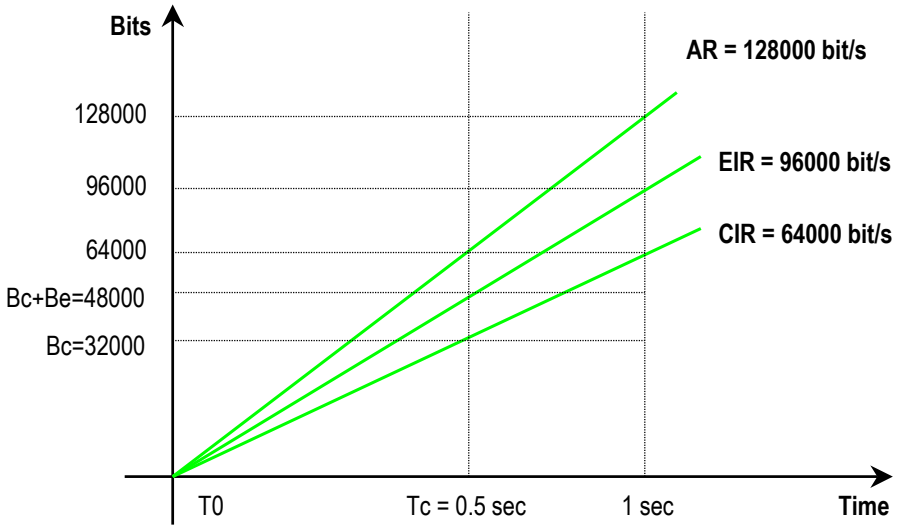
Parameter Example 3



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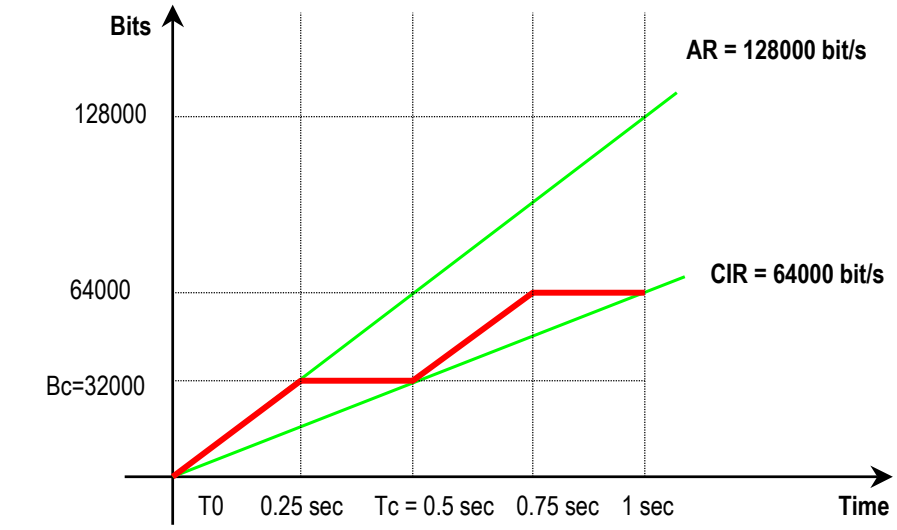
Possible Frame Relay Usage (CIR 3)



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Traffic Management Aspects

- **examples for CIR1, 2, 3 are theoretical**
  - frame transmission cannot be stopped at a certain point
  - hence additional buffering at the frame relay switch must be done to balance this fact
- **principle task of traffic management**
  - limit the amount of traffic an user injects into the network using traffic contract parameters as decision base
    - CIR, EIR predefined per DLCI
  - can be done with traffic shaping
    - task of FR-DTE
  - can (must) be done with traffic policing
    - task of FR-DCE

Traffic Management Options

- **differentiate between important and optional frames**
  - FR-DTE or FR-DCE marks optional frames with DE = 1
  - network may drop optional frames in case of congestion using DE bit
- **inform the user about congestion situations**
  - using FECN and BECN bits
  - but flow control features are optional
    - switch vendors need not implement them in order to be compatible with the frame relay standard
    - FECN and BECN are indications to end systems only, end system need not take care of them

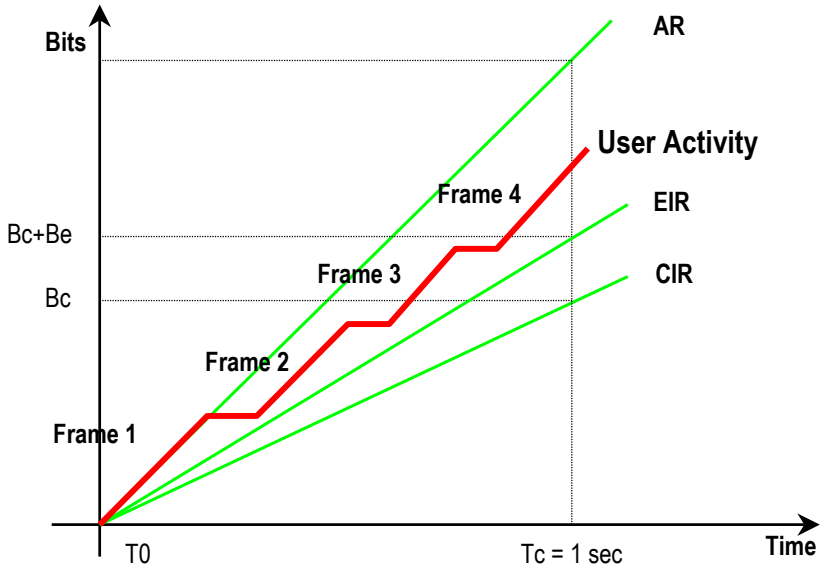
Traffic Shaping / Traffic Policing

- **traffic shaping**
  - end users should limit their traffic
- **traffic policing**
  - network measures the traffic injected by the user
  - if traffic is within contract, o.k.
  - if traffic exceeds contract, network must react in order to avoid congestion in the network
  - implemented for example with techniques like
    leaky bucket or token bucket

Examples for Traffic Management

- **examples for traffic policing**
  - discard all frames above contract
  - mark all frames above contract as candidates for discarding (DE set to 1) but try to deliver these frames if enough resources are available
  - other switches will discard frames with DE=1 first in case of congestion
- **end systems could mark frames with DE=1 if CIR is exceeded**
  - time critical traffic within CIR with DE = 0
  - best effort traffic above CIR with DE = 1
  - if switch would drop randomly critical traffic may be lost

User Activity Scenario



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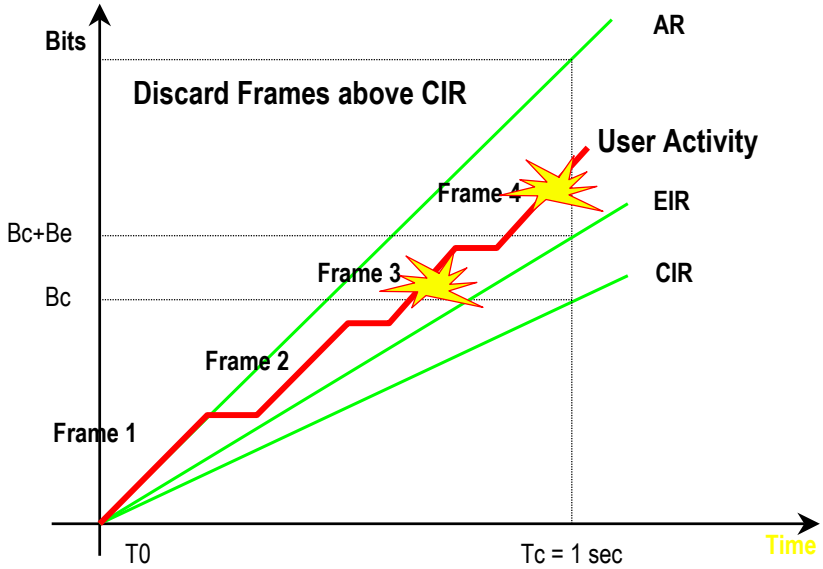
Traffic Control Strategy 1



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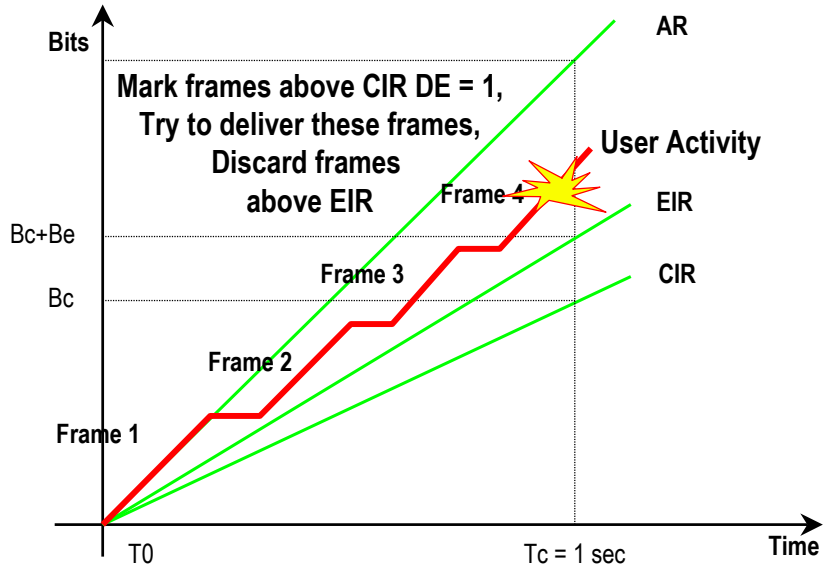
Traffic Control Strategy 2



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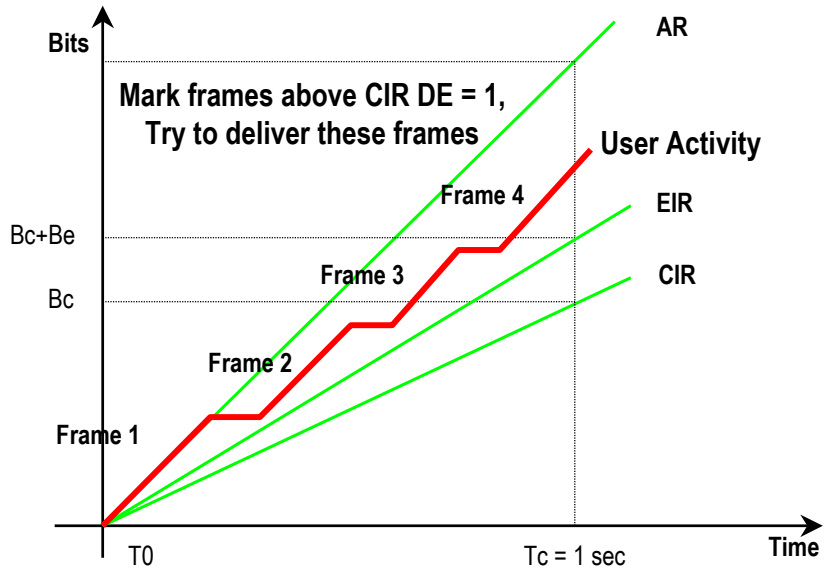
Traffic Control Strategy 3



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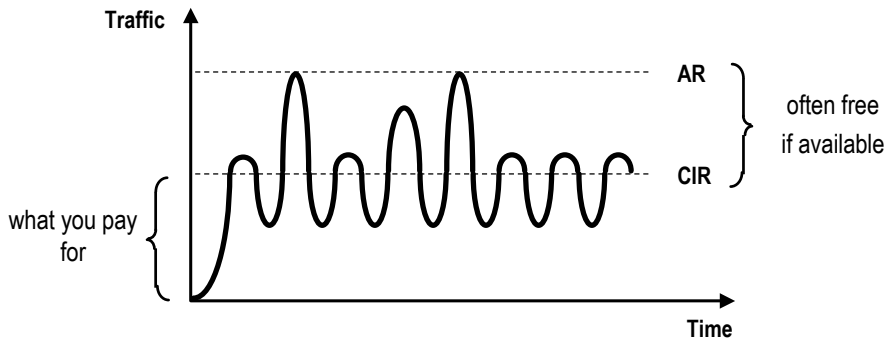
CIR/Traffic Policing/Prices



FECN / BECN and Flow Control

- **a frame relay switch experiencing congestion may set the FECN and BECN bits**
  - BECN is set in frames towards the source
  - FECN is set in frames towards the destination
- **a source receiving frames with BECN set should decrease the traffic injected into the network**
- **a destination receiving frames with FECN set should inform higher layer protocols to introduce a flow control action**
  - for example slow down acknowledgement or reduce the window size

FECN, BECN problems

- **major problems with congestion handling mechanisms based on FECN, BECN**
  - FECN and BECN are carried inside data frames
    - with the lack of data frames no congestion indication can be signaled
  - mechanism based on FECN only relies upon flow control done by end systems in higher layers
    - more difficult to implement and in case of high bit rates too slow
  - example for this problem:
    - end system has no data to send in opposite direction and mapping of FECN to higher layer not implemented
    - hence data frames with BECN never arrive at the other side
    - but this side may be possibly the source of congestion

