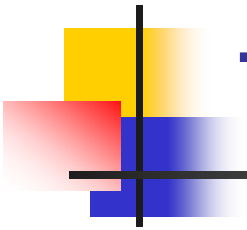
Internet Directions

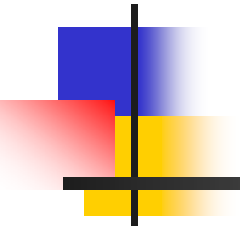
Geoff Huston

Telstra



Thanks to

- Fred Baker of Cisco for some of the material used in this presentation

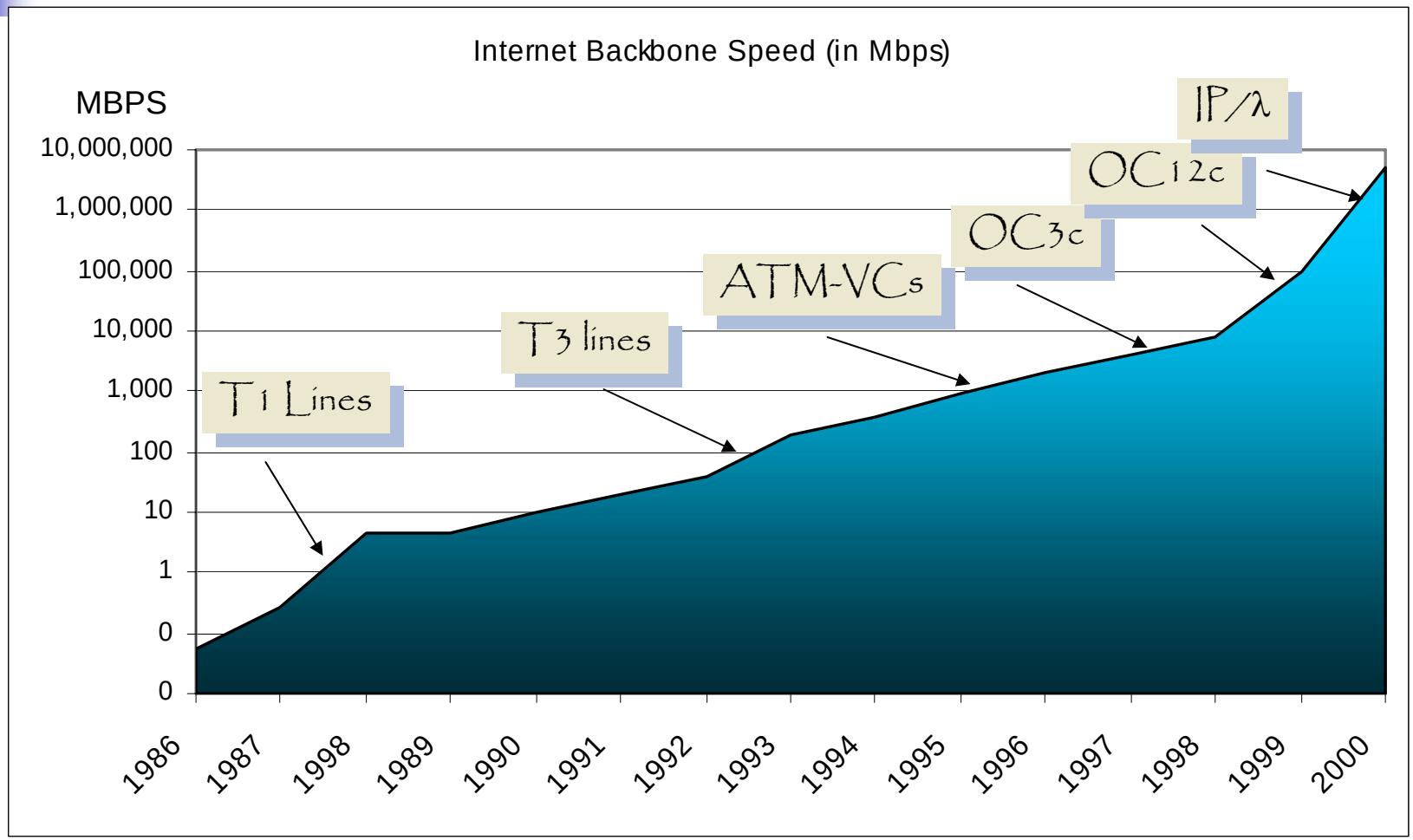


It’s a speed thing...

“Man will one day travel faster than a horse can run...”

René Descartes

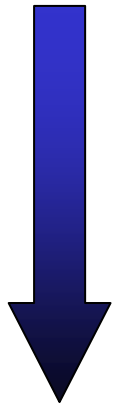
Internet Backbone Speeds



Transmission Technologies

Core Networks

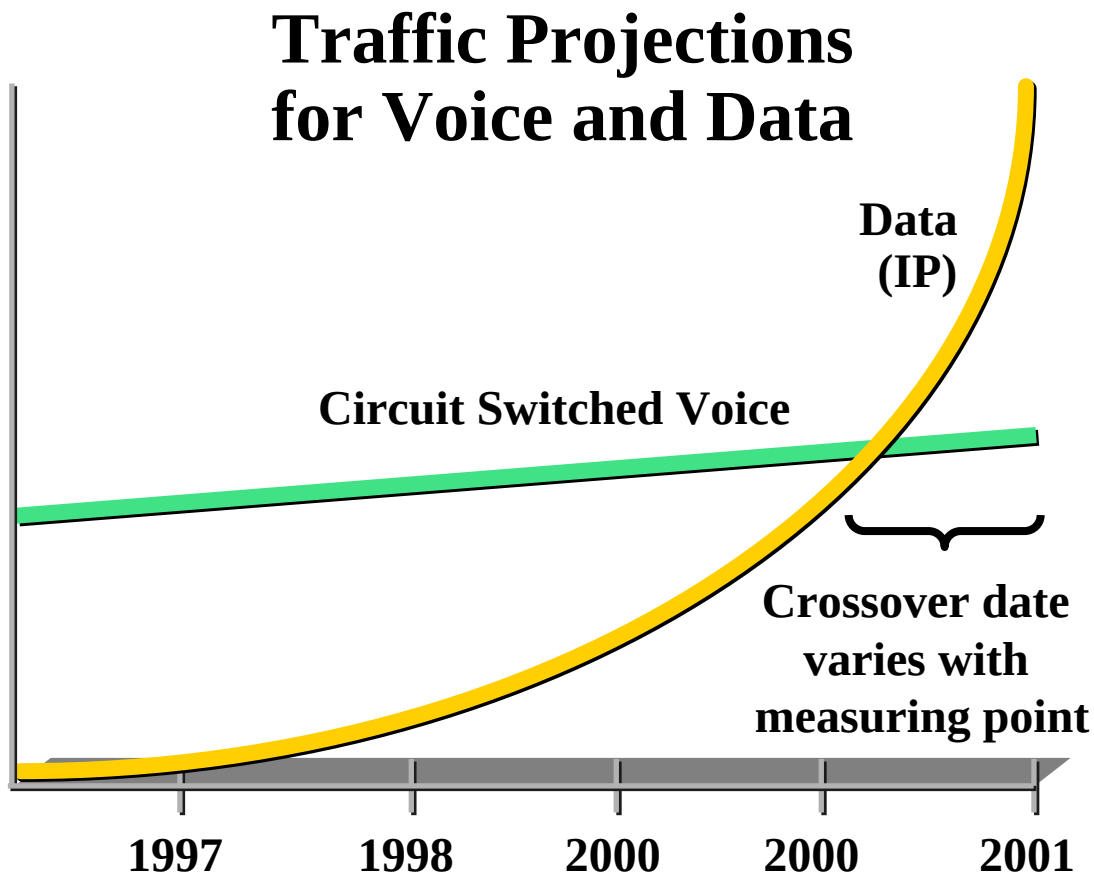
Access Networks



- The optical switched backbone
  - Gigabit to Terabit network systems using multi-wavelength optical systems
  - Single hop routing to multi-hop optical Traffic-Engineering control planes
- Access networks are changing...
  - xDSL, cable modem, 3G wireless
  - 100MFE and GigE fibre access systems

Growth of IP Traffic

- Messaging
- Information search/access
- Subscription services/“push”
- Conferencing/ multimedia
- Real time Video/imaging
- Entertainment services
- MP3
- DVD



Bandwidth Supply and Demand

- Fibre installation is now exceeding Mach 4 per hour for single optical strand equivalent
- Dense Wave Division Multiplexing is lifting per-strand optical capacity
  - from 2.5Gbps to 3.2Tbps (320 wavelengths, each of 10Gbps per lambda) per optical strand

“Raw” Bandwidth will get cheaper per unit

Likely trend from demand pull to massive overhang of excess supply in the wholesale trunk carriage market

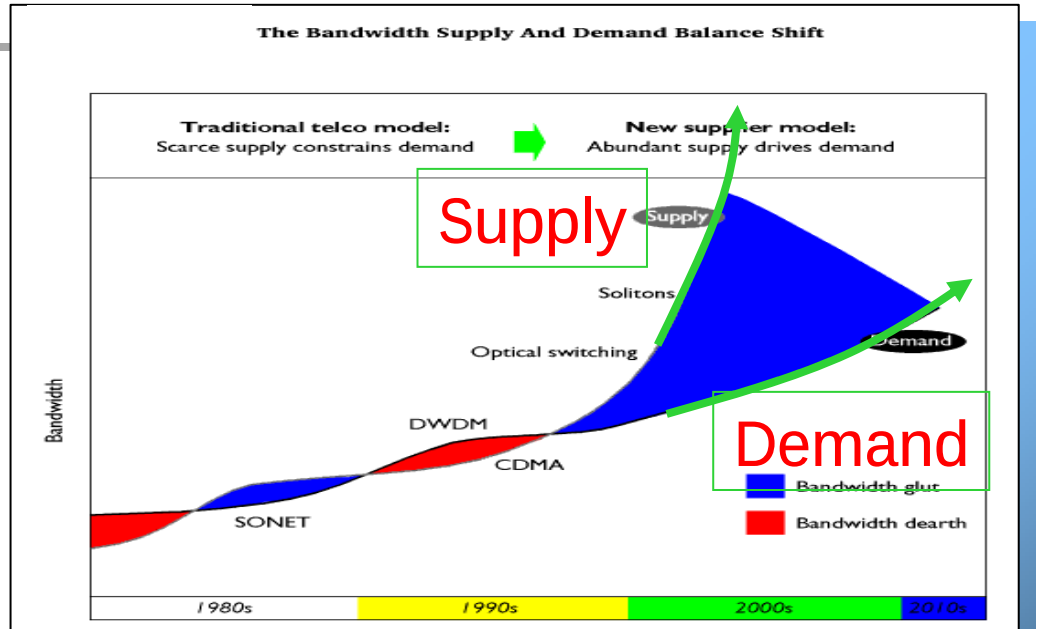
Bandwidth Supply and Demand

"An emerging combination of new technologies, and new service suppliers will create a long-lasting abundance of bandwidth permanently altering the supply-demand equation."

Forrester Dec 97.

"The potential capacity between major [European] cities will rise one-thousand fold over the next three years"

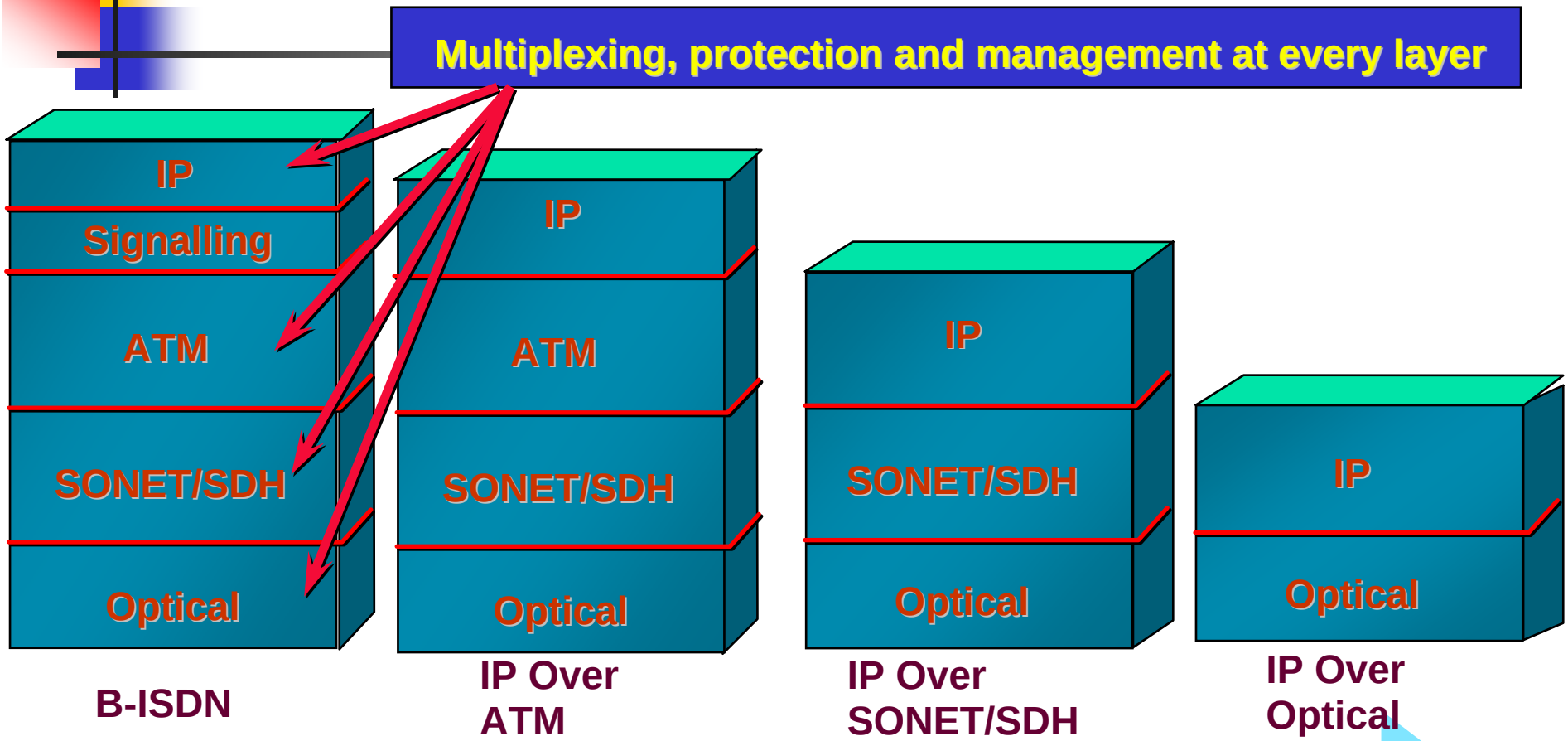
Yankee Group Aug 98.

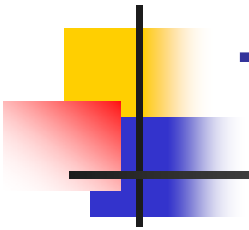


Technology	Description	Time frame
SONET	▪ Synchronous Optical Network ▪ Increases fiber speed from 45 Mbps to 10 Gbps	late 1980s
CDMA	▪ Code Division Multiple Access ▪ Expands wireless capacity tenfold	mid 1990s
DWDM	▪ Dense Wavelength Division Multiplexing ▪ Divides fiber into multiple wavelengths ▪ Increases fiber capacity to 100 Gbps and beyond	late 1990s
Optical switching	▪ Speeds up switching and transport by removing electro-optical conversions	early 2000s
Solitons	▪ Reduce cost of long-distance transport by removing fiber amplifiers	late 2000s

Source: Forrester Research, Inc.

High Speed IP Network Transport





The GigaNet

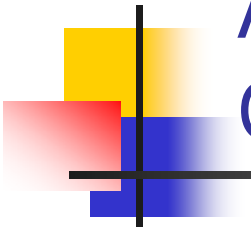
- An Internet equipped with
  - Gigabit Backbones
  - Gigabit Access
  - Billions of connected devices

Carriage Networks and IP packets

- Each speed shift places greater functionality into the IP packet header and requires fewer services from the carriage system
- Networks need to get faster, not smarter

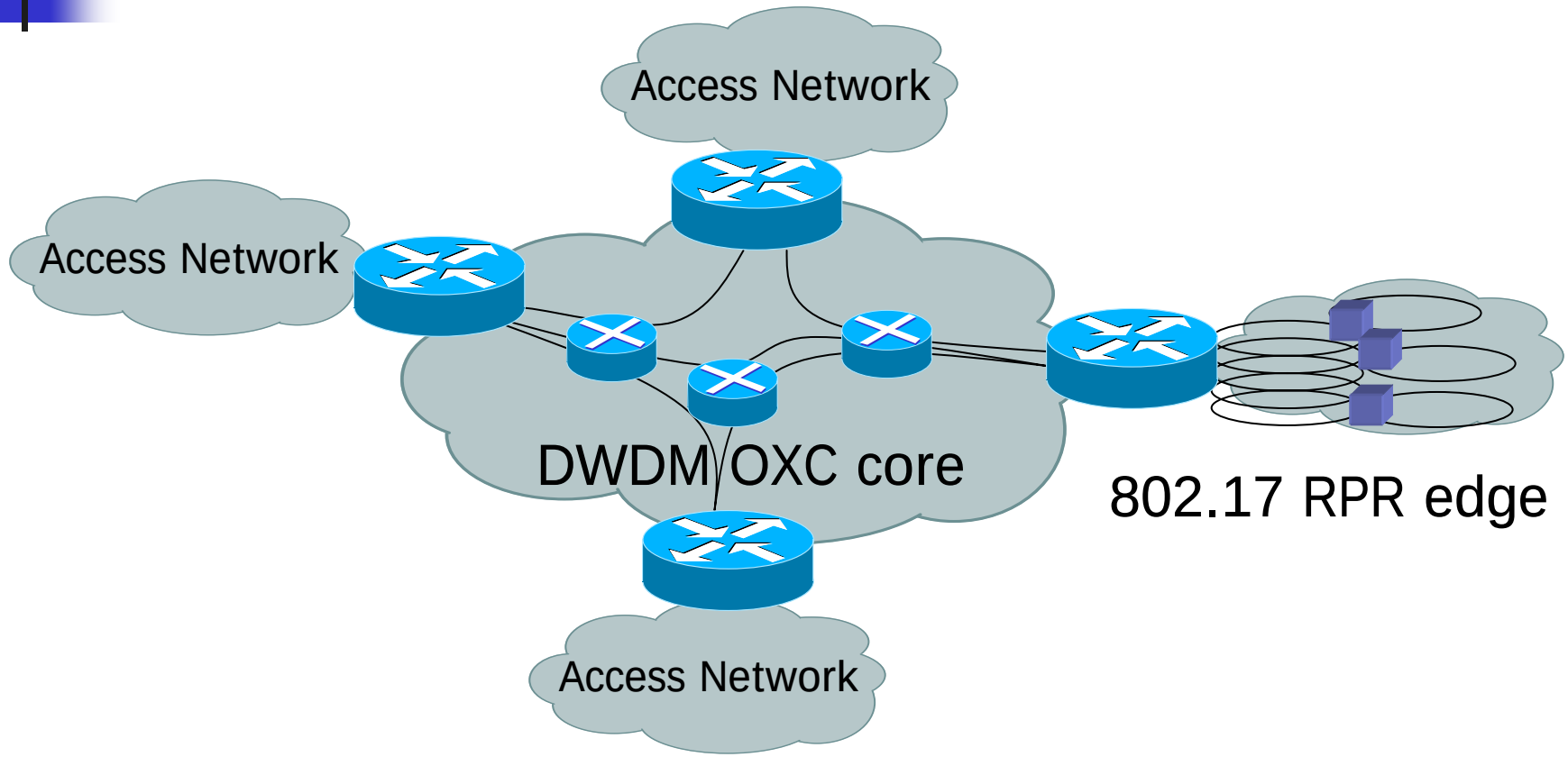
NETWORK	→	PACKET
real time bit streams		**asynchronous data packet flows**
network data clock		**per-packet data clock**
end-to-end circuits		**address headers and destination routing**
fixed resource segmentation		**variable resource segmentation**
network capacity management		**adaptive dynamic utilization**
single service platform		**multi-service payloads**

A whole new Terminology Set: Gigabit Networking Technology Elements

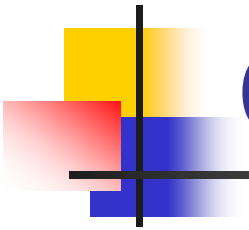


- Ethernet packet frames
  - Faster Ethernet: 100mFE, GigE, 10GigE
  - VLANs: 802.1Q
  - Rings (802.17) and T-Bit Fast Switches
- Optical Transports
  - CWDM / DWDM
  - Wavelength-Agile Optical Cross-Connect control systems
- Traffic Engineering
  - Rapid Response, Rapid Convergence IP Routing Systems
  - MPLS to maintain path vector sets

GigNetwork Architecture



Network architectures must be simple in order to be fast



GigNetwork Architecture

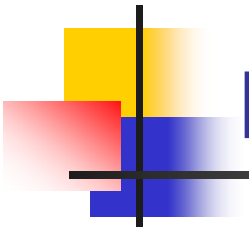
- Abundant end-to-end capacity will remain elusive, despite DWDM backbone cores
  - Last mile access deployments are faster and denser than longhaul deployments

    (the laws of physics and economics still hold)
  - The access / backbone interface will remain a service quality chokepoint

Gigabit networks will bring gigabit applications

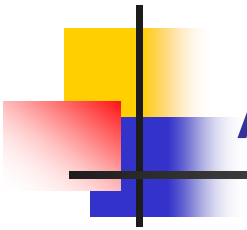
As for the future, your task is not to foresee, but to enable it.”

Antoine de Saint-Exupéry



Network Abundance

- Large edge bandwidth
  - High speed, always available, fibre and copper delivery systems to home and businesses
    - xDSL copper access
    - HFC cable access
    - FTTB / FTTH fibre access systems
- Flexible edge bandwidth
  - Wireless
    - IP Mobility - Handsets
    - Fixed Wireless
    - Wireless Service LANs
    - Personal LANS – e.g. Bluetooth



An Abundant Network Will Enable…

- Bandwidth-hungry applications
  - Electronic “mail order” shopping and other commerce
  - MP3 music delivery
  - Mesh DVD delivery
  - Remote Sensing and Imageing apps
  - Wide-scale teleconferencing
    - Remote learning, remote presence
  - Your idea here…
- Massive use in small dedicated applications
  - Online appliances with embedded communications functions

Announcements for just one day...
22nd June 2000

Microsoft, Compaq Computer Corp., and Intel announced Tuesday that they are teaming with San Francisco, California-based Digital Island to build a streaming video network.

The companies say that the network will provide broadcast-scale streaming media for the first time over the Internet, with a reach "roughly comparable" to that of a prime-time TV program.

A couple of Colorado cable cowboys have galloped into the midst of a complex European waltz around the future of broadband access involving a company called Chello.

Chello is the Internet subsidiary of Europe's second biggest cable operator,United Pan-Europe Communic
twice this spring as Europe's answer to
has instead been performed in private
public offering (IPO).

Can a 10th-century king rise from the dead a thousand years later and conquer the world?
It sure looks that way. Bluetooth--named after King Harald II of Denmark,who apparently had one bad tooth--is poised to become a globally accepted communications technology for the wireless world.
Using radio signals, Bluetooth will let computers and handheld devices talk to each other over a distance of a few yards without the need for wires or cables. That means you'll soon be able to synchronize the information in your cell phone with the database in your Palm Pilot. Or print photos directly from a digital camera. Or use your cell phone as a modem for your laptop. Eventually, the technology could evolve to the point where consumer swearing a small Bluetooth-enabled device could shop by having their credit information conveyed directly to the store's computer.

In the corridors of AT&T Labs, Ma Bell is preparing wireless technology that could make today's "wireless Web" look like an old-fashioned telegraph system.

Dubbed "fourth generation," or 4G, the technology is aimed at supercharging wireless access to the Internet over cell phones and other mobile devices.Where today's mobile-phone connections run at about a quarter the speed of dial-up modems, these systems could start about 90 times faster than a dial-up modem and go up from there.

America Online's interactive television service, AOLTV, will be available in eight U.S. cities by mid July, the company announced today. The service will directly compete with Microsoft's WebTV.

AOL's 22.5 million members will be able to buy the service for $14.95 a month. Non-members will be charged $24.95. All subscribers must also pay$240 for the accompanying set-top box 56k modem, infrared keyboard remote control.

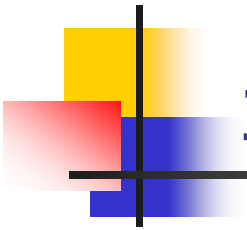
BT Cellnet launched the world's first "always-on" mobile network on Thursday, introducing GPRS technology that is expected to revolutionize the way people use the Internet.

It’s a people thing...

Value = Users^2

“The value of a network can be expressed as equal to the square of the number of users...”

Bob Metcalfe



1 Billion Internet Users ... or more!

- The true value of a network lies in its ubiquity, not in its functionality
- Ubiquity is where we are heading with the Internet...

Where are these billions of users?

- PCs and the fixed network
- Laptops with wireless lans
- Mobile devices and PDAs
- Appliances with embedded IP

Mobile is coming now

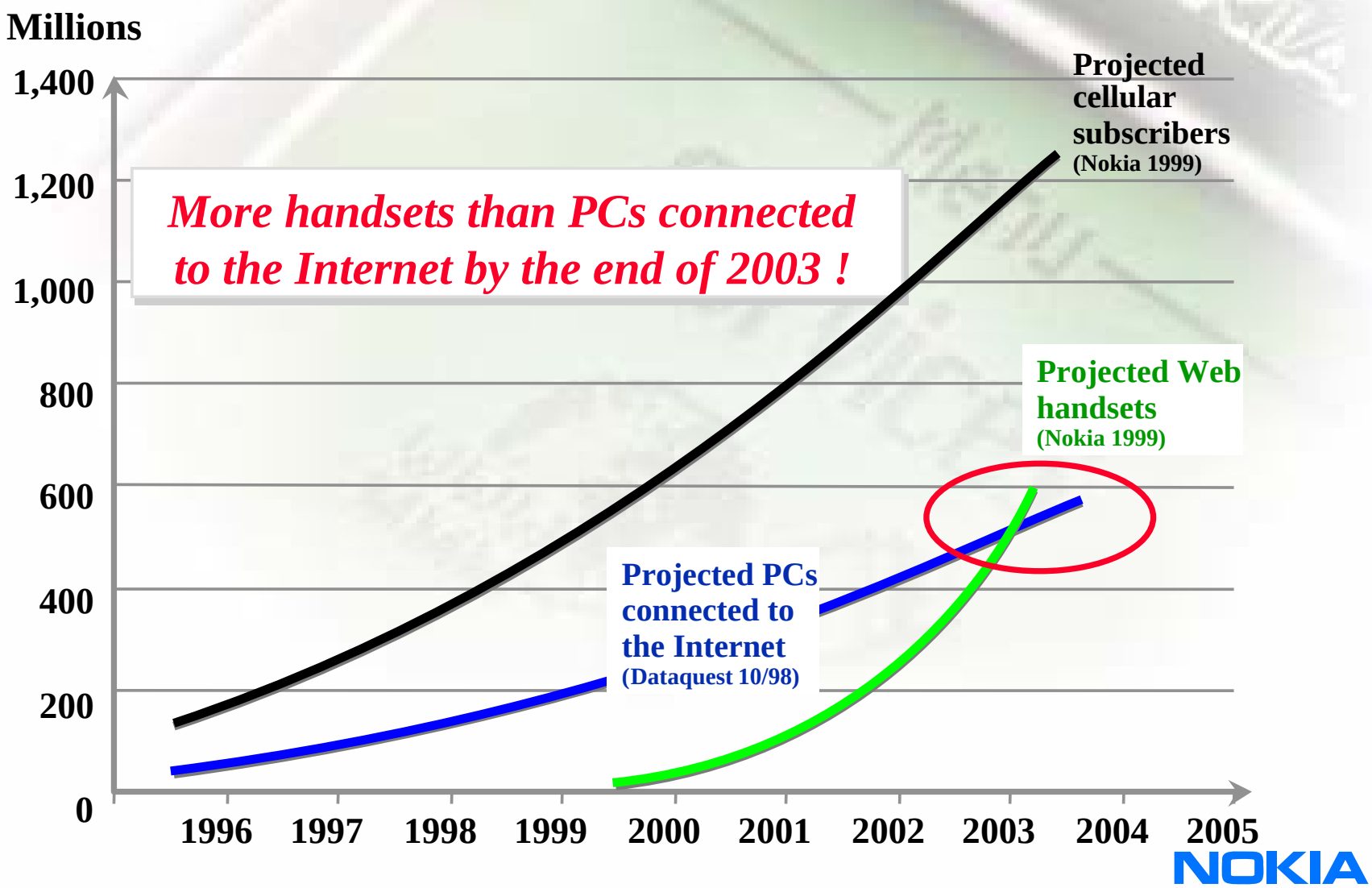
Appliances will come next

1 Billion **Mobile** Users

"Mobility is hard"

Just about anyone who has worked on IP mobility

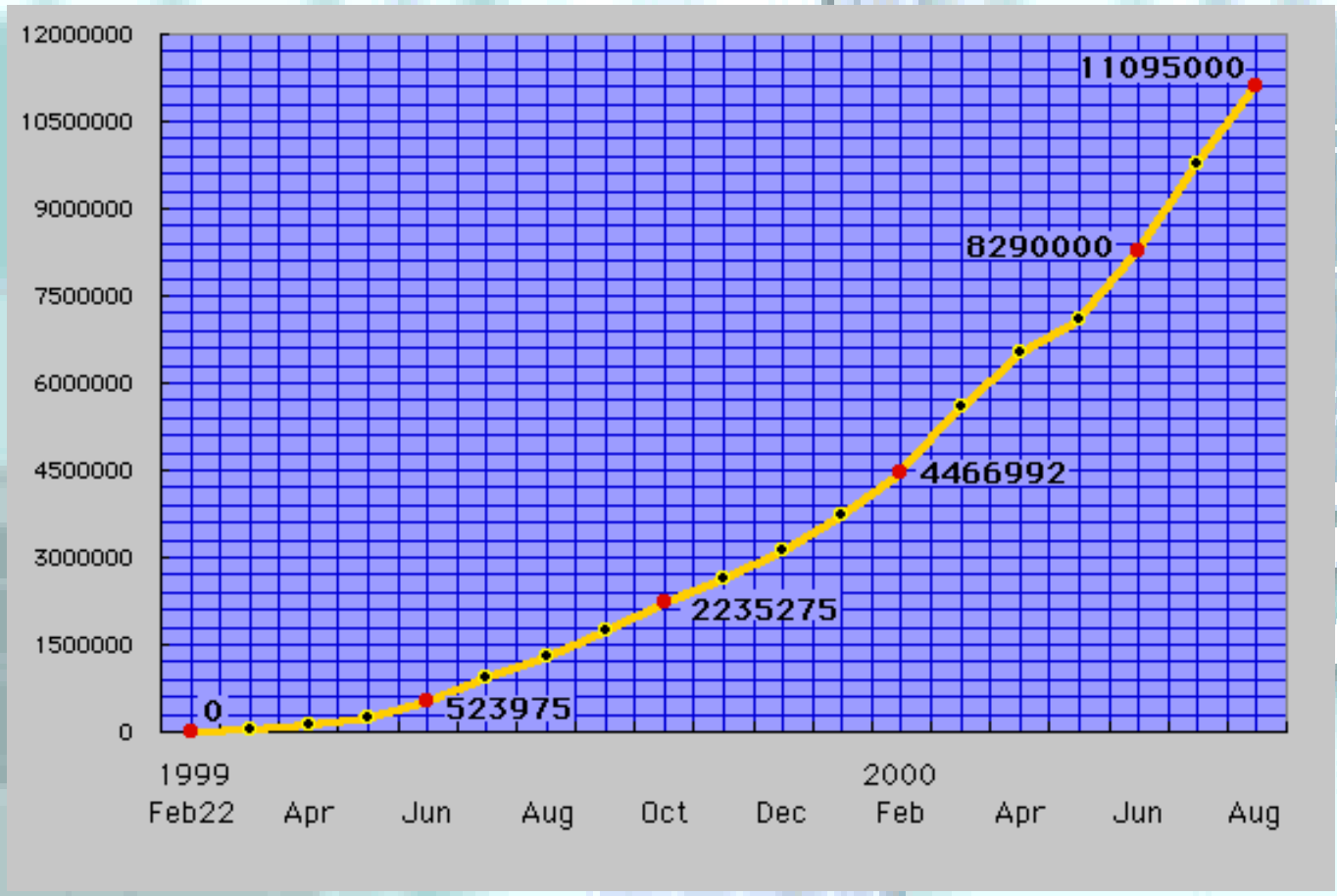
Mobile Internet Outlook



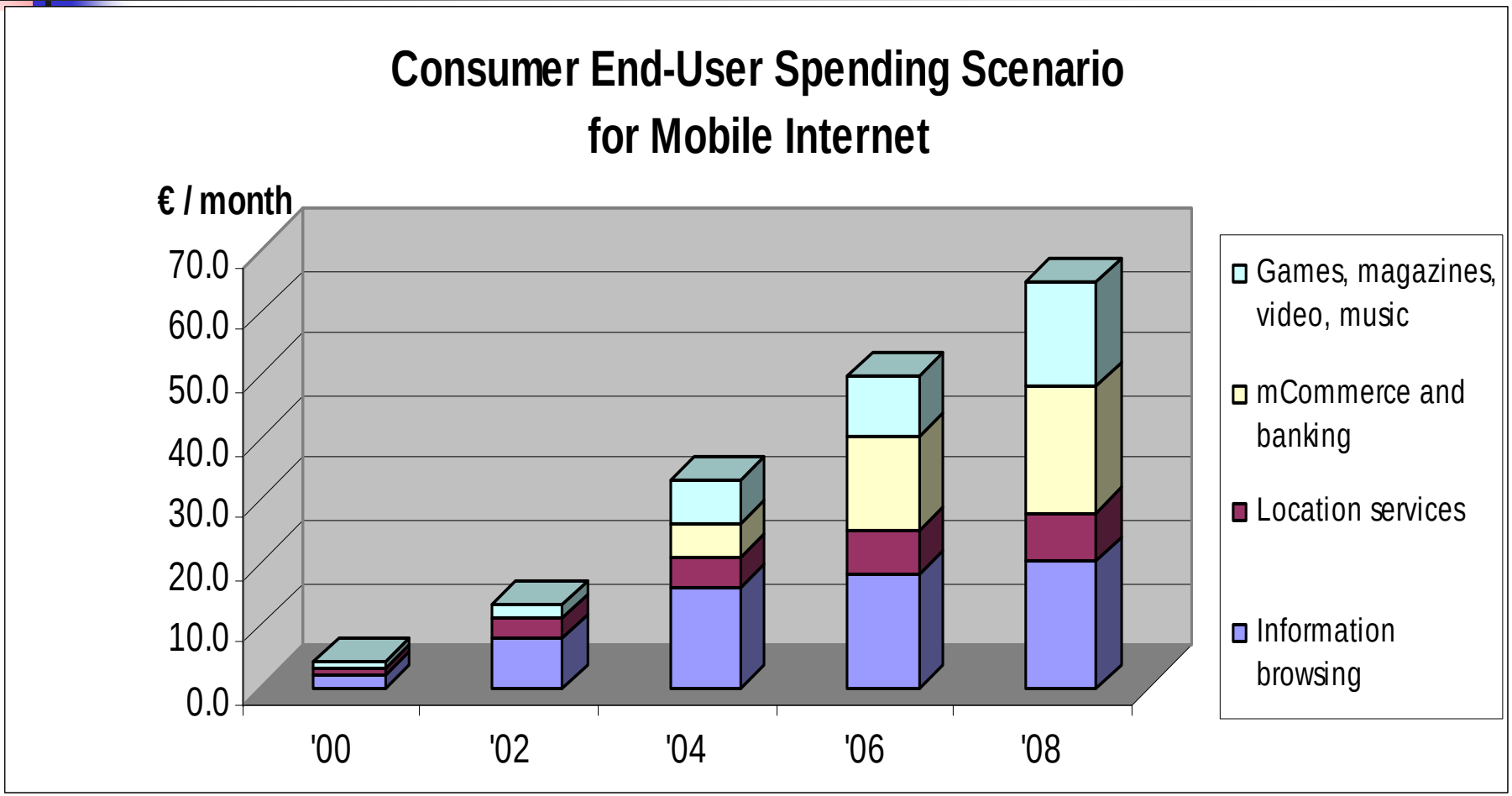
NOKIA

NTT DoCoMo I-mode Subscriber Growth

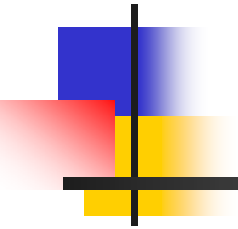
The number of i-mode customers exceeded **13,329,000** as of October 15, 2000.



Fueling the Mobile Market



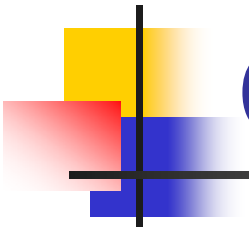
Source: NOKIA



There are Significant Issues, However

"Here there be dragons"

Scott Bradner, V-P Standards, ISOC

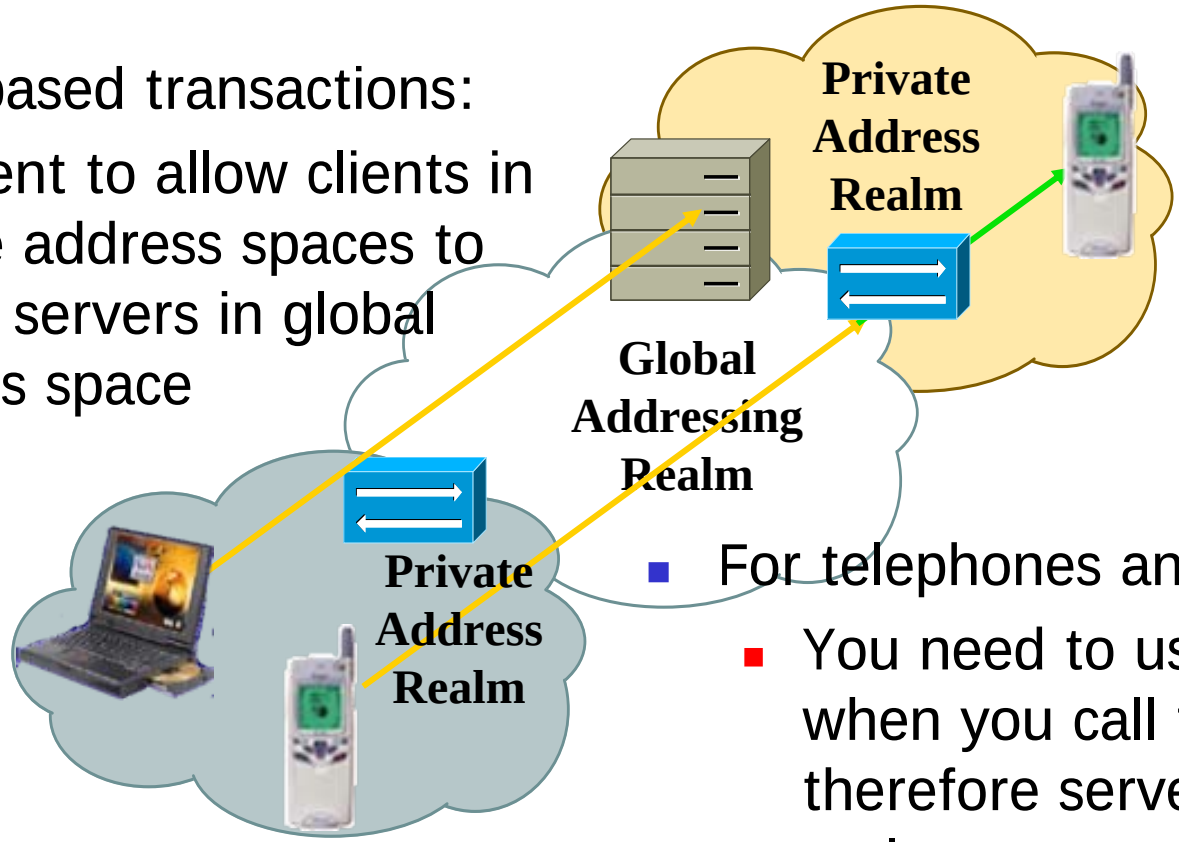


GigaNet Service Architecture

- Very large networks introduce new issues in service architectures
- ‘flat’ service point address architectures are breaking down – private service identification schemes with translation points are already a large part of today’s internet
- This is acceptable for client / server, but not for other service models

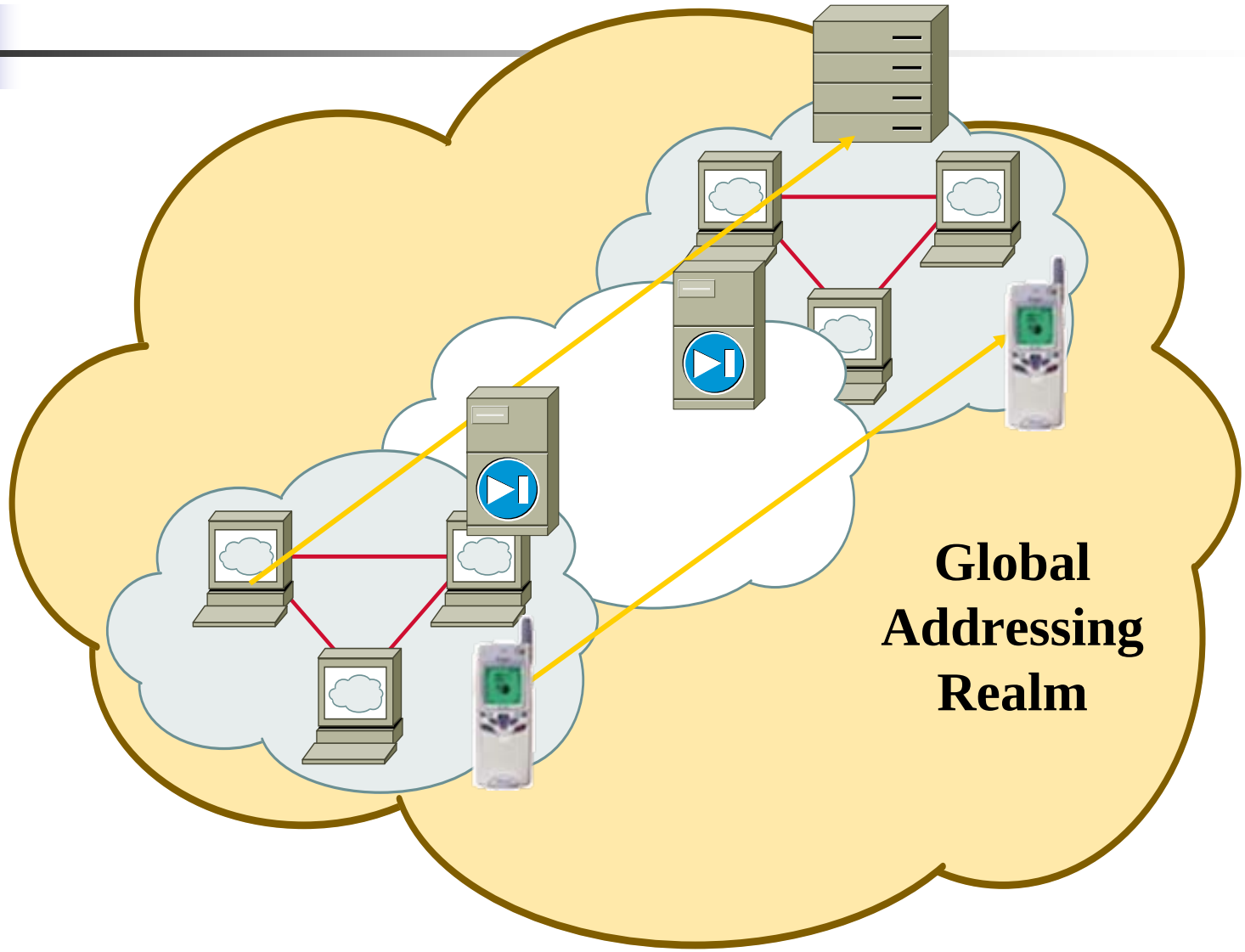
Client/Server Architecture is breaking down

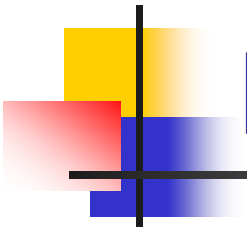
- For web-based transactions:
  - Sufficient to allow clients in private address spaces to access servers in global address space



- For telephones and I-Msg
  - You need to use an address when you call them, and are therefore servers in private realm

We need an end to end naming and addressing architecture for agile apps





Big issues in the Big Internet

1: Scale

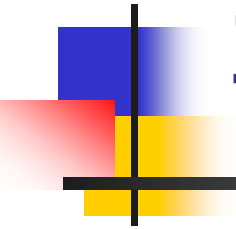
- How big can it get?

2: Trust

- Increasingly, trust is a major issue

3: Predictability

- Does the network behave as intended?

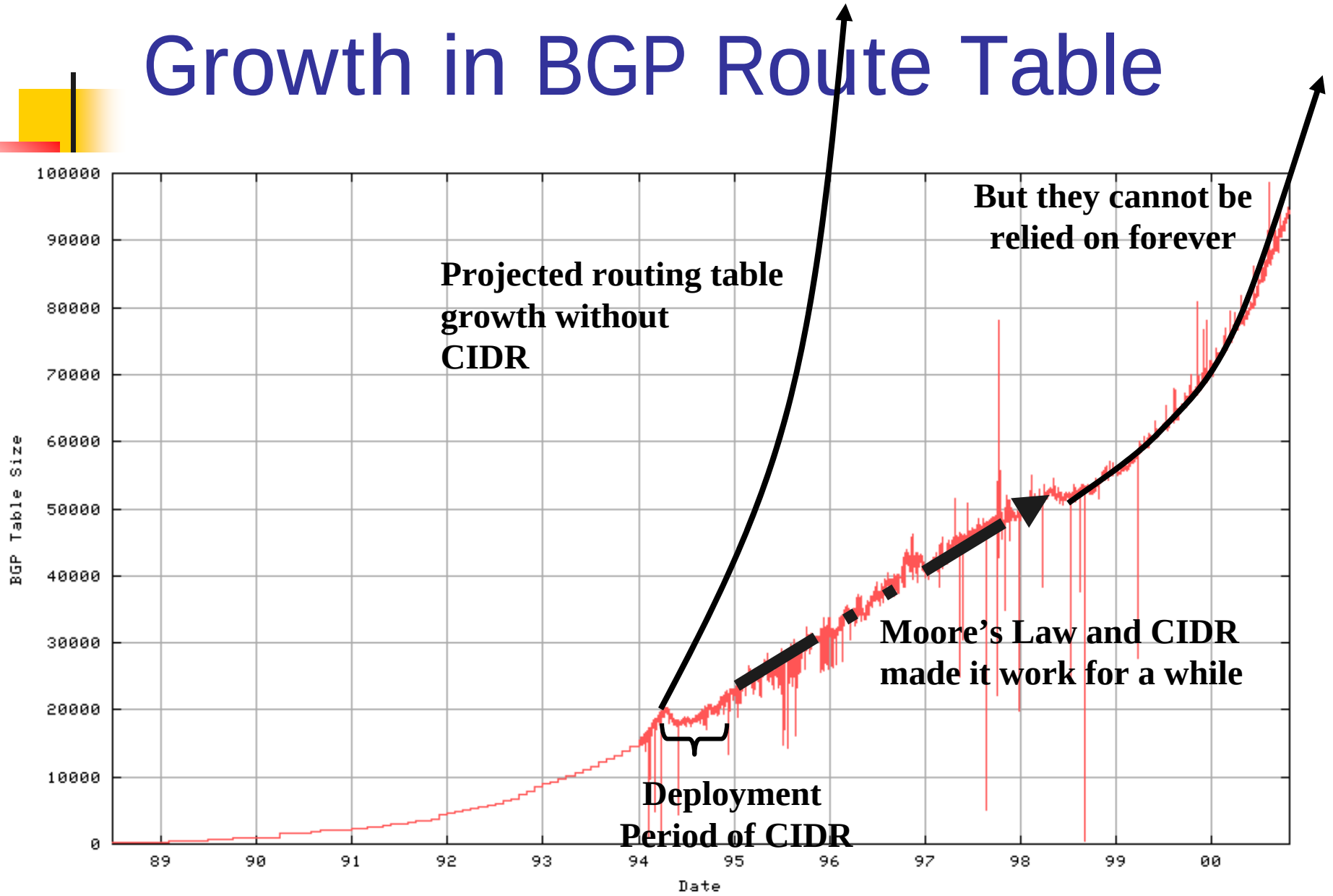


1 - Scale

"Scaling is the issue for the Internet"

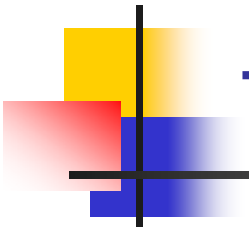
Mike O'Dell, Chief Scientist, UUNET

Growth in BGP Route Table

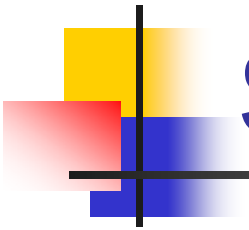


Source: http//www.telstra.net/ops/bgptable.html

Routing and Addressing in the Billion Node Network

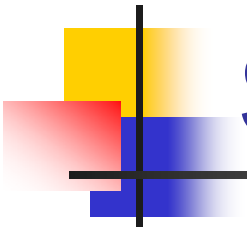


- Address Efficiency and Route Aggregation
  - Using addresses more efficiently
  - Adopt hierarchies within addresses allow for remote abstraction of routing information
- Private Addressing .. Maybe!
  - Using less public addresses when we can
  - Network Address Translation (NAT) and Real-Specific IP (RSIP)
- Address extension
  - Getting more addresses by changing protocol platforms
  - IPv6 and the next address pool



Scale-Related Engineering

- Use optical switching to increase versatility of the underlying optical bearers
- Damp down transient variations in the routing tables
- Use Traffic Engineering to spread network load
- Use end-to-end IP network architectures and eliminate per-packet reprocessing in flight by assuring that addresses needed are available



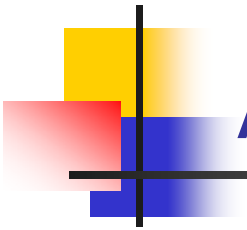
Scale

- Responding to scaling pressures in the network is a moving target, juggling demands for:
  - Addresses
  - Routes
  - Routing system stability
  - Traffic load management

Scale and Constrained Systems

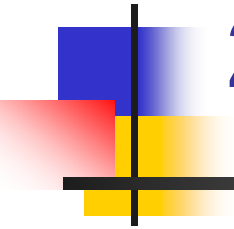
- Scaling pressures will introduce additional constraints into the Internet model
  - Large systems take longer to stabilize and are easier to push into instability
    - Multi-homed networks increase routing instability – multi-homing will be progressively discouraged
    - Address hierarchies will be stricter, and attendant hierarchical business models will become common
    - Congestion events will take longer to resolve – sustained congestion conditions cannot be supported

A very large system is difficult to operate using anarchic principles of distributed control



A new Protocol for the GigaNetwork?

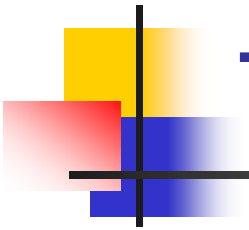
- IP overloads the role of an address
  - Identify an attached device
    - NAME
  - Locate an attached device
    - ADDRESS
  - Reach an attached device
    - ROUTE
- In a very large network these concepts may need to be de-coupled:
  - “What is my best ROUTE to reach the current ADDRESS of this NAMEd device?”



2 - Trust (and Fear)

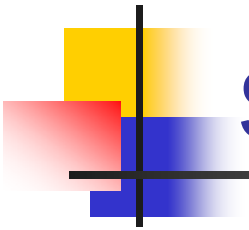
“Fear is driving design behavior on the Internet”

Eric Schmidt, Novell



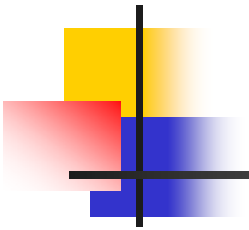
Trust

- The Internet model is one that has no strict requirement for imposed authority sources.
- The integrity of most Internet infrastructure operations is based on some level of mutual trust:
  - IP address assignment
  - IP routing advertisements
  - DNS integrity
  - End-to-End packet delivery
  - Message delivery systems



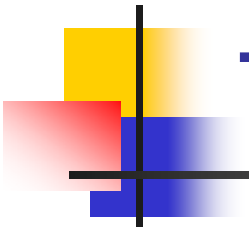
Security/Privacy affects Commerce

- Security issues:
  - User: Security by obscurity vs. explicit barriers
  - Service: Authentication services
- Service Attacks exploit trust models
  - Denial of Service
  - Spam
  - Getting Hacked



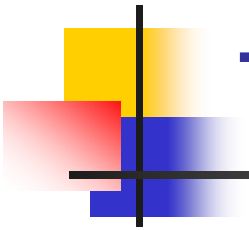
IETF work in Security

- We have done:
  - Significant work to secure routing and infrastructure
  - Made guaranteed privacy possible via encryption and authentication
- Key issues remain in
  - Software stability
  - Deployment of secure systems
  - Political issues surrounding privacy



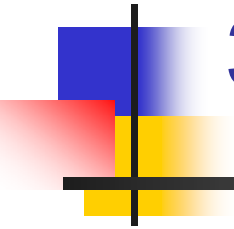
Trust and Scale

- The original IP model uses trust at various levels:
  - Domain Name System, Routing, Packet Forwarding, Email, web fetches
- Larger systems require trust to be based on an explicit exchange of credentials and capabilities
  - We have more work to do...



Trust and Scale

- Network designs based on fear of the unknown does not produce rational technology or scaleable networks that can host agile new applications



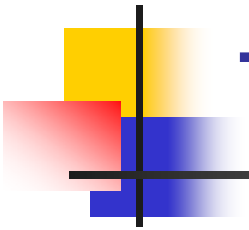
3 - Predictability

“If you’re not afraid, you don’t understand”

Mike O’Dell, Chief Scientist, UUNET

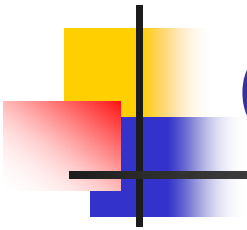
What do we mean by “predictability”?

- Includes many factors:
  - Software reliability
  - Traffic flow management
  - Traffic engineering
  - Route exchange control
  - Failure management



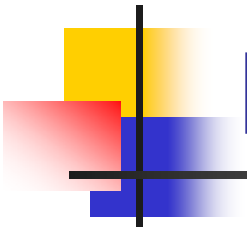
Traffic flow management

- Not all applications have the same needs
  - Voice/video needs certain jitter and bandwidth characteristics
  - TCP prefers at most one drop per round trip
- Routing needs differ as well:
  - ISPs want to maximize use of infrastructure
  - Edge networks want to minimize end to end delays



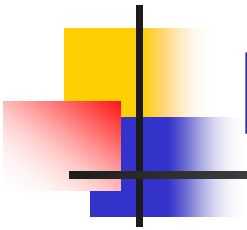
Ongoing work in predictability

- Major research focus
- Product focus from vendors
- Deployment focus by ISPs
  - “If I deploy this will my network crash sometime in the next second?”



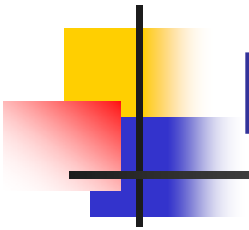
Predictability and Scale

- Can a large network service individual service requirements of billions of requests per second?
- Can a very large network with dynamic routing driven from the edges converge to a stable operating state and remain in this state for extended periods of time?



Predictability and Protocols

- Are we expecting too much of the network and thinking too little about the end-to-end protocol?
- The largest network is often the simplest network – that might mean no network level middleware!
- Allowing end-to-end applications to drive a preferred service model across a passive network may well be the only approach that will scale into true Giganets and beyond



Predictability and Middleware

- Does middleware help or hinder?
  - Is network-level interception and redirection the right tool to allow popular content to be rapidly multi-sourced through local caching? Can it scale?
  - Is the need to introduce network-level interception actions an admission of particularly poor content retrieval protocol design?
    - Would better application level protocols assist in high quality content retrieval with application-level directed middleware?
  - Can active network middleware scale to millions of packets per second in a Giganet architecture?

Going forward

There's a massive and different "out there" out there.

Somewhere – we just need to know where to look