Frame Relay

Bigger, Longer, Uncut

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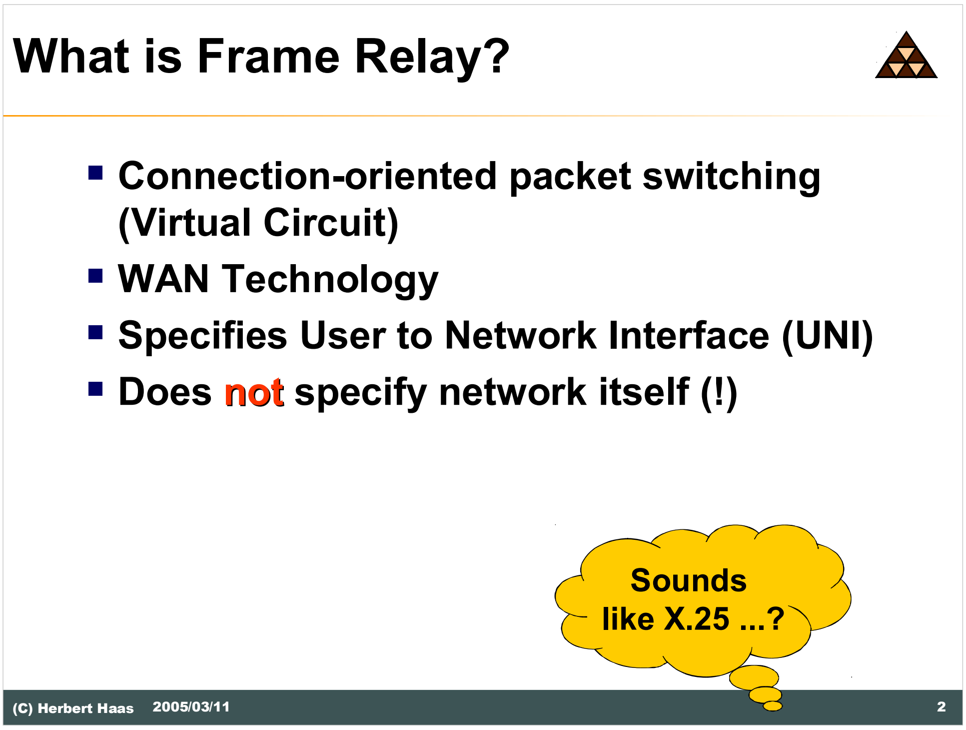

Frame-relay is a technolology that appeared in the beginning of the 1990´s and was developed to replace X25 WAN technology.

Frame-relay like X25 is based on the technique of Virtual Call Service. So Frame-relay is a connection oriented WAN technology, today mainly used as a PVC service instead of leased line services.

Originally, Frame Relay only specifies the User Network Interface (UNI) while the switch-to-switch communication inside the providers cloud is not standardized. In order to support the connection of two different frame relay networks, an Network to Network Interface (NNI) standard was created.

Basic Difference to X.25

- Reduced overhead
  - No error recovery (!)
  - Hence much faster
  - Requires reliable links (!)
- Outband signaling
- Good for bursty and variable traffic
  - Quality of Service *Ideas*
- Congestion control

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The most important difference to X.25 is the lack of error recovery and flow control. Note that X.25 performs error recovery and flow control on each link (other than TCP for example). Obviously this extreme reliable service suffers on delays. But Frame Relay is an ISDN application—and ISDN provides reliable physical links, so why use ARQ techniques on lower layers at all?

The second important difference is that X.25 send virtual circuit service packets and data packets in the same virtual circuit. This is called "Inband Signaling". Frame Relay establishes a dedicated virtual circuit for signaling purposes only.

Thirdly, Frame Relay can deal with traffic parameters such as "Committed Information Rate" (CIR) and "Ecxess Information Rate" (EIR). That is, the Frame Relay provider guarantees the delivery of data packets below the CIR and offers at least a best-effort service for higher data rates. We will discuss this later in much greater detail.

And finally, although Frame Relay does not retransmit dropped frames, the network at least responds with congestion indication messages to choke the user's traffic.

Basically, Frame Relay can be viewed as a streamlined version of X.25, especially tuned to achieve low delays.

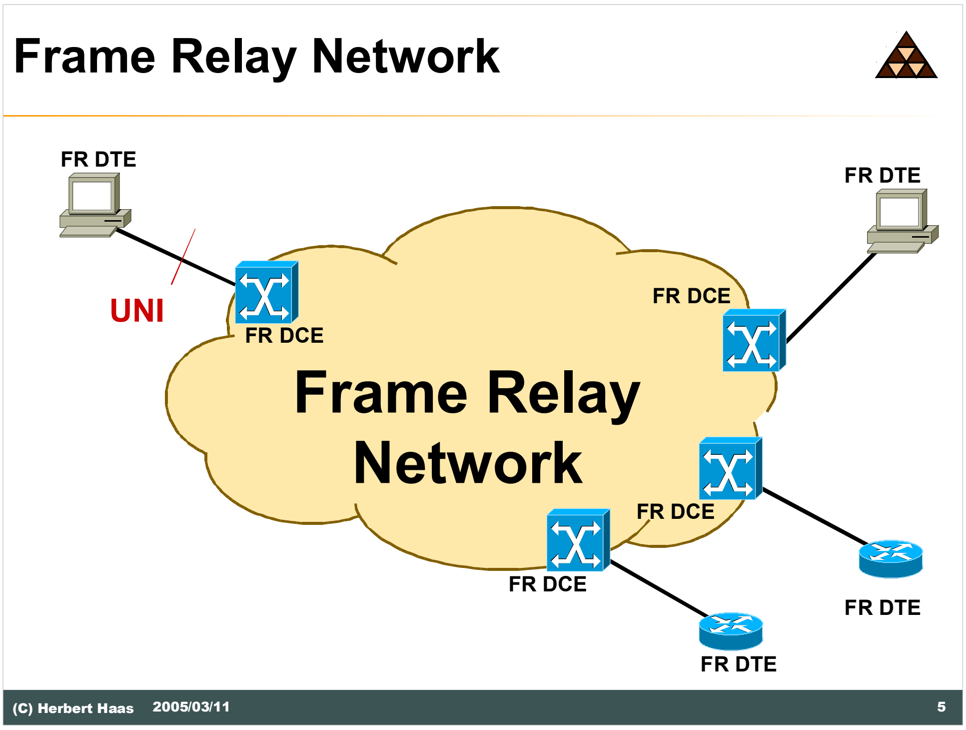
History of Frame Relay

- First proposals 1984 by CCITT
  - Original plan was to put Frame Relay on top of ISDN
  - Slow progress
- 1990: Cisco, Northern Telecom, StrataCom, and DEC founded the Gang of Four (GoF)
  - Focus on Frame-Relay development
  - Collaborating with CCITT
- ANSI specified Frame Relay for USA
- GoF became Frame Relay Forum (FRF)
  - Joined by many switch manufacturers

In 1988 the ITU-T recommendation I.122 had been released, entitled "Frameworking for Providing Additional Packet Mode Bearer Services", today known as "Frame Mode Bearer Service", or simply "Frame Relay". I.233 describes Frame Relay between two S/T reference points.

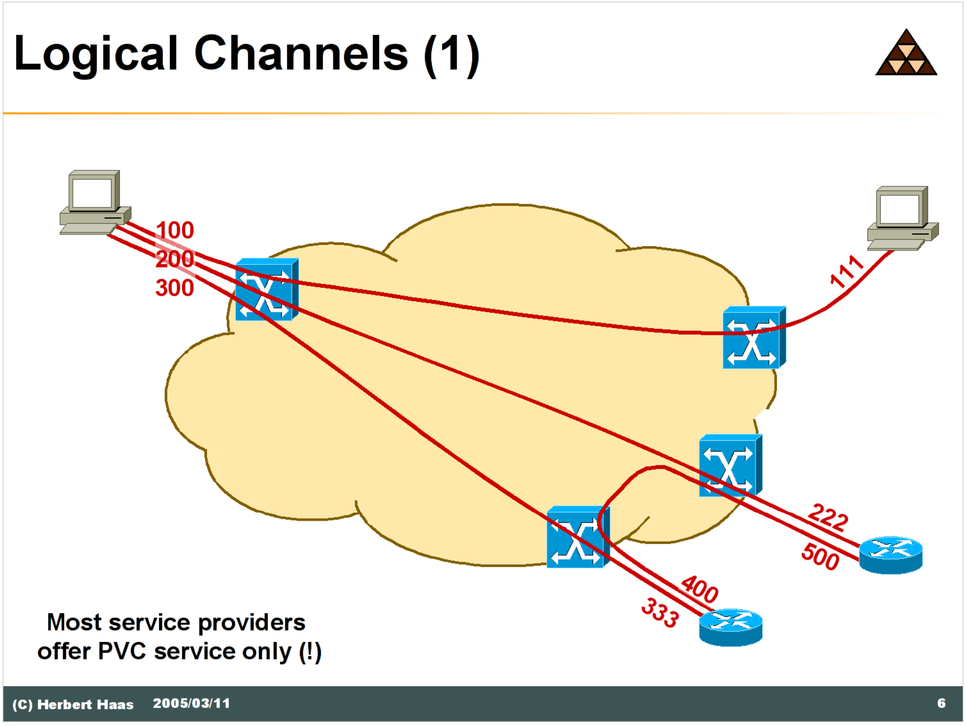
Due to the slow standartization process by the ITU-T formerly the CCITT a private organization the Gang of Four (GOF) or Frame Relay Forum was founded to push the developments of new Frame-relay standards.

Additionally the ANSI came up with its own Frame-relay standards for the US market. Though we have the situation today that there are three different standartization institutes with in some parts of the Frame-relay technique different standards.



The network consists of four components:

1) Data terminal equipment (DTE), which is actually the user device and the logical Frame-relay end-system
2) Data communication equipment (DCE, also called data circuit-terminating equipment), which consists of modem and packet switch
3) Packet Switching Exchange (PSE), or simple: the packet switch itself.
4) The provider cloud which is not covered by the Frame-relay standard



Frame-relay is using virtual circuit identifiers to build up logical channels on one and the same physical Frame-relay connection. The virtual identifiers have local meaning only, that means the must be unique per physical connection only.

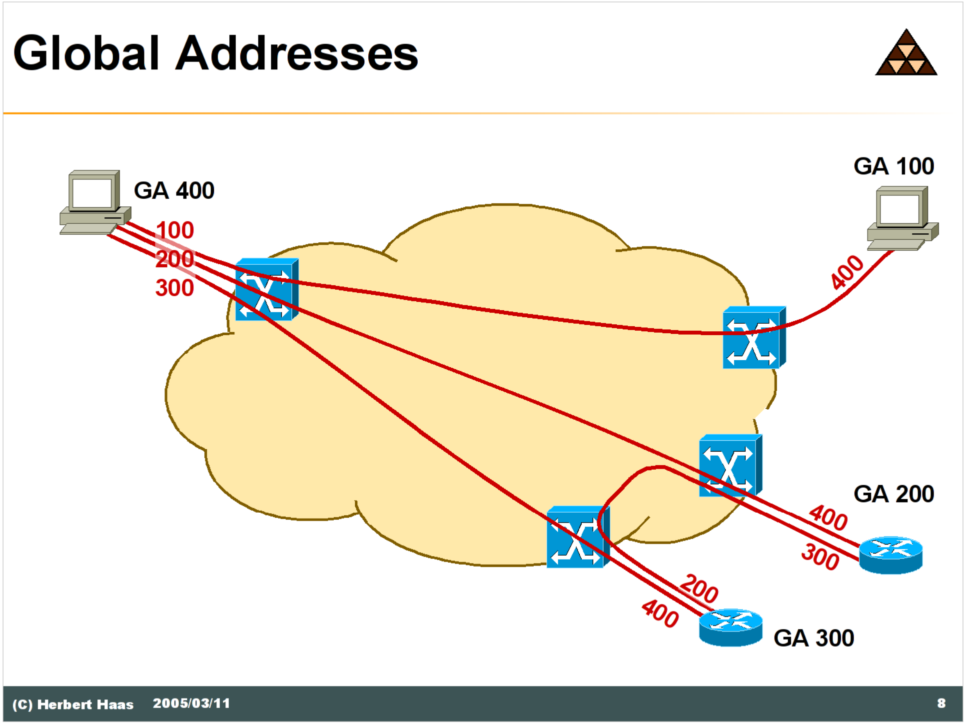
Although Frame-relay SVC service is covered by the standards it is used very little today. Mainly Frame-relay PVC service is used which saves the provider additional costs for signaling and billing procedures required by Frame-relay SVC service.

Logical Channels (2)

- Data Link Connection Identifier (DLCI)
  - Identifies connection
  - Only locally significant
- Some implementation support so-called "Global addresses"
  - Actually also locally significant
  - Destination address = DLCI

The virtual circuit identifiers are called Data Link Connection Identifiers (DLCI) in Frame-relay technique. Ten bit in the Frame-relay header are reserved for the DLCI, so up to 1024 different DLCI values are possible. Some of them are reserved by the different standards for signaling and congestion indication.

Some implementation of Frame-relay even support so called “global addresses”, where the DLCI might be used as a Destination address.



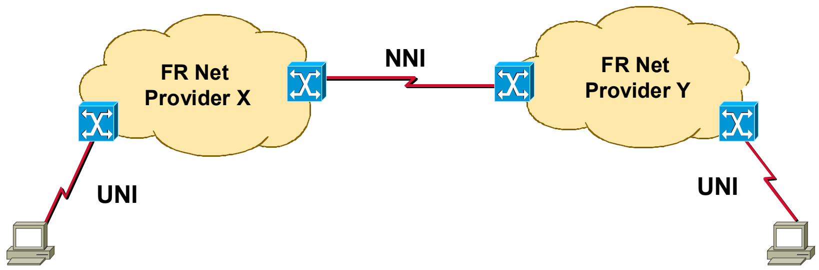
Global Addresses had been introduced with the LMI protocol in 1990 by Cisco Systems, StrataCom, and Northern Telecom and Digital Equipment Corporation (GOF). The LMI global addressing extensions gives DLCI values global rather than local significance. Practically, each DTE within a Frame Relay WAN is assigned an unique global address. Global addressing supports standard address resolution and discovery techniques such that the entire Frame Relay WAN appears to be a typical LAN to the routers (DTEs).

Addressings for SVCs

- (Public) FR networks using SVCs use either
  - X.121 addresses (X.25)
  - E.164 addresses (ISDN)
- Advantage of X.121 addresses:
  - Contain DNICs (Data Network Identification Codes) which are obligatory

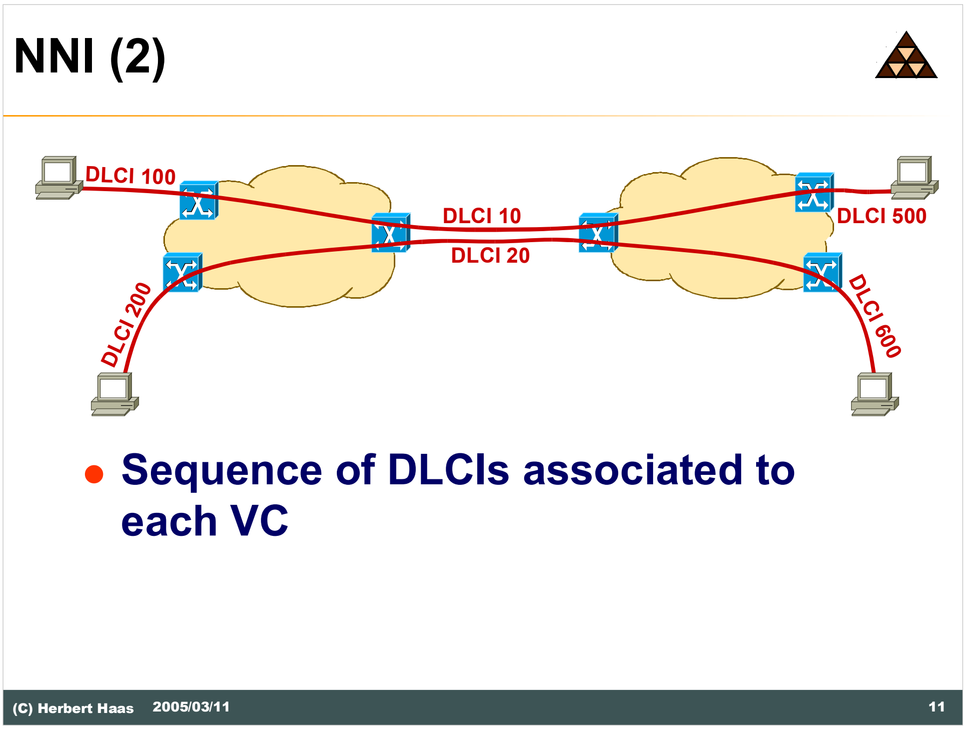
Although only a few service providers offer SVC Frame Relay service it is still possible and part of the standard. In order to establish an SVC a DTE must know a globally unique host address of the destination. Typically, the X.121 or E.164 address plans are also utilized for Frame Relay. Don't confuse X.121 and E.164 addresses with the priviously mentioned global addresses.

NNI (1)



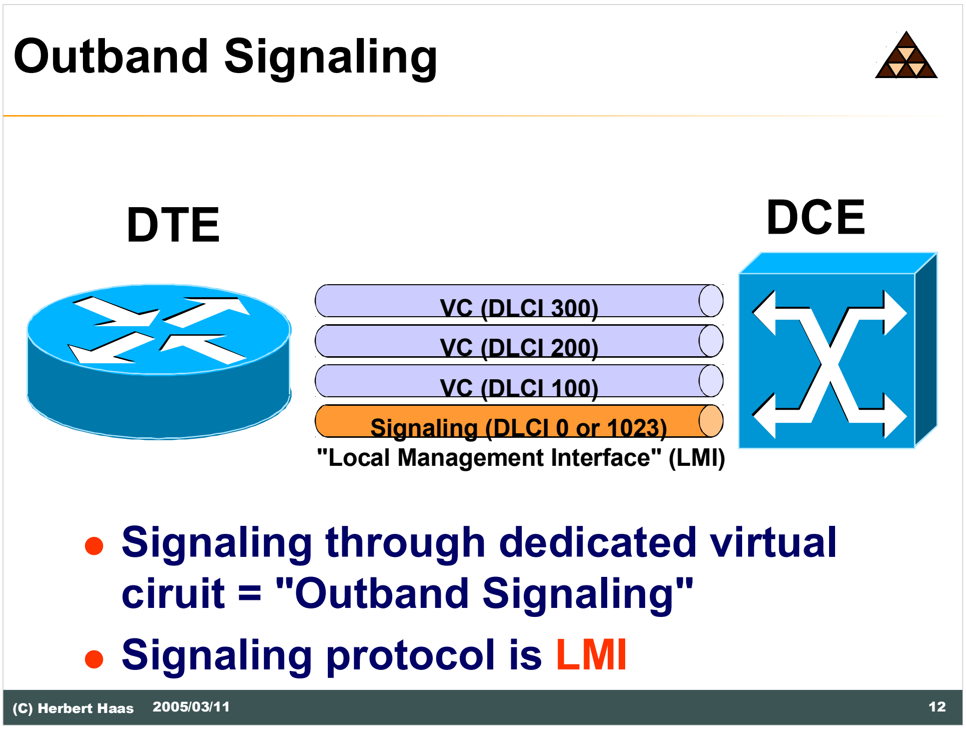
- **NNI had been defined to connect different Frame Relay networks together**
- **Example: Public FR Net with Private**

Due to the fact that the Frame-relay standards to not cover the Frame-relay cloud itself a Frame-relay Network to Network Interface (NNI) was standardized to allow the connection of different Frame-relay networks under the use of different vendor equipment. The NNI interface standardizes the FR-DCE to FR-DCE communication e.g. in the case of connection a private Frame-relay network to a public Frame-relay network.



By the use of the Frame-relay NNI interface a sequence of DLCI´s is established which represent the virtual connection. This means the connection between two FR-DTE´s with each other is determined by a sequence of DLCI´s like in our example DLCI 200 – 20 – 600.

The DLCI number in the Frame-relay header is changed appropriately by the UNI and NNI interface, when a Frame-relay frame travels through the network.



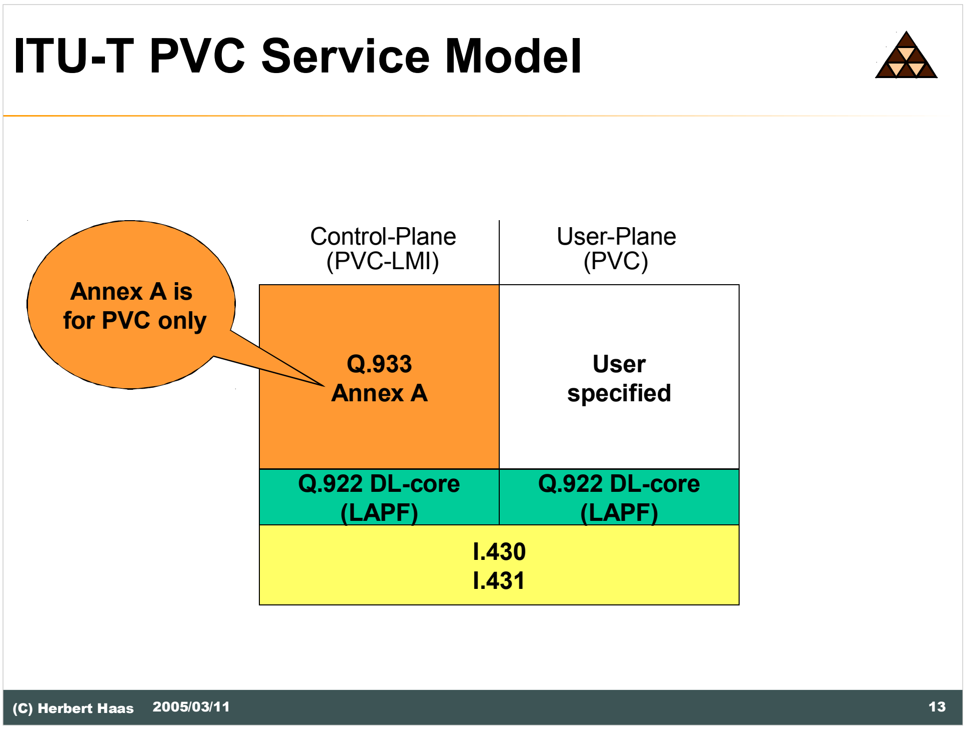
The Local Management Interface (LMI) was developed to inform the Frame-relay users about the condition of the Frame-relay network itself.

With the LMI protocol the addition, deletion and status of DLCI´s can be announced by the Frame-relay provider to the users.

Unfortunately LMI is differently implemented by the standardization organizations. All of them use LMI out-band signaling but on different DLCI´s and with partly different functionality.

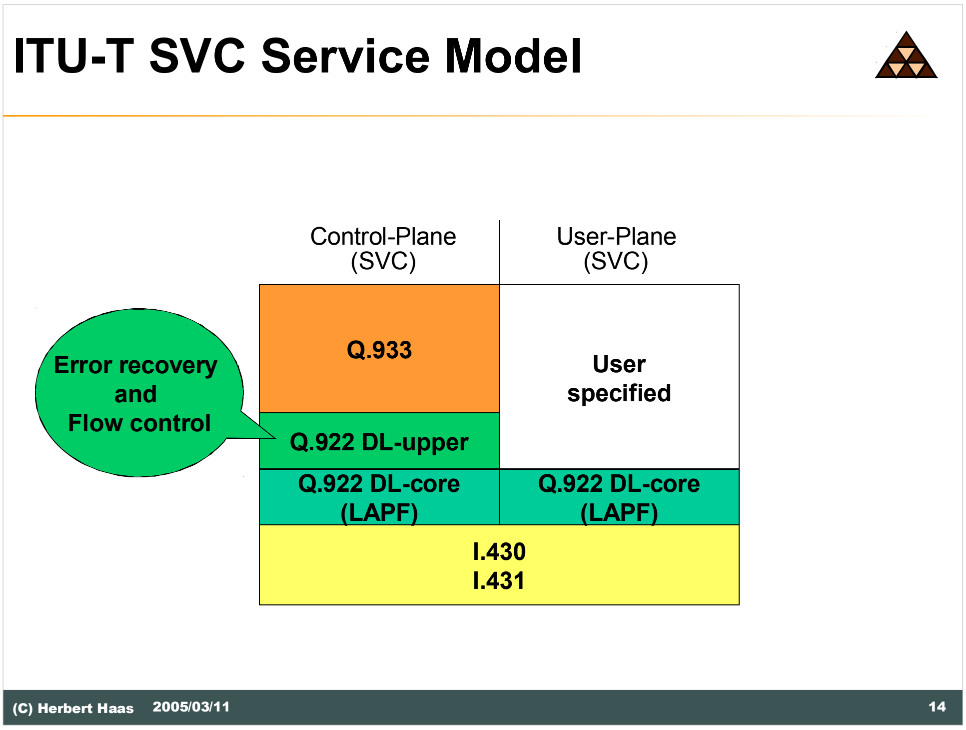
The ITU-T with its Q922 Annex A standard is using DLCI 0 as well as the ANSI with its T1.617 Annex D. Both standards only allow the announcement of addition deletion and the status (active or inactive) of a PVC.

The FRF uses DLCI 1023 for LMI service and allows additionally the announcement of bandwidth and flow control parameters.

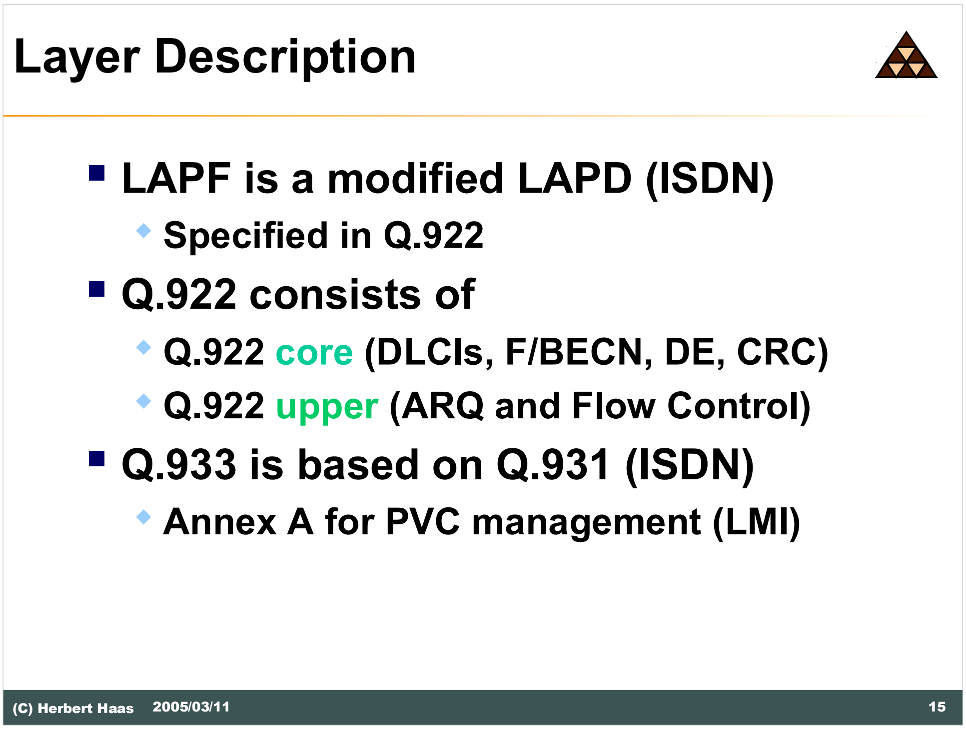


Every protocol that employs outband signaling has a vertically divided layer architecture. Here the left part (in the slide above) correspond to the layers used for outband signaling while the layer stack on the right hand handles data packet delivery through virtual circuits. Additionally, the outband path is called the "Control Plane" and the data-VC path is called the "User Plane". Take it as it is.

Most Frame Relay service providers only offer so-called "Annex-A" service, in other words they only support PVCs with LMI support.



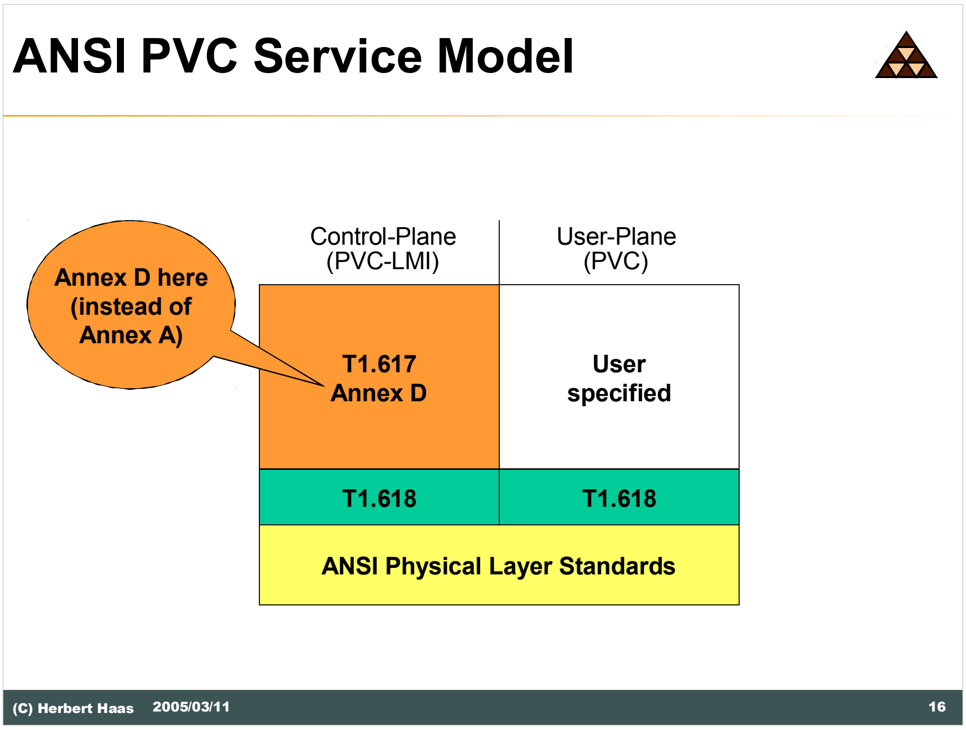
But Frame Relay can also support SVC services. In this case we don't use Annex A but rather plain "Q.933". Furthermore SVC mode requires a reliable Q.922 connection to the DCE, which is handled by the so-called "Q.922 DL-upper". The Frame Relay layer itself is the Q.022 DL-core layer, which must be always existent.



The Link Access Procedure Frame-relay (LAPF) is a modified variant of the Link Access Procedure D-channel (LAPD) used on the D-channel by ISDN to reliable transport Q931 signaling messages.

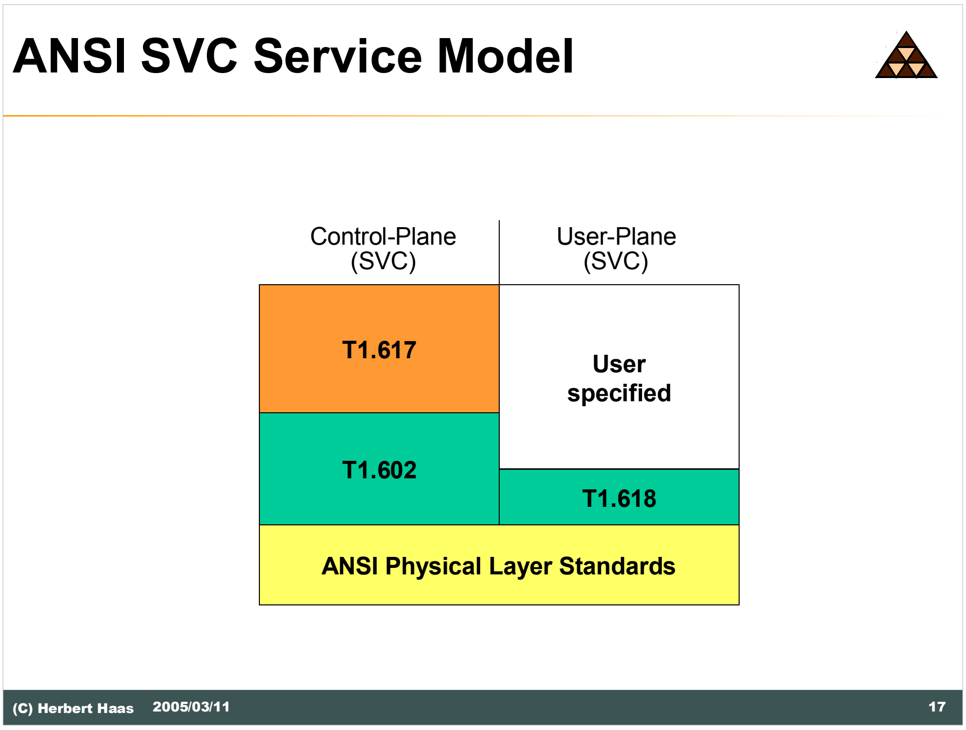
The LAPF protocol is divided in two sub variants, the Q922 core which is used for PVC service with LMI status reports, and the Q922 upper used with Frame-relay SVC technique for the reliable transport of Q933 Frame-relay signaling messages.

The Q933 is based on the Q931 signaling protocol and it supports the connection setup and tear down of Frame-relay SVC´s by the help of E164 or X121 addresses. The Q933 Annex A is used in combination with PVC services only.



In this slide the corresponding standards of the ANSI committee for Frame-relay PVC service can be seen. The ANSI standard T1.618 describes the basic Frame-relay frame with DLCI, BECN, FECN, etc. and it corresponds to the Q922 core standard from the ITU-T.

The T1.617 Annex D standards describes the LMI service and can be seen equivalent to the Q933 Annex A standard from the ITU-T.



The ANSI T1.602 standard is equivalent to the ITU-T Q922 core + upper standard and supports the reliable transport of signaling messages to set up Frame-relay SVC´s.

The T1.617 is equivalent to the Q933 standard and uses E164 and X121 addresses for the set up of SVC´s.

ANSI Layer Description

- T1.602 specifies LAPD
  - Based on Q.921
- T1.618 is based on a subset of T1.602 called the "core aspects"
  - DLCIs, F/BECN, DE, CRC
- T1.617
  - Signaling specification for Frame Relay Bearer Service
  - Annex D for PVCs (LMI)

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This is a summary of the ANSI Frame-relay standards discussed so far.

Frame Relay Forum (FRF)

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

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This list gives us an overview of the standards published by the FRF.

The FRF.1.1 standard describes the UNI interface and can be seen in combination with the FRF.4 standard as an equivalent to the Q922, Q933 standard of the ITU-T.

The FRF.2.1 standard specifies the connection of Frame-relay DCE to DCE for mixed vendor support.

The FRF.11 describes the direct transport of voice on top of Frame-relay frames and the FRF.12 deals with fragmentation. The FRF.11 and the FRF.12 are needed in combination to establish voice over Frame-relay networks.

Voice over FR

- **VoFR Standard FRF.11 (Annex C)**
  - **Multiple subframes in a single FR-Frame**
  - **30 Byte Voice Payload per subframe**
  - **Additional identifier CID (Channed ID) to identify separate streams**
  - **Dedicated CID for signaling (Cisco: CID 0)**
- **Voice + Data in same PVC: Delay Problem**
  - **Solution: FRF.12 (Fragmentation)**
  - **Data packets are fragmented and interleaved with voice packets**
  - **Voice-frames should keep "inter-frame-delay" <10ms**
  - **Adjustments of fragment-size based on AR**
    - **Cisco: fr-fragment-size**

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The FRF.11 standard describes how multiple voice communication channels can be transported across a Frame-relay network. The voice channels are packed into separate subframes, of up to 30 byte in length ,with an additional FRF.11 header in front of them. The FRF.11 header carries a Channel ID (CID) which is needed to distinguish between the different voice channels. Several subframes can be transported by one Frame-relay frame depending on the maximum allowed frame size.

Here the FRF.12 standards comes into play, because the size of the Frame-relay frames needs to be reduced to adopt to the delay and jitter requirements needed by voice communication. Normally Frame-relay depending on the standard allows max. payload sizes between 1600 to 8192 bytes. In Voice over Frame-relay systems the maximum payload size is configurable between 16 and 1600 bytes. Cisco uses a default value of 53 bytes.

Physical Interfaces

- Some UNI Specifications (FRF.1)
  - ITU-T G.703 (2.048 Mbps)
  - ITU-T G.704 (E1, 2.048 Mbps)
  - ITU G.703 (E3, 34.368 Mbps)
  - ITU-T X.21
  - ANSI T1.403 (DS1, 1.544 Mbps)
  - ITU-T V.35
  - ANSI/EIA/TIA 613 A 1993 High Speed Serial Interface (HSSI, 53 Mbps)
  - ANSI T1.107a (DS3, 44.736 Mbps)
  - ITU V.36/V.37 congestion control

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Frame-relay is a typical Data-link technology which can be used on top of many different layer 1 techniques. In this graphic a short overview of the most common used layer 1 techniques in combination with Frame-relay is shown.

Layer 2 Tasks

- **Q.922 Annex A (LAPF) or T1.618 specifies**
  - **Frame multiplexing according DLCI**
  - **Frame alignment (HDLC Flag)**
  - **Bit stuffing**
  - **16-bit CRC error detection but no correction**
  - **Checks minimum size and maximum frame size**
  - **Congestion control**

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The Q922 Annex A or the T1.618 ANSI cover following tasks:

•Both describe the multiplexing of different communication channels on one physical connection by the help of the according DLCI.

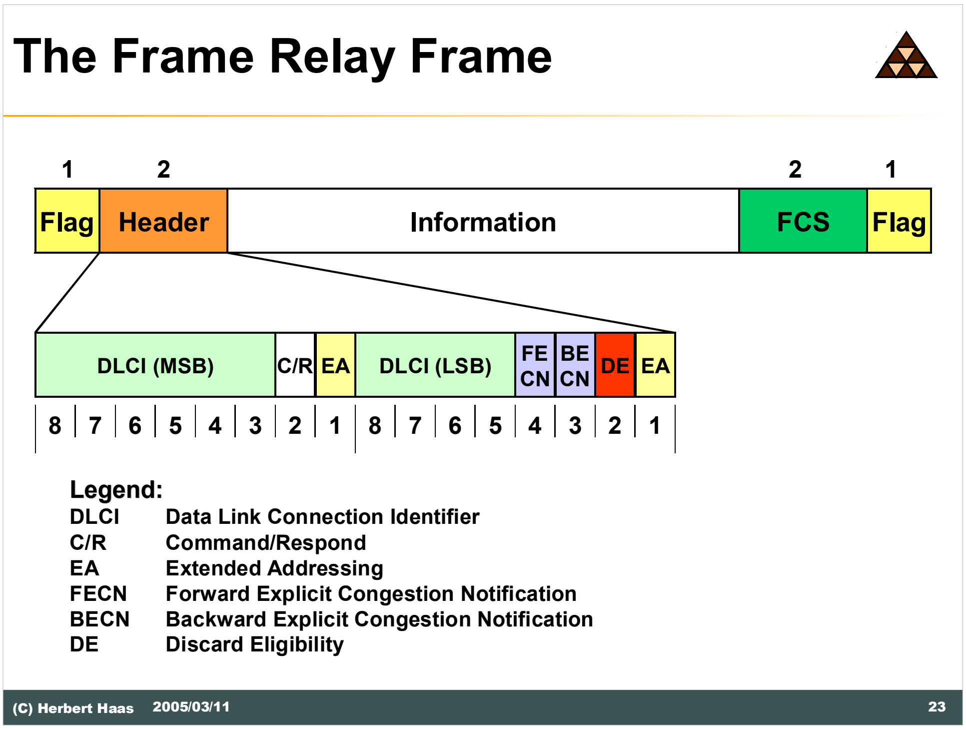
•Frame alignment which means start and end of frame detection plus synchronization with the help of the HDLC flag.

•Bit stuffing to prevent the appearance of the Flag bit pattern inside the payload area of the frame.

•16 bit Cycle Redundancy Check for error detection inside the Frame-relay network. Frames in error will be discarded only, there are no error recovery functions implemented.

•Determination of maximum and minimum Frame-relay frame sizes depending on the configurations (e.g. voice)

•Congestion control and indication with the help of the FECN, BECN bits or the CLLM system.



The DLCI field length is typically 10 bits. Optionally, it can be extended using the EA bit (max 16 bits according FRF and GOF). The EA bits are used such that the first and middle DLCI address octets are indicated by EA=0 whereas the last address octet is indicated by EA=1.

Note that the second address octet always contains:

•The FECN, BECN, and DE bit. Currently only 10 bit DLCIs are supported, but the EA flag allows the use of longer DLCIs in the future. Today, MPLS utilizes the Extended Address field of the FR header.

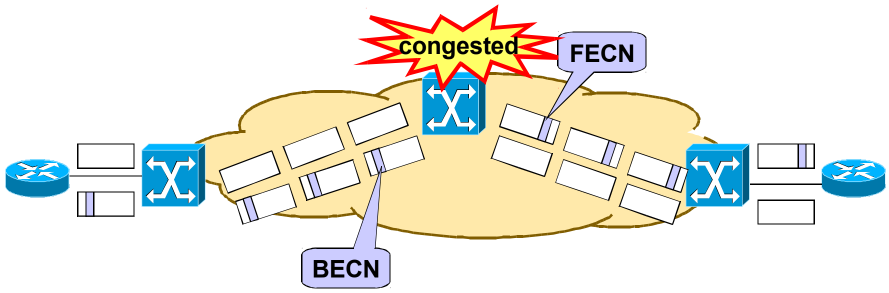
•The C/R bit is a rudimentary bit, inherited from HDLC. It is not used within Frame Relay!

According to FRF, the maximum length of the information field is 1600 bytes. The other standards allow lengths up to 8192 (theoretically) but the CRC-16 only protects 4096 bytes. Practically, maximimum frame siztes of up to 1600 bytes are used.

The usage of the FECN and BECN bit is explained in a few seconds...

Congestion Control (1)

- **FECN indicates congestion to the receiver**
- **BECN indicates congestion to the sender**
- **Problem: DTEs do not need to react (!)**



The Frame-relay network is able to indicate congestion situations to its users by the help of the BECN and FECN bit located in the Frame-relay header.

With the help of these two bits not only a congestion situation but also the direction of the congestion can be indicated. In the direction of the congestion the FECN bit in the Frame-relay header of the by passing packets is set, by the congested Frame-relay switch, while in the opposite direction the BECN bit will be set.

Congestion Control (2)

- Routers can be configured to react upon receiving a BECN
- Only a few higher layer protocols react upon receiving a FECN
  - Only some OSI and ITU-T protocols
  - TCP does not

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So the sender will receive its packets with the BECN bit set while the receiver receives packets with the FECN bit set. Now its completely up to the sender to reduce the amount of traffic it injects (traffic shaping configurable by software).

Typically routers do not react on the receive on packets with the FECN bit set. But in the case that there is no return traffic, routers can be configured to send dummy Frame-relay packets back to the sender to allow the BECN bit to be set.

CLLM

- Consolidated Link Layer Management
- ITU-T and ANSI development
- Optional out-band signaling for congestion indication messages
  - DLCI 1023
- Before congestion, DCE sends CLLM message to DTE
  - Associated DLCIs specified

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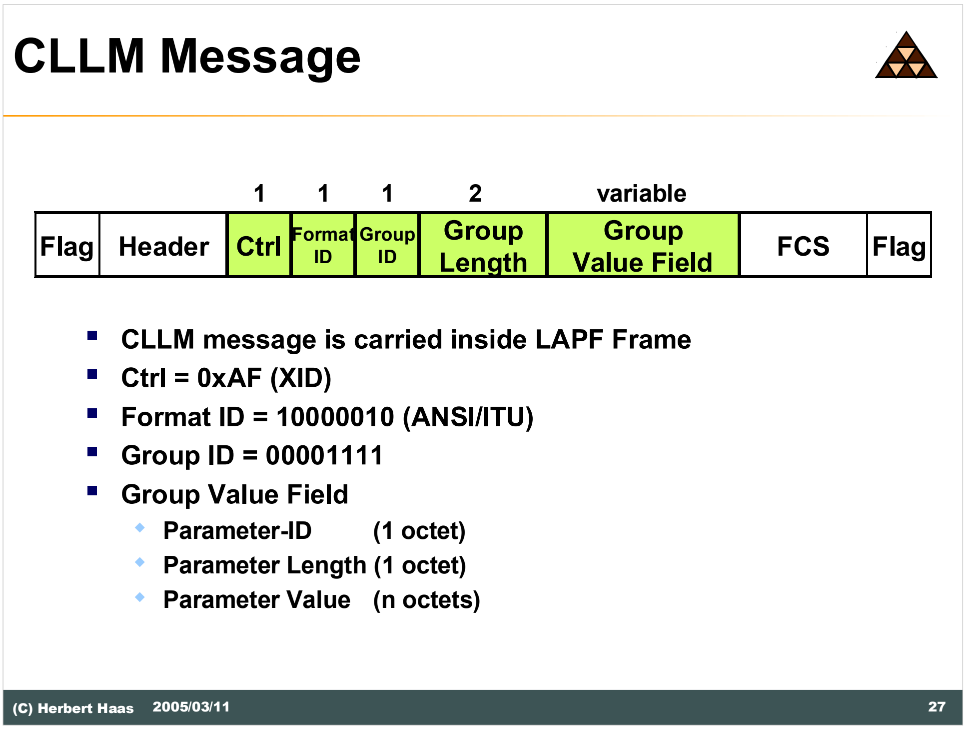
The Consolidated Link Layer Management was developed by the ITU-T and ANSI to provide a more sophisticated tool for congestion indication.

An additional out-band channel (DLCI 1023) is used to actively signal congestion situation towards the users, before the congestion actually happens.

Compared to the FECN and BECN bit which is based on reactive congestion indication CLLM provides a proactive congestion indication tool.



This is an example of an CLLM message carried inside an LAPF frame.

The control field is set to 0xAF which corresponds to an Exchange Identification (XID) message. The Format ID field indicates the standardization organizations.

The group ID and the group value field inform which DLCI´s are congested and apart from congestion indication CLLM is also able to inform the users about the cause of congestion e.g. short term network congestion due to excessive traffic or long term equipment failure.

Traffic Control

- Statistical multiplexing is cheaper for service providers than deterministic-synchronous multiplexing
- Users are supposed to require less than the access rate on average
- Otherwise congestion will occur and frames are dropped
  - Which causes the end-stations to retransmit...and further overload the network

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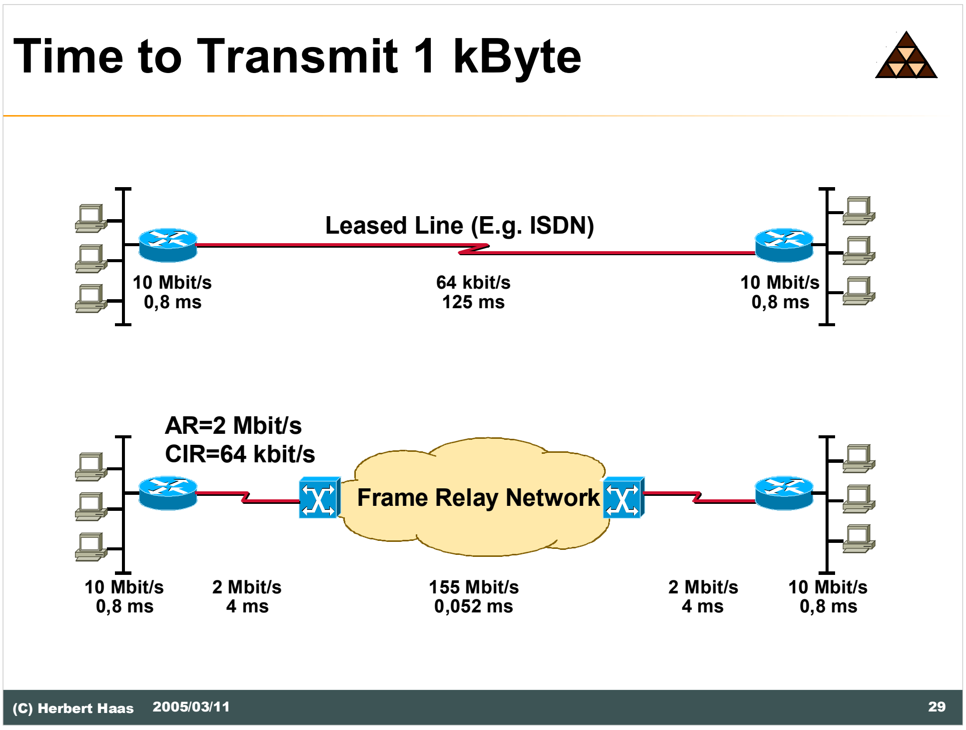
The traffic control in Frame-relay is based on statistical TDM where connections are typically dimensioned on the average traffic needs of all connected users. The service providers try to take advantage of the users traffic behavior, because its very unlikely that all users at the same time use their complete access rate towards the provider.

But nevertheless if congestion happens frames are dropped by the Frame-relay switches, which causes retransmissions by the end-stations due to the use of error recovery functions on higher network layers e.g. TCP. This behavior my lead to an further overload of the network.



In this example we want to show the advantages of Frame-relay compared to leased line services.

In the case of a leased line connection the bandwidth and therefore the capacity and the delay of a connection is fixed.

In Frame-relay we will find several values which determine the properties of a Frame-relay connection. The Committed Information Rate (CIR) that is agreed between provider and customer is based on the average usage of the connection. This is what the customer pays for. The actual physical Access Rate supplied by the provider is typically higher than the agreed CIR.

This means in our example the customer gets the same guaranted bandwidth of 64 Kbit/s as in the leased line example, but has a much smaller delay because of the 2 Mbit/s access rate towards the service provider. In times of low provider network utilization (maybe during the night) the customer may even try to send more than the agreed 64 Kbit/s.

Practically Frane Relay is more cost effective rather than cheap.

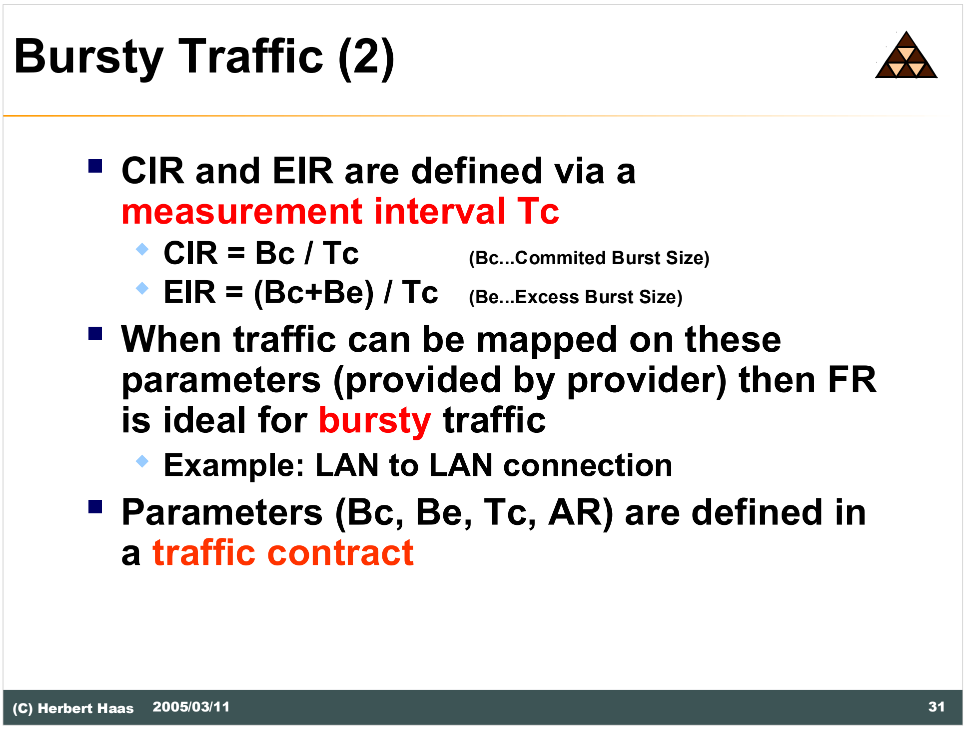
Bursty Traffic (1)

- FR allows to differentiate between Access Rate (AR) and Commited Information Rate (CIR)
  - CIR corresponds to average data rate
  - AR > CIR
- Sporadic bursts can use line up to AR
- Optionally limited by Excess Information Rate (EIR)

As already discussed before the main parameters that determine the transport capacity of a Frame-relay connection are the physical AR, the CIR and the Excess Information Rate (EIR).

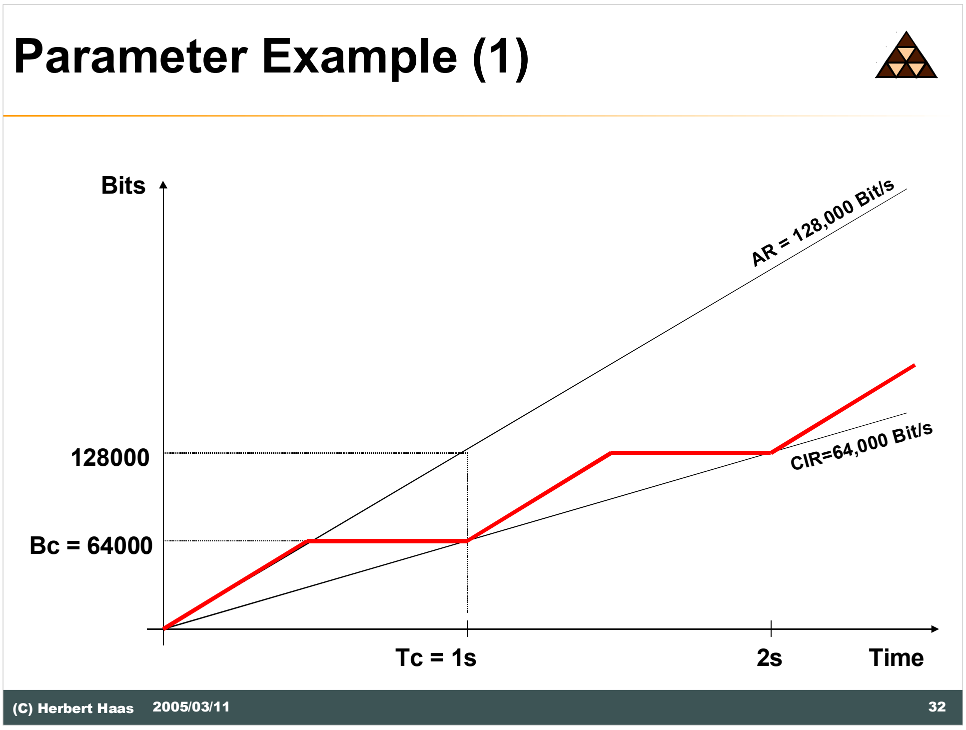
Typically the capacity of the CIR is guaranteed by the service provider at any time. In burst situations the customer may try to send more data than the CIR allows, but for this additional data no guarantees for delivery are given by the service provider.

Most service provider allow over utilization up to the AR, some others may limit the over utilization with a separate traffic parameter called the EIR.

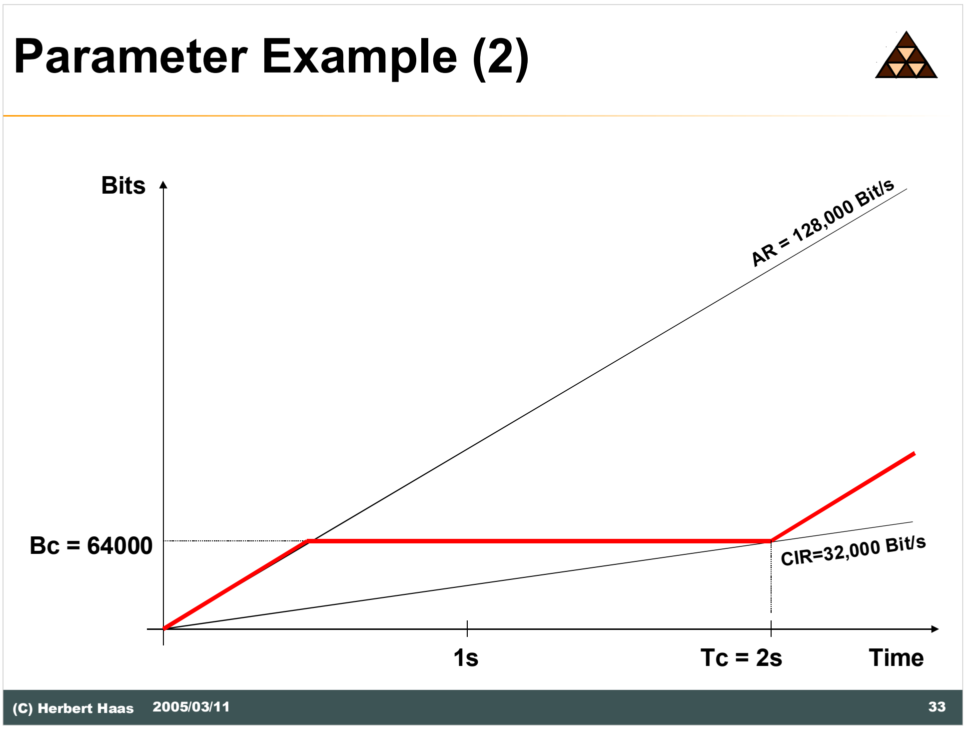


The CIR and the EIR are defined via a measurement time interval Tc, which is set to 1 second in most cases. The committed burst size Bc defines the amount of bits per Tc with guaranteed delivery. The Excess Burst Size Be specifies the maximum allowed oversubscription of bits per Tc, for which the delivery will not be guaranteed.

All of these parameters plus the physical AR need to be negotiated with the service provider and are written down in a traffic contract.

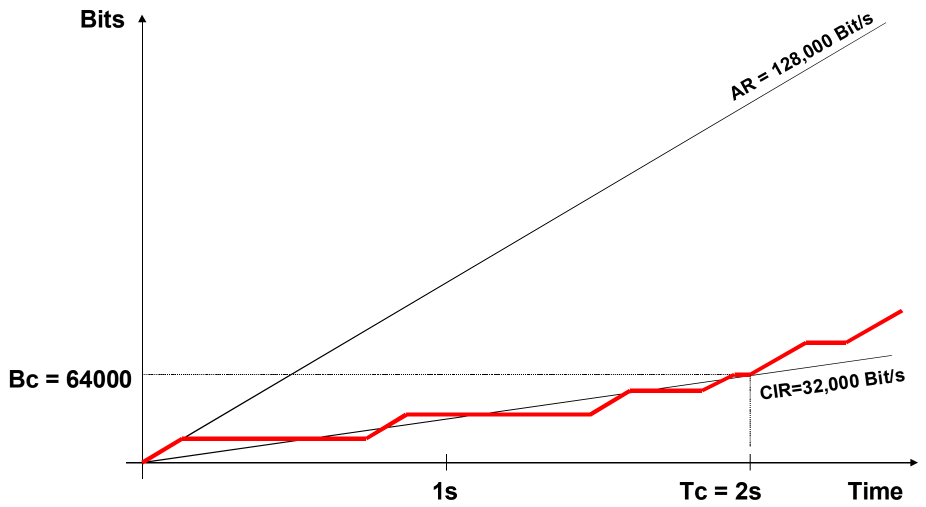


In this example the measurement time interval Tc is set to 1second, the Bc to 64000 bits and the physical access rate is 128 Kbit/s. The red line indicates the actual traffic pattern used on this connection. In this scenario the traffic characteristic remains within the CIR of 64 Kbit/s.



In this scenario a measurement interval Tc of 2 seconds is chosen. The committed burst size Bc is 64000 bits, so the CIR according to the formula *CIR = Bc / Tc* will be 32 Kbit/s. The actual traffic pattern indicated by the red line remains again within the borders of the CIR.

Parameter Example (3)



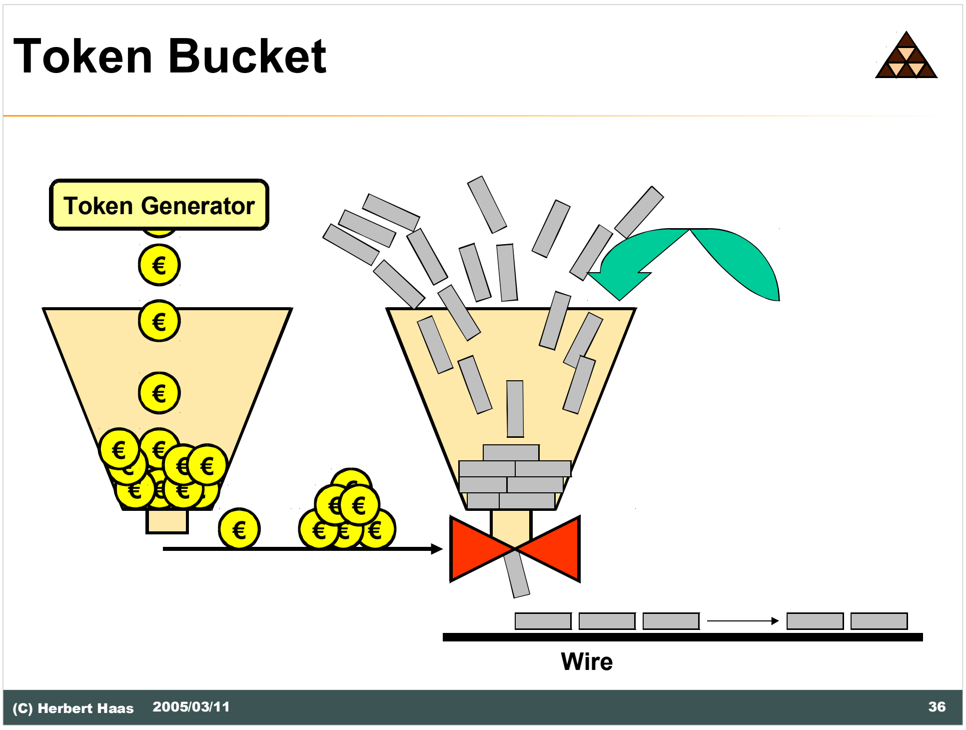
This example shows a more realistic scenario with a lot of small data bursts which in sum do not exceed the CIR. Actually router manufactures use a burst interval much smaller than the Tc. For example a cisco router per default would send out small data burst every 125 milliseconds on a Frame-relay connection. The maximum size of these bursts is calculated from the parameters Tc, Bc, Be and AR which are defined in the traffic contract.

Traffic Management

- **Traffic Shaping**
  - **Users task**
  - **Goal: smooth traffic profile, mitigiate bursts**
  - **Token bucket methods**
- **Traffic Policing**
  - **Provider's task**
  - **Goal: Drop (excess) frames violating the traffic contract**

Traffic shaping according to the negotiated parameters is in the responsibility of the end users. End users traffic that is outside the traffic contract will be discarded by the first Frame-relay switch in the providers network.

So its for the benefit of the user itself to smooth and shape its traffic according to the parameters. Traffic shaping according to the token bucket method might be used to achieve this goal.



The token bucket method consists of a token bucket and a data bucket. The valve of the data bucket, which controls the amount of data that can be sent out, can only be opened by inserting a token. This means data can only be sent if there are tokens available in the token bucket.

The token generation in the token bucket is done according to the Frame-relay traffic parameters. So these tokens guarantee that the negotiated traffic parameters will not be hurt by the user.

Traffic Shaping

- TB = Token Bucket (=Bc+Be)
- Maximal speed = TB/Tc
- Typically, traffic above maximal speed is buffered in a traffic shaping queue

So the size of the token bucket itself corresponds to the value of *Bc* + *Be* and the rate of token generation corresponds to the term *Bc* + *Be* / *Tc*.

Traffic Shaping for Voice

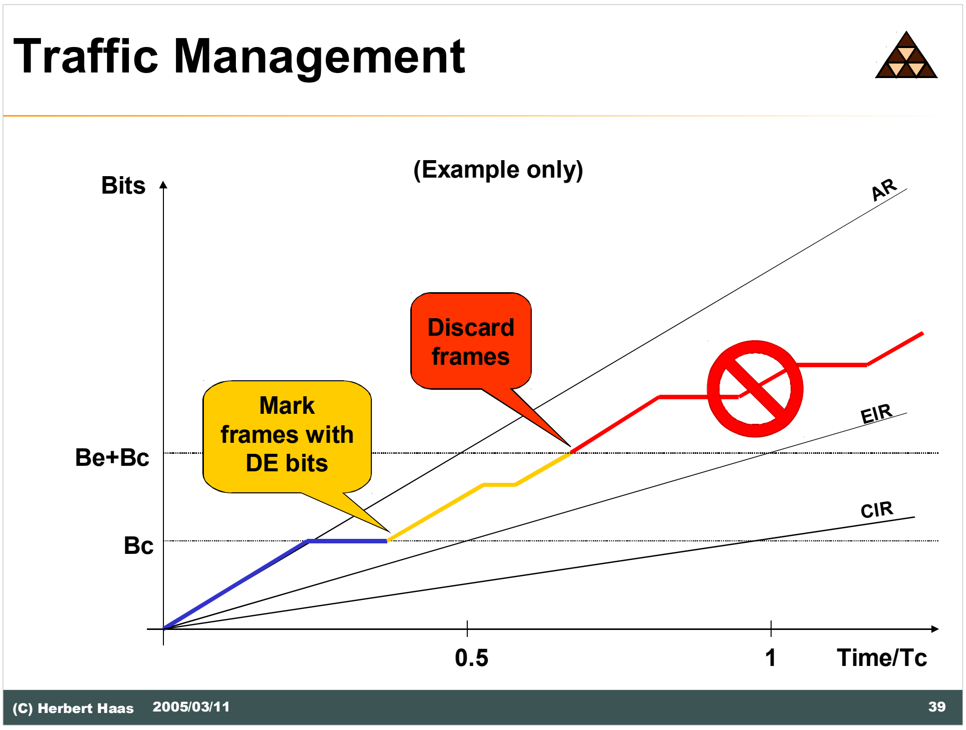
- **Tc<=10ms**
  - **Provides continuous traffic flow**
- **Additionally BECN can be used to decrease CIR**
  - **Cisco: MinCIR – Traffic shaping not calculated using provider-CIR but for higher values**
  - **On receiving of BECN traffic-rate is reduced to MinCIR (= Provider CIR)**
- **Cisco Proactive Trafficshaping: "Forsight"**
  - **Throttles traffic before congestion occurs**
  - **Only supported on Cisco FR-Switches**

Traffic shaping for voice is much more delay and jitter sensitive than for data. To accomplish to the needs of voice Tc is set from 125 milliseconds used for data to a value below 10 milliseconds to generate a continuous traffic flow with minimum jitter. These needs to be done obviously in combination with the configuration of smaller datagram sizes between 50 to 100 bytes.

In the case of congestion, indicated by the BECN bits in the header, the traffic rate is reduced, if traffic shaping is switched on. The way the router shapes can be adjusted on cisco devices by the help of the *mincir* and the *cir* parameter. Typically the *cir* parameter is set to the EIR or AR and the *mincir* parameter is set to the CIR.

Under normal conditions the router will send out data with the rate of the *cir* parameter (EIR or AR) and in case of BECN bits the router will gradually reduce the speed until the *mincir* parameter (CIR) is reached.

Cisco has also developed a proprietary method for Frame-relay traffic shaping called foresight, which allows proactive traffic shaping even before the actual congestion occurs. By the use of foresight the Frame-relay switch is able to determine the maximum data rate that might be used by the Frame-relay DTE. This technology can only be used between Cisco routers and Cisco (former StrataCom) Frame-relay switches.

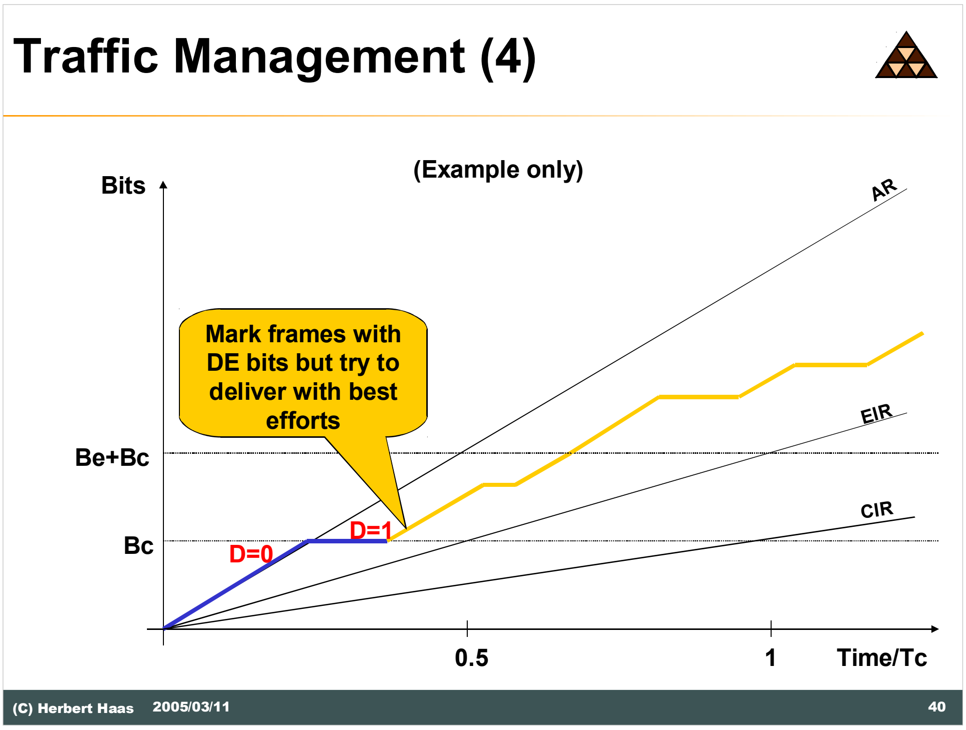


This example shows us what might happen if more traffic is injected than the Frame-relay traffic parameters allow. Obviously the behavior in real life is completely up to the traffic contract negotiated and might be different from our scenario.

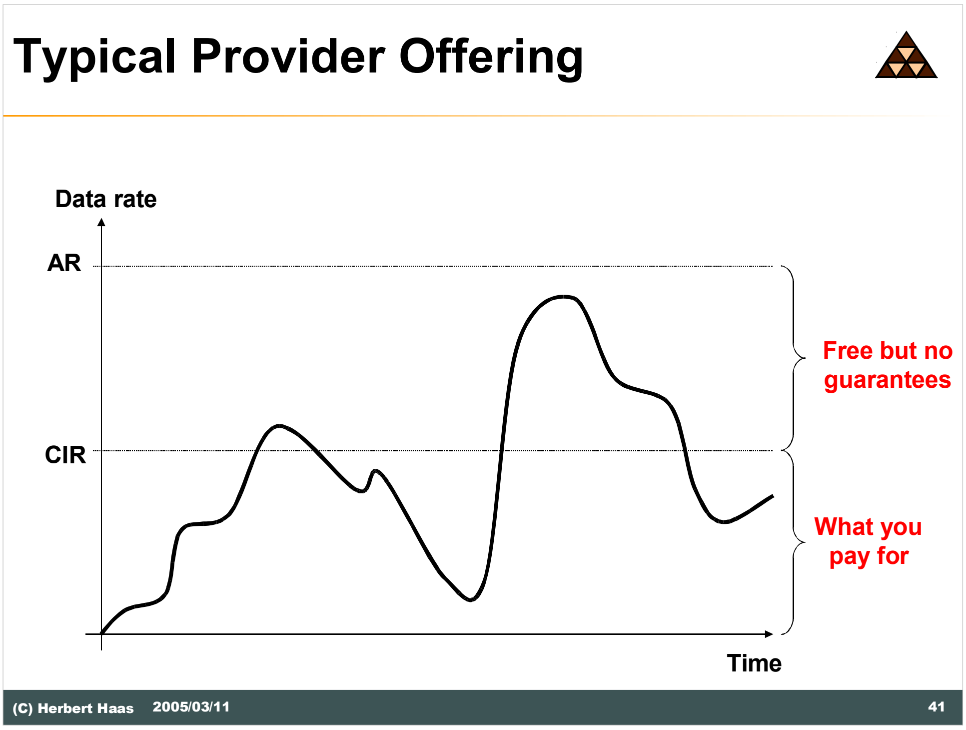
As long as the traffic remains within the borders of the CIR all frames are accepted by the Frame-relay switch and will be delivered to their destination. Data frames above the CIR but below the EIR will be marked with the Discard Eglibility (DE) bit. This bit is located in the Frame-relay header and can be set either by the end user itself or by the first Frame-relay switch in the provider cloud. All frames marked with the DE bit will be discarded firstly in the case of congestions inside the provider cloud.

So it might be better for the end user to set the DE bit himself, simply to control which type of traffic should definitely arrive and which one might get lost.

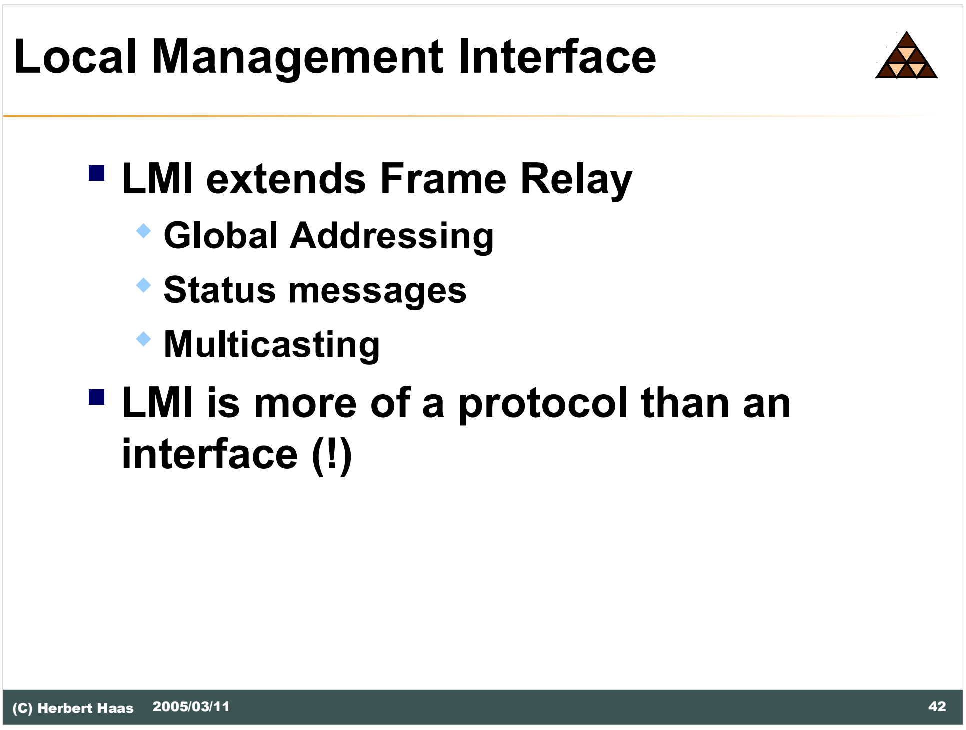
All traffic, in our scenario, above the EIR will be discarded by the provider.



This is the typical service provider behavior. Typically, a customer just pays for the CIR and the rest of the bandwidth – up to the access rate – is free. However, there is no gurantee that every excess packets is delivered to the receiver.



This graph shows us the benefits of a Frame-relay connection. The CIR is what you pay for but very often it is possible to use provider capacities above the CIR which are for free.



The Local Management Interface (LMI) is a protocol that runs on a reserved DLCI to supply you with information about the conditions of your PVC´s.

But it also supports global addressing and the use of multicast PVC´s.

LMI Details

- **Three LMI Types**
  - **ANSI T1.617 (Annex D)**
  - **ITU-T Q.933 (Annex A)**
  - **LMI (Original, FRF)**
- **No fragmentation of LMI messages (!)**
  - **MTU determines maximal PVC number**
  - **E.g. MTU 1500 allows 296 DLCIs**

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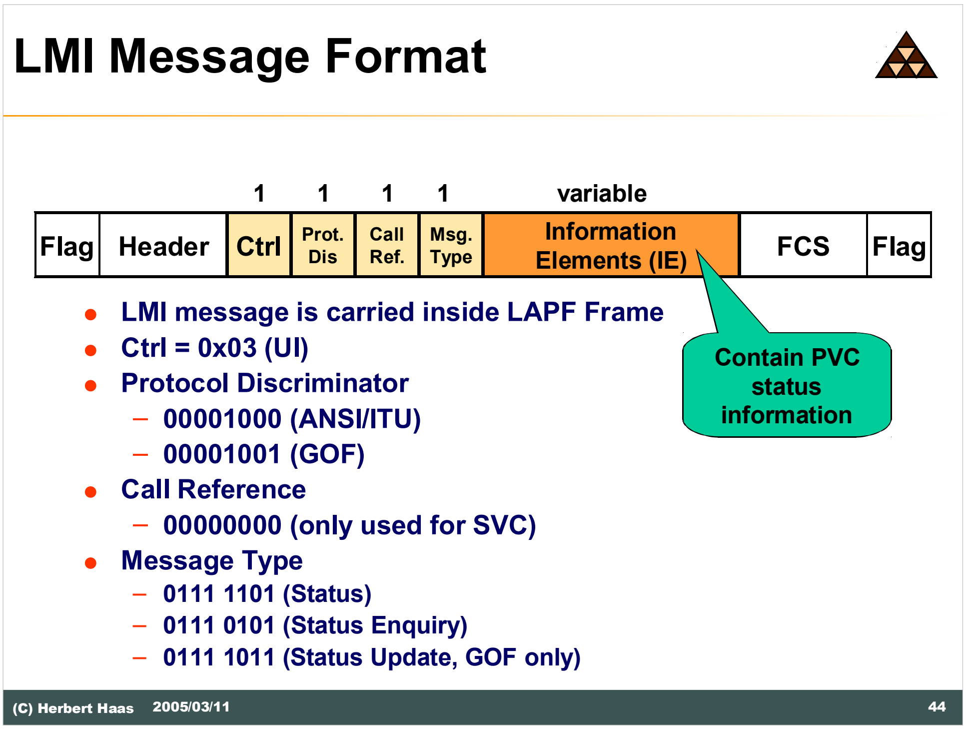
Each Standardization Organization developed its own LMI. In fact, only the FRF LMI is named LMI, but don't be too subtle. Unfortunetaly (you might expect it) these signaling standards are not compatible. Practically, our service provider must tell us which standard is supported by her DCEs, or some modern routers perform an auto-sensing and determine the switch-type automatically.

Full Status Messages contain all currently used DLCIs within a single frame. Because of this the maximum number of PVCs is limited by the MTU for this link. LMI messages must not be fragmented.

Note: When the frame MTU size is too small, not all PVC status messages can be communicated . One symptom for this mistake is the observation of bouncing PVCs (repeated up/down indications).

You can easily calculate the maximum number of DLCIs per interface by yourself. The equation is Max_DLCIs=(MTU_bytes – 20)/5, because each entry has 5 bytes. For example a MTU of 4000 Bytes supports 796 DLCIs.



The LMI messages are packed in standard Frame-relay frames and are transported on DLCI 0 according to the ITU-T and ANSI standard or on DLCI 1023 according to the FRF standard.

The LMI messages are sent in a connection-less mode indicated by the value of the control field (0x03).

The Protocol Discriminator holds the information whether FRF, ANSI or ITU-T standard is used.

The Call Reference is only used in combination with SVC service, its needed to distinguish between the different connection setup procedures.

The Message Type specifies whether LMI message is a status enquiry, status report or full status update including bandwidth and congestion information. The full status update is only supported by the FRF standard.

Finally the information field itself holds the complete status information of all PVC´s in use.

LMI Operation

- Every 10 seconds the DTE polls the DCE with a Status Enquiry message
  - Either for a dumb response ("Yes I'm here")
  - Or for a Channel status information
- (Full) Status Response
  - Contains information about VCs

Every 5-30 seconds (typically 10 seconds) the DTE polls the DCE to receive a status information.

The response from the DCE might be a small Hello message or a full status report about the PVC´s in use every 60 seconds.

Inverse ARP

- **Automatic remote-node-address to local-DLCI mapping**
  - **Supports IP, IPX, XNS, DECnet, Banyan VINES, AppleTalk**
- **Extension of existing ARP**
- **Not only for Frame Relay**
- **RFC 1293**

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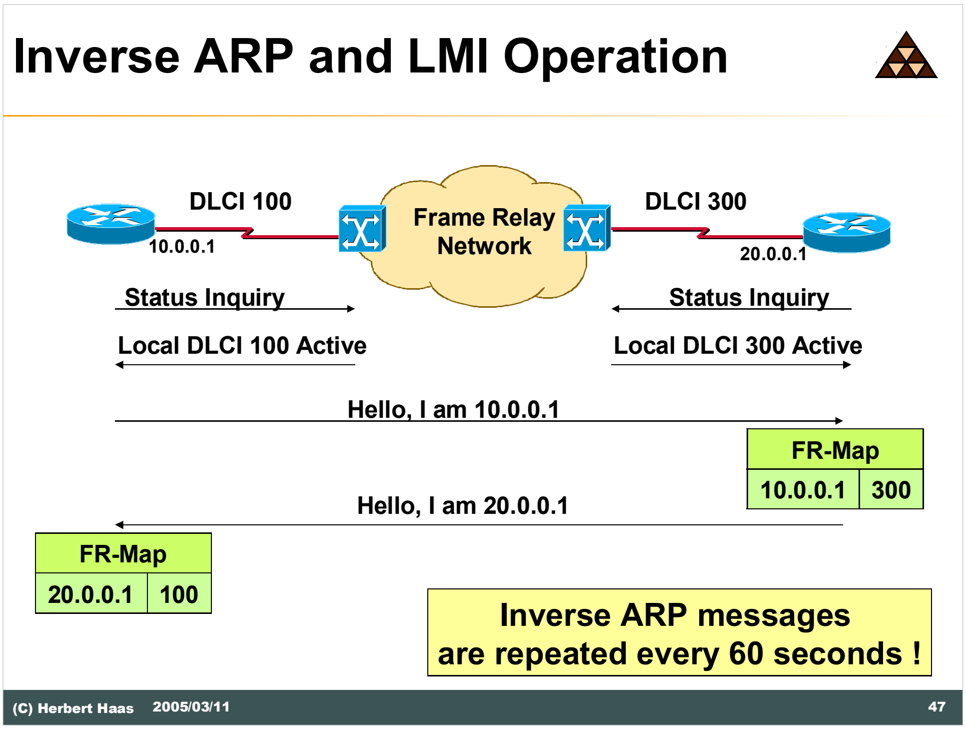
If a layer 3 protocol like IP, IPX, XNS, etc. is transported via a Frame-relay connection layer 2 to layer 3 address mapping needs to be done. The layer 2 address might be a DLCI number in case of PVC service or a E164/X121 address in case of SVC service.

In case of PVC service the Inverse ARP protocol was developed to allow the automatic mapping between DLCI number and according layer 3 addresses. In X25 technology the predecessor of Frame-relay this had to be done manually by configuration.

In Frame-relay SVC service the mapping between E164/X121 address and the according layer 3 address needs to be done manually by configuration, because the E164 address is needed before the actual connection is up to start the connection setup procedure.



In this scenario the function and the interaction of the LMI and the Inverse ARP protocol is shown.

With the help of the status enquiry and the status report messages of the LMI protocol both nodes on either ends are informed about their DLCI number and the condition of the DLCI.

Now both nodes on either end send small Hello messages with their according layer 3 address into their active DLCI. This Hello procedure is repeated every 60 seconds.

Now both nodes can build up a Frame-relay mapping table which includes their own DLCI number and the layer 3 address of the opposite site. So they know who´s on the other side.

DLCI Plan

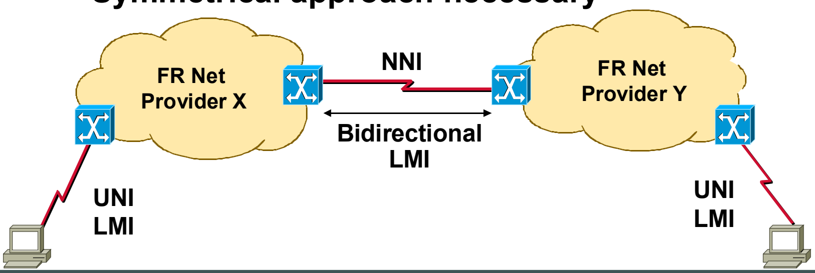
- 0 — LMI (ANSI, ITU-T) or FRF In-channel signaling
- 1023 — LMI (FRF) or ITU-T/ANSI In-channel signaling
- 1-15 — reserved
- 993-1007 — Frame Relay bearer service Layer 2 management (ANSI/ITU-T)
- 1008-1018 — reserved
- 1019-1022 — multicast connections
- **FRF: Usable DLCIs from 16 to 1007**
- **ANSI/ITU-T: Usable DLCIs from 16 to 992**

This slide gives us an overview about the reserved DLCI´s for signaling and the DLCI´s that may be used for user traffic.

So according to the FRF the DLCI´s in the range of 16 to 1007 and according to ANSI/ITU-T specifications the DLCI´s 16 to 992 can be used to transport user traffic.

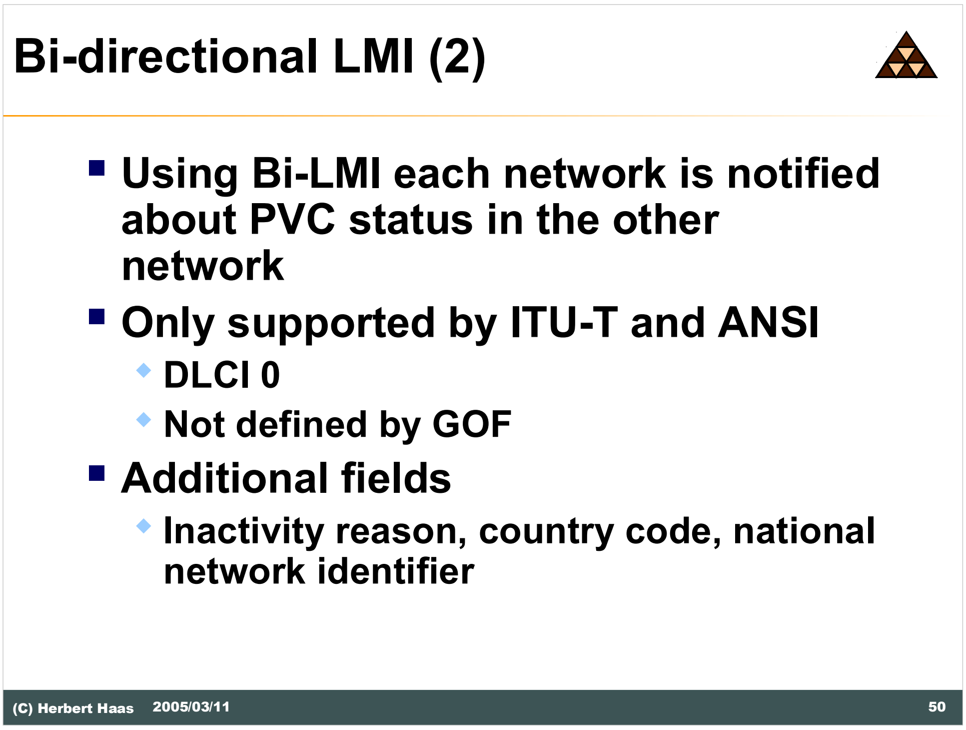
Bi-directional LMI (1)

- **Standards LMI is unidirectional**
  - **Sufficient for UNI signaling**
- **NNI signaling requires a bi-directional LMI variant**
  - **PVC status must be reported in both directions**
  - **Symmetrical approach necessary**



Common LMI is unidirectional and can only be used for UNI interfaces.

In the case of an NNI connection between two different Frame-relay clouds a bidirectional LMI protocol needs to be supported to report the PVC status to either ends.



When bidirectional LMI is used every network gets the PVC status information of the opposite side. Bidirectional LMI is only supported by the ANSI and the ITU-T standard and uses the same DLCI number that is used for unidirectional LMI.

Some additional information needs to be transported by the bidirectional LMI like country codes and network identifiers.

Summary

- Frame Relay has reduced overhead compared to X.25
- Outband signaling (LMI)
- Efficient for bursty traffic
  - Parameters (Bc, Be, Tc or CIR, EIR)
- Congestion Notification
  - FECN, BECN
- Frame Relay Forum, ITU-T, and ANSI

Quiz

- What's the Tc when using Voice over Frame Relay?
- What's the main difference between FR and Ethernet, when putting IP upon them?
- What's the typical practical usage of BECN?

Hints

- Q1: Milliseconds (min 10 ms)
- Q2: Broadcast medium. Main problem with routing protocols
- Q3: BECN is used by the provider to throttle the customer if he violates the traffic contract