Frame Relay Networking Technology

Historical Perspective

Technology Overview

- Frame Format and Procedures
- Signaling
- Applications
- Comparisons with Other Networking Technologies

Link-by-Link *vs*. End-to-End Error Control Analysis

- Simple Comparison
- M/M/1/K Model

Traffic and Congestion Control

- Access Rate Control and Policing
- Network Congestion Functions

Wrap-Up

Frame Relay: Historical Perspective

Digital Transmission System Proliferation

- High Speeds
- Low Error Rates

ISDN Standards Development

Link Protocol for ISDN (LAPD)

- Use on D Channel (Signaling Plus Data)
- Statistical Multiplexing at Layer 2

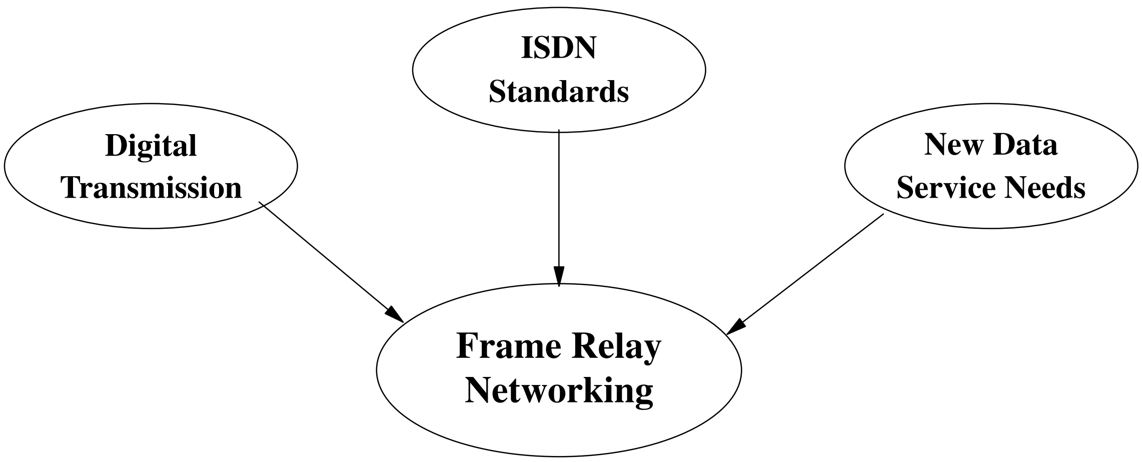
Out-of-Band Signaling

- For Network Call Control (Layer 3)
- Message-Oriented Signaling (Q.931/I.451)

New Data Service Needs

LAN Interconnect

- Wide Area Coverage
- Efficient Transmission BW Usage
- High Throughput (> 100 kb/s)



Frame Relay: What Is It?

A New Data Networking Service/Interface/Protocol Providing:

- Frame Delimiting, Alignment, Transparency
    - Variable Length Frames
- Frame Multiplexing via Link Level Connection Address
- Detection of Transmission, Format and Operational Errors
- Transparent, In-Order Transport of Frames
- No Frame Acknowledgement (Within the Network)
- Congestion Control Functions

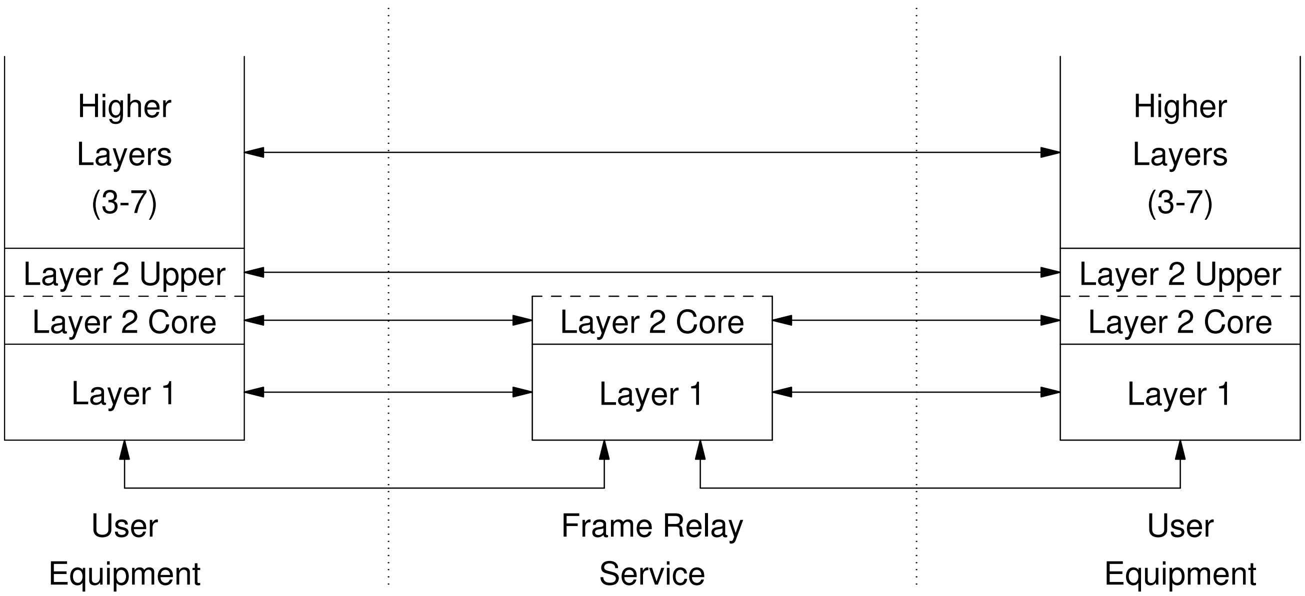
Frame Relay Pre-requisites:

- Low-Error Rate Digital Transmission
    - T1/T3 Rates Preferable
- End-to-End Protocols for Error Recovery, Flow Control, etc.

Frame Relay Frame Format

Muller, *Guide to Frame Relay*, 1991, pp. 57,58.

Frame Relay Procedure Overview



L2 Core Responsibilities:

Routing: DLCI Translations

Error Checking: Discard Errored Frames

Congestion Management: Later in Talk

L2 Core *Not* Responsible For:

Error Correction (*e. g.*, Retransmission)

Flow Control (*e. g.*, Windows)

Signaling in Frame Relay

Initial Networks Need No Signaling

- Small Number of Logical Connections per Endpoint
- Use Permanent Virtual Circuits (PVCs)
- Manage PVCs with Local Management Interface (LMI) On DLCI=1023

Common Channel Signaling For Switched Virtual Circuits (SVCs)

- DLCI=0 on Each Physical Link
- Level 3 (Network Control) via Q.931 Extended
- Common Signaling Protocol for Integrated Services

Muller, *Guide to Frame Relay*, 1991, p. 60.

LAN Interconnect via Frame Relay

LANs Connect to Routers

Routers Connect to Switching/Multiplexing Equipment

Interface is Frame Relay (Fractional T1, T1, T3)

High Speed (T1/T3) Digital Network Interconnect

Internal Transport Method Not Specified

Network Can Be Private or Public

Muller, *Guide to Frame Relay*, 1991, p. 62.

How Other Networking Technologies Differ From Frame Relay

Circuit Switching

- Limited BW Sharing
- Slow Connection Set-Up

Packet Switching (X.25)

- More Per-Link Processing (Slower)
- In-Band Signaling

Switched Multimegabit Data Service (SMDS)

- Metropolitan Area
- Higher Speeds
- Just Now Being Introduced
- ATM (Small, Fixed Cell Size) Technology

Broadband ISDN

- Integrated Traffic (Voice, Data, Image, Video)
- Higher Speeds Still
- ATM/SONET Technology
- Not Available For 4+ Years

Frame Relay Vendors and Service Providers

Equipment Vendors

- Cisco
- DEC
- Northern Telecom
- Stratacom
- Many Others

Public Frame Relay Service Providers

- WilTel (3/91)
- BT Tymnet (3Q91)
- Sprint (3Q91)
- Many Others

Link-by-Link *vs*. End-to-End Error Control

Simple Single-Link Error Recovery Delay Analysis

Notation:

P_b = link bit error probability (indep errors)

B = data block size (bits)

P_B = block error probability

T_p = fixed processing and propagation time for link

T_x = transmission time per block

T_r = recovery (timeout) time for errored block

$E(N)$ = expected number of tries to transmit block error-free

$E(T_l)$ = expected link delay for block

Assumptions:

No Queuing Delay or Buffer Overflow Loss (Low Load)

Fixed Block Sizes

No "Cut-Through" Operation

Simple Single-Link Error Recovery Delay Analysis (Cont)

Equations

$P_B =$

Approximation for P_B:

$E(N) =$

$E(T_l) =$

Homework (Details In Handout)

Find Expected Delay For L Links Assuming:

Link-by-Link (LL) Error Recovery

End-to-End (EE) Error Recovery

LL and EE Processing and Timeout Times Different

For:

Different Link Bit Error Rates

Different Link Transmission Rates

Repeat for M/M/1/K Assumptions (Paper)

Traffic and Congestion Control in Frame Relay

Negotiated Traffic Parameters (Per DLCI)

- Committed Information Rate (CIR)
- Committed Burst Size (B_c)
- Excess Burst Size (B_e)
- Measurement Interval ($T = B_c$/CIR)

Access Traffic Control

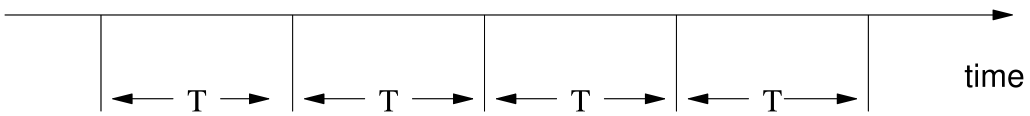
- Accept and "Guarantee" Delivery of Up To B_c in Any T (CIR)
  - High Loss Priority (DE=0)
- Accept Up To B_e More In Any T
  - Low Loss Priority: Network May Discard If Congested (DE=1)
- Excess Over ($B_c + B_e$) in T Discarded At Access Point

Relationship of Access Control Parameters

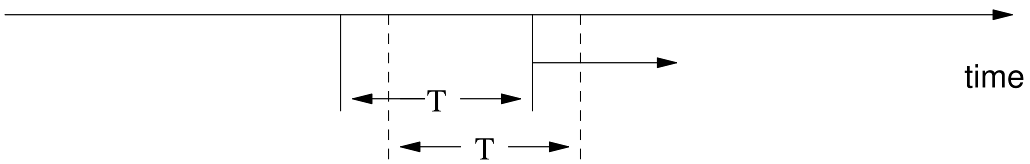
ANSI T1S1/90-175R4, Addendum #1 (Congestion Management) to T1.606, 1990, p. 8.

Measurement Interval (T) Management Possibilities

Synchronous T's



Sliding (Moving) Window



Leaky Bucket

Measurement Interval Is Somewhat Elastic

Long Term Average Rate Enforced

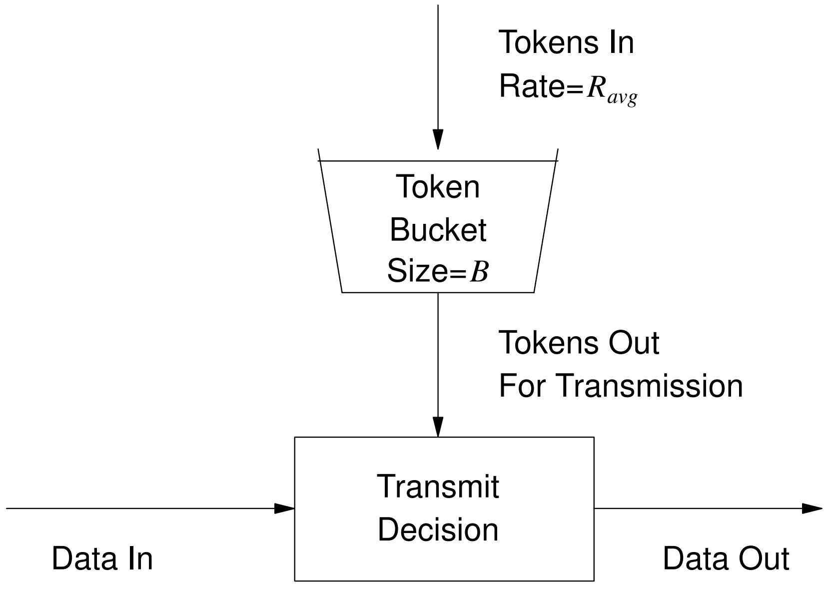
Leaky Bucket Access Rate Control

Token (or Credit) System

- To Transmit Data Units, Need Tokens
- "Bucket" Controls Tokens
- Visualize As Tokens "Leaking" Out or "Dripping" In (Below)

Operational Overview

- Token Depletion: When Frame Transmitted, *If* Sufficient Tokens
- Token Replenishment: Steady Rate R_{avg}
- Bucket Capacity (Credit Limit) Is B



More Leaky Bucket Access Rate Control

Simple Discarding Leaky Bucket Controller

F_t Is Frame Size Arriving At t, $b(t)$ Is Bucket Fill At t

Token Depletion

- If $F_t \le b(t)$, then transmit and set $b(t) = b(t) - F_t$
- Else, discard frame and $b(t)$ unchanged

Token Replenishment

- If $b(t) < B$, $b(t)$ increases with rate R_{avg}
- Else, $b(t)$ stays at B (no accumulation beyond B)

Questions:

- What is *maximum* average transmission rate?

- What is *maximum* # data units transmitted in single frame?

- What is *maximum* # data units transmitted in τ seconds?

Frame Relay B_c Controller

Excess Frames Sent to B_e Controller, Instead of Discarded

$B =$

$R_{avg} =$

Max Burst Size in T:

Leaky Bucket vs. Sliding Window Enforcement

(Courtesy Lyn Neir)

Parameters:

- $B_c + B_e$ = 11,952 bits
- $(B_c + B_e)/T$ = 14.4 kb/s
- Access Line Rate = 19.2 kb/s
- Mean Burst Size = 3625 bits
- Max Burst Size = 19,500 bits
- Max Frame Size = 8192 bits

Traffic and Congestion Control (Continued)

Network Congestion Functions

- Notify User(s)
  - FECN, BECN, CLLM, LMI
- Discard Frames With DE=1
- Discard Frames With DE=0
- Clear Connections, etc.

Congestion Indications To User

- Implicit
  - Frame Discard (via Upper Protocol Levels)
- Explicit Congestion Notification From Network
  - Forward (Toward Destination) -- FECN
  - Backward (Toward Source) -- BECN, CLLM, LMI

Illustration of Frame Relay Congestion Notifications

Muller, *Guide to Frame Relay*, 1991, p. 59.

User Reaction To Congestion Indications

Optional (User Can Ignore)

Rate-Based Control

- Reduce Rate Upon Indication (Implicit/Explicit)
- Gradually Increase When Cleared
- Implement With Buffered "Shaping" or "Metering" Function

Window Size Control

- Frame Losses Imply Insufficient Buffers
- Buffer Requirements Depend On VC Window Sizes
- Throughput (Rate) Also Affected By Window Size
- So, Reduce Window Size During Congestion
- Slowly Increase When Congestion Passes
  - Explicit Notification or N Correct Receptions

Oscillations? (Fundamental Control Problem)

Examples of Window Size Control

Nassehi, "Window Flow Control in Frame Relay Networks," IEEE Globecom ’88, pp. 1786, 1787.

Frame Relay Standards References

CCITT Recommendations

I.122 ISDN: Framework For Providing Additional
Packet Mode Bearer Services

I.233 ISDN: Frame Mode Bearer Service

Q.922 ISDN: Data Link Layer Specification for
Frame Mode Bearer Service

I.3xx ISDN: Congestion Control In Frame Mode Bearer Services

I.5xz ISDN: Frame Mode Bearer Service Interworking

ANSI Standards

T1.606 Frame Relaying Bearer Service: Architectural Framework
and Service Description

T1.606 Addendum 1: Congestion Management

T1.618 ISDN: Core Aspects of Frame Protocol for use with
Frame Relay Bearer Service

T1.617 Signaling Specification for Frame Relay Bearer Service

De-Facto Standards

Frame Relay Specification With Extensions (4 Vendors)

Mostly Incorporated Into Standards Now

Conclusions

Frame Relay Is Not the Final Answer...

- Data Only
- Questions About Congestion Control, Scalability, etc

But Is Likely to Be a Transitional Step...

- Frame Relay Interfaces
- High-Speed, Cell-Based Internal Transport

To Broadband ISDN

- The "Ultimate" Integrated Communications Network