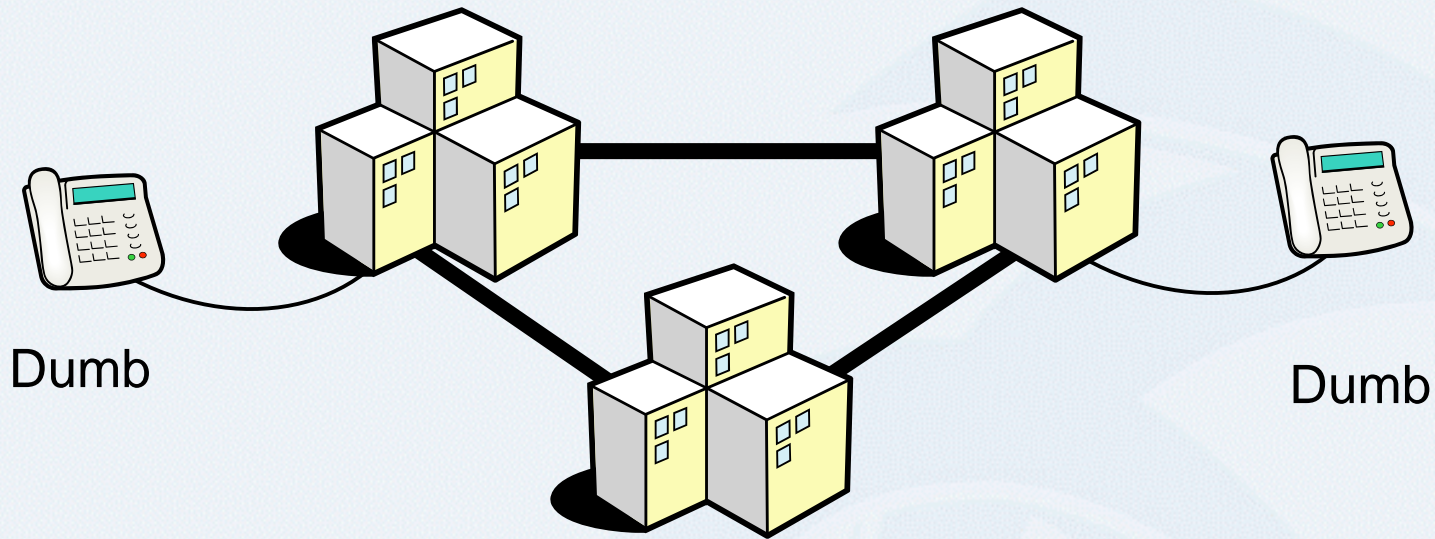


# End-to-End and Innovation

Geoff Huston  
Chief Scientist, APNIC

# The Architecture of Telephony

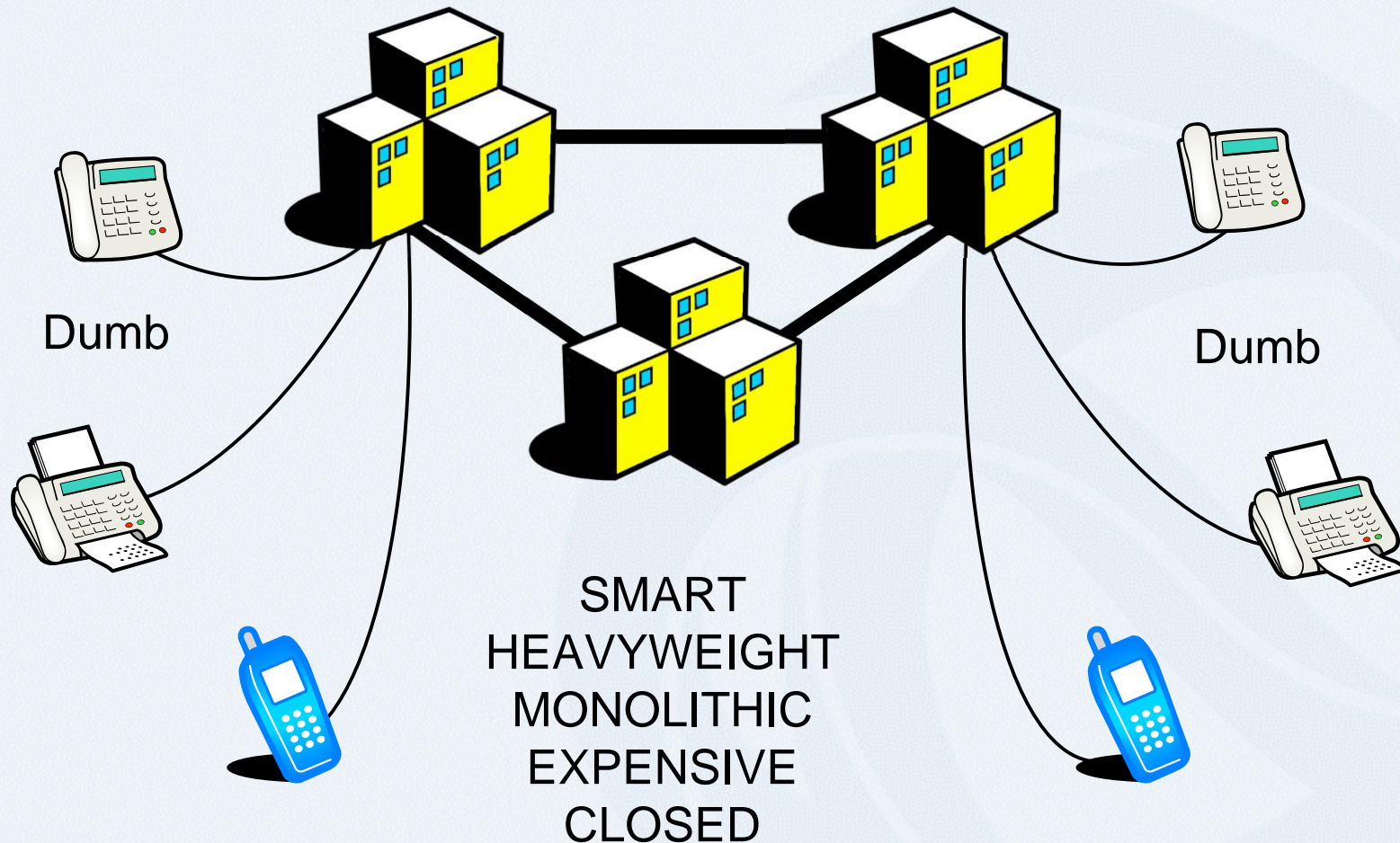


Dumb

Dumb

SMART  
HEAVYWEIGHT  
MONOLITHIC  
EXPENSIVE  
CLOSED

# Evolution of the Telephone Network



New services = new networks (X.25, GSM, GPRS, 3G etc etc)

## The Original “End-to-End” Argument

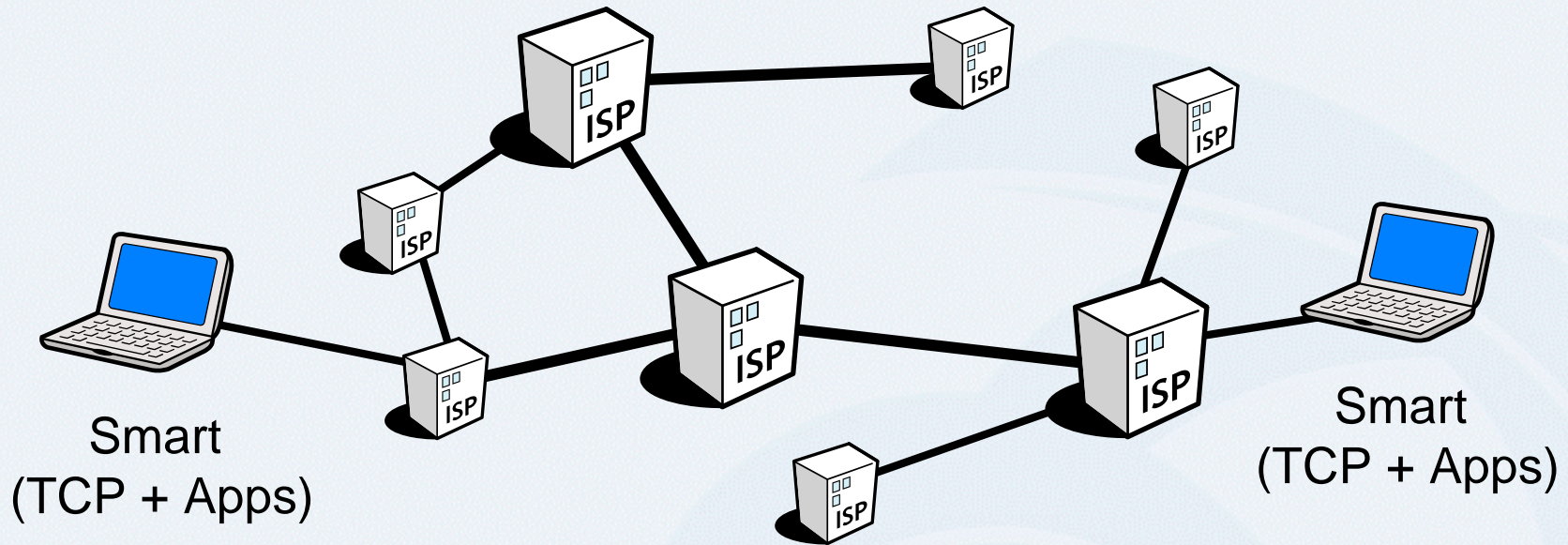
*“The function in question can completely and correctly be implemented only with the knowledge and help of the application standing at the end points of the communication system. Therefore, providing that questioned function as a feature of the communication system itself is not possible.”*

“End-to-End Arguments in System Design”, Saltzer, Reed and Clark, 1981

# The End-to-End Internet

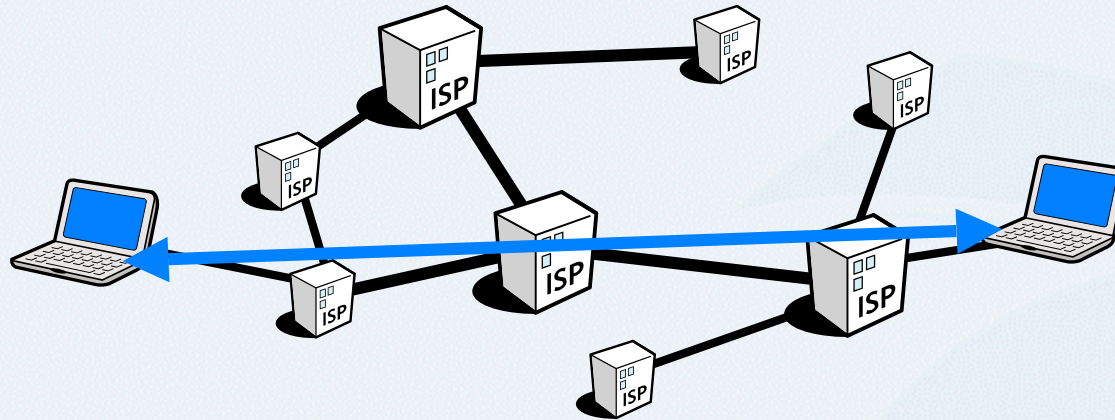
- Taking a unreliable datagram delivery network to its logical extension:
  - Dumb Network
    - Simple network behaviors of connectionless packet switching
  - Smart Ends
    - Complex end system behaviors that support data reliability, contention resolution, service definition and presentation

# The End-to-End Internet



Dumb  
(IP)  
Simple,  
Lightweight  
Diverse  
Cheap  
Open

# The End-to-End Internet



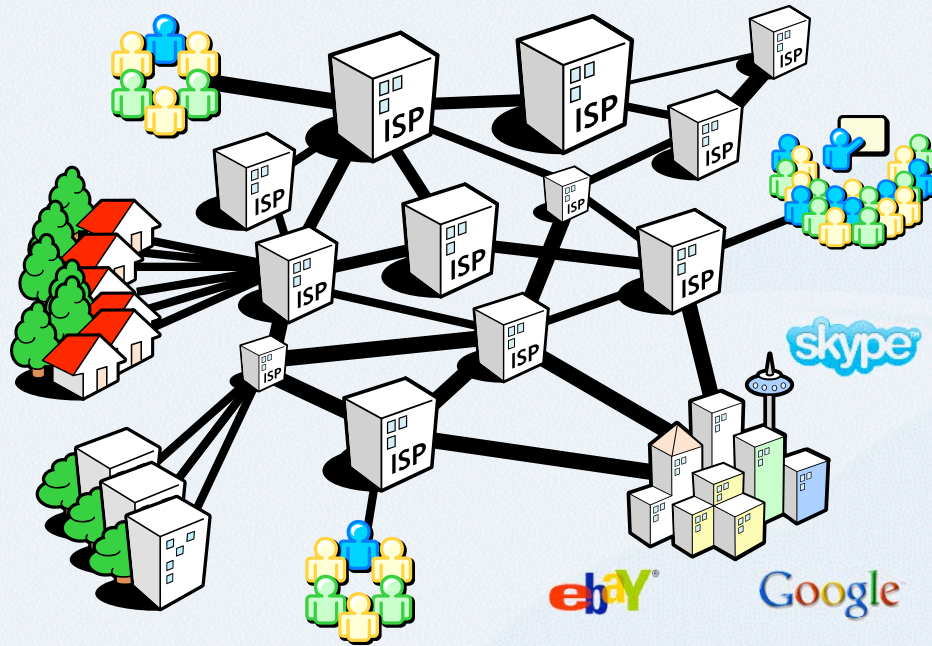
- The network provides basic packet delivery services
- Layered end-to-end services provide more complex services, implemented in the end hosts, not the network
  - reliable data streams (TCP), application rendezvous (DNS), service definition, ...
- The network is unaware of the services that are layered above it
- Applications and services do not need to be coordinated or synchronized with the network

# What does “End-to-End” imply for the Network?

- **Unbundling** the provision of services from the operation of the network
- **Openness** and **Neutrality** of the network for use any and every service
- **Utility** model of network operation to support the Internet’s basic common service profile



# The Internet's End to End Landscape



- On the Internet every service is just another end-to-end application
  - Voice, video and data services are simply applications operating end-to-end across the Internet
  - New applications can be deployed at any time in any place
  - Applications can choose to compete or cooperate with each other
  - Applications need not conform to any particular model
    - Two party conversation, multi-party groupware, peer-to-peer dynamic groupings

# Threat and Response with End-to-End

- NATs, Filters, Port blockers, ALGs, Interceptors, ...
  - Various motivations for deployment
  - Place various impediments in the path of an open, neutral, end-to-end network
- Generating a new class of highly innovative application behaviors that extend the end-to-end architecture in novel ways:
  - context-aware applications
  - Self-discovery and self-configuring application behaviors
  - application mimicry

## Its no longer just “End-to-End”

- Innovation continues ...
- We’ve taken this model of abstraction of functionality well beyond the traditional two-party virtual circuit model
  - Its still an overlay across a basic network
  - Its still defined and supported at the “ends”
  - Its no longer a two party model - its multi-party peering
  - Its no longer a single behavior - it’s a combination of context discovery and adaptation
  - Its no longer a single vertical stack - it’s a mesh of applets and modules operated across a virtual mesh of resource platforms

# Stretching the Preconceptions

Innovation in application evolution to challenge the traditional concepts of computing and information

- Where is “data”?
- What constitutes “information”?
- What constitutes a “computing resource”?
- Where is the “state” of a communication?

## End-to-End in Context

- The End-to-End model is the essence of the Internet's effectiveness
  - A completely neutral platform framework that supports all forms of both cooperation and competition
  - Ad hoc, distributed, uncoordinated innovation and creative efforts layered above a basic network substrate
  - An open and unbiased competitive marketplace for innovative solutions and services

Thank You