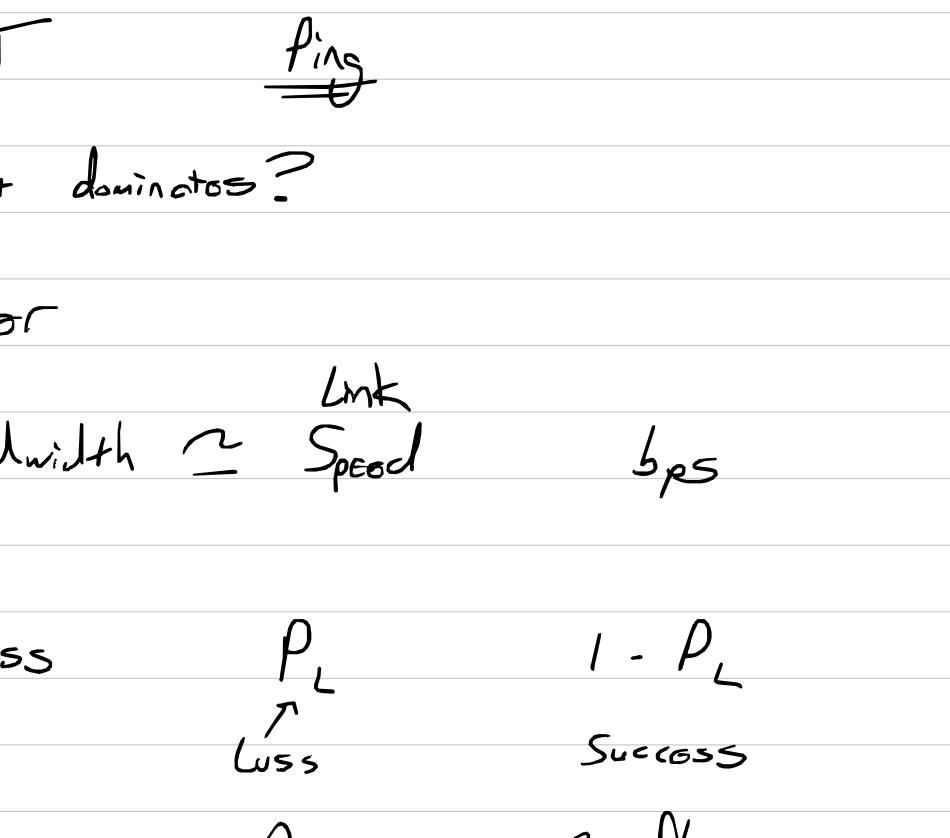


Lecture 2 - 1/4/26

Blog → B/W Links / Properties

$$G = V, E$$



Delay \approx Latency

- (1) Prop Delay
- (2) Transmission Delay
- (3) Processing Delay
- (4) Queuing Delay

ms
bytes/second
TCATM/Table

R/TT \approx Ping

What dominates?

Jitter

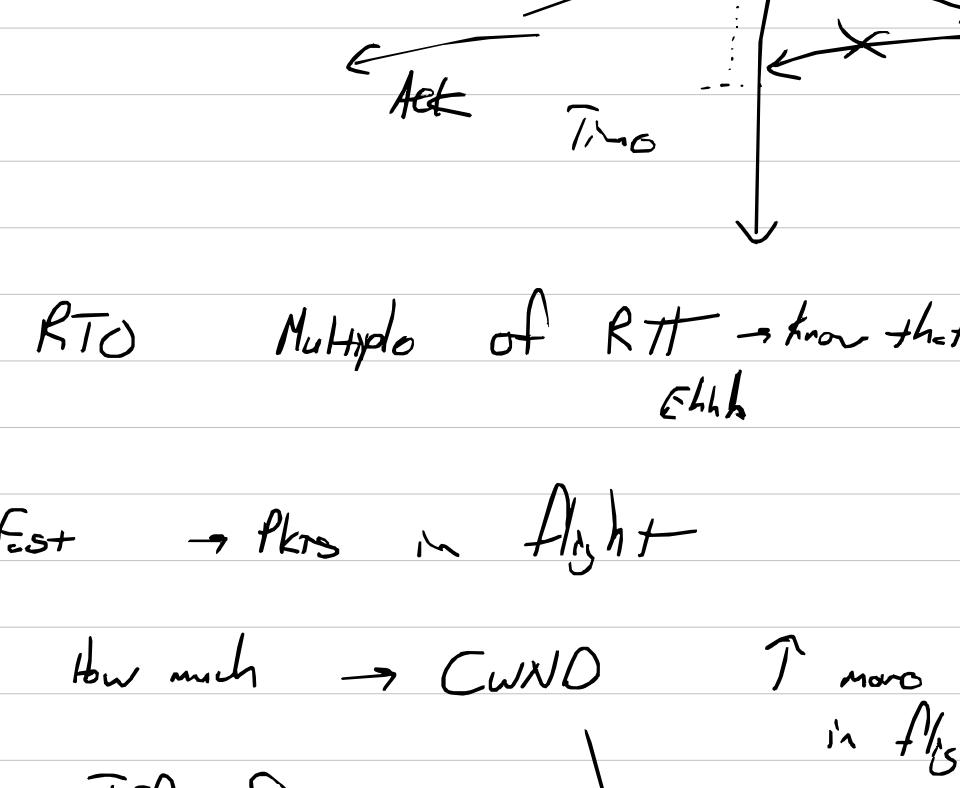
Bandwidth \approx Link Speed bps

Loss P_L $1 - P_L$
Loss Success

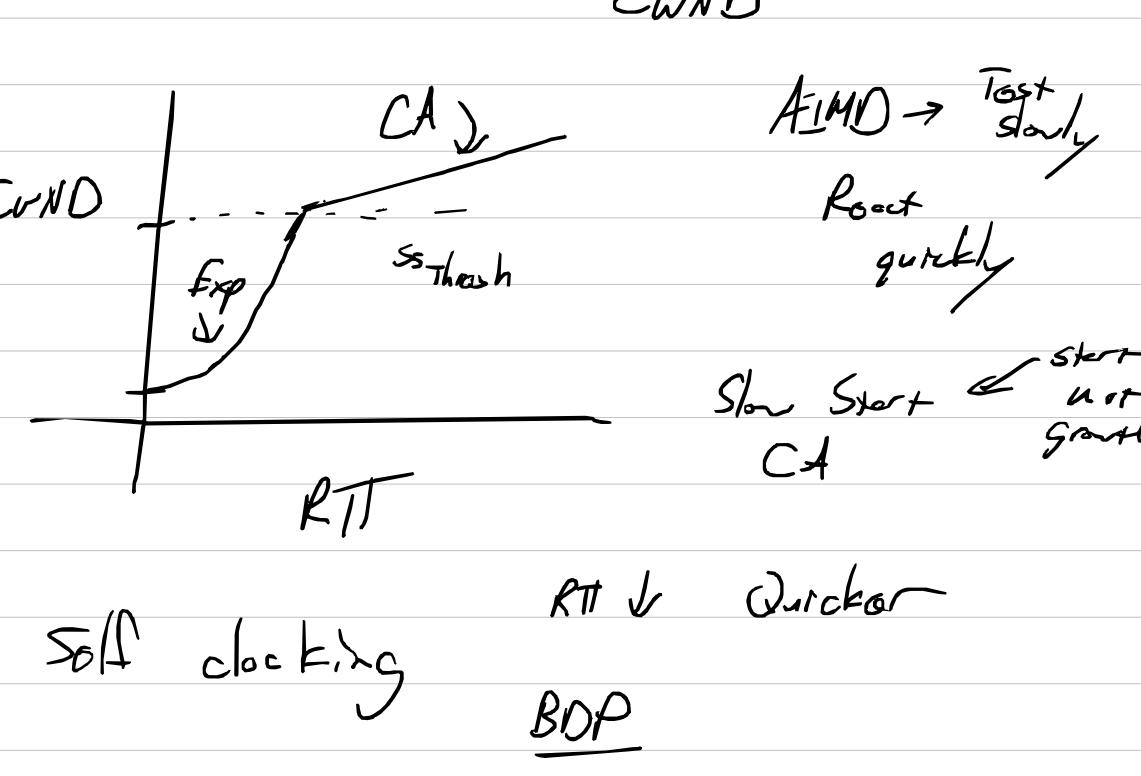
Sources: Queue \rightarrow Overflow

Transmission \rightarrow wireless $\begin{matrix} \text{usually} \\ \text{weak} \end{matrix}$

1 Link Bi-directional Symmetric



Multiple Links



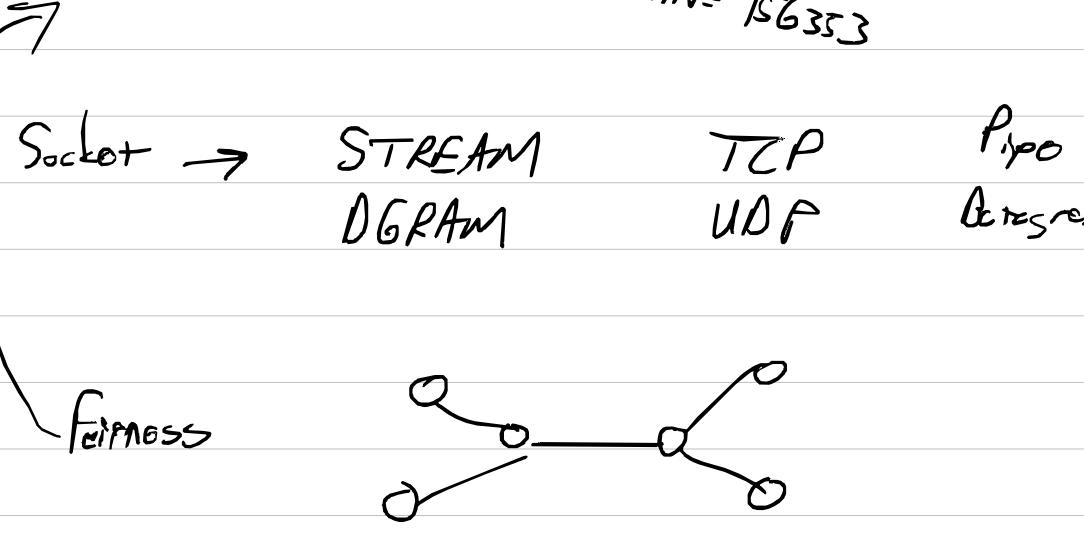
\rightarrow Ensure reliable delivery in-order Share network

TCP Client \rightarrow Server

connects

IP Node Street
Port Application/ Apt #

80 HTTP < 1K \rightarrow Root
443 HTTPS



Network is dumb \rightarrow Can't ask distributed w/delay

How do we know overload? Congestion \rightarrow overflows

\therefore Loss \rightarrow Overloaded

Signal

Congestion Control \rightarrow # Pkts in Flight + CWND

TCP Connection \rightarrow SYN, ACK, RST, FIN

3-way handshake

Fast Recovery \rightarrow Pkts in flight

Slow Recovery \rightarrow CWND = 1

Slow Recovery \rightarrow CWND = 1

Can we know earlier?

In-order SN AN

Slow Start \rightarrow CWND = 1

Exponential backoff \rightarrow CWND = 2

Fast Recovery \rightarrow CWND = 3

Fast Recovery \rightarrow CWND = 4

Slow Start \rightarrow CWND = 5

Exponential backoff \rightarrow CWND = 6

Slow Start \rightarrow CWND = 7

Exponential backoff \rightarrow CWND = 8

Slow Start \rightarrow CWND = 9

Exponential backoff \rightarrow CWND = 10

Slow Start \rightarrow CWND = 11

Exponential backoff \rightarrow CWND = 12

Slow Start \rightarrow CWND = 13

Exponential backoff \rightarrow CWND = 14

Slow Start \rightarrow CWND = 15

Exponential backoff \rightarrow CWND = 16

Slow Start \rightarrow CWND = 17

Exponential backoff \rightarrow CWND = 18

Slow Start \rightarrow CWND = 19

Exponential backoff \rightarrow CWND = 20

Slow Start \rightarrow CWND = 21

Exponential backoff \rightarrow CWND = 22

Slow Start \rightarrow CWND = 23

Exponential backoff \rightarrow CWND = 24

Slow Start \rightarrow CWND = 25

Exponential backoff \rightarrow CWND = 26

Slow Start \rightarrow CWND = 27

Exponential backoff \rightarrow CWND = 28

Slow Start \rightarrow CWND = 29

Exponential backoff \rightarrow CWND = 30

Slow Start \rightarrow CWND = 31

Exponential backoff \rightarrow CWND = 32

Slow Start \rightarrow CWND = 33

Exponential backoff \rightarrow CWND = 34

Slow Start \rightarrow CWND = 35

Exponential backoff \rightarrow CWND = 36

Slow Start \rightarrow CWND = 37

Exponential backoff \rightarrow CWND = 38

Slow Start \rightarrow CWND = 39

Exponential backoff \rightarrow CWND = 40

Slow Start \rightarrow CWND = 41

Exponential backoff \rightarrow CWND = 42

Slow Start \rightarrow CWND = 43

Exponential backoff \rightarrow CWND = 44

Slow Start \rightarrow CWND = 45

Exponential backoff \rightarrow CWND = 46

Slow Start \rightarrow CWND = 47

Exponential backoff \rightarrow CWND = 48

Slow Start \rightarrow CWND = 49

Exponential backoff \rightarrow CWND = 50

Slow Start \rightarrow CWND = 51

Exponential backoff \rightarrow CWND = 52

Slow Start \rightarrow CWND = 53

Exponential backoff \rightarrow CWND = 54

Slow Start \rightarrow CWND = 55

Exponential backoff \rightarrow CWND = 56

Slow Start \rightarrow CWND = 57

Exponential backoff \rightarrow CWND = 58

Slow Start \rightarrow CWND = 59

Exponential backoff \rightarrow CWND = 60

Slow Start \rightarrow CWND = 61

Exponential backoff \rightarrow CWND = 62

Slow Start \rightarrow CWND = 63

Exponential backoff \rightarrow CWND = 64

Slow Start \rightarrow CWND = 65

Exponential backoff \rightarrow CWND = 66

Slow Start \rightarrow CWND = 67

Exponential backoff \rightarrow CWND = 68

Slow Start \rightarrow CWND = 69

Exponential backoff \rightarrow CWND = 70

Slow Start \rightarrow CWND = 71

Exponential backoff \rightarrow CWND = 72

Slow Start \rightarrow CWND = 73

Exponential backoff \rightarrow CWND = 74

Slow Start \rightarrow CWND = 75

Exponential backoff \rightarrow CWND = 76

Slow Start \rightarrow CWND = 77

Exponential backoff \rightarrow CWND = 78

Slow Start \rightarrow CWND = 79

Exponential backoff \rightarrow CWND = 80

Slow Start \rightarrow CWND = 81

Exponential backoff \rightarrow CWND = 82

Slow Start \rightarrow CWND = 83

Exponential backoff \rightarrow CWND = 84

Slow Start \rightarrow CWND = 85

Exponential backoff \rightarrow CWND = 86

Slow Start \rightarrow CWND = 87

Exponential backoff \rightarrow CWND = 88

Slow Start \rightarrow CWND = 89

Exponential backoff \rightarrow CWND = 90

Slow Start \rightarrow CWND = 91

Exponential backoff \rightarrow CWND = 92

Slow Start \rightarrow CWND = 93

Exponential backoff \rightarrow CWND = 94

Slow Start \rightarrow CWND = 95

Exponential backoff \rightarrow CWND = 96

Slow Start \rightarrow CWND = 97

Exponential backoff \rightarrow CWND = 98

Slow Start \rightarrow CWND = 99

Exponential backoff \rightarrow CWND = 100

Slow Start \rightarrow CWND = 101

Exponential backoff \rightarrow CWND = 102

Slow Start \rightarrow CWND = 103

Exponential backoff \rightarrow CWND = 104

Slow Start \rightarrow CWND = 105

Exponential backoff \rightarrow CWND = 106

Slow Start \rightarrow CWND = 107

Exponential backoff \rightarrow CWND = 108

Slow Start \rightarrow CWND = 109

Exponential backoff \rightarrow CWND = 110

Slow Start \rightarrow CWND = 111

Exponential backoff \rightarrow CWND = 112

Slow Start \rightarrow CWND = 113

Exponential backoff \rightarrow CWND = 114

Slow Start \rightarrow CWND = 115

Exponential backoff \rightarrow CWND = 116

Slow Start \rightarrow CWND = 117