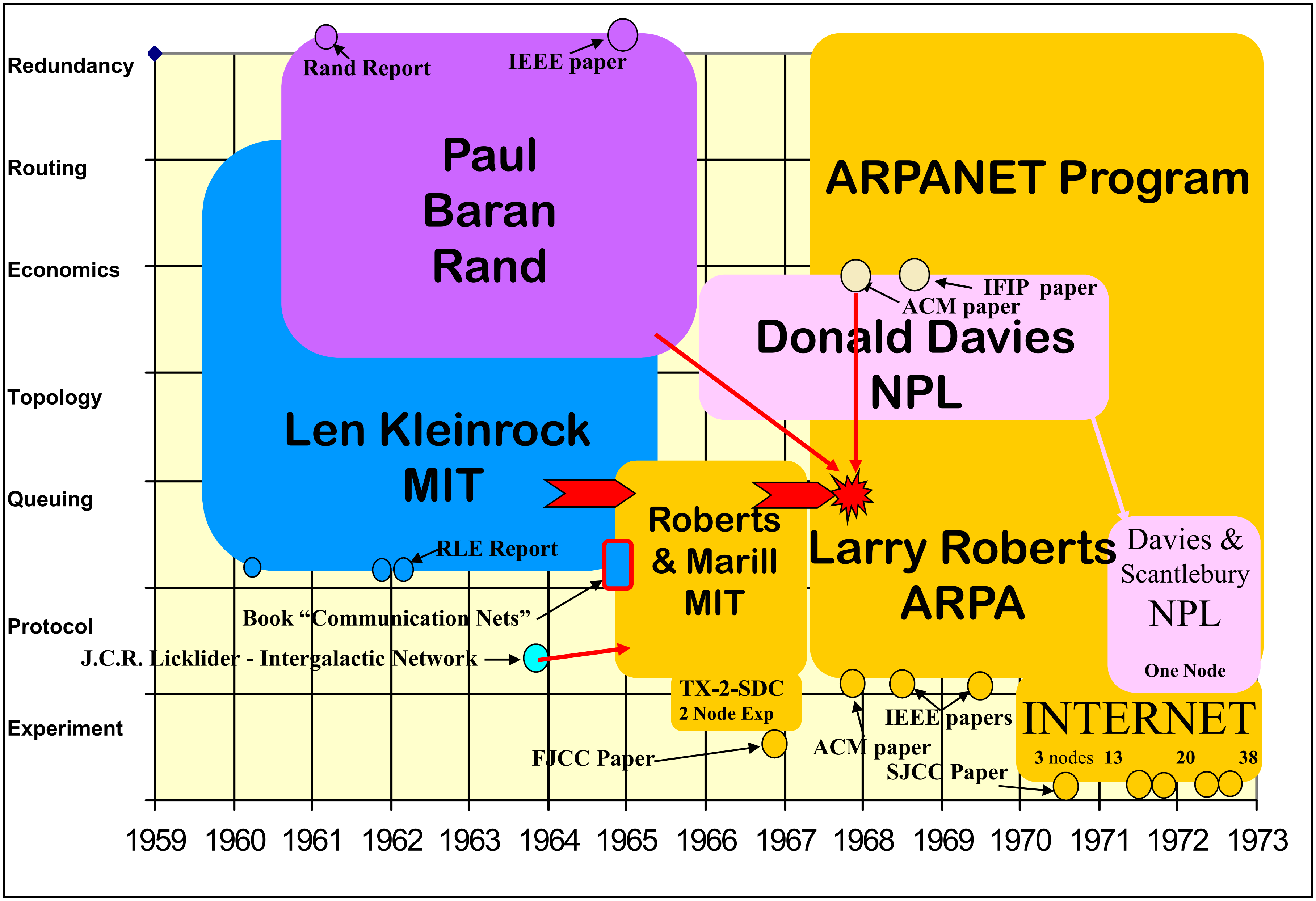
Internet History and Future

Dr. Lawrence Roberts

Founder, Chairman, Anagran

ANAGRAN

Early Packet Switching History



The Beginning of the Internet and ARPANET became the Internet

1965 – MIT- 2 Computer Experiment

- Roberts designs packet structure
- Len Kleinrock – queuing theory

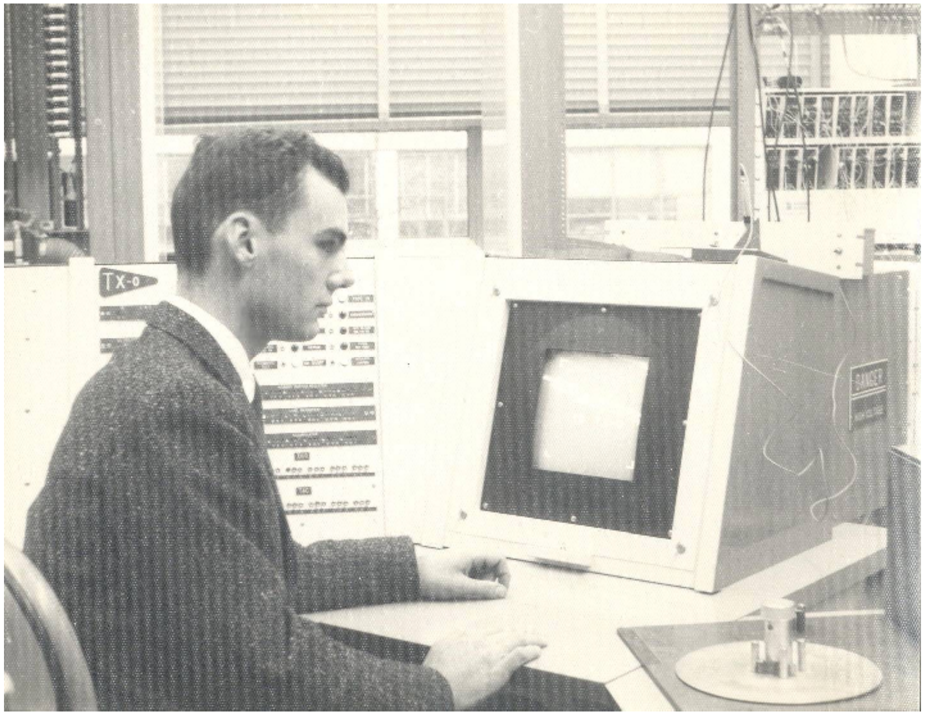
1967 – Roberts moved to ARPA

- Designs ARPANET

1969 – First 4 nodes installed

- UCLA, SRI, UCSB, University of Utah

1971 - Email created → Main traffic soon



Roberts at MIT Computer

1972 – Bob Kahn joins Roberts at ARPA

1973 – Roberts leaves and starts Telenet; first commercial packet carrier in the world

1974 – TCP design paper published by Bob Kahn and Vint Cerf

1983 – TCP/IP installed on ARPANET and required by DOD

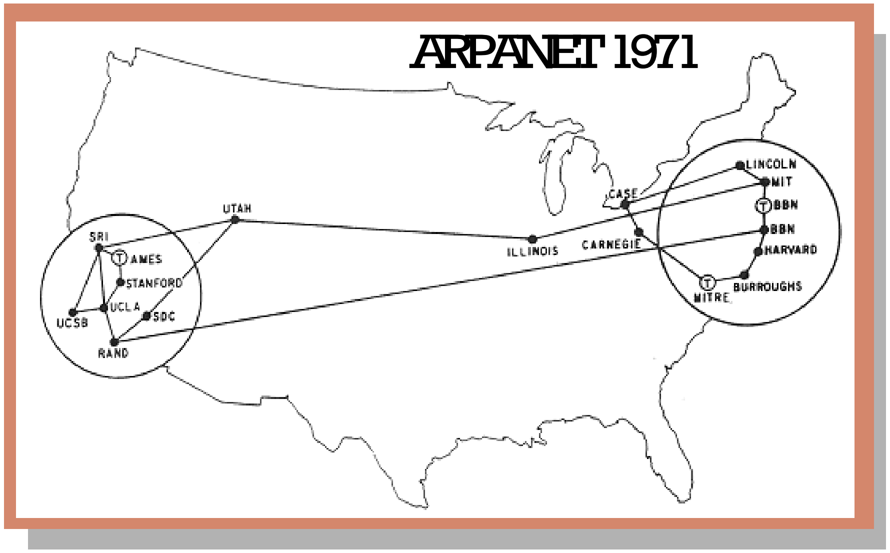
1993 – Internet opened to commercial use

Original Internet Design - *It Was Designed for Data*

File Transfer and Email main activities

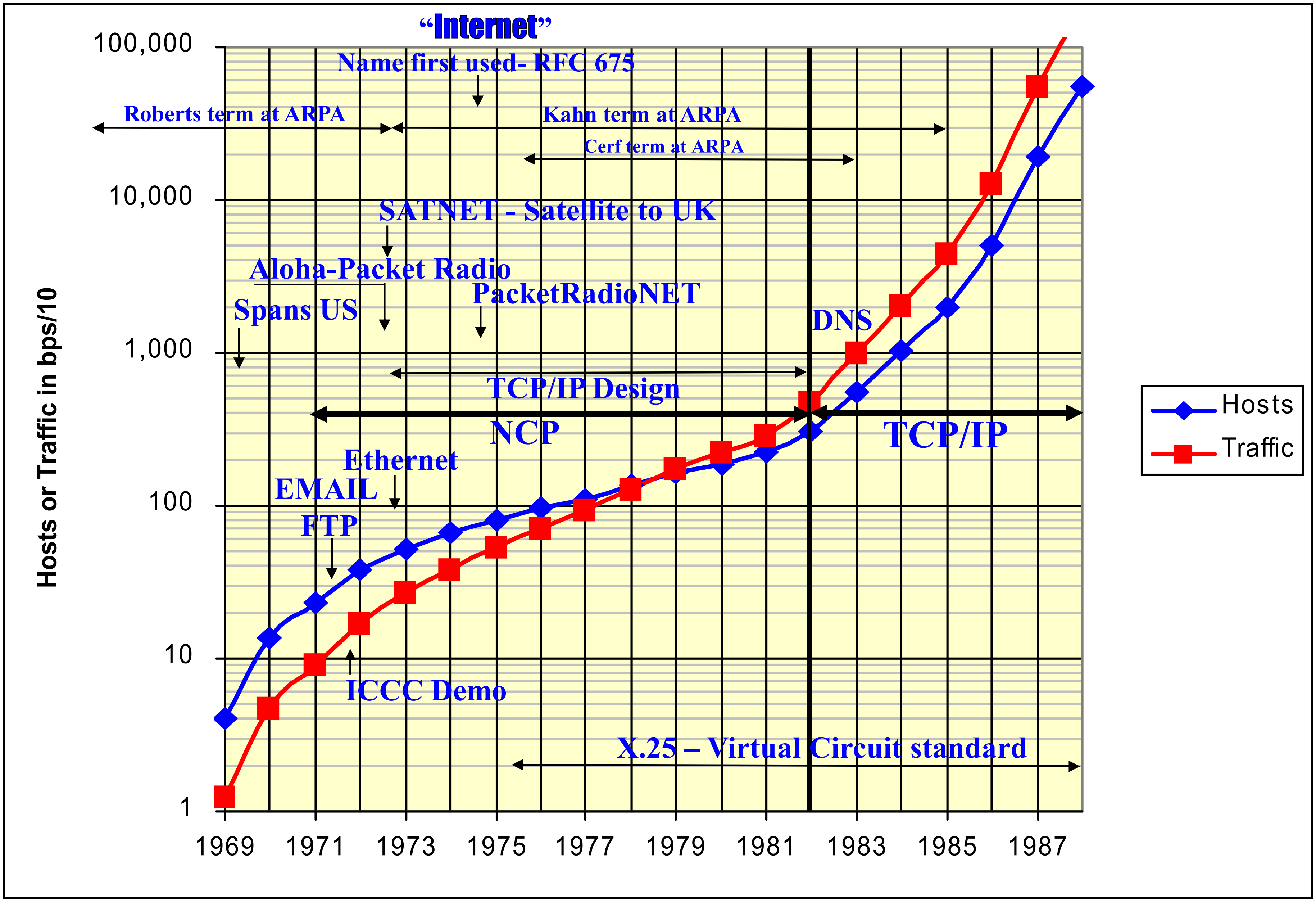
Constrained by high cost of memory

- Only Packet Destination Examined
- No Source Checks
- No QoS
- No Security
- Best Effort Only
- Voice Considered
- Video thought not feasible

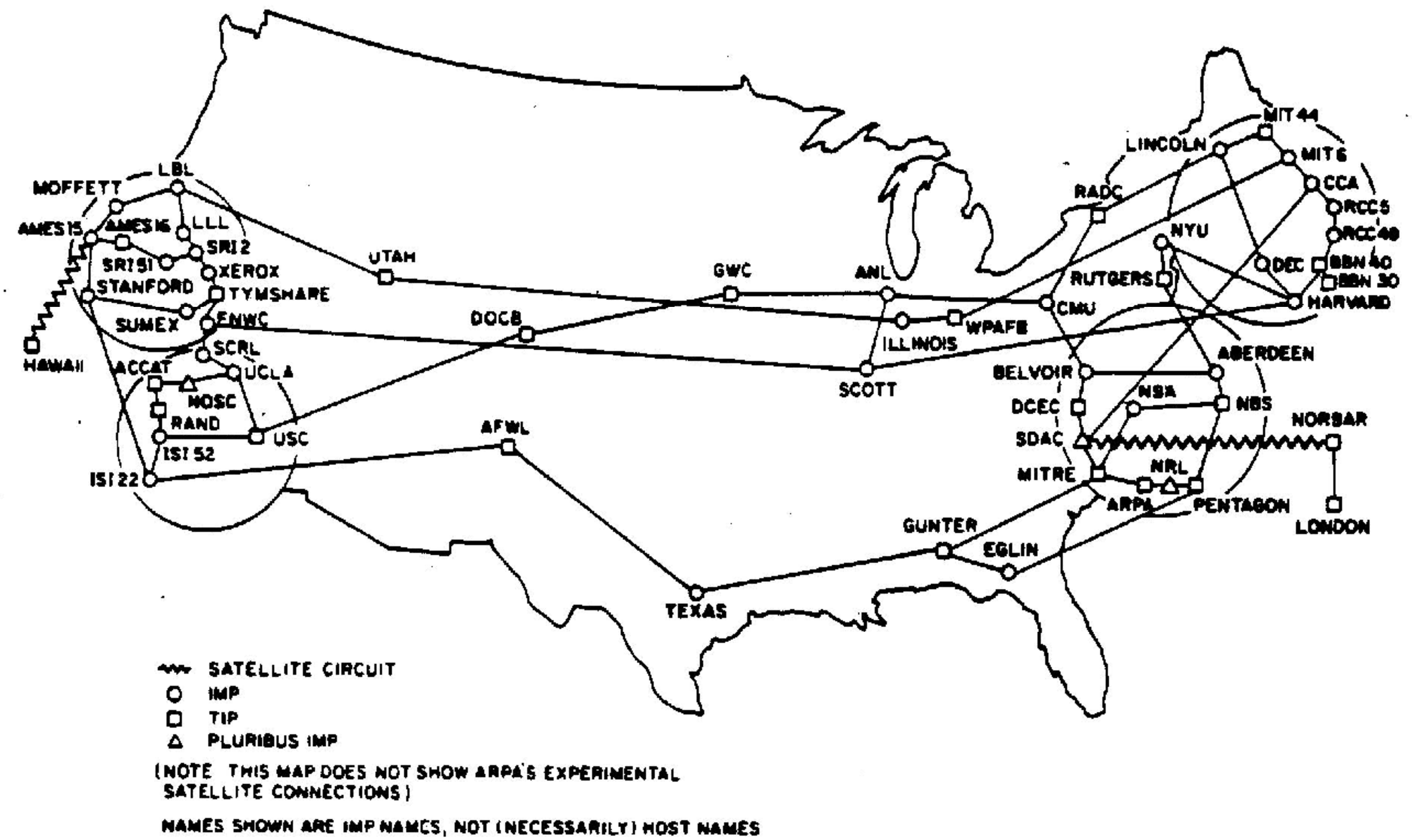


Not much change in packet switching since then

Internet Early History



ARPANET Expansion



ARPANET July 1977

NAE Draper Award Laureates Feb. 20th, 2001
For creating the Internet

Roberts Kahn Kleinrock Cerf

Prince of Asturias Award for Technical and Scientific Research, Oct 25, 2002

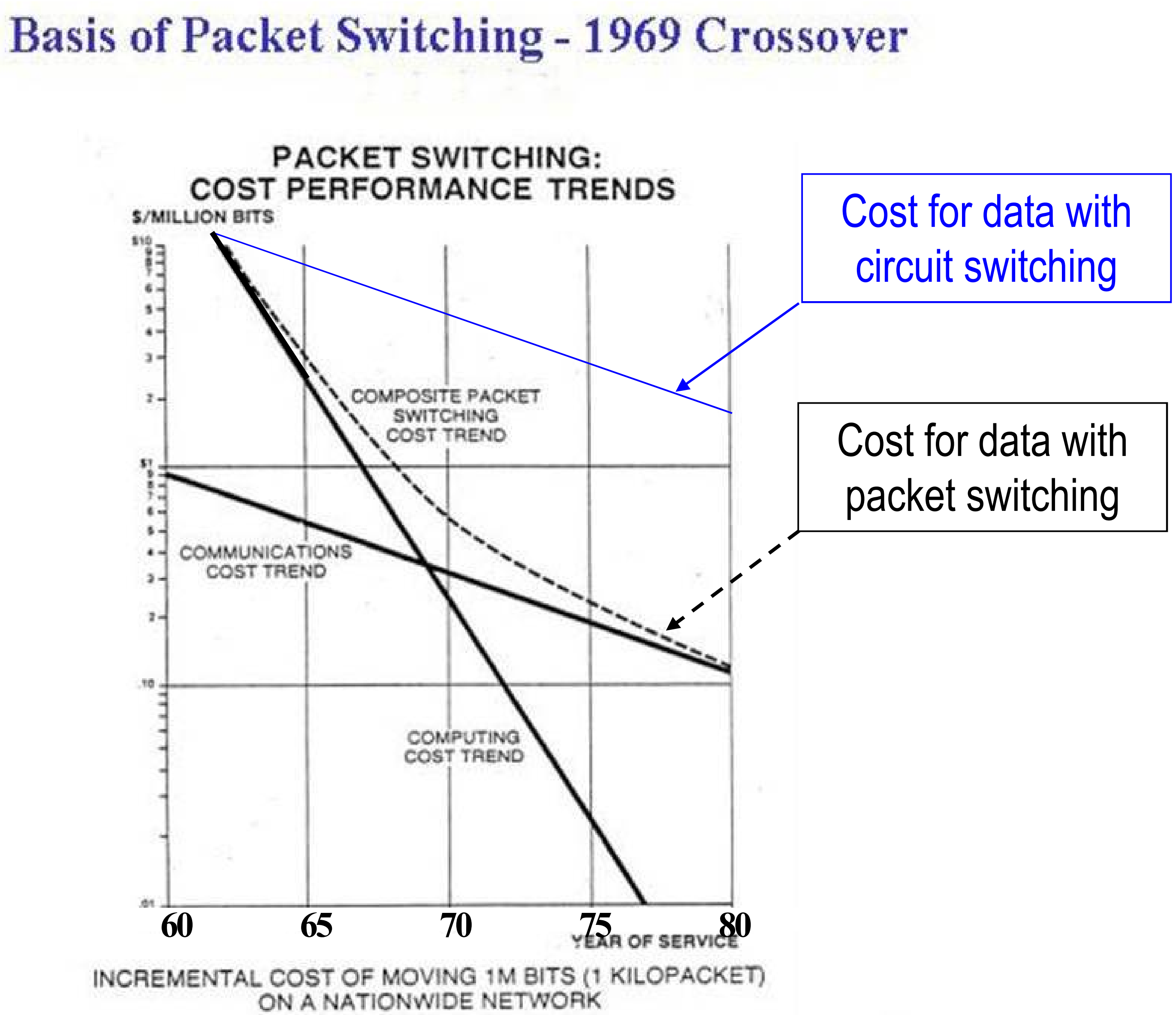
Roberts Kahn Cerf Berners-Lee

Prince of Asturias Award for Technical and Scientific Research, Oct 25, 2002

Major Internet Contributions

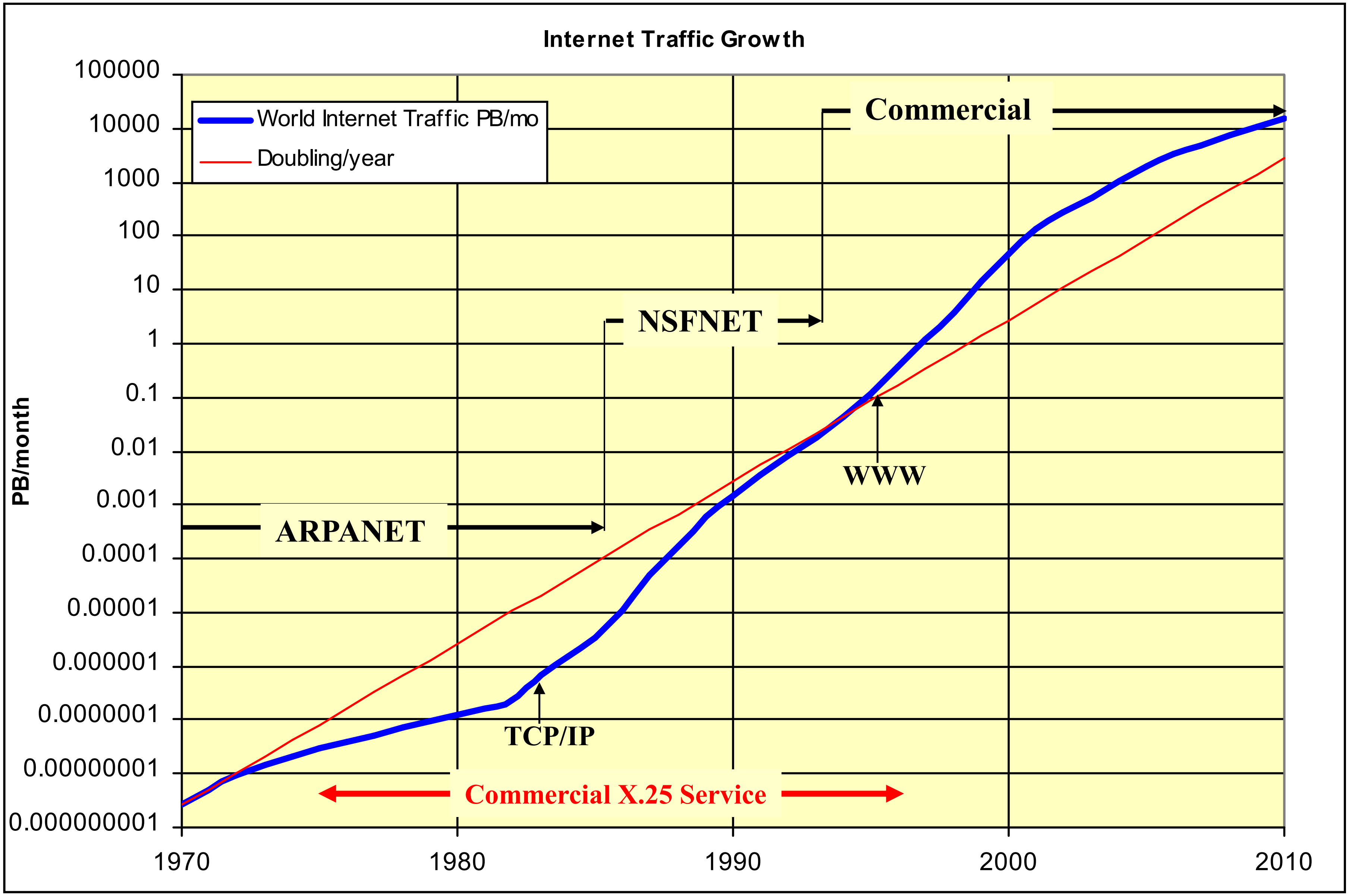
- **1959-1964 - Kleinrock** develops packet network theory proving that packets could be safely queued with modest buffers at network nodes
- **1965 – Roberts** tests a two node packet network and proves telephone network inadequate for data, packet network needed
- **1967-1973 - Roberts** at ARPA designs ARPANET, contracts parts out (routers, transmission lines, protocol, application software), growing network to 38 nodes and 50 computers
- **1973-1985 - Kahn** at ARPA, manages ARPANET, converting to TCP/IP, and standardizing DoD (also world) on TCP/IP
- **1975-1983 - Cerf** at ARPA designs TCP/IP and helps grow network
- **1990-1993- Berners-Lee** designs hypertext browser (WWW)

Packet Switching – 1969 Cost Crossover



From: "Data by the Packet," IEEE Spectrum, Lawrence Roberts, Vol. 11, No. 2, February 1974, pp. 46-51.

Internet Traffic History: Growth = 6 Trillion in 40 years



Internet Traffic has doubled every 11 months from 1970 to 2010

Some Network Problem Persist

Fairness - Broadband & Wireless Access

- 5% of users take 70%-80% of shared capacity
- Current network is unfair; Each flow gets equal capacity
  - Multi-flow applications thus use unfair portion of capacity
  - Multi-flow applications: P2P, Maps, content caching

Quality of Experience

- Queuing adds delay, delay jitter and TCP stalls
  - Web access much slower than needed
  - Video stalls, Wireless voice breaks up

Utilization

- Current network utilization is very low at network edge

Security

Internet Technology – Finally Some Changes

For 40 years network equipment still uses the same technology as ARPANET in 1969 - Queues

- Moore's Law has allowed for major speed increases
- But network equipment still uses queues to control traffic overload
- Every packet is processed independently (at high cost)
- Average flow rate needed is achieved but flow rates are randomized

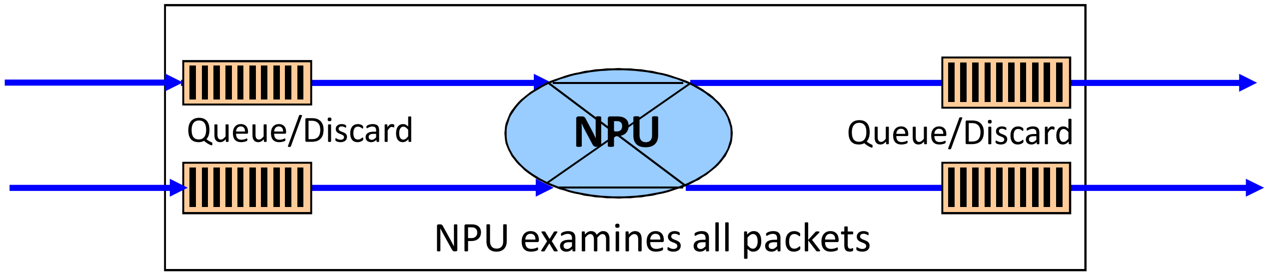
Flow Rate Control (FRC) provides a new solution

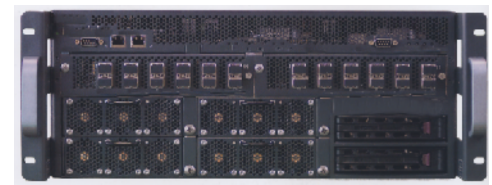
- A Flow is a sequence of packets – file transfer, voice, video, etc.
- ***Flow Rate Control*** controls the rate of every flow without queues
- Maximum trunk capacity is held just below limit – thus no congestion
- Computation reduced: First packet examined, most are streamed out
- Cost, power, and size reduced 5:1

FSA Signaling protocol offers nearly ideal network service & greatly improved network security

Controlling Overload – Queues vs Flow Rate Control

Current Packet Queuing Design of Network Equipment

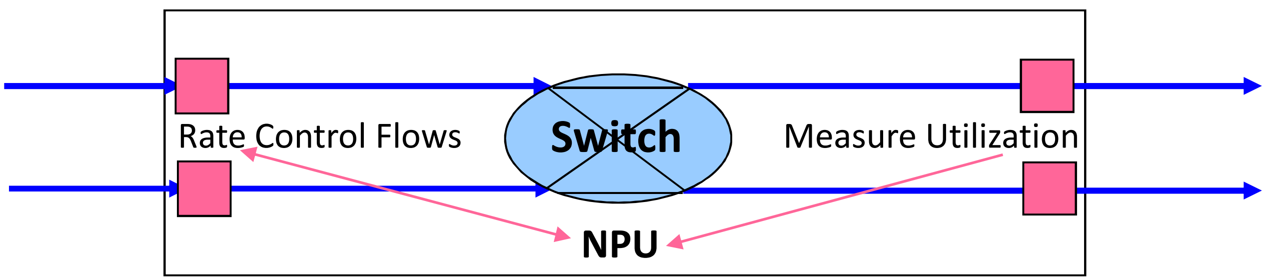




4 U 1500 Watts

Today, network equipment uses packet queues which handle overload by delaying and discarding random packets - result is delay, delay jitter, and TCP stalls.

New Flow Rate Control (FRC) Design of Network Equipment

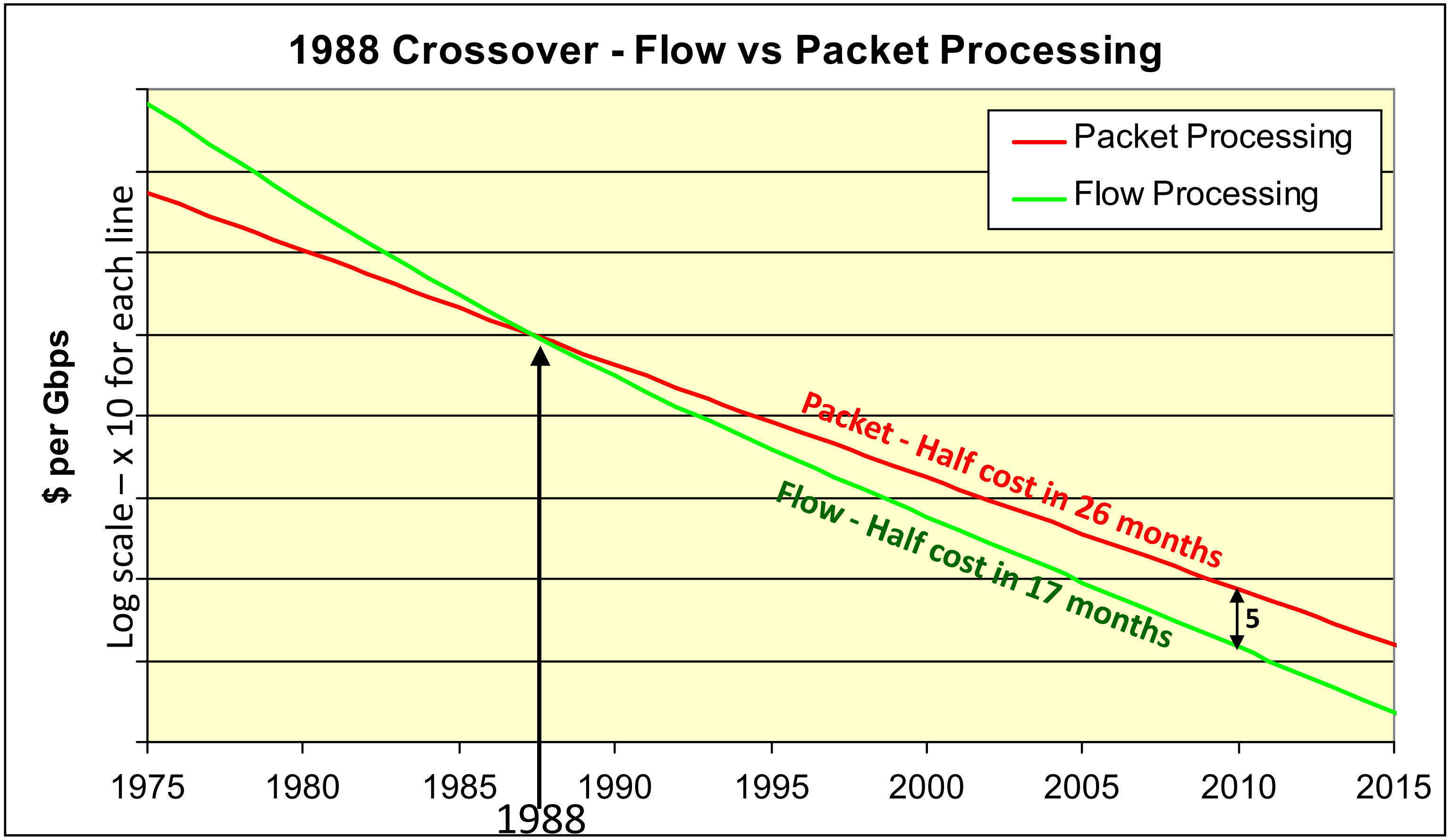


NPU only looks at 7% of packets

1 U 300 Watts

Anagran's new approach uses FRC to intelligently manage overload, reduce delay, increase throughput, provide equalization, and support multiple levels of service.

Power & Cost is Lower for Flow vs. Packet Processing



Flow processing depends more on memory cost than on computing.
Memory cost has fallen faster than computing. Flow was too expensive before 1988.
Flow processing is now it is ***5 times less power and cost*** than packet processing and flow processing's advantage is continuing to increase.

Fixing Network Problem Areas

Fairness

- TCP and queuing lead to equal capacity per flow_& congestion
- Flow Rate Control (FRC) can provide ***Subscriber Equalization***
    - Equal Capacity for Equal Pay
    - Supports multiple pay classes, each with increased average rate

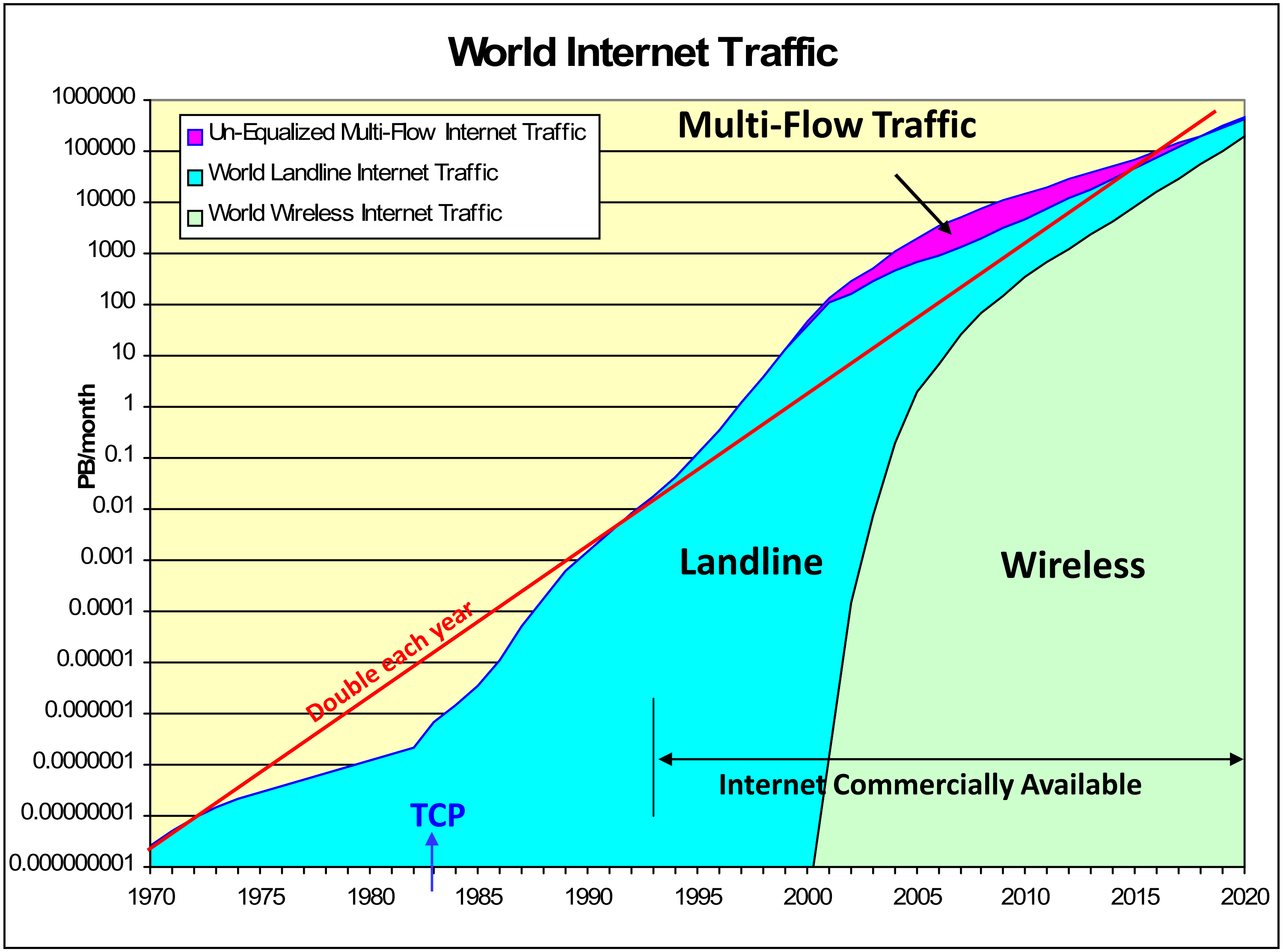
Quality of Service (QoS)

- Replace queues with **Flow Rate Control** (FRC)
    - No delay added - ***Streaming video runs faster, no stalls***
    - No delay jitter - ***Good voice quality even on wireless***
    - No TCP stalls or resets ***- All flows run smoothly at controlled rate***

Utilization

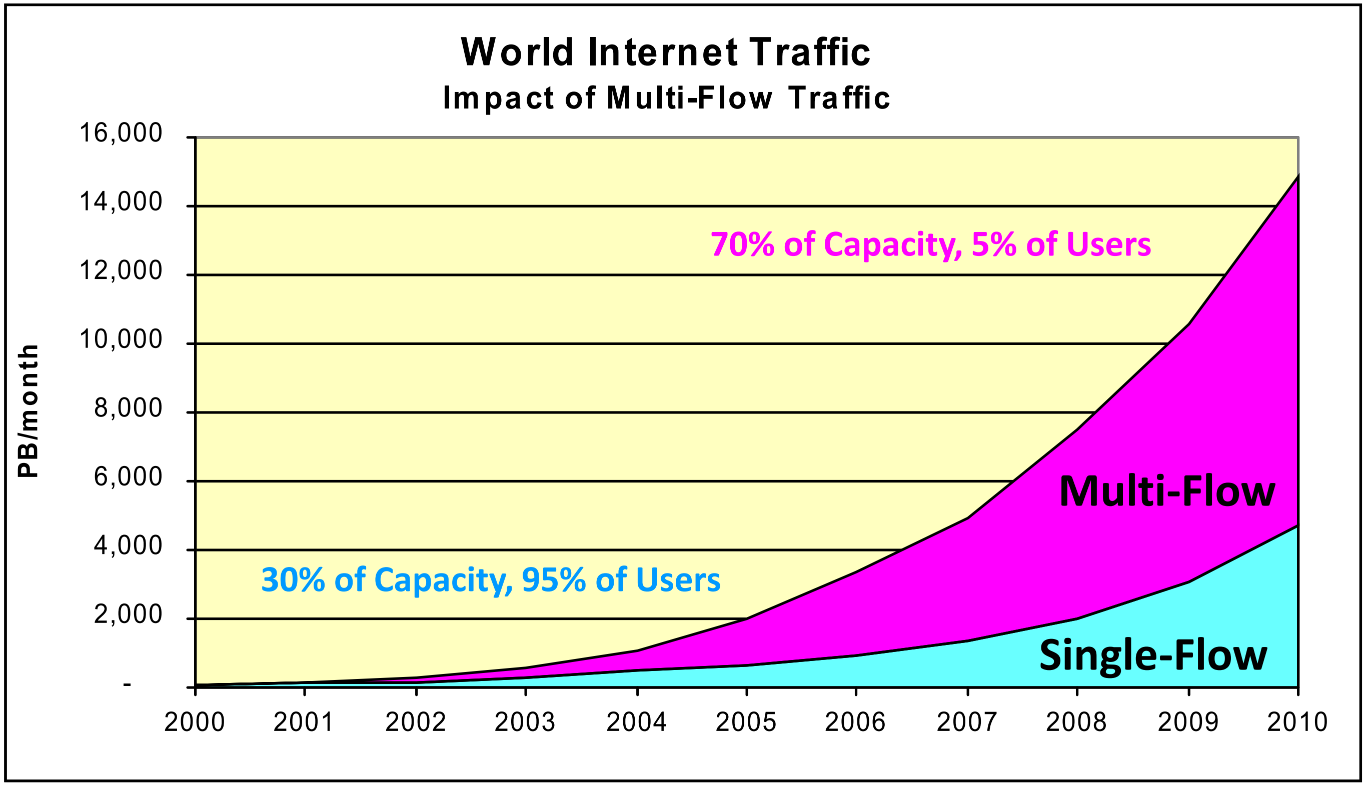
- If current QoS is ok, Utilization can be increased substantiality

Internet Traffic Projection – Fairness Issue



In 1999 Multi-Flow applications, starting with P2P, grew to consume up to 70% of the Internet capacity
Subscriber Equalization should slowly return capacity to the normal user
Currently Wireless Internet traffic is exploding and will soon equal landline traffic

Multi-Flow Traffic



Major problem today is that Internet allows unfairness

- Each flow is given equal capacity
- Multi-flow applications receive unfair fraction of capacity
- Generally 5% of users get 70% of shared capacity

Subscriber Equality is needed (Get what you pay for)

Flow Rate Control Exists in the Anagran FR-1000
Transitioning from Packet to Flow Traffic Management

Anagran *Fast Flow Technology™* (patents pending)

- “Delay-less” Architecture … Zero output buffer queuing
- Packet processing bypassed on 95%+ of all packets

Bump in the Wire or L3 Routing

Product Specs …

- 40 Gbps throughput, 10 GE and 1 GE (10/100/1000) ports
- 1,500,000 simultaneous flows … up to 8,000 distinct flow classes or VLANs
- Supports 75,000 subscribers with rate caps, service classes, and subscriber equalization
- Redundant power, hot swappable modules, and HA via dual unit configuration
- 100% NetFlow available even at 40 Gbps

Issues in Education Networks

Student Access, Priority and Equality

- Eliminate P2P overload with student equality
- Guarantee minimum and maximum total fraction of Internet
- Prohibit or limit certain external activity like social networking

Faculty Access, Priority and Equality (perhaps by groups)

Access Limitations to Servers by person or Group

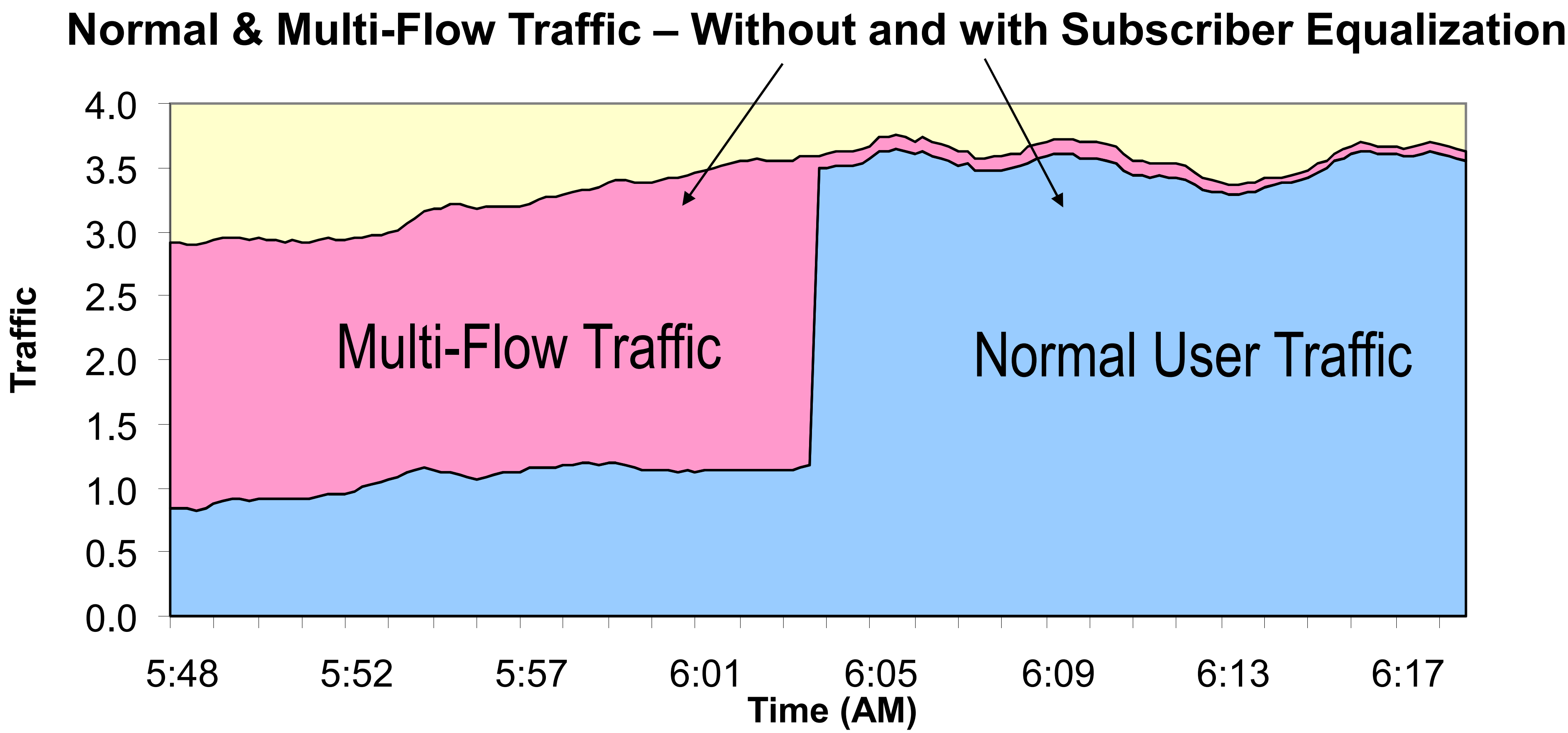
- Assured Capacity for Selected Servers and Services

Distance Learning Video Priority and Guarantees

Utilization of LAN and WAN typically increased 100%

Major Cost savings on Equipment and Communication

Multi-Flow Traffic Control with Subscriber Equalization



- Data from University Installation with Subscriber Equalization using FRC
- Multi-Flow traffic was reduced from 67% to 1.6%
- Normal traffic could then be increased by 4:1
- Network Neutrality Positive – Does not look at applications, just traffic level

"Priority" = Rate Multiplication

For services like TCP, Priority is used as a Rate Multiplier

- Example

  3 groups

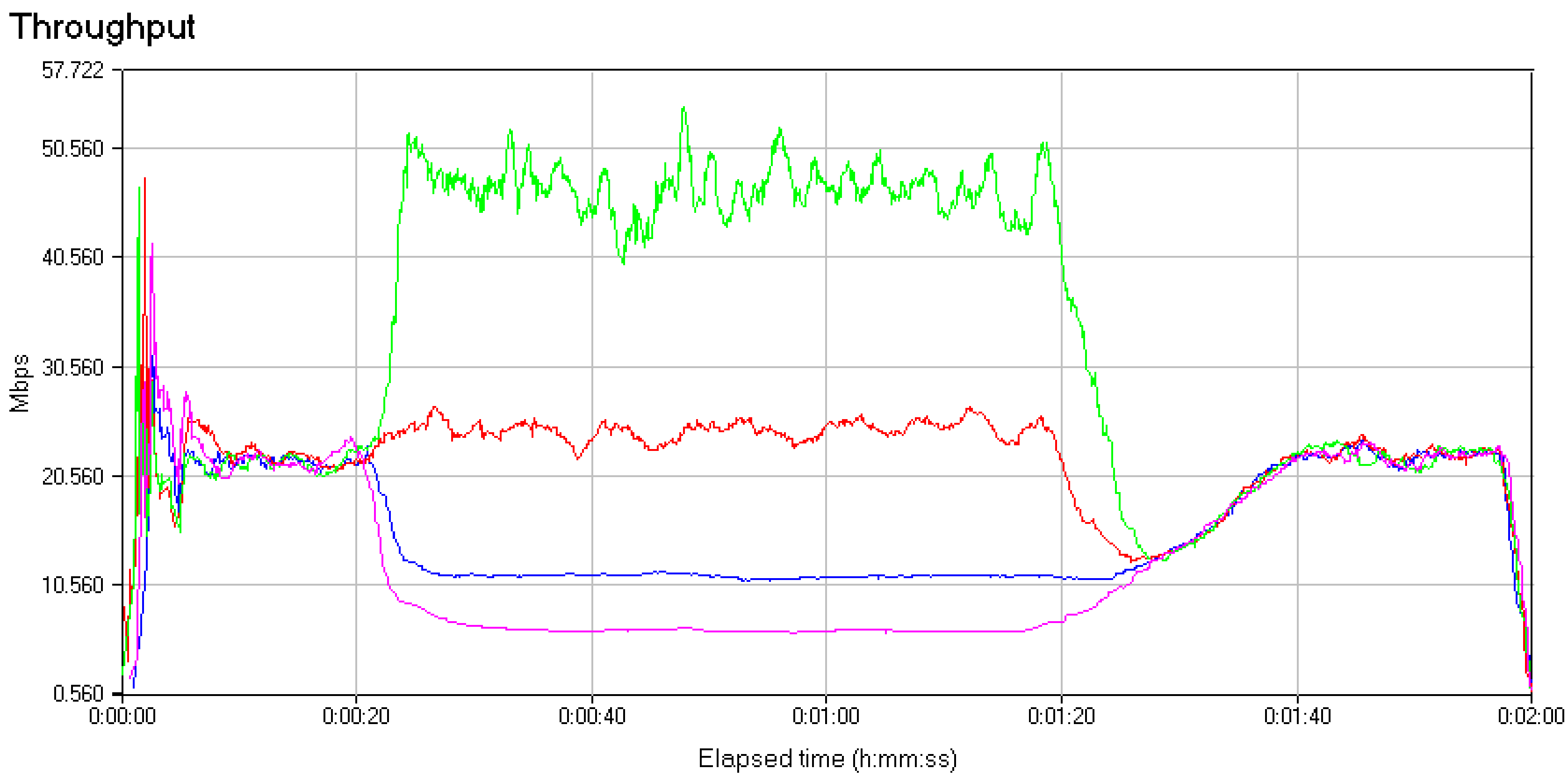
Group	# Users	Priority	Mbps/User	Mbps/Group
Admin	20	6	12	247
Teachers	100	3	6	616
Students	2500	1	2	5,137
All	2620	1.1	2.3	6,000

- Without Priority all users would have received 2.3 Mbps
- Within a group User Equalization is optional
  - This eliminates P2P overload even if it is encrypted
- Also, Admin and Teachers could have 500 Mbps "Assured"

Capacity for Educational Video can also be Assured

- This will guarantee perfect video
- If too many for capacity, last will be rejected until capacity available

Example of Multiple Service Tiers



Four Rate Multipliers activated from 0:00:20 to 0:01:20

Each tier gets increased average rates based on their payment class all the time, not just a higher peak rate when there is no congestion

Web Access Response Time

Web page response time depends on the slowest flow

- Typically there are 40-100 flows (separate files) per page
- All must complete before the page is ready

Queue discards cause divergence in the flow rates

- Some are hit hard and stall, others miss hits and go fast
- Result is the slowest flow of 40 slow each page by ~ 10:1 from ideal

FRC however allows them all to finish close together

- Thus FRC improves web page response by ~ 3:1
- Also eliminates the less frequent major page delays

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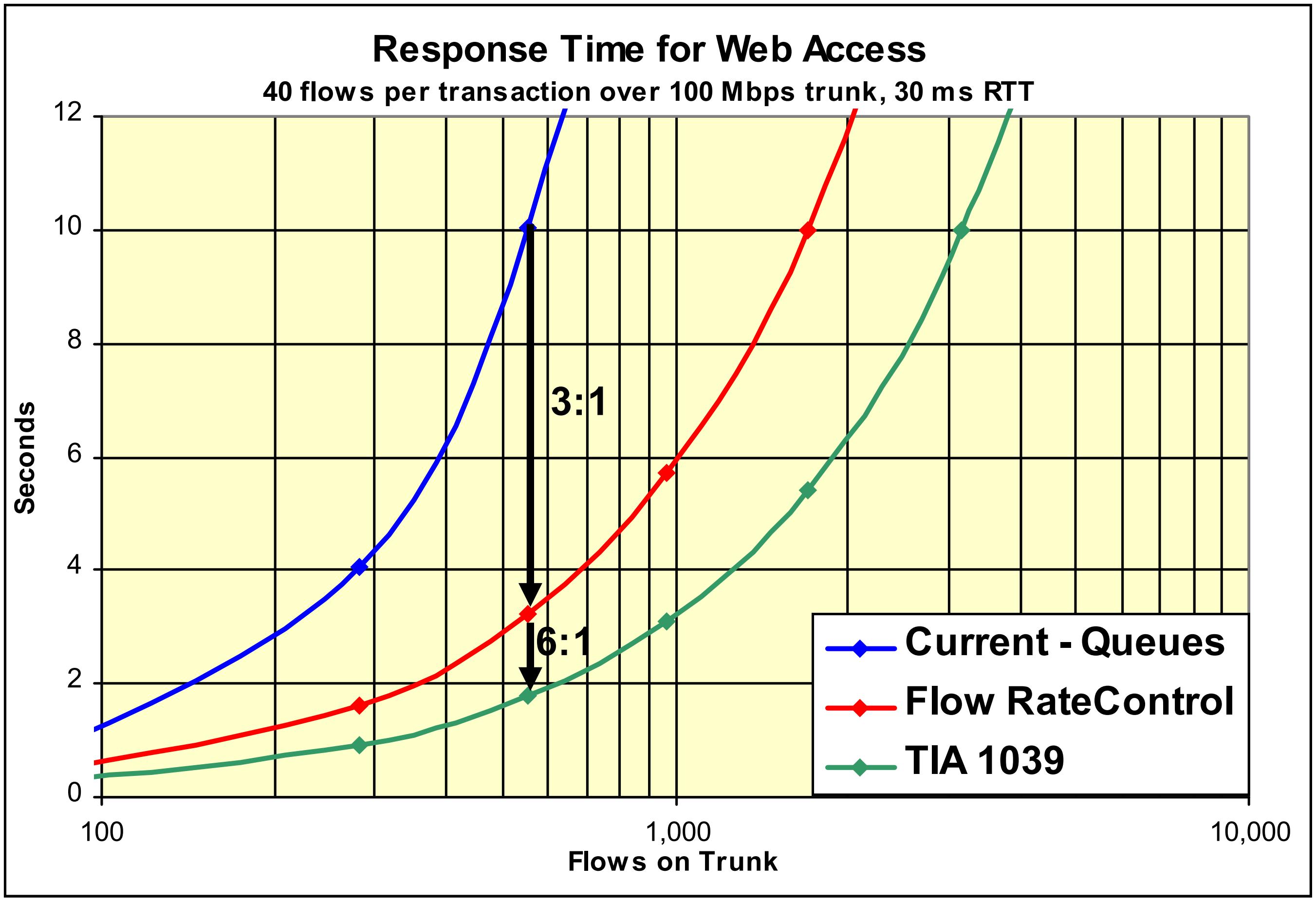
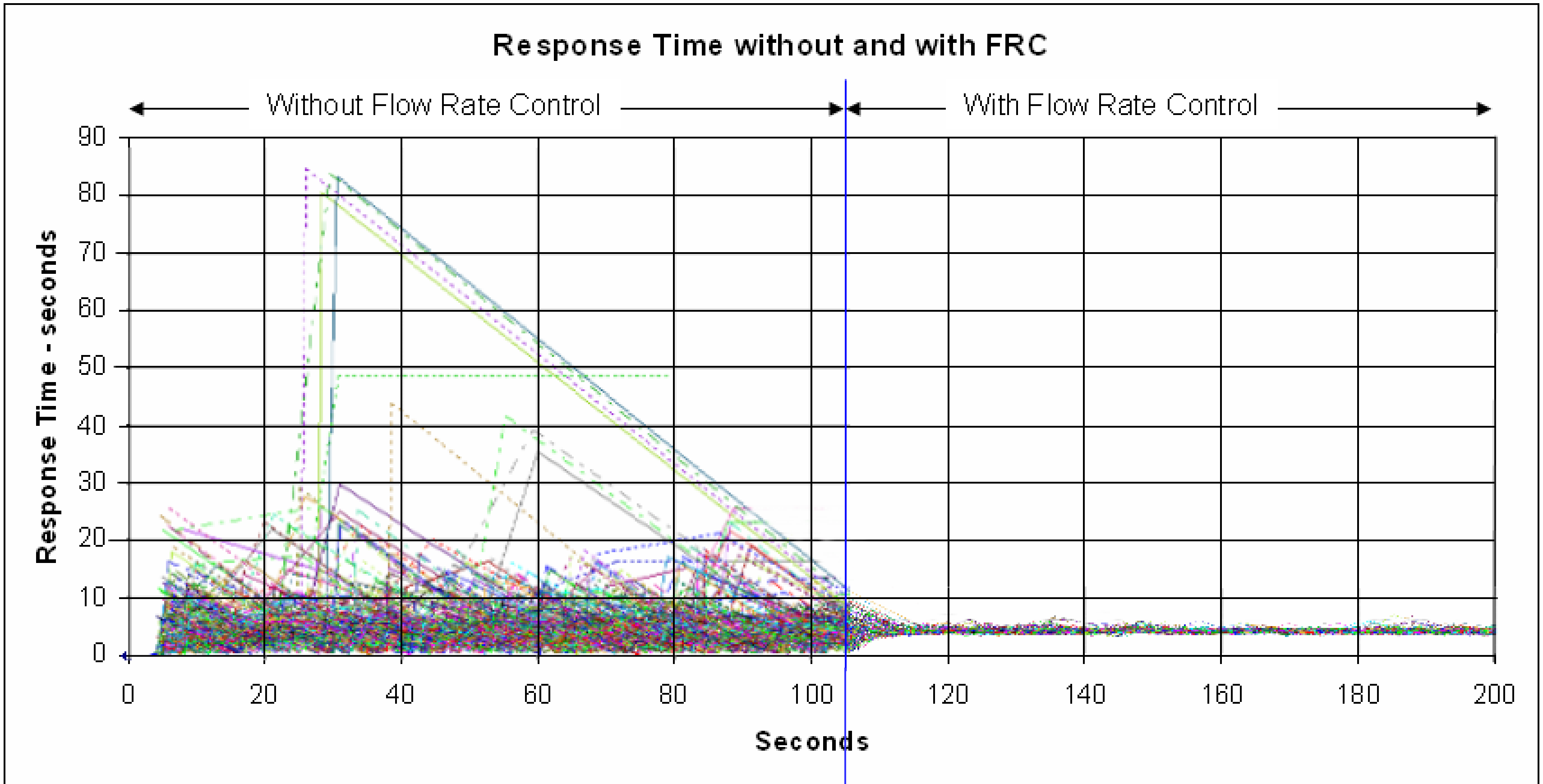
Improved QoS – Two New Options



Using Flow Rate Control, response time can be reduced by 3:1 over the current queue based load control

Using TIA 1039, response time can be reduced by 6:1 (not yet in field)

Measured Response Time Improvement



Avg. web page takes 12 sec. max 85 sec ***Avg. web page takes 4 sec., max 6 sec.***

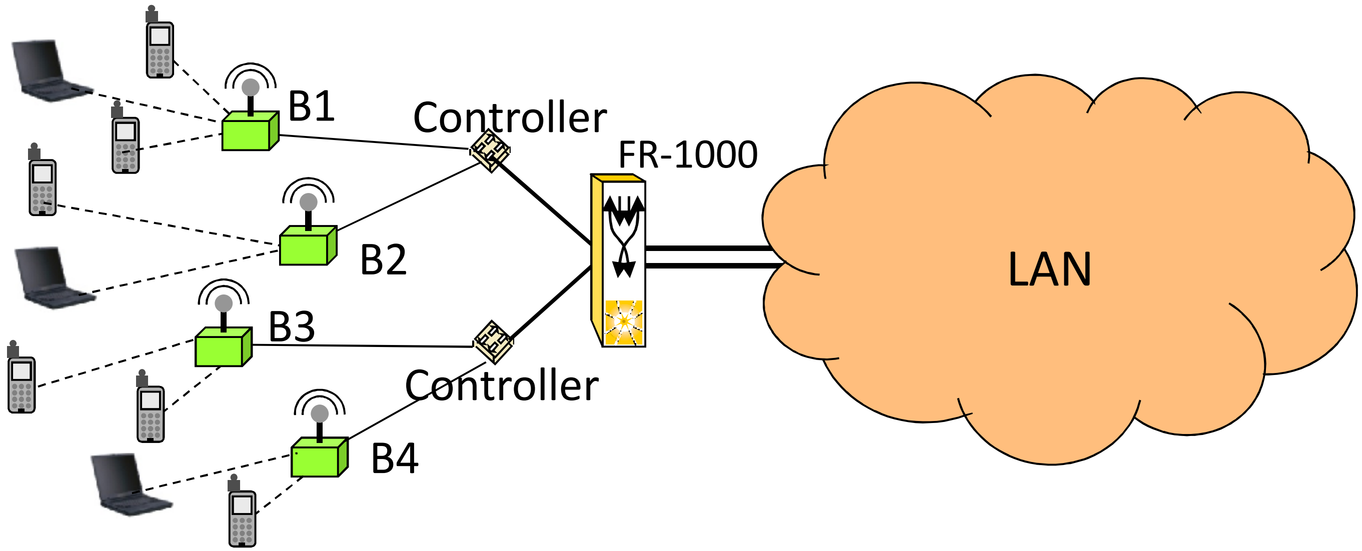
With no turbulence all flows stay at the same rate

For a Web Page, all parts must complete before the page is done

The typical web page appears 3-5 times faster with Flow Rate Control

Similar but even greater gains with FSA Signaling

WiFi – VoIP Quality Assured, Response Time Improved

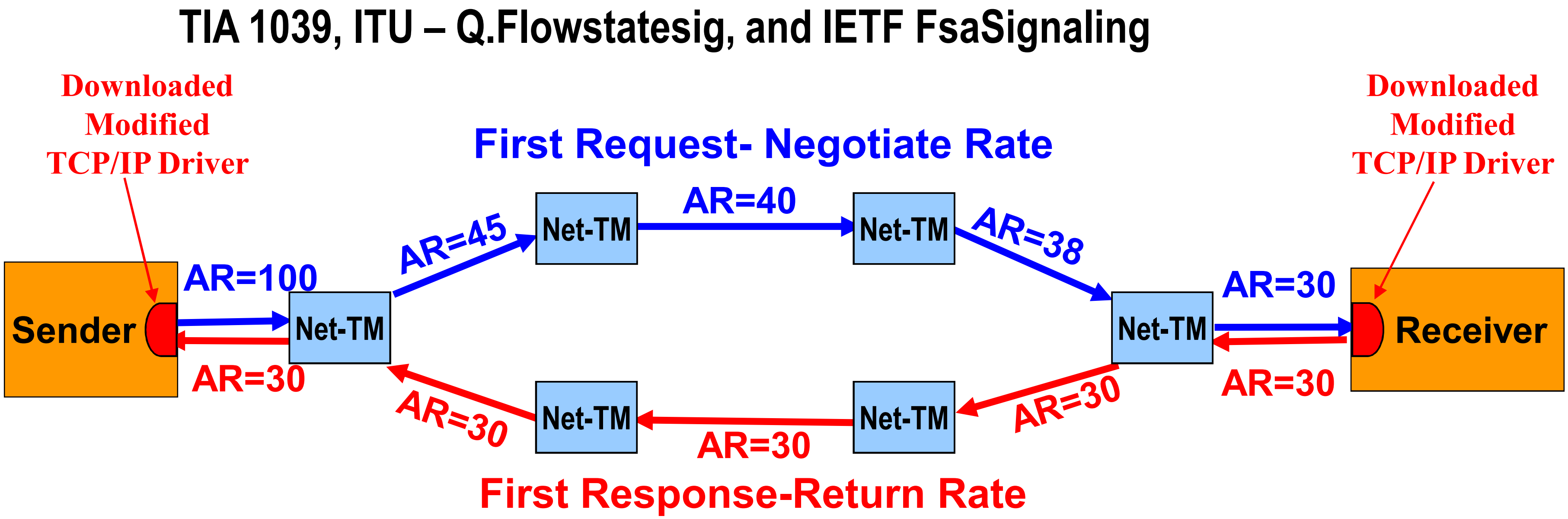


WiFi Utilization must be controlled to <100%

- Double exponential delay for Upload due to Slotted Aloha*
- FRC can assure base station does not saturate
- Users associated with base station through management info
- VoIP found be unsuitable on all systems without Anagran
- Web Access speed tripled, Utilization doubled

** Slotted Aloha, invented by L. Roberts in 1971, uses exponential backoff if collision*

Flow State Aware (FSA) Signaling



FSA Signaling standard currently is TIA 1039, ITU and IETF versions ongoing

Signaling Packets go in-band along flow path with rate request

Each network node (Net-TM) confirms or changes the requested rate & QoS

The confirmed rate is returned to the sender

TCP can then jump to the full rate, no slow start, no stalls

QoS and Utilization are very near ideal; no loss, no jitter

TIA 1039, ITU Q.Flowstatesig & IETF FSA Signaling

May 2006 - TIA 1039 adopted

Sept 2007 - ITU adopted same requirements as Y.2121

Nov 2010 - IETF starting on FSA Signaling

ITU now completing Protocol, Q.Flowstatesig

- Slight modifications from TIA 1039
- Desirable to make TIA 1039 compatible

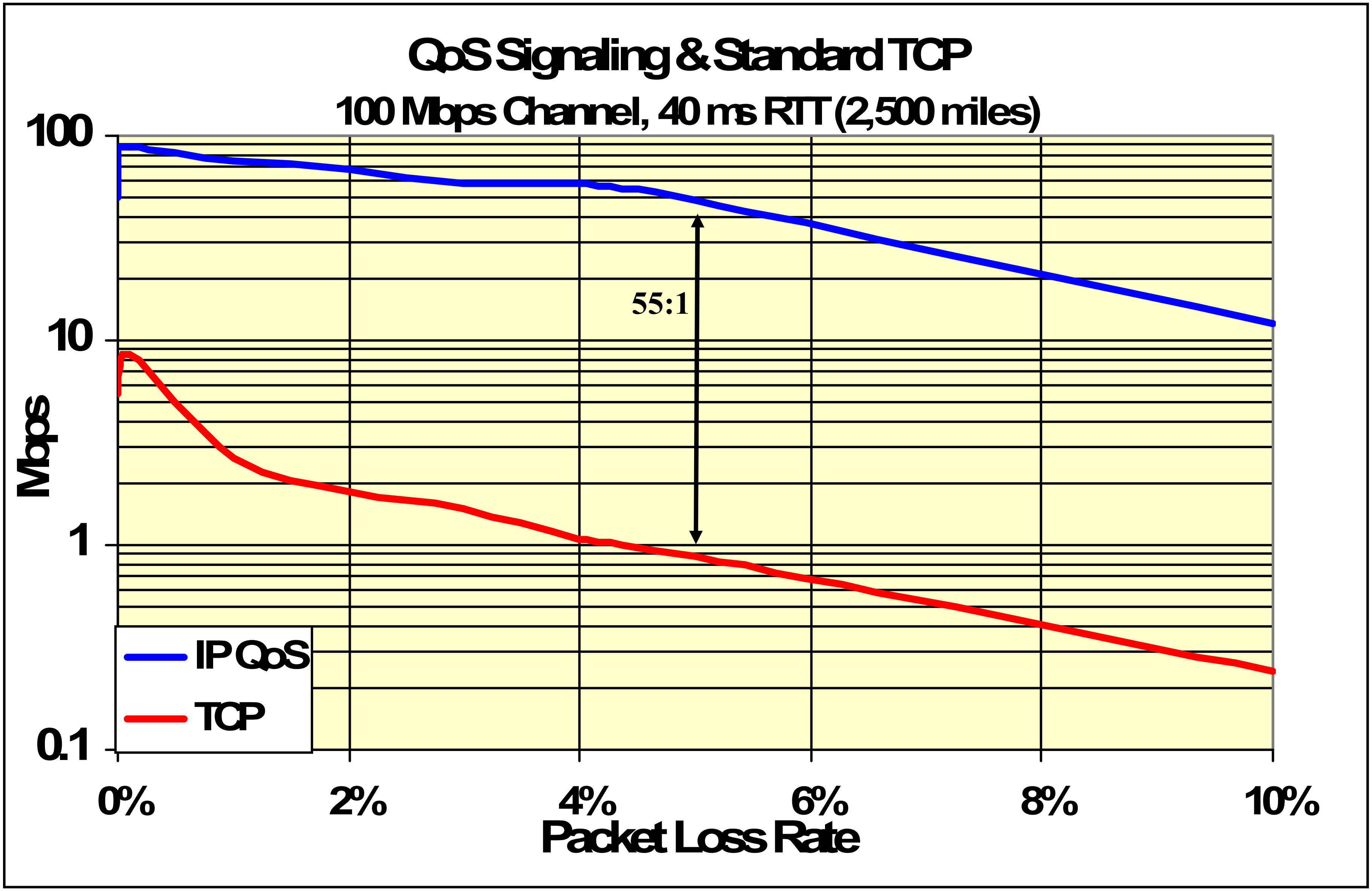
DARPA has now contracted work to add secure authentication

- Session Authentication block follows QoS block to authenticate user
- Allows network verify user and obtain his priority attribute
- Allows receiver to request senders attributes

Goal is to add security process to the standards

- Will enable military, emergency services, and secure Internet activity

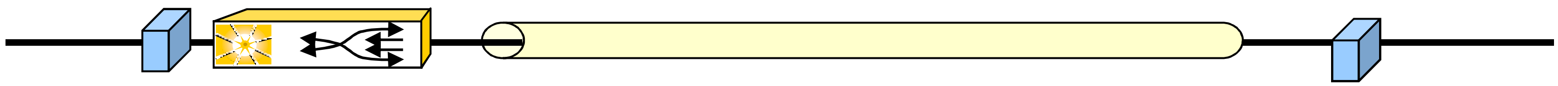
TCP Throughput Improvement at 40 ms RTT



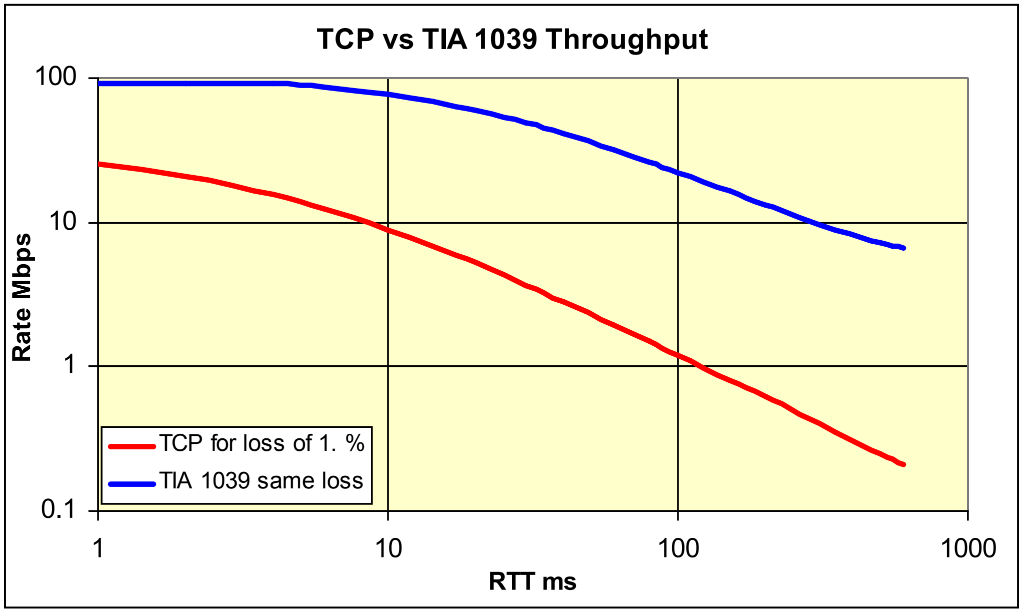
Higher Throughput Capability

The Anagran FR-1000 supports TIA 1039 protocol

- Together with proxies, it greatly improves TCP throughput
- TCP slows down with distance but not much with TIA 1039



- The FR-1000 tells the proxies what rate is available
- The proxy locally ACKs and then streams the data at the maximum rate
- Gains are from 4:1 up to 32:1
- Tests against satellite PEP systems prove TIA 1039 is 4 times superior
- Packeteer's SKYX publishes gains for satellite of 8:1 vs. the 32:1 for TIA 1039, again 4 times less effective



TCP & TIA 1039 Data Rate for RTT's up to satellite distance – gain locally is 4:1 and satellite gain is 32:1

TCP Utilization Improvement for Satellites

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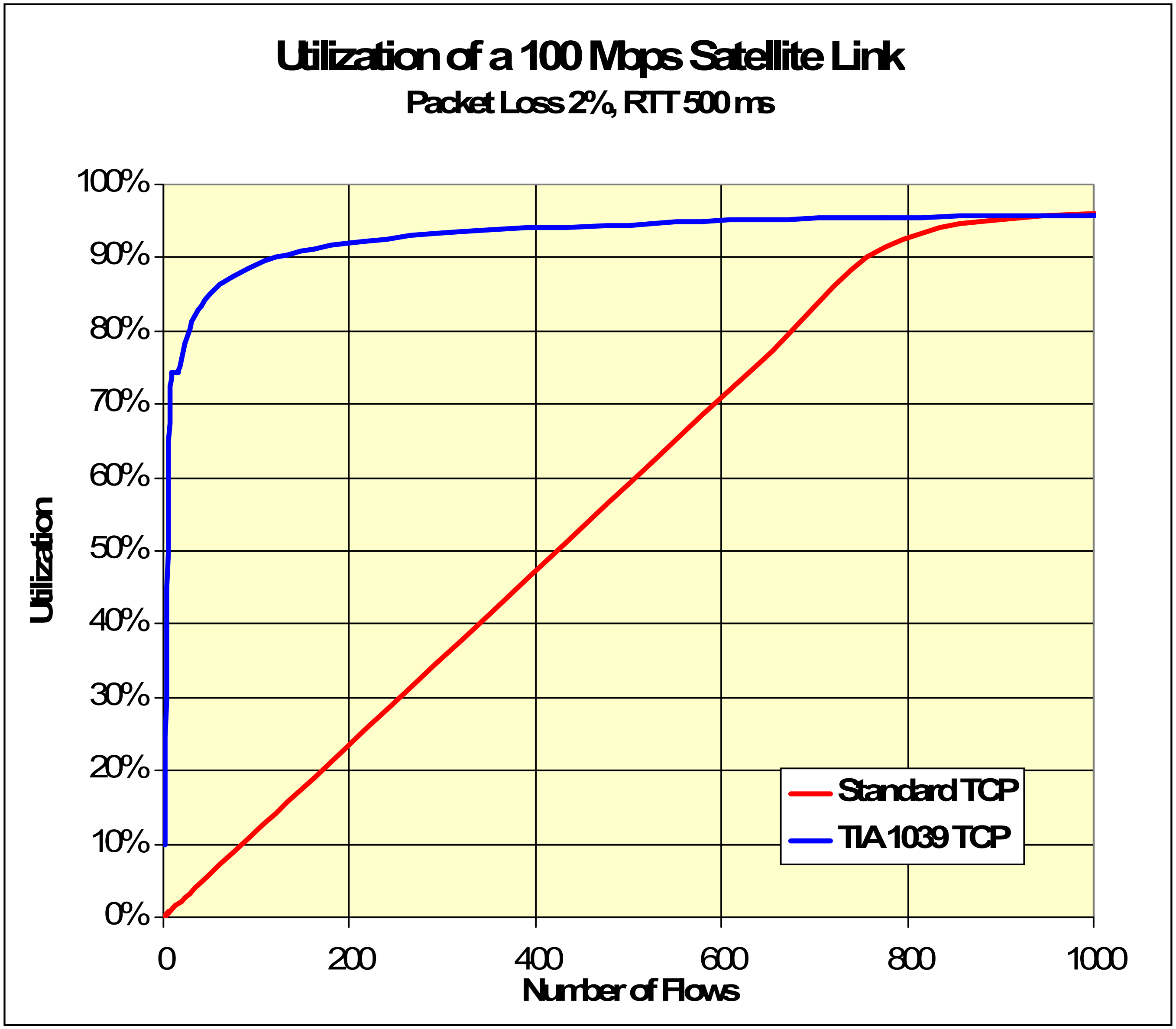
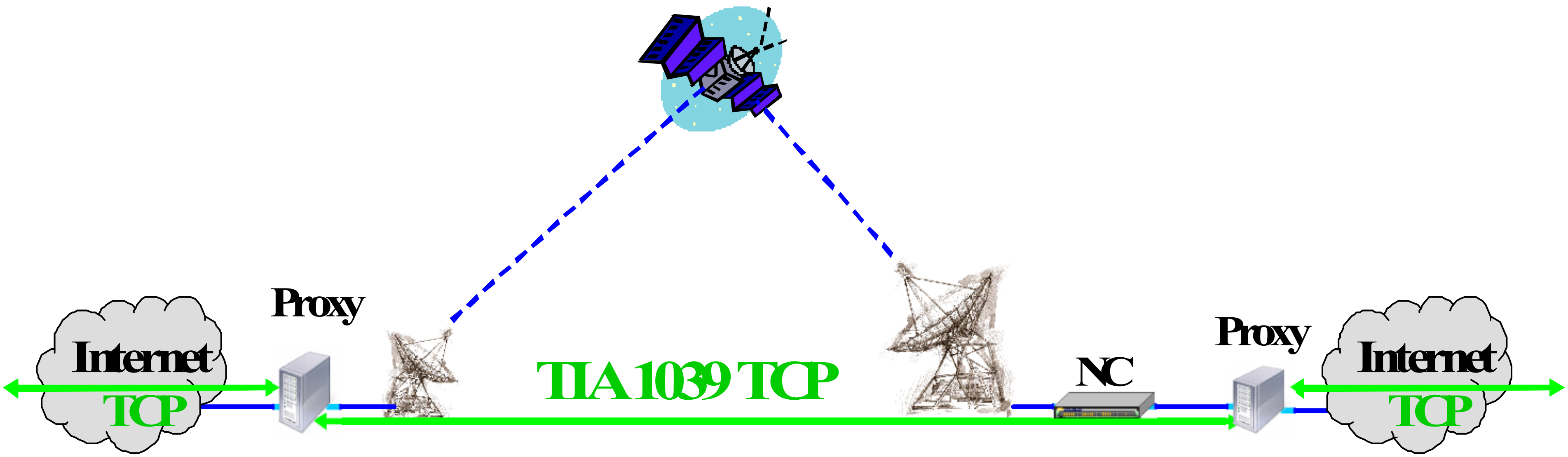


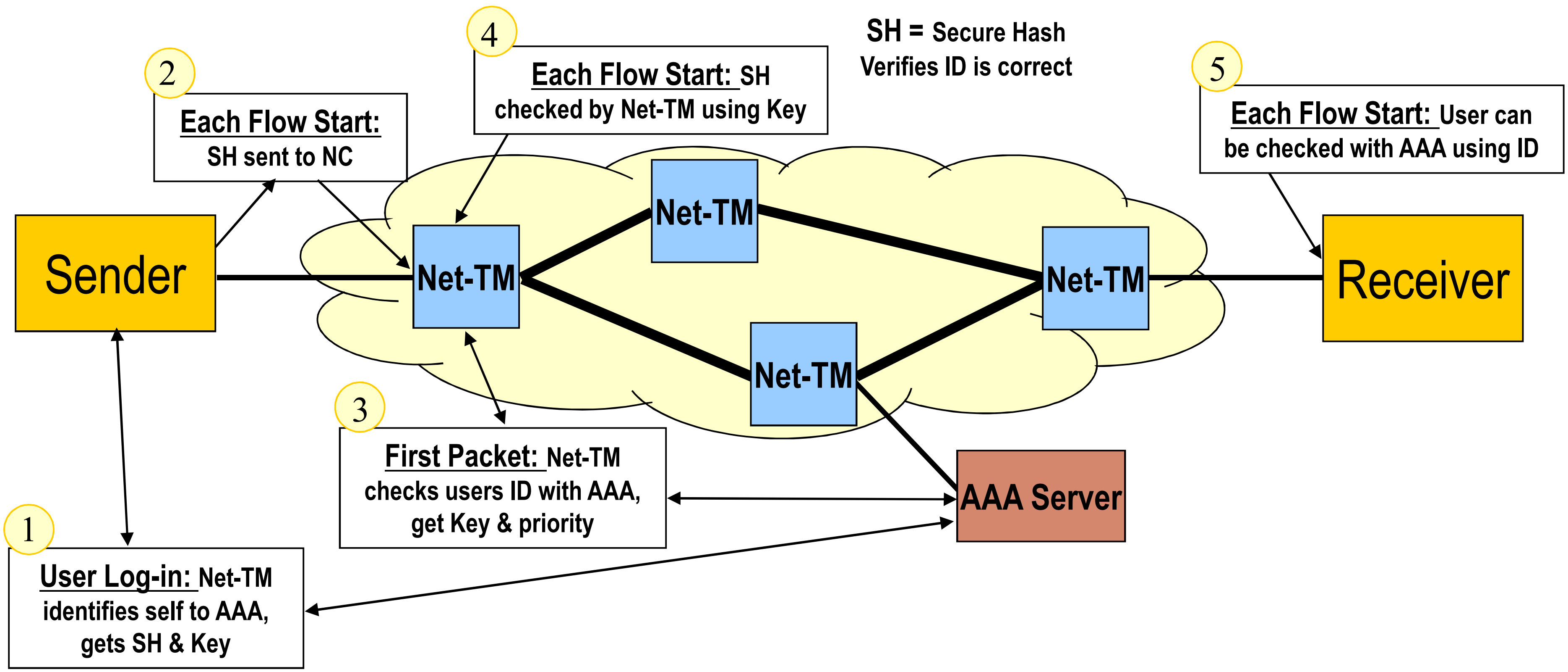
Standard TCP over a satellite is slow – it takes many users to get good utilization

TIA 1039 using Proxies for a Satellite Span



This configuration shows how a single satellite span, or a hub and spoke satellite system can utilize TIA 1039 to obtain the maximum throughput and flow rates over a satellite. The traffic coming in and leaving is standard TCP and UDP but across the satellite it is marked as AR and MR. The users either side of the proxies do not need to consider TIA 1039. With a hub and spoke system, only one NC is required at the hub since it is controlling the rates or flows in both directions and to all spokes.

Network Authenticates User with FSA Signaling extension



- **Emergency Services supported**; users priority is securely verified
- Receiver can obtain those attributes of user that it is authorized to see
- Network security greatly improved for all those using FSA Signaling

Device Use
5.2 B People Need a Device to get on Internet by 2020

Desktop Computer

- Big in 90’s, usage decreasing

Laptop Computer

- Strong growth in developed countries
- Business – now typically issue laptop to every employee

Netbook

- Developed countries (1.2 B people) – Usage growing but users used to laptop and smart phone – thus slower growth
- ***Developing countries (5.5 B people) – Netbooks using cloud computing will take off as most cost effective computing option for the masses***

Smart Phone

- Currently growing rapidly in both developed and developing countries, however limited use for computing

Simple phone plus Netbook

- Will compete with smart phone in developing countries and for many in developed countries – larger screen, compute capable

Future Changes to Expect with 4G Wireless

Smartphones with fast Wireless and Clouds

- ***Major usage changes will start evolving as speed increases***
- ***“Presence” means we will interact with nearby things***
  - Smart locks, payments, ads, interrupt priority, reminders
  - Quick lists of nearby places, stores, products, people
  - Auto connect & control of nearby TV, radio, computers, devices
- ***All your devices and data linked***
  - Computer or car screen take over your phones functions
  - Phone takes over your computer(s) functions
  - Car augmented by phones communication & compute power

Changes will impact our lives in ways we don’t imagine

Summary

Today's Internet needs Fairness, Quality & Utilization improvements

- Fairness: Equal capacity for equal pay is critically needed
- Utilization, Response time and delay can all be improved finally
- The technology (FRC) is available and it also reduces cost & power
- The new protocol, FSA Signaling, will provide near ideal throughput & QoS

Growth of Internet

- Already grown by 7 trillion over 40 years with 2.1 B users (31% world)
- Next decade users will grow to 7.4 B (99% world), traffic up 30-60:1
- That will add 5.2 B users, all of whom need Internet devices
- Most of additions will be from developing world
  - They will either get Smart phone or Netbook due to cost
  - Netbooks with cloud computing will be least expensive computing option

Once 4G wireless networks supports FSA Signaling protocol, an app for Smartphones will allow greatly improved quality and security

