Frame Relay

Principles, Standards, LAPF
Traffic Control Aspects, LMI, CLLM, Q.933 (SVC)

Agenda

- Overview and Principles
- Standards
- Frame Relay User Plane
- Traffic Management
- Local Management Interface
- Switched Virtual Circuits

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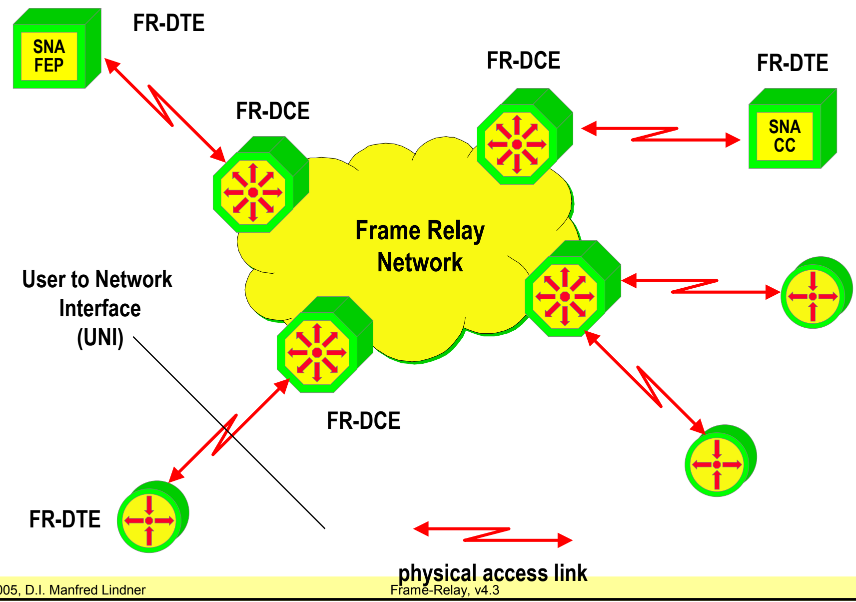
What is Frame Relay?

- **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

Frame Relay Basic Topology



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)**

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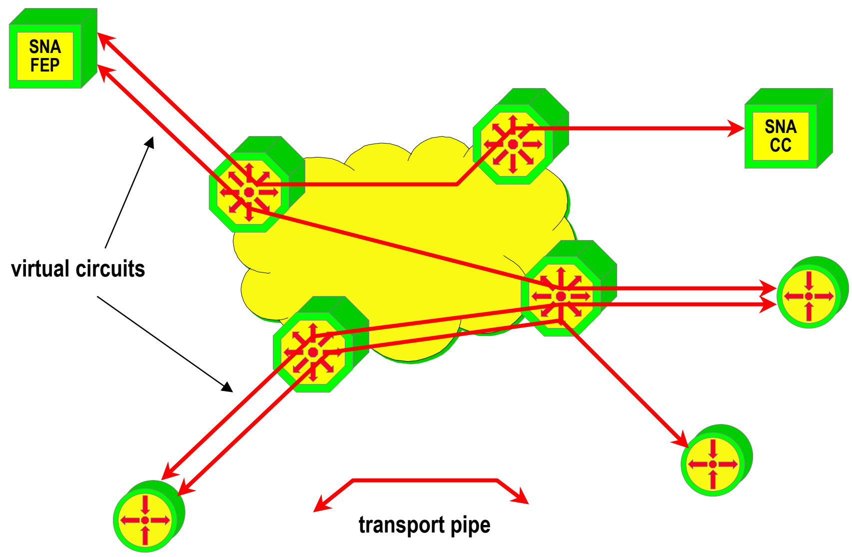
Frame Relay Virtual Circuits



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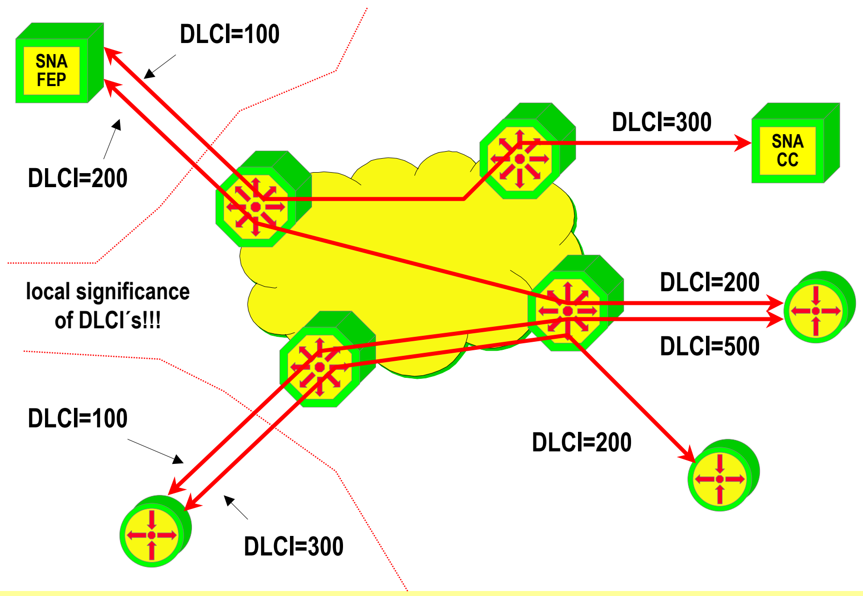
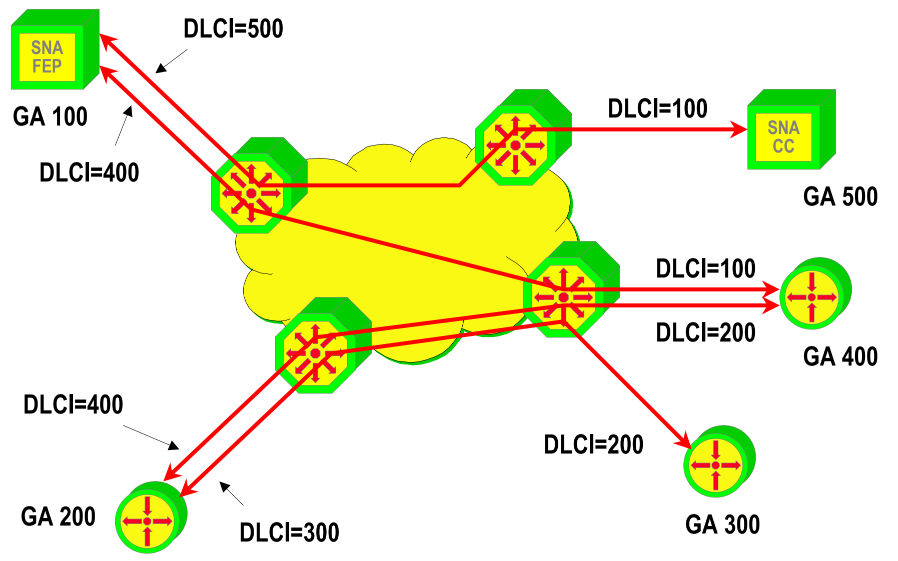
Frame Relay DLCI

- 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

Data Link Connection Identifier (DLCI)



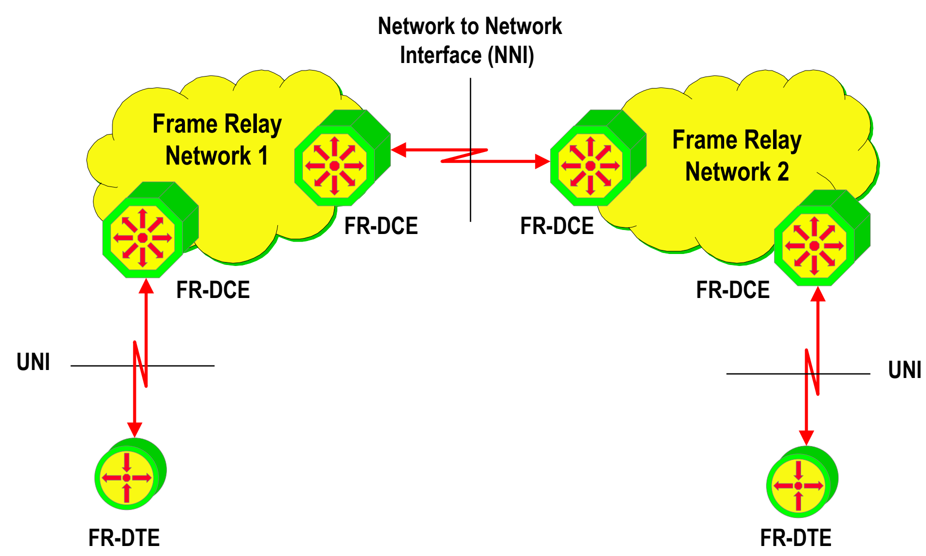
DLCI Global Addressing



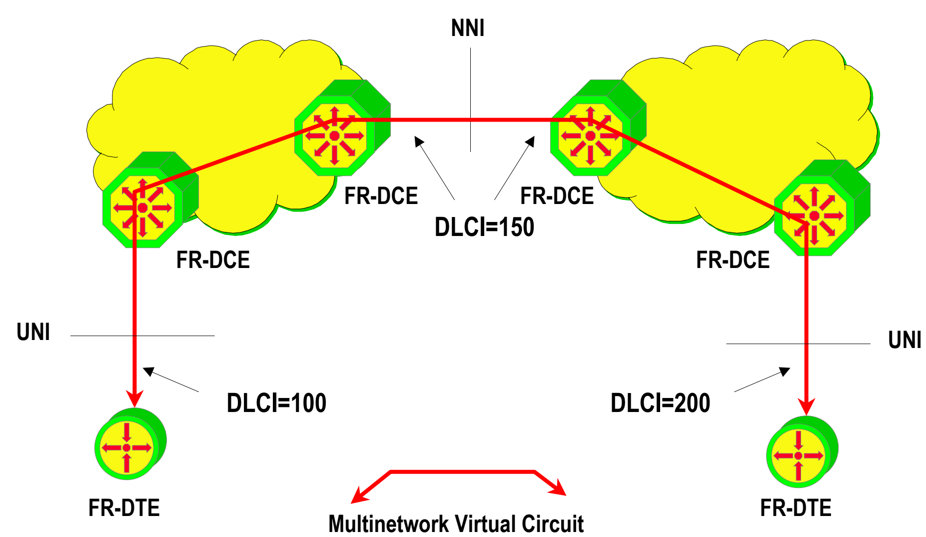
Frame Relay Interconnections

- **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



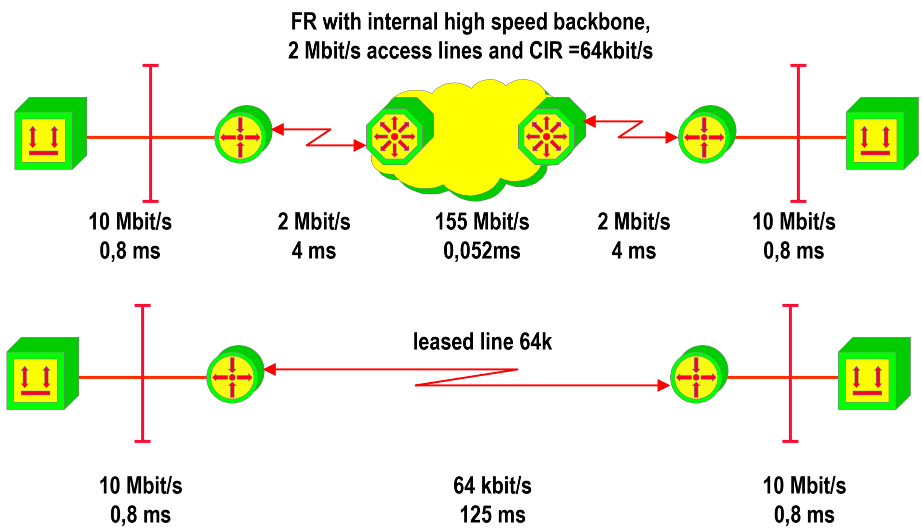
Frame Relay versus X.25

- **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)

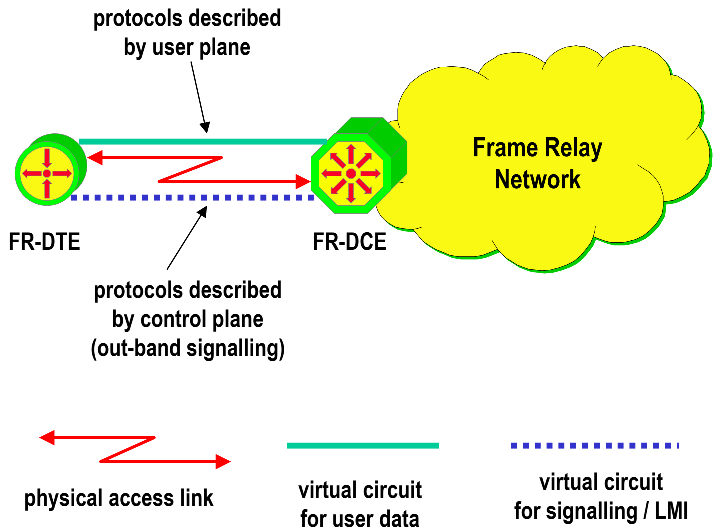
Agenda

- **Topology and Principles**
- **<u>Standards</u>**
- **Frame Relay User Plane**
- **Traffic Management**
- **Local Management Interface**
- **Switched Virtual Circuits**

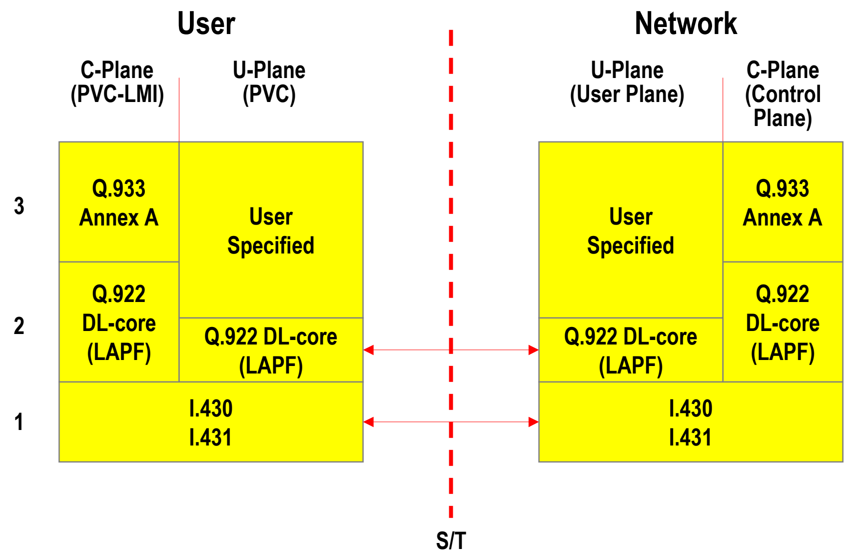
Frame Relay Standardization

- 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

Control Plane <-> User Plane



ITU-T Frame Relay Protocol Architecture



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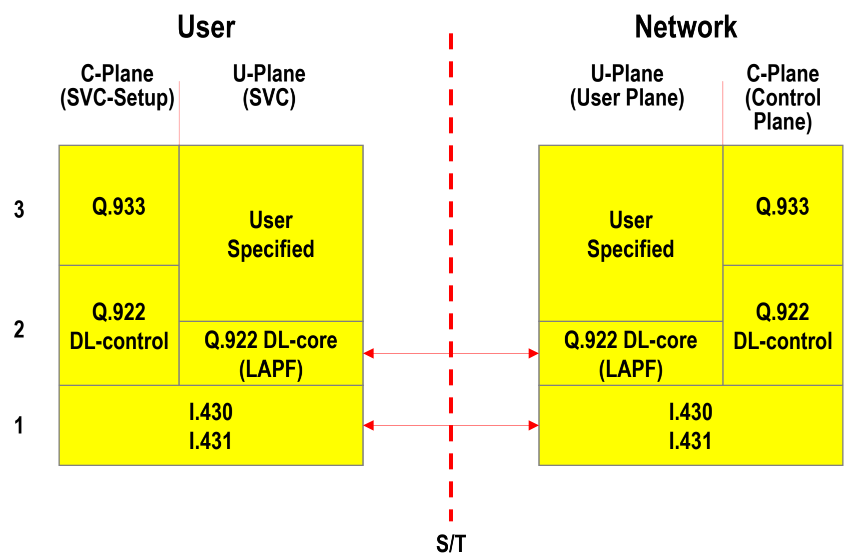
ITU-T Frame Relay Protocol Architecture



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ITU-T Frame Relay Standards

- **ITU-T architectural model defines control plane and user plane**
  - control plane is used for establishing SVCs or maintaining PVCs
  - user plane provide transparent transport pipe after SVC or PVC is established
- **I.233 - frame mode bearer services**
  - describes bi-directional transfer of LAPF frames from one ISDN S or T reference point to another (I.430/I.413 used as physical layer)

ITU-T Frame Relay Standards

- **Q.922 - link access procedures to frame mode bearer services (LAPF)**
  - enhancement of LAPD (ISDN L2 on D-Channel)
  - Q.922 Annex A
    - specifies framing, DLCI, error detection, bit stuffing, congestion control (data link core)
  - Q.922
    - specifies procedures on DLCI 0 in order to maintain a data link connection for layer 3 call control messages (data link control; acknowledged protocol with sequence checking and error recovery)

ITU-T Frame Relay Standards

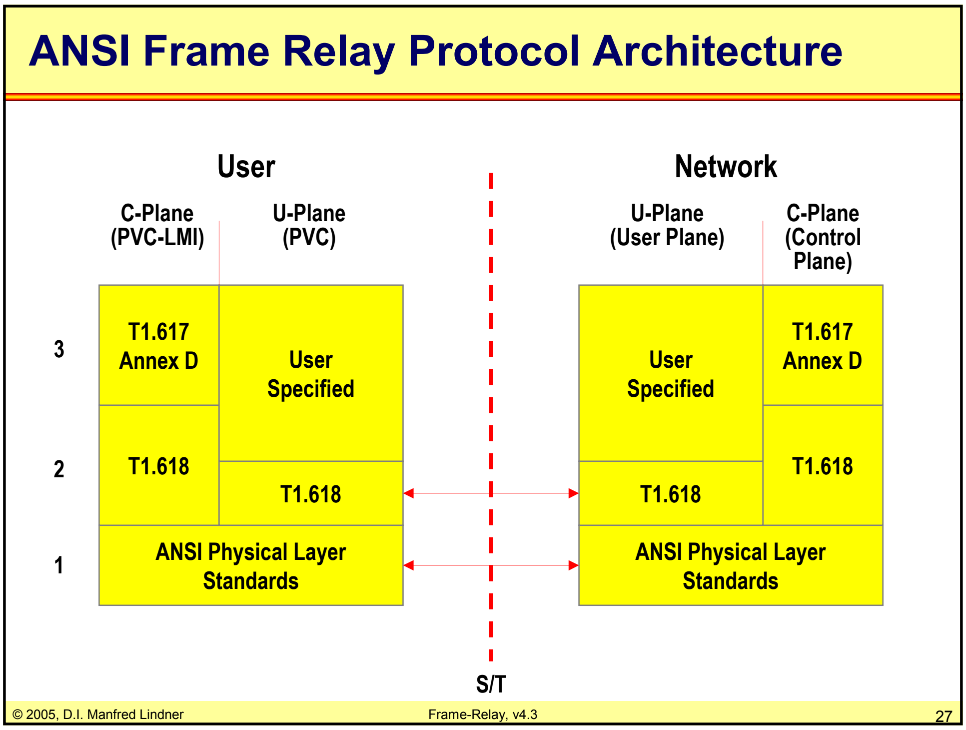
- **Q.933 - ISDN signaling specification for frame mode bearer services**
  - based on I.451/Q.931 ISDN call control protocol
    - mechanisms for setting up frame relay connections (SVC) as well as procedures for permanent virtual circuits
  - Q.933 Annex A
    - PVC management
    - LMI (Local Management Interface)

ITU-T Frame Relay Standards

- **I.370 - congestion management for the ISDN frame relaying bearer service**

- **I.372 - frame mode bearer service network to network interface requirements**

- **I.555 - frame mode bearer service interworking**
  - guidelines for interworking between frame relaying, X.25, circuit switching and broadband ISDN as well as interconnection of LANs


ANSI Frame Relay Protocol Architecture
User
Network
C-Plane (PVC-LMI)
U-Plane (PVC)
U-Plane (User Plane)
C-Plane (Control Plane)
3
2
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T1.617 Annex D
User Specified
T1.618
T1.618
ANSI Physical Layer Standards
User Specified
T1.617 Annex D
T1.618
T1.618
ANSI Physical Layer Standards
S/T
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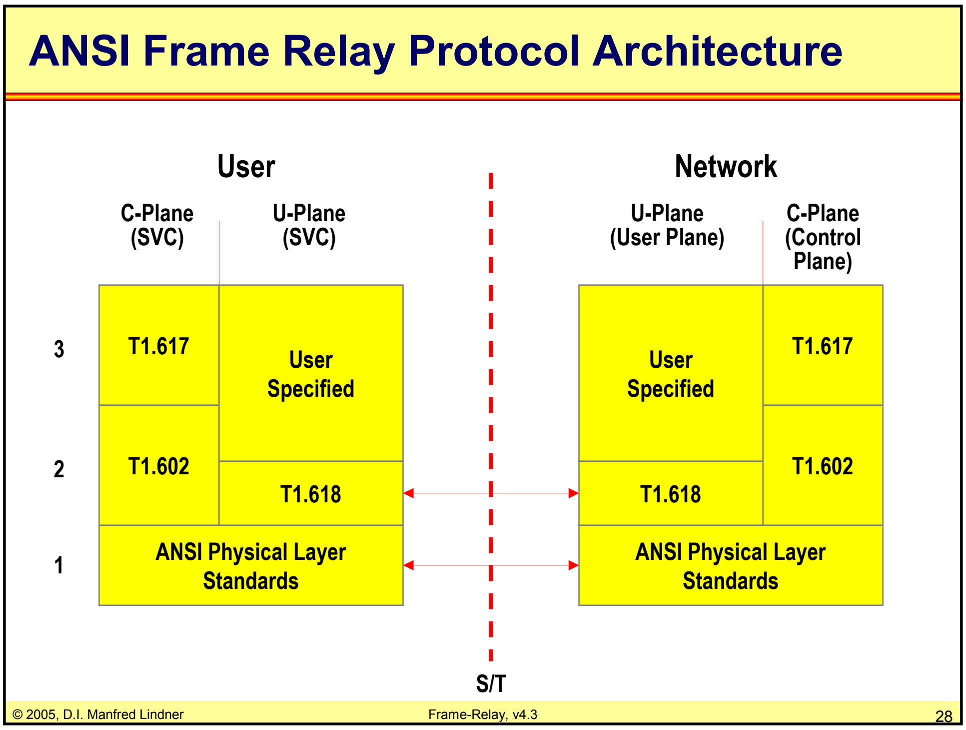
ANSI Frame Relay Protocol Architecture
User
Network
C-Plane (SVC)
U-Plane (SVC)
U-Plane (User Plane)
C-Plane (Control Plane)
3
2
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T1.617
User Specified
T1.602
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User Specified
T1.617
T1.618
T1.602
ANSI Physical Layer Standards
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ANSI Frame Relay Standards

- T1.602 telecommunications ISDN data link layer signaling specifications for applications at the user network interface
- T1.606 frame relaying bearer services (architectural framework and service description)
- T1.617 signaling specification for frame relaying bearer service
- T1.618 core aspects of frame protocol for use with frame relay bearer service

ITU-T versus ANSI Standards

ITU-T		ANSI
I.233	<–>	T1.606
Q.922	<–>	T1.602
Q.922 Annex A	<–>	T1.618
Q.933	<–>	T1.617
Q.933 Annex A	<–>	T1.617 Annex D
Q.370	<–>	T1.606a

FRF Implementations Agreements

- FRF ...... Frame Relay Forum
- FRF.1.1 User to Network Interface (UNI)
- FRF.2.1 Network to Network Interface (NNI)
- FRF.3.1 Multiprotocol Encapsulation
- FRF.4 SVC
- FRF.5 FR/ATM Network Interworking
- FRF.6 Customer Network Management (MIB)
- FRF.7 Multicasting Service Description
- FRF.8 FR/ATM Service Interworking

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FRF Implementations Agreements

- FRF.9 Data Compression
- FRF.10 Network to Network SVC
- FRF.11 Voice over Frame Relay
- FRF.12 Fragmentation
- FRF.13 Service Level Agreements
- FRR.14 Physical Layer Interface
- FRF.15 End-to-End Multilink
- FRF.16 Multilink UNI / NNI

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Agenda

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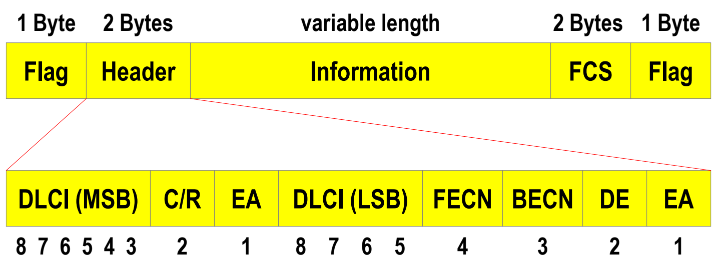
Frame Relay Layer 1

- 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)

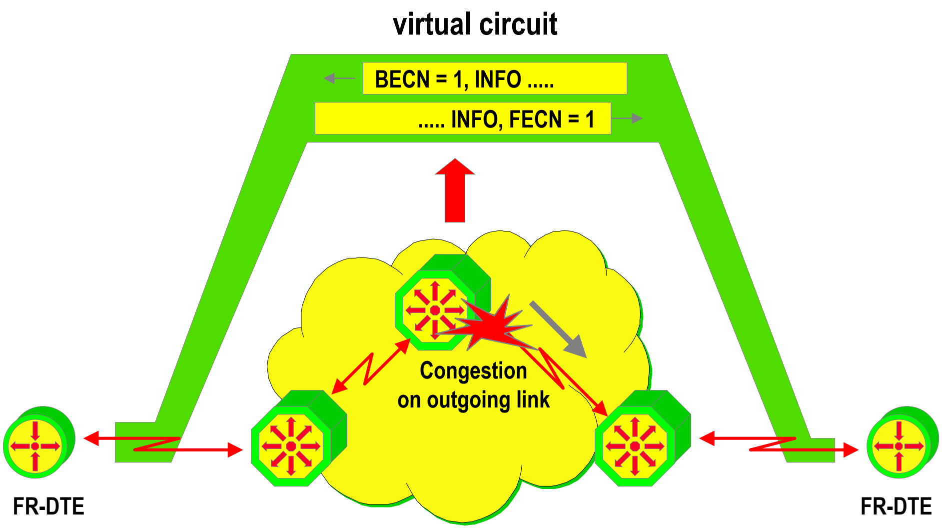
Frame Format

- **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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Agenda

- **Overview and Principles**
- **Standards**
- **Frame Relay User Plane**
- **<u>Traffic Management</u>**
- **Local Management Interface**
- **Switched Virtual Circuits**

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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**

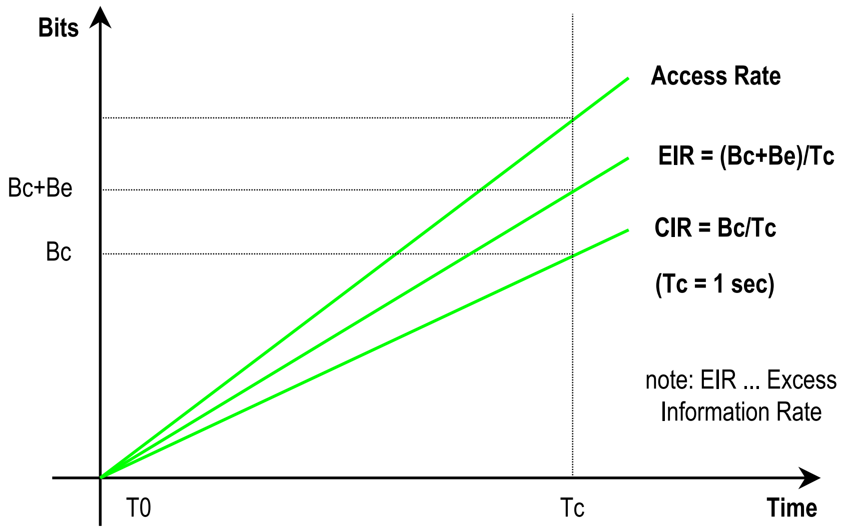
Traffic Contract Parameters

- **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



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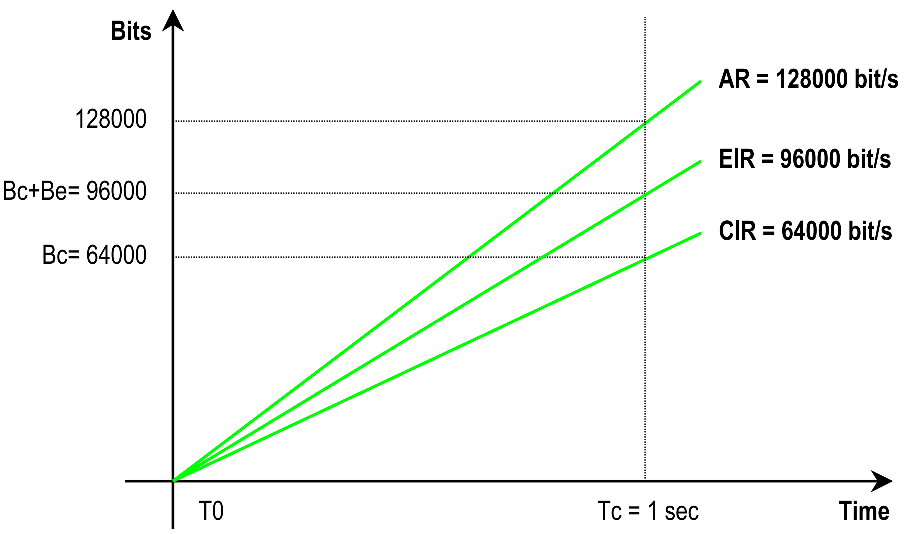
Parameter Example 1



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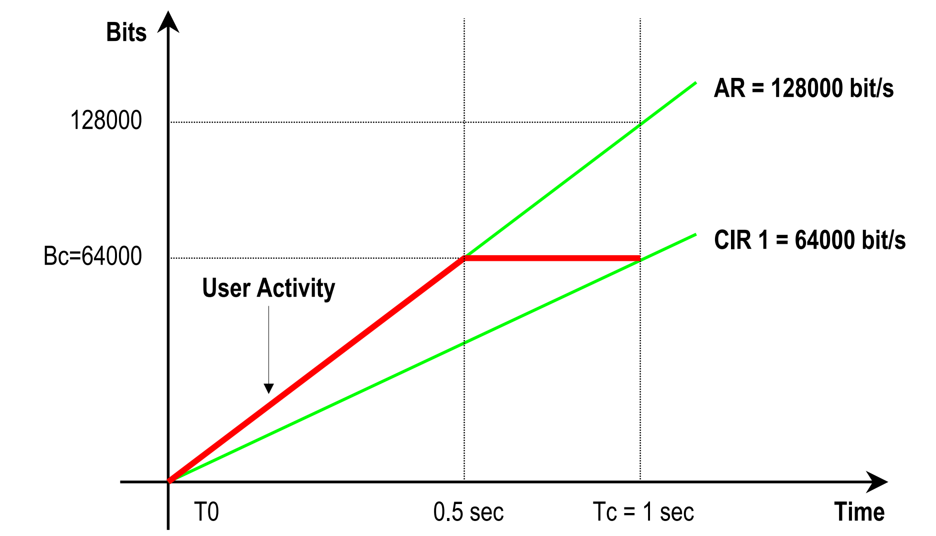
Possible Frame Relay Usage (CIR 1)



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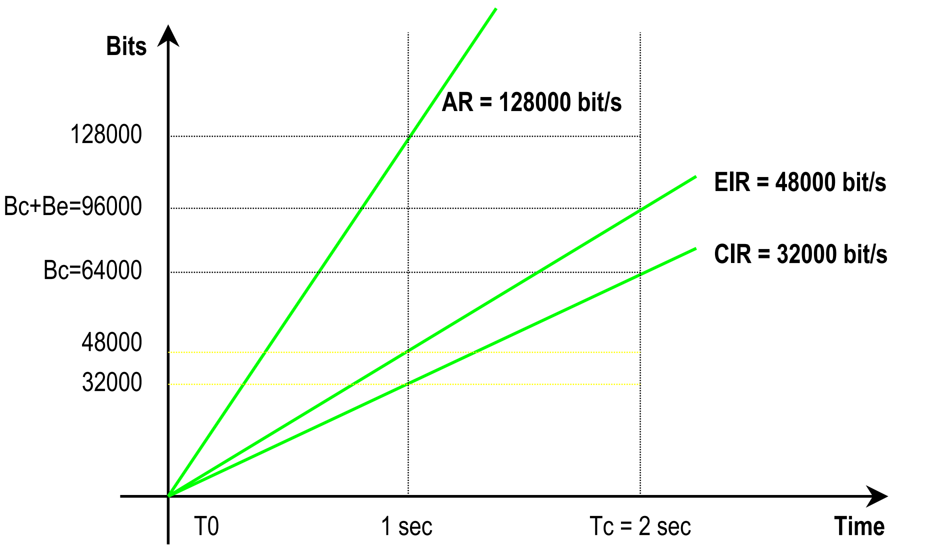
Parameter Example 2



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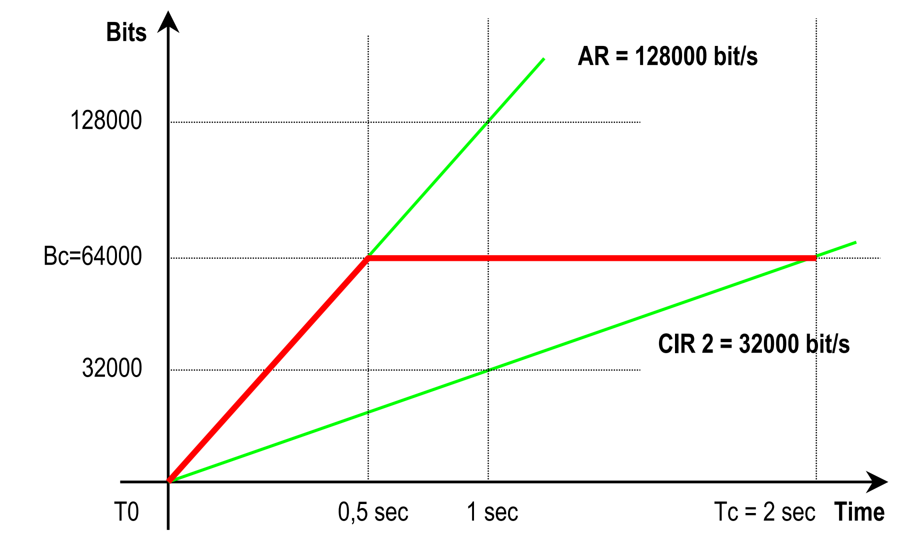
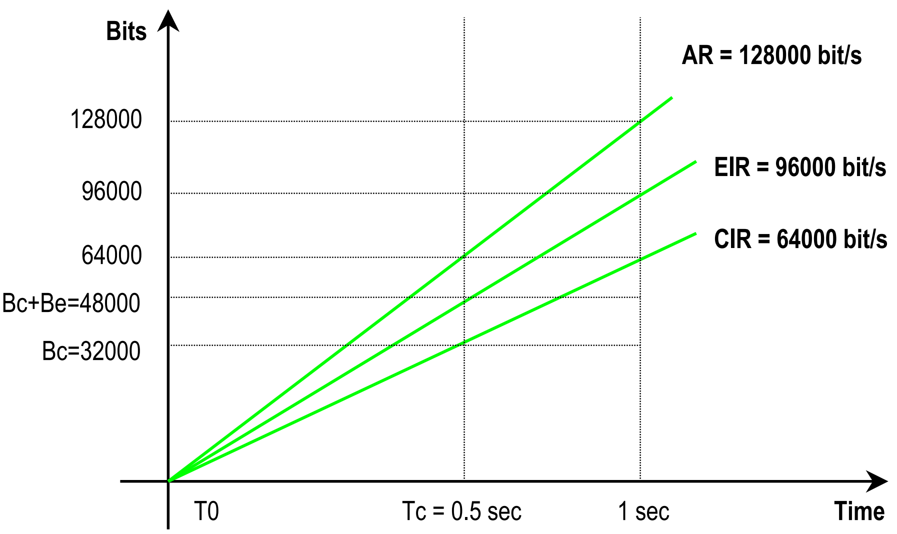
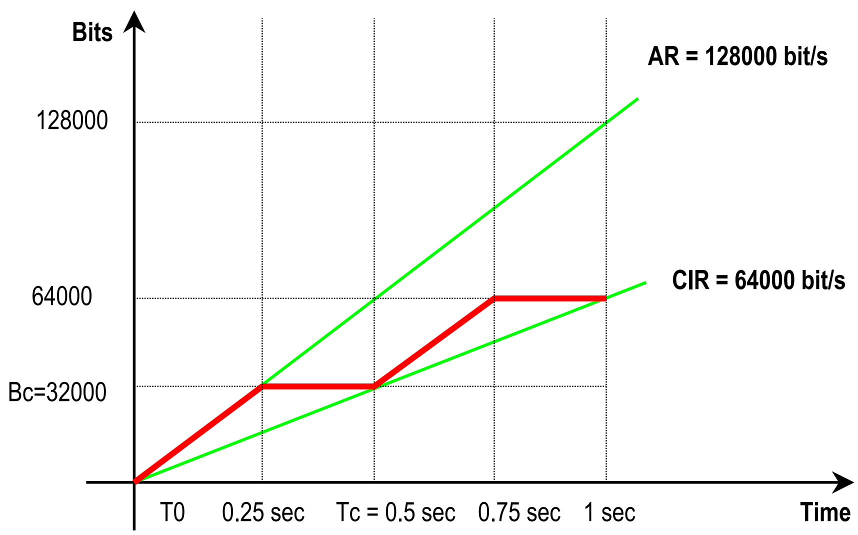
Possible Frame Relay Usage (CIR 2)



Parameter Example 3



Possible Frame Relay Usage (CIR 3)



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

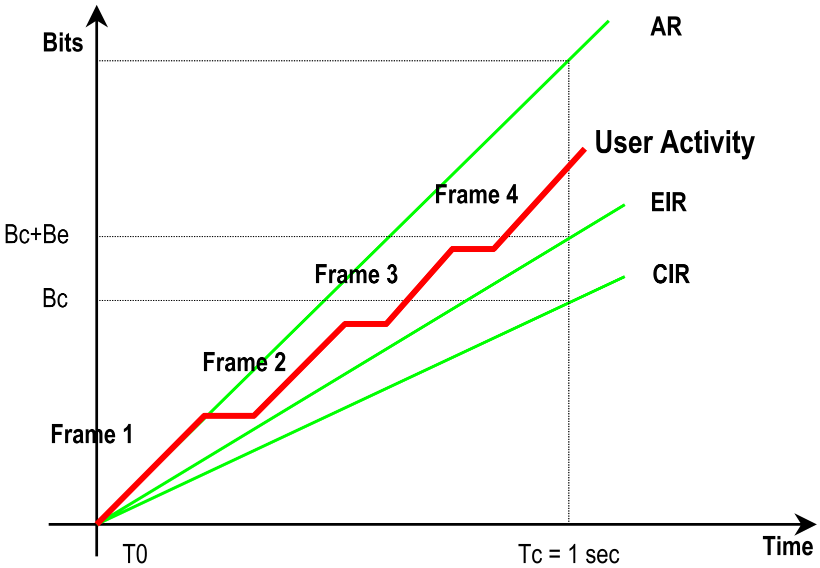
- **traffic shaping**
  - end users should limit their traffic
- **traffic policing**
  - network measures the traffic injected by the user
  - if traffic is within contract, o.k.
  - if traffic exceeds contract, network must react in order to avoid congestion in the network
  - implemented for example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

    leaky bucket or token bucket

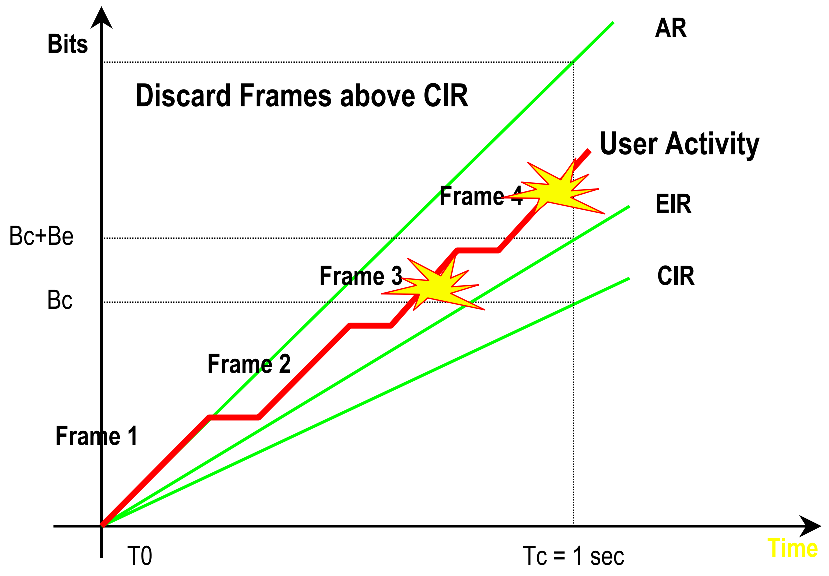
Examples for Traffic Management

- **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

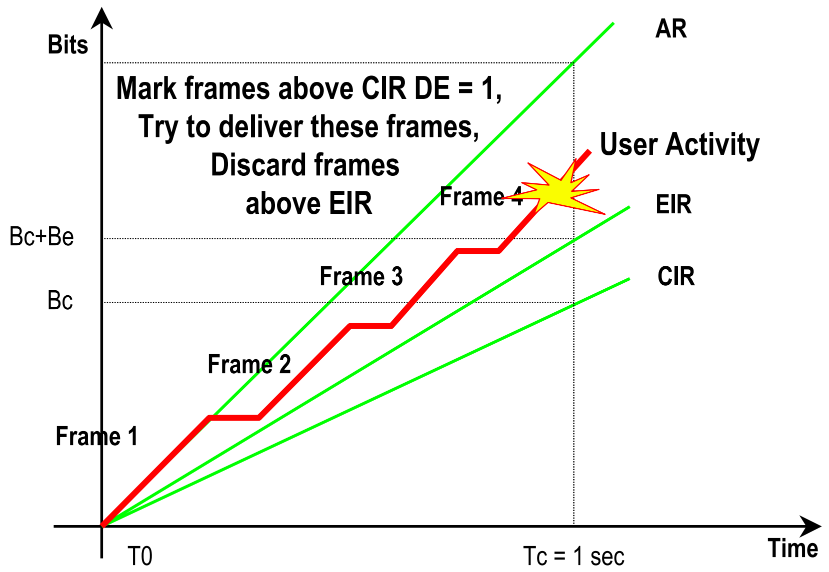
User Activity Scenario



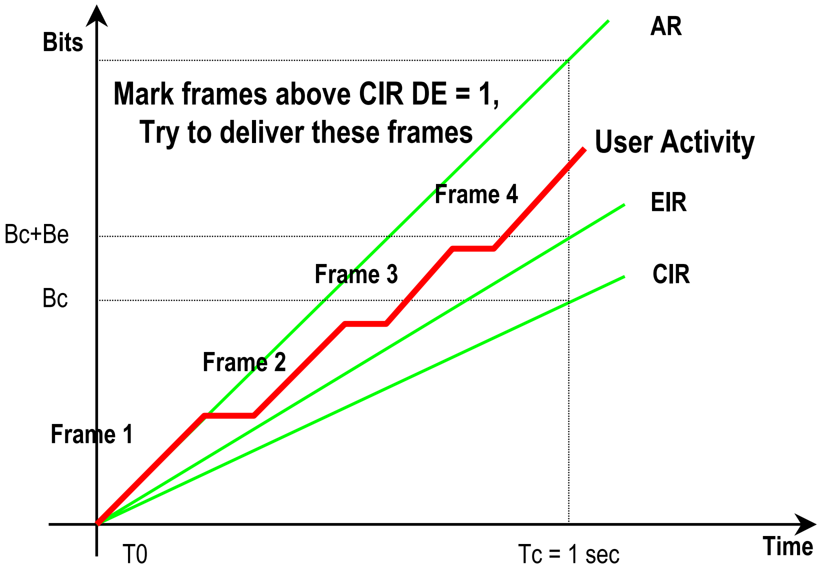
Traffic Control Strategy 1



Traffic Control Strategy 2



Traffic Control Strategy 3



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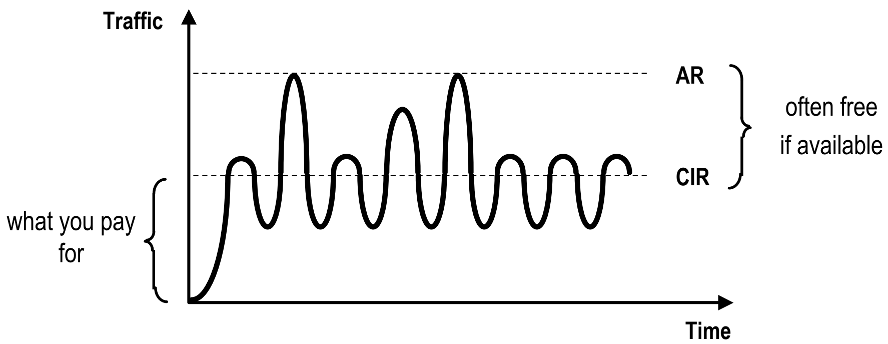
CIR/Traffic Policing/Prices



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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

Consolidated Link Layer Management

- different approach to solve these problems
  - out-band signaling of congestion
  - independent from data frames
- therefore ANSI and ITU-T developed and optional signaling mechanism
  - CLLM
    - Consolidated Link Layer Management

Agenda

- Overview and Principles
- Standards
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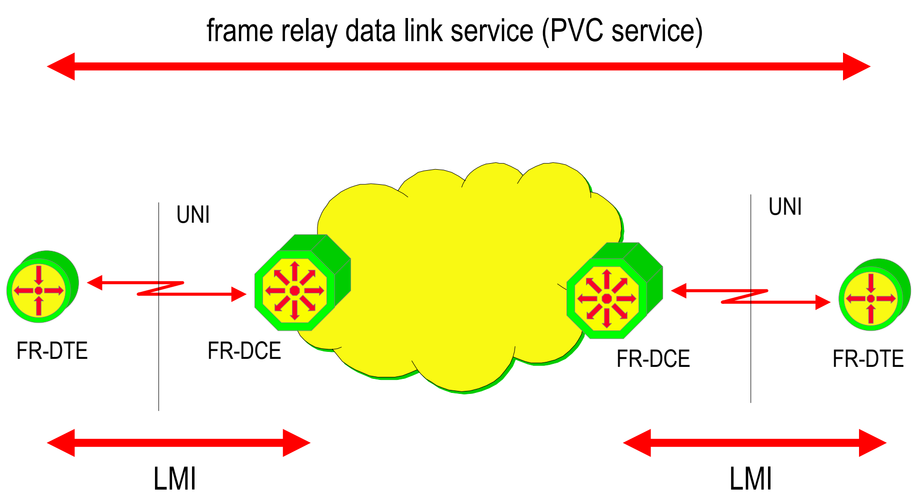
Local Management Interface (LMI)

- **FR data link service is sufficient to transport data across a frame relay network in PVCs**
- **no special communication is necessary between FR-DTE (end system) and FR-DCE (switch) to provide a PVC service**
- **in order to detect certain errors more quickly a local control / management protocol was defined**
  - LMI Local Management Interface
  - local communication between FR-DTE and FR-DCE on reserved DLCI
  - out-band management

LMI

- **LMI is used**
  - to provide the end system with status and configuration information about PVC´s
    - Addition/Deletion of PVCs
    - PVC Status (Active, Inactive)
    - optional information (bandwidth, flow control (GOF))
  - to control the local connection to the switch (keepalive mechanism)
    - Link Integrity
- **three variants available**
    - Gang of Four (GOF, Consortium) using DLCI 1023
    - ITU-T Q.922 Annex A using DLCI 0
    - ANSI T1.617 Annex D using DLCI 0 (FRF)

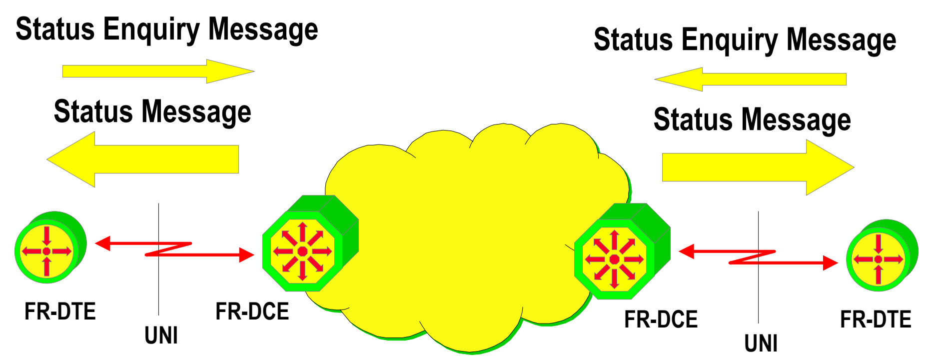
Scope of Unidirectional LMI



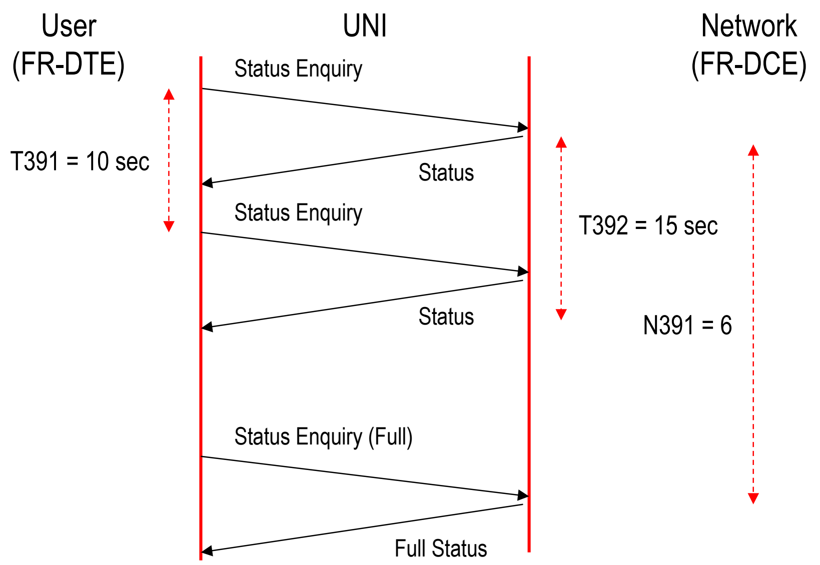
Unidirectional LMI Procedures

- **asymmetric protocol between user (FR-DTE) and network (FR-DCE)**
  - FR-DTE polls FR-DCE at regular intervals using Status Enquiry Messages (interval determined by T391 timer)
  - FR-DCE answers Status Enquiry Messages with a Status Message and starts a T392 timer
  - next Status Enquiry Messages must be received by FR-DCE before T392 timeout reached
  - every Status Enquiry Messages triggers a Sequence Number Exchange (keepalive testing)
  - every N391th Status Enquiry Message ask additionally for a full PVC status report
  - every Status Message contains Sequence Number Exchange and - if requested - full PVC status

Unidirectional LMI Operation



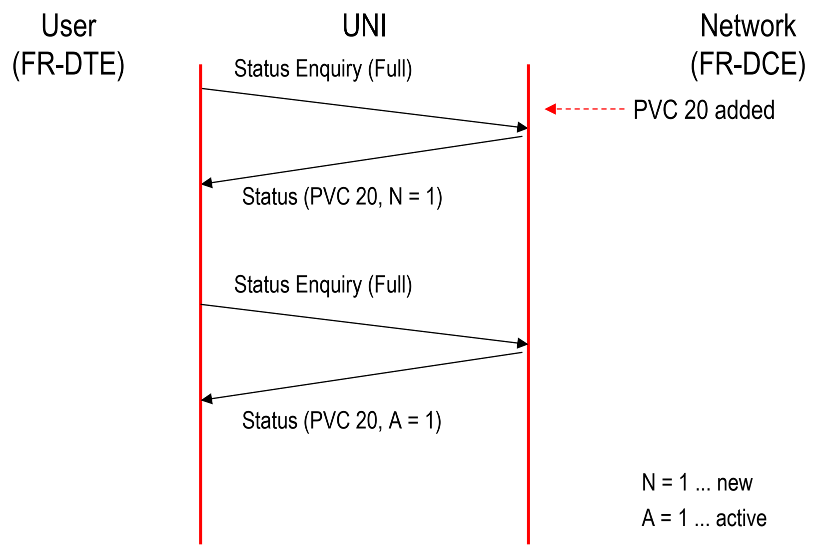
Unidirectional LMI Operation



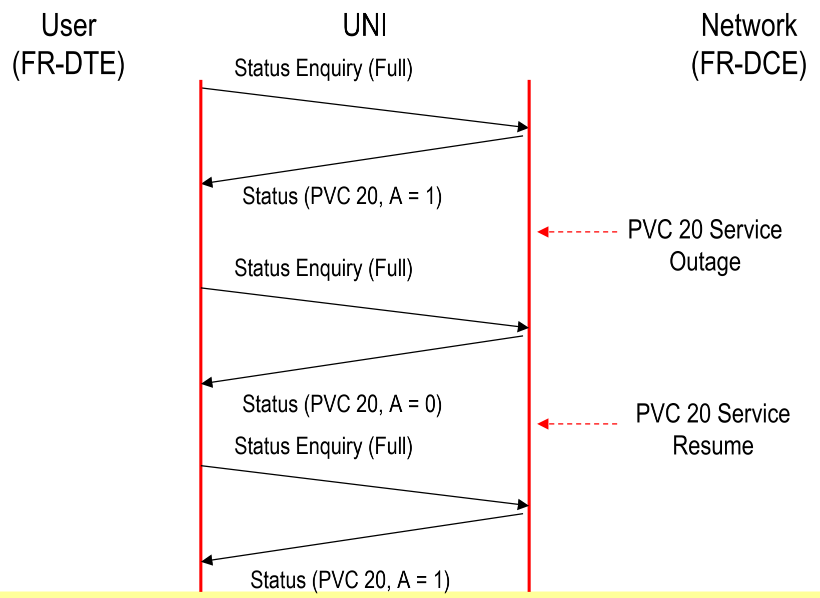
Unidirectional LMI Timer/Numbers

- **T391 Timer (range 5-30, typically 10 seconds)**
- **T392 Timer (range 5-30, typically 15 seconds)**
- **N391 Number (range 1-255, typically 6)**
- **N392 Error Number (range 1-10, typically 3)**
- **N393 Event Number (range 1-10, typically 4)**
- **UNI is declared inactive**
  - if there N392 errors in N393 events
- **UNI is declared active**
  - if N393 consecutive polls are successful

Adding PVC



PVC Service Outage



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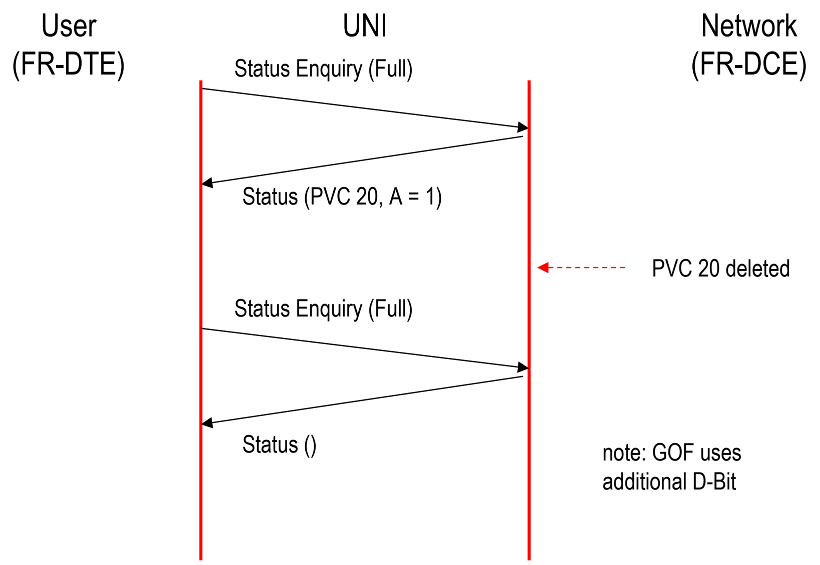
Deleting PVC (ANSI/ITU)



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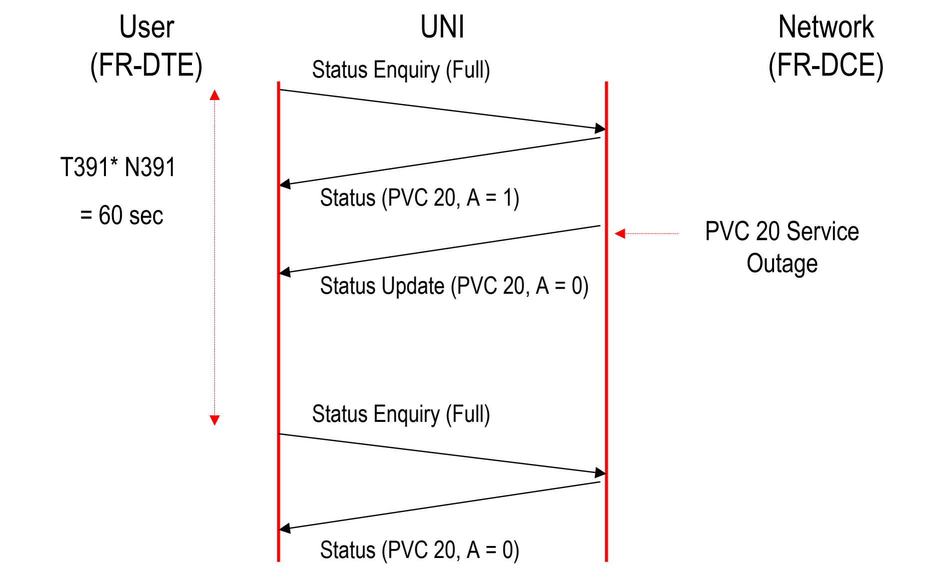
LMI PVC Limitations

- **LMI uses basic transport service on special DLCI**
  - no fragmentation of LMI messages
    - all LMI messages must fit into maximum allowed frame relay frame size
- **Full Status message contains information about all PVC´s**
  - maximum LMI message length means limitation of manageable PVCs on a physical link
    - e.g. 1600 bytes (default GOF, FRF) -> 317 PVC´s max.
    - e.g. 4096 bytes -> 817 PVC´s max.

Asynchronous Update status

- **weakness of LMI status updating**
  - full status only every N391th Status Enquiry
  - worst case for end system to be informed of the inactive status of a PVC -> 60 seconds (using defaults)
- **solution**
  - asynchronous update status messages sent by FR-DCE in case of an event
- **asynchronous update status**
  - contains information about only one PVC (ANSI/ITU)
  - contains information about all concerned PVC´s (GOF)
  - ANSI/ITU and GOF differently implemented

PVC Service Outage (asynchronous)



LMI Format

LMI Message

1	2	1	1	1	1	Variable	2	1
Flag	Frame Relay Header	Ctrl.	Protocol Dis.	Call Ref.	Message Type	Info. Elements (IE)	FCS	Flag

- **LMI Header based on Q.931 ISDN Signaling protocol**
- **Frame Relay Header**
  - GOF -> DLCI 1023
  - ANSI/ITU -> DLCI 0
- **Protocol Discriminator**
  - 00001000 ANSI/ITU
  - 00001001 GOF
- **Control**
  - 0x03 UI
- **Call Reference**
  - 00000000
  - used only for SVC
- **Message Type**
  - 0111 1101 Status
  - 0111 0101 Status Enquiry
  - 0111 1011 Status Update (GOF)

LMI Information Element

General Format IE

8	7	6	5	4	3	2	1
0	Information Element Identifier						
Information Element Length							
Contents of Information Element							

- **Report Type IE**
  - IE Identifier = 00000001 (ANSI)
    = 01010001 (ITU)
  - always first IE of a LMI message (except ANSI -> Locking Shift IE between message type and first IE)
- **Link Integrity IE**
  - IE Identifier = 00011010 (ANSI)
    = 01010011 (ITU)
    = 00000011 (GOF)
  - Keepalive procedure
- **PVC Status IE**
  - IE Identifier = 00000111 (ANSI)
    = 01010111 (ITU)
  - difference between ANSI/ITU and GOF !!!

Report Type IE

General Format IE

8	7	6	5	4	3	2	1
0	Information Element Identifier						
Information Element Length							
Contents of Information Element							

Report Type IE

8	7	6	5	4	3	2	1
0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	1
Report Type Content							

- **Report Type Content:**
  - 00000000 Full Status
  - 00000001 Link Integrity Verification Only (ANSI/ITU); Sequence Number Exchange Message (GOF)
  - 00000010 Single PVC Asynchronous Status (ANSI/ITU)

Link Integrity IE

General Format IE

8	7	6	5	4	3	2	1
0	Information Element Identifier						
Information Element Length							
Contents of Information Element							

Link Integrity IE

8	7	6	5	4	3	2	1
0	0	0	1	1	0	1	0
0	0	0	0	0	0	1	0
Send Sequence Number							
Receive Sequence Number							

- **IE identifier = ANSI style in above example**
- **IE identifier different for ITU and GOF**
- **IE name = Link Integrity IE (ANSI/ITU)**
- **different name used by GOF**
  - Sequence Number Exchange IE

PVC Status ANSI/ITU IE

- **Information Element PVC Status ANSI/ITU**
  - IE Identifier = 00000111
  - Length 3
  - Content:
    - DLCI
    - Status-Bits
      - New (N)
      - Active (A)

PVC Status IE

8	7	6	5	4	3	2	1
0	0	0	0	0	1	1	1
0	0	0	0	0	0	1	1
0	0	DLCI (msb)					
1	DLCI (lsb)			spare			
1	spare		N	0	A	0	

PVC Status GOF

- **Information Element PVC Status GOF**
  - IE Identifier = 00000111
  - Length 6
  - Content:
    - DLCI
    - Status-Bits
      - New (N)
      - Deleted (D)
      - Active (A)
      - Receiver not Ready (R)
      - Priority (P)
    - PVC Bandwidth

PVC Status IE

8	7	6	5	4	3	2	1
0	0	0	0	0	1	1	1
0	0	0	0	0	1	1	0
0	0	DLCI (msb)					
1	DLCI (lsb)				spare		
1	spare		P	N	D	A	R
PVC bandwidth (msb)							
PVC bandwidth							
PVC bandwidth (lsb)							

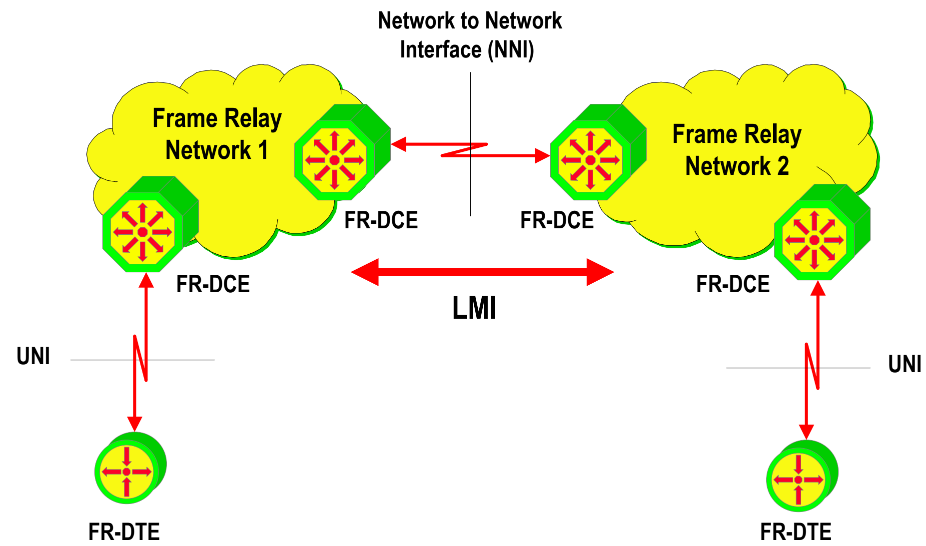
Bi-directional LMI

- **unidirectional LMI procedures sufficient between FR-DTE and FR-DCE (UNI)**
- **unidirectional LMI not sufficient between FR-DCE and FR-DCE (NNI)**
  - PVC status of a multinetwork VC must be reported in both directions
  - therefore symmetrical approach necessary
- **bi-directional LMI is defined on NNI and used**
  - to inform the other frame relay network about the PVC status within the own network

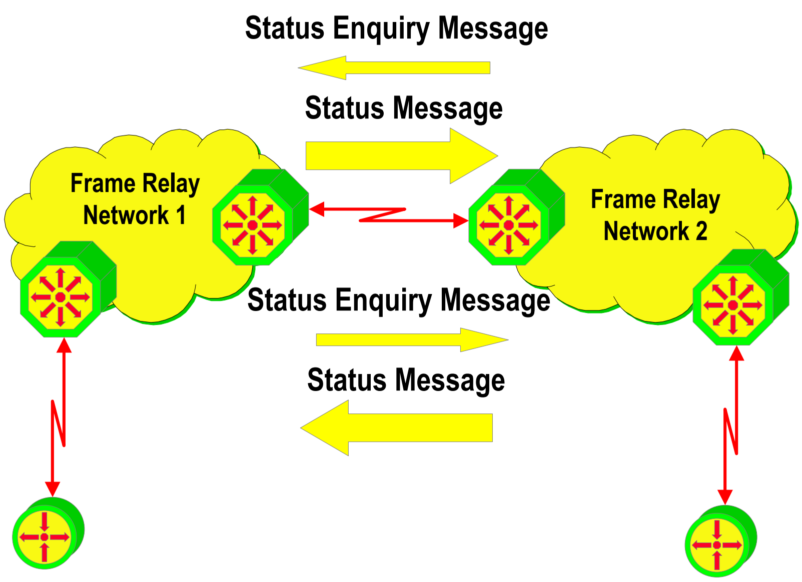
Bi-directional LMI

- **internal communication between switches of one frame relay network guarantees**
  - that information about PVC status (active or inactive) appears end to end to FR-DTEs
- **bi-directional LMI not defined by GOF**
- **two variants available**
  - ITU-T Q.933 Annex A using DLCI 0
  - ANSI T1.617 Annex D using DLCI 0
- **PVC Status Message contain additional fields**
  - inactivity reason, country code, national network identifier, etc.
  - see FRF.2 for details of LMI messages and procedures

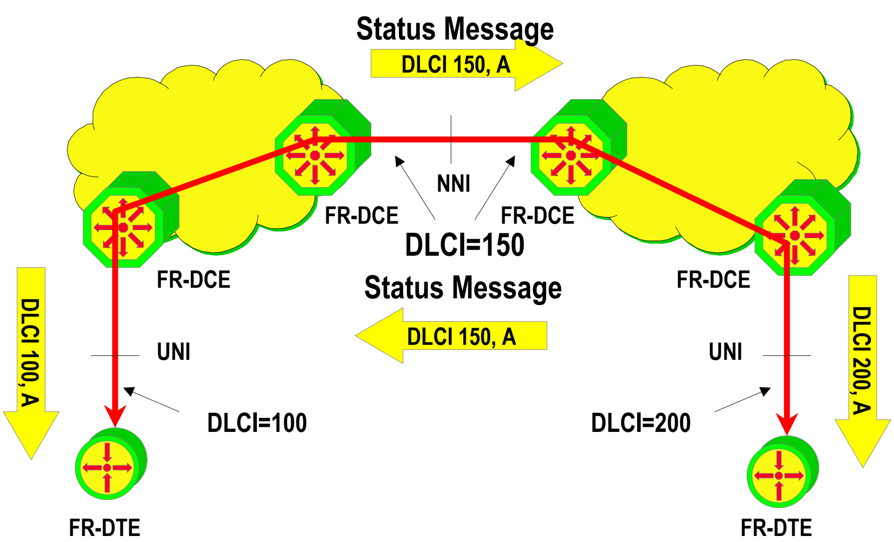
Scope of Bi-directional LMI



Bi-directional LMI Operation



LMI with Multinetwork PVC



Consolidated Link Layer Management

- **approach to overcome problems of congestion management done by FECN, BECN**
  - out-band signaling of congestion
  - independent from data frames
- **optional signaling mechanism developed by ANSI and ITU-T developed**
  - CLLM
  - uses a separate DLCI, number 1023
- **message formats of CLLM**
  - originates from the ISDN implementation
  - LAPD XID frame with Group Identifiers and Group Values

CLLM

- **CLLM messages**
  - are sent by FR-DCE (network) in case of congestion
  - inform FR-DTE (user) about a list of DLCIs that are likely to be causing congestion
  - inform FR-DTE about cause for congestion
- **upon receipt of a CLLM message**
  - user should suspend transmission temporarily
- **CLLM messages may contain**
  - optional list of non-active DLCIs

CLLM Format

LMI Message

1	2	1	1	1	2	Variable	2	1
Flag	Frame Relay Header	Ctrl.	Format ID	Group ID	Group Length	Group Value Field	FCS	Flag

- **Frame Relay Header**
  - ANSI/ITU -> DLCI 1023
  - FECN, BECN, DE don´t care
- **Control**
  - 0xAF (10101111) XID
- **Format Identifier**
  - 10000010 ANSI/ITU
- **Group Identifier**
  - 00001111
- **Group Value Field**
  - 1 octet parameter - ID
  - 1 octet parameter length
  - x octets parameter value

CLLM Group Value Field

General Format
Group Value Field

8	7	6	5	4	3	2	1
0	Parameter Identifier						
Parameter Length							
Contents of Parameter							

- **parameter set ID**
  - Identifier = 00000000
  - Length = 4
  - contents = I122 (IA5-character)
  - always first parameter of CLLM message
- **cause identifier**
  - Identifier = 00000010
  - Length = 1
  - contents = cause of congestion
- **DLCI identifiers**
  - Identifier = 00000011
  - Length = 2n
  - contents = n times DLCI values (list of congested DLCIs)

CLLM Cause Description

- **cause values**
  - 00000010 short term network congestion due to excessive traffic
  - 00000011 long term network congestion due to excessive traffic
  - 00000110 short term equipment failure
  - 00000111 long term equipment failure
  - 00001010 short term maintenance action
  - 00001011 long term maintenance action
  - 00010000 short term congestion - unknown cause
  - 00010001 long term congestion - unknown cause

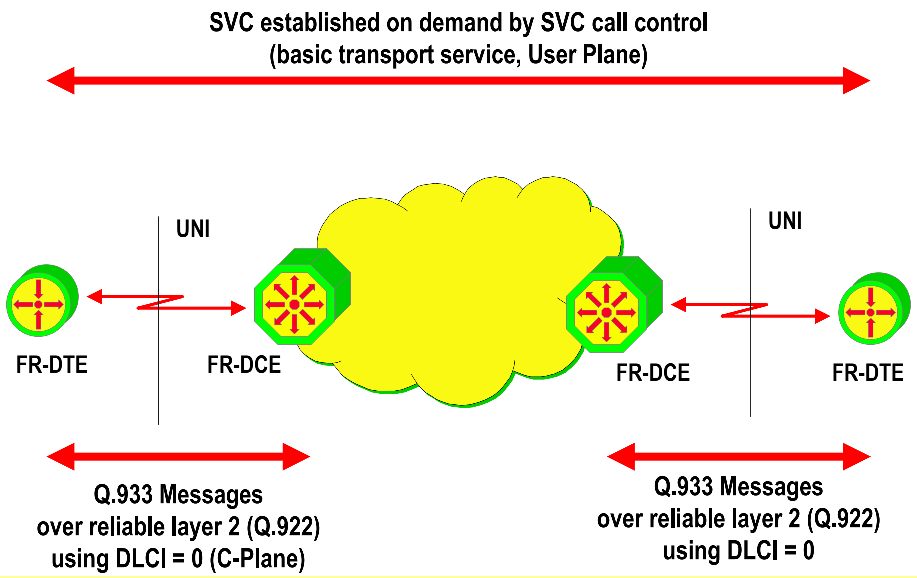
Agenda

- **Overview and Principles**
- **Standards**
- **Frame Relay User Plane**
- **Traffic Management**
- **Local Management Interface**
- **Switched Virtual Circuits**

Switched Virtual Circuits

- most configurations today are hub and spoke
  - peer-to-peer connection not required in most such cases
  - usually route peer-to-peer traffic through hub
  - PVCs are adequate for most such instances
- for temporary peer-to-peer traffic
  - virtual circuits on demand are useful when accounting is based on time of usage
  - SVC frame relay service
- only few switch vendors support FR SVCs today
  - SVC call control procedures must be implemented
- SVC support not defined by GOF

Scope of SVC Call Control



SVC Call Control Layer 2

- **DL control procedures of data link layer protocol ITU-T Q.922, ANSI T1.602/606**
  - reliable delivery of call control messages for call (SVC) establishment and clearing
  - LAPD (Q.921) kind of operation
    - SABME, UA, I, RR, RNR, REJ, DISC, DM, FRMR
    - DLCI used instead of SAPI/TEI
    - no TEI assignment and removal
  - all call control messages are transported in I-frames on single Layer 2 management circuit (DLCI = 0)
    - similar to ISDN Signaling in D - channel
    - call reference field of Q.933 header used to distinguish different calls

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SVC Call Control Layer 3

- **Signaling protocol ITU-T Q.933, ANSI T1.617**
  - procedures for establishing, maintaining and clearing call connections (SVC) at the user network interface (UNI)
  - same message format as for LMI messages
  - additional message types defined for call establishment, call clearing
  - additional information elements defined
  - end systems (FR-DTEs) identified by unique E.164 or X.121 address
  - other relevant standards
    - ANSI T1.607
    - ITU Q.931, Q.951
  - FRF.4 implementation agreement

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Q.933 Format

Call Control Message

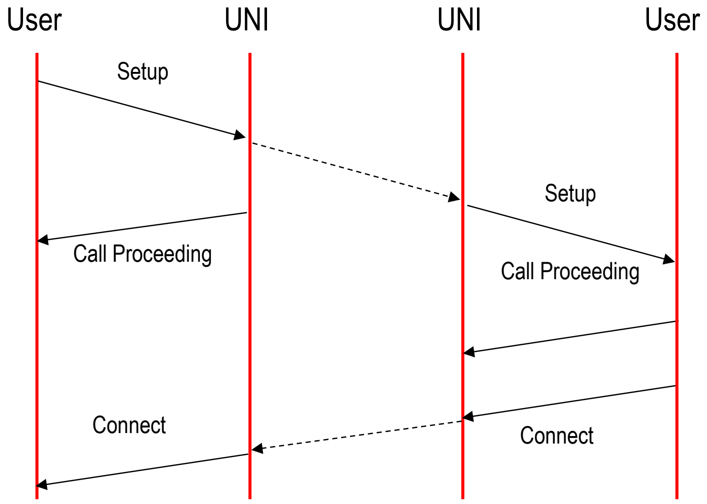
1	2	1	1	3	1	Variable	2	1
Flag	Frame Relay Header	Ctrl.	Protocol Dis.	Call Ref.	Message Type	Info. Elements (IE)	FCS	Flag

- **Frame Relay Header**
  - ANSI/ITU -> DLCI 0
- **Control**
  - I-Frame
  - must be established by SABME and UA before any Layer 3 message can flow
- **Protocol Discriminator**
  - 00001000 ANSI/ITU
- **Call Reference**
  - Multiplexing of calls
- **Message Type**
  - 0000 0000 Call Proceeding
  - 0000 0111 Connect
  - 0000 0101 Setup
  - 0100 0101 Disconnect
  - 0100 1101 Release
  - 0100 1010 Release Complete

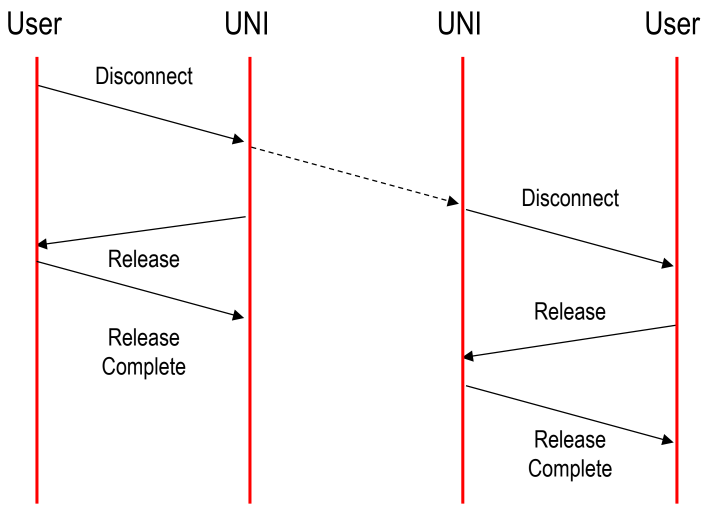
Call Control Messages Types

- **call establishment phase**
  - Setup
  - Call Proceeding
  - Connect
- **call clearing phase**
  - Disconnect
  - Release
  - Release Complete
- **informational phase**
  - Status
  - Status Enquiry

SVC Call Establishment Procedure



SVC Call Disconnect Procedure



Call Control Information Elements IE

- **call establishment phase**
  - Bearer Capability
    - only for consistency with ISDN specifications
  - DLCI Identifier
    - DLCI for SVC
  - Link Layer Core Parameter
    - Quality of Service (QoS)
    - throughput (CIR), Bc, Be,
    - maximum frame mode info field (FMIF, maximum frame size)
  - Calling Party Number/Subaddress
  - Called Party Number/Subaddress
  - Calling Party Subaddress
  - Called Party Subaddress

Call Control Information Elements IE

- **call establishment phase (cont.)**
  - Low Layer Compatibility
    - indication of Layer 2/Layer 3 protocol used by end systems on requested frame relay SVC
  - User-User
    - transparent user to user info during SVC setup
  - Connected Number
    - number of responder to call
  - IE exchange in this phase used for parameter negotiation
    - for example check whether requested CIR can be supported
      - if unable to support requested CIR but able to support CIR larger than minimum acceptable CIR, call is processed
      - if not, call is cleared

Call Control Information Elements IE

- **call clearing phase**
  - Cause
    - reason for SVC clearing
      - idle timer expiry, interface down
      - layer 2 indicates link down, SVCs are de-configured
- **informational phases**
  - Call State
    - Call Initiated
    - Call Present
    - Disconnect Request
    - Release Request

Mandatory/Optional IEs 1

Information Elements	Setup	Call Proc.	Connect	Disconn.	Release	Rel. Cpl.	Status	St. Enq.
Originator	u / n	u / n	u / n	u / n	u / n	u / n	u / n	u / n
Bearer Capab.	m / m							
DLCI	/ m	m / m	m / m					
Link Core Parameter	o / m		m / m					
Calling Number	o / m							
Called Number	m / m							

u ... user, n ... network, m ... mandatory, o ... optional

Mandatory/Optional IEs 2

Information Elements	Setup	Call Prc.	Connect	Disconn.	Release	Rel. Cpl.	Status	St. Enq.
Originator	u / n	u / n	u / n	u / n	u / n	u / n	u / n	u / n
Lower Layer Comp.	o / o							
User- User	o / o		o / o					
Connected Number			o / o					
Cause				m / m	m / m	m / m	m / m	
Call State							m / m	

u ... user, n ... network, m ... mandatory, o ... optional

Summary 1

- **derived from ISDN packet mode bearer service**
- **connection oriented packet switching network using virtual channels**
  - identified by DLCI
- **simplified protocol stack to make it faster than X.25**
  - basic transport service
  - no error recovery
  - congestion indication instead of flow control
- **standards developed by ITU-T/ANSI**
  - implementation agreements by FRF
  - proprietary specifications by GOF

Summary 2

- **traffic management mechanism based on**
  - CIR, Bc, Be (traffic contract)
  - FECN, BECN, DE
  - but traffic management implementation within switches not required by the standard
- **Local Management Interface between end system and network**
  - three variants on UNI, two variants on NNI, be careful
- **PVC operation primarily used**
- **SVC operation defined but not widely implemented nowadays**