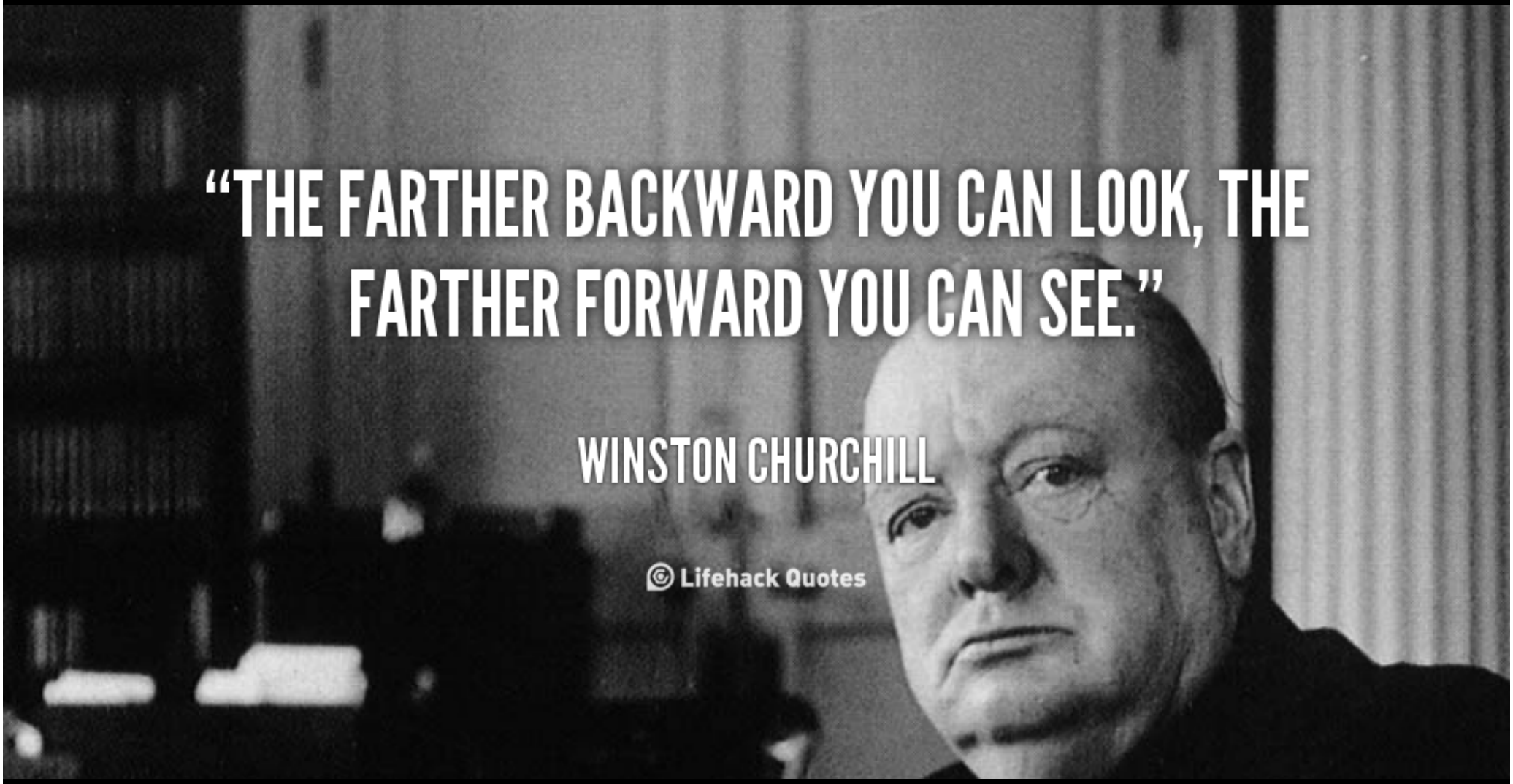
Looking back, looking forward: Why We Need A New Internet Architecture

Lixia Zhang

UCLA Computer Science Department

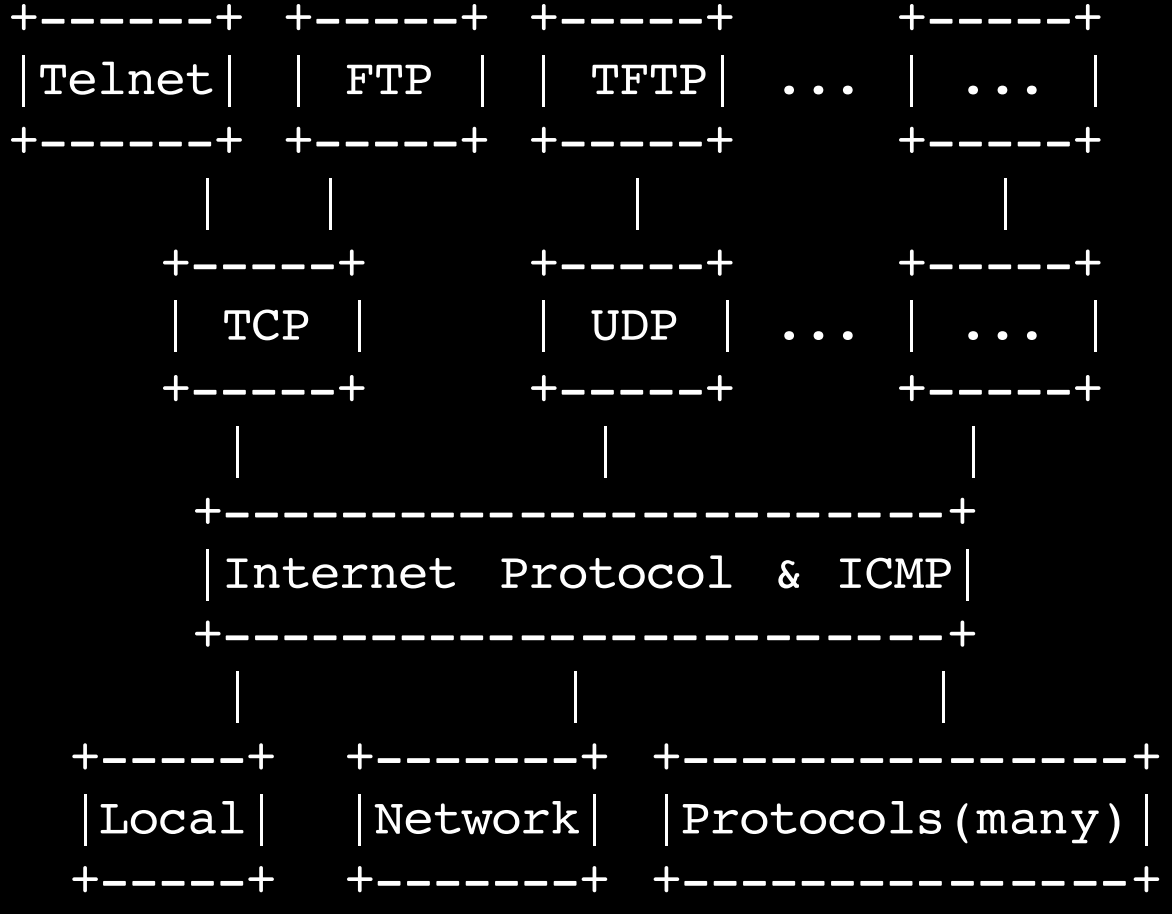
June 2016

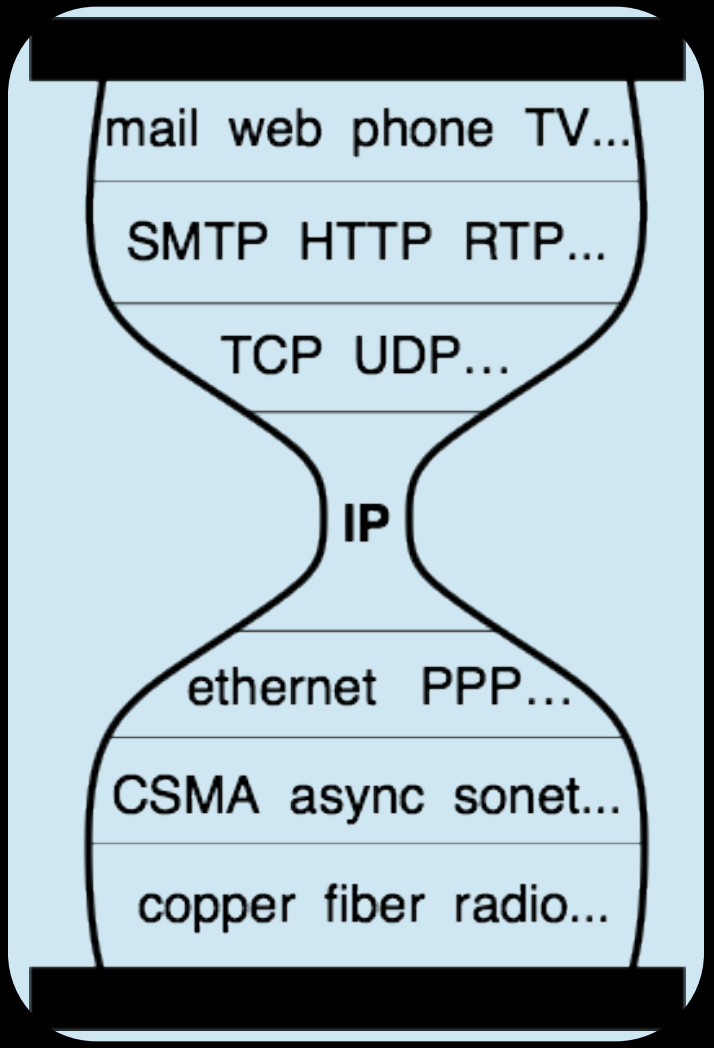

“THE FARTHER BACKWARD YOU CAN LOOK, THE FARTHER FORWARD YOU CAN SEE.”
WINSTON CHURCHILL
Lifehack Quotes

The future is a door, the past is the key

- What is today's Internet protocol architecture
- Its success stories
- Why change, and how to change it
- How to roll out a new architecture

Today's Internet Protocol Architecture



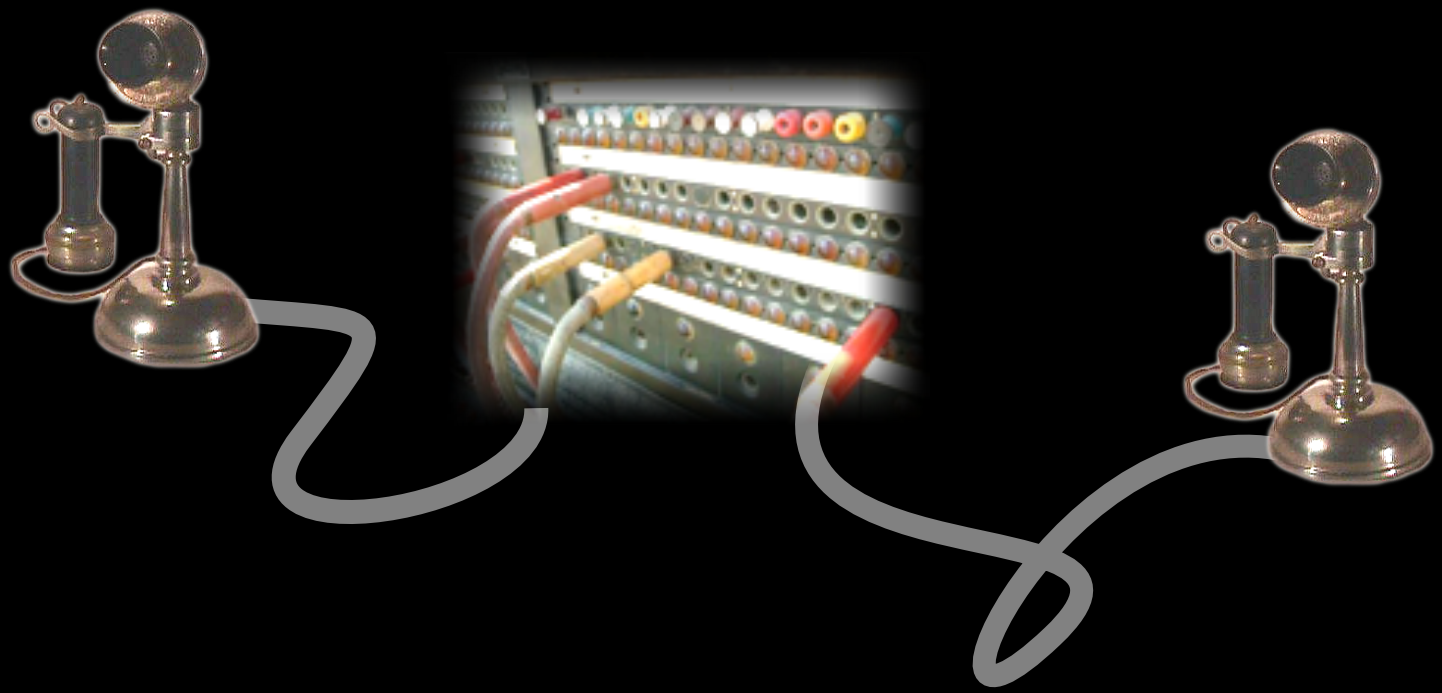


RFC791: Internet Protocol Specification

Generally speaking,

- At network layer: all a network does is to ship lots of bits
- How to ship: *defined by the network layer protocol*
- Where to ship: determined by its *namespace*

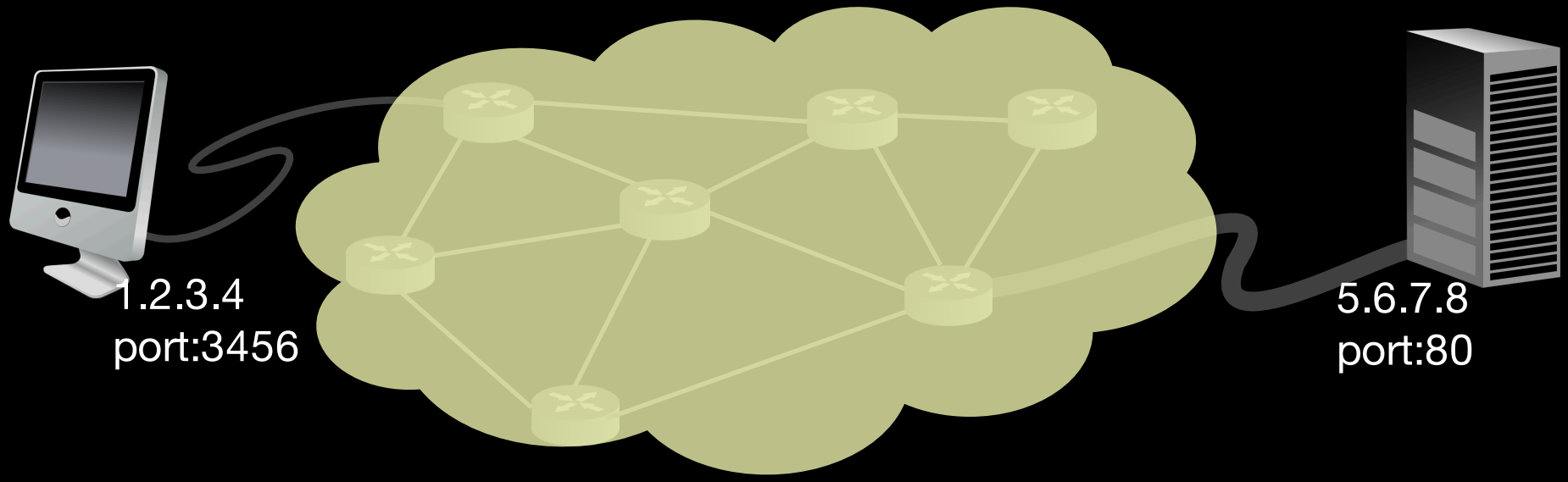
Telephone Network as the 1st Communication system



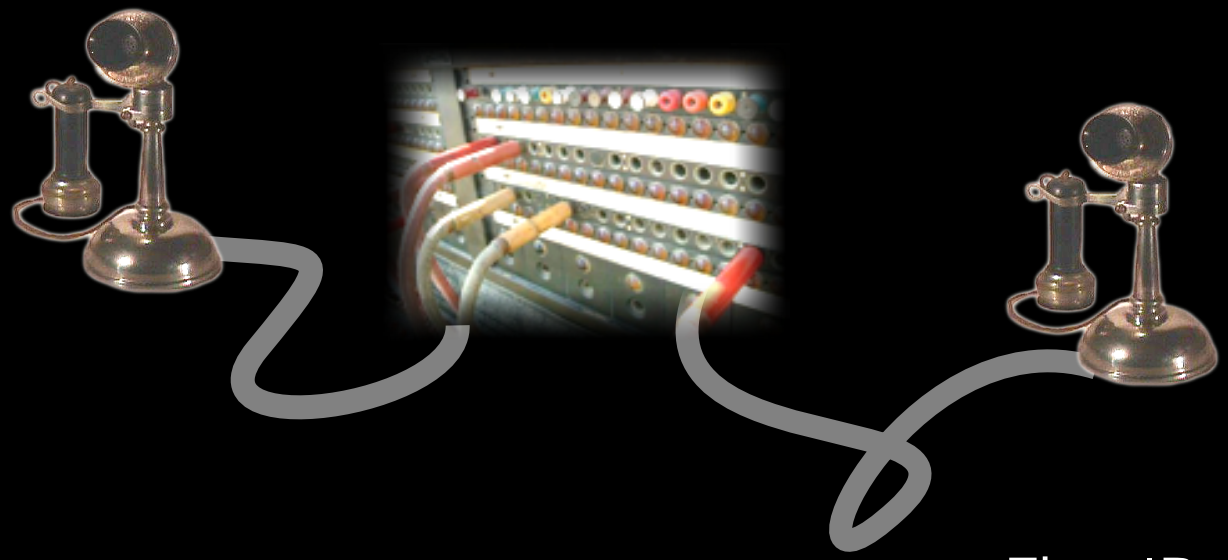
Focused on building the *wire* between the 2 ends

IP changed the way of how to build communication systems

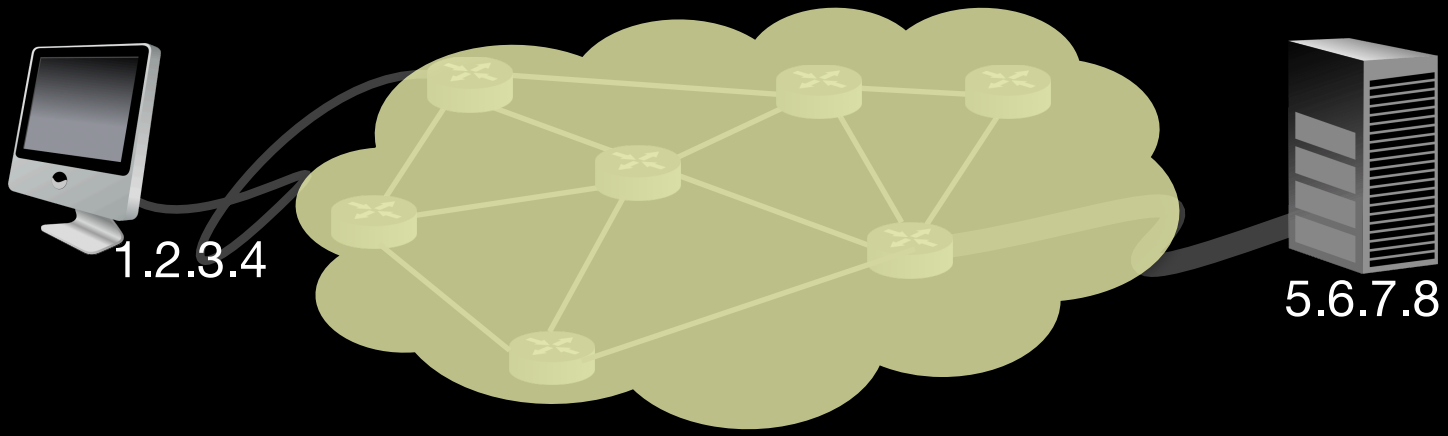
RFC791: Internet Protocol Specification



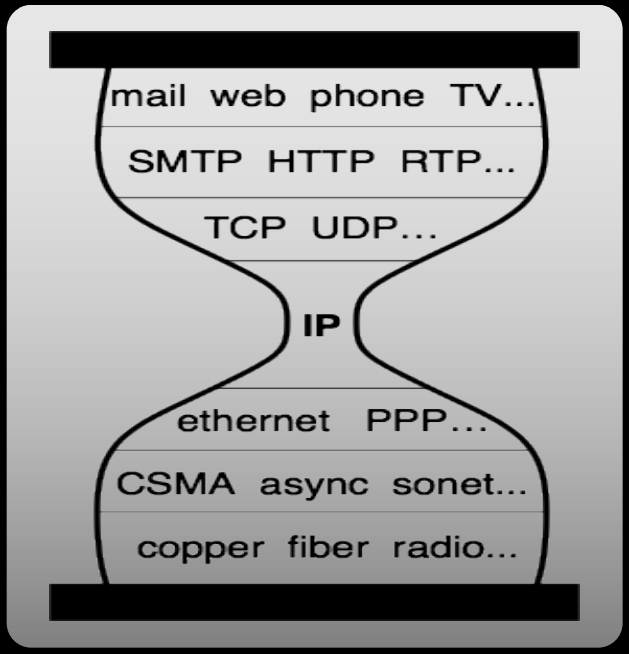
Focused on delivering packets to destination *node*



The IP model separates source-to-destination packet delivery from the specifics of which paths to take

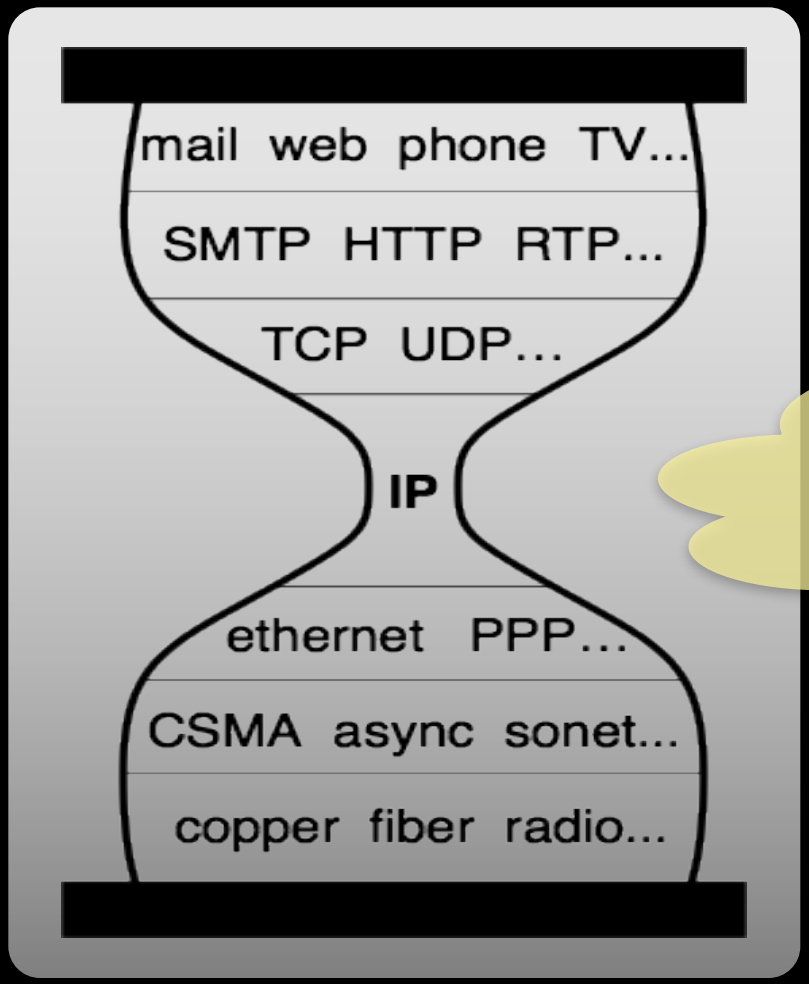


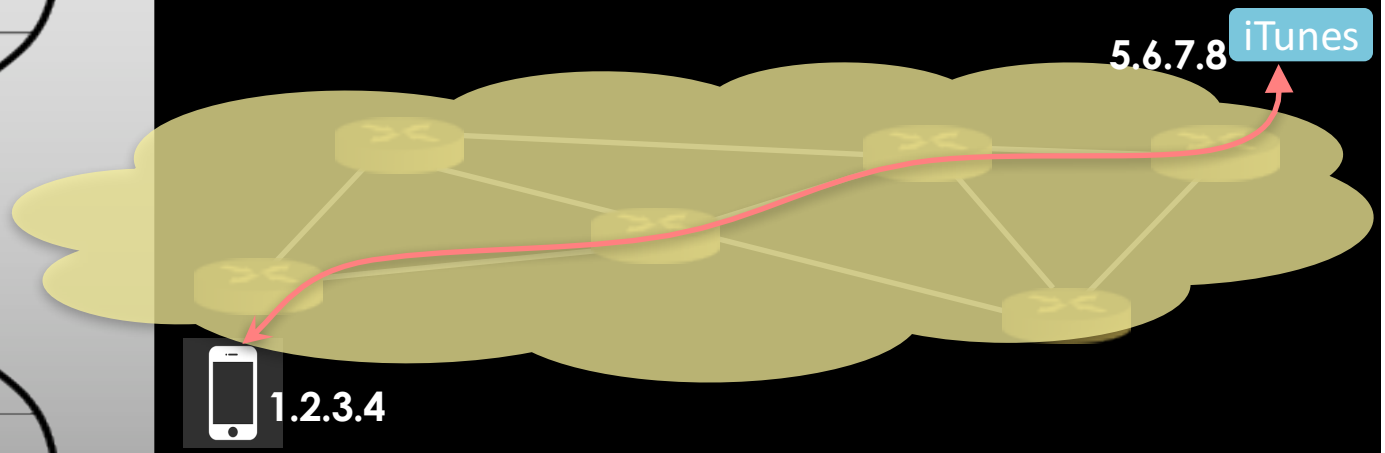
- TCP/IP protocol architecture was developed almost 40 years back



- **Large-size computers, wired connectivity**
- **Networking was modeled after point-to-point telephone conversations**

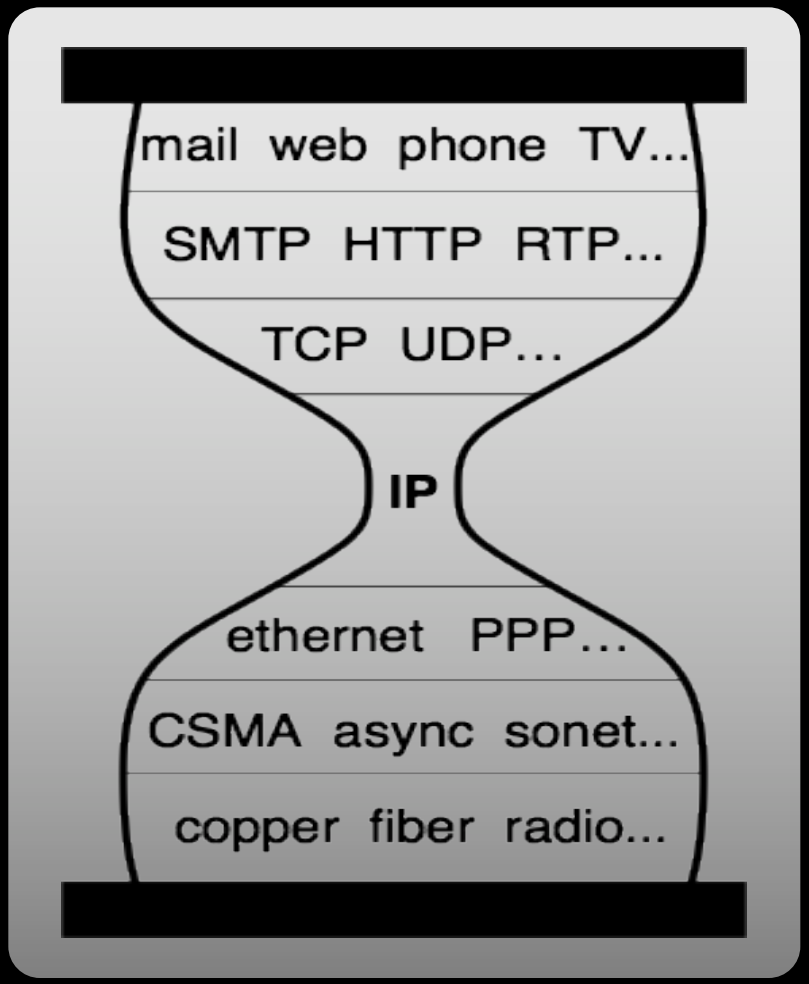
Communication relying on IP address & infrastructure





- Infrastructure first, communicate after
  - build topology
  - nail down IP addresses

TCP/IP: design principles



From years of experimentation since late 60's

- Hourglass protocol architecture
- Distributed control
- Datagram delivery
- End-to-end reliability

Result: a splendid success

Three Observations from the success

1. The success of Internet = the success of Internet applications
2. The success of Internet applications ← Innovations from the global user community

3. Innovations from the global user community: fueled by two enablers

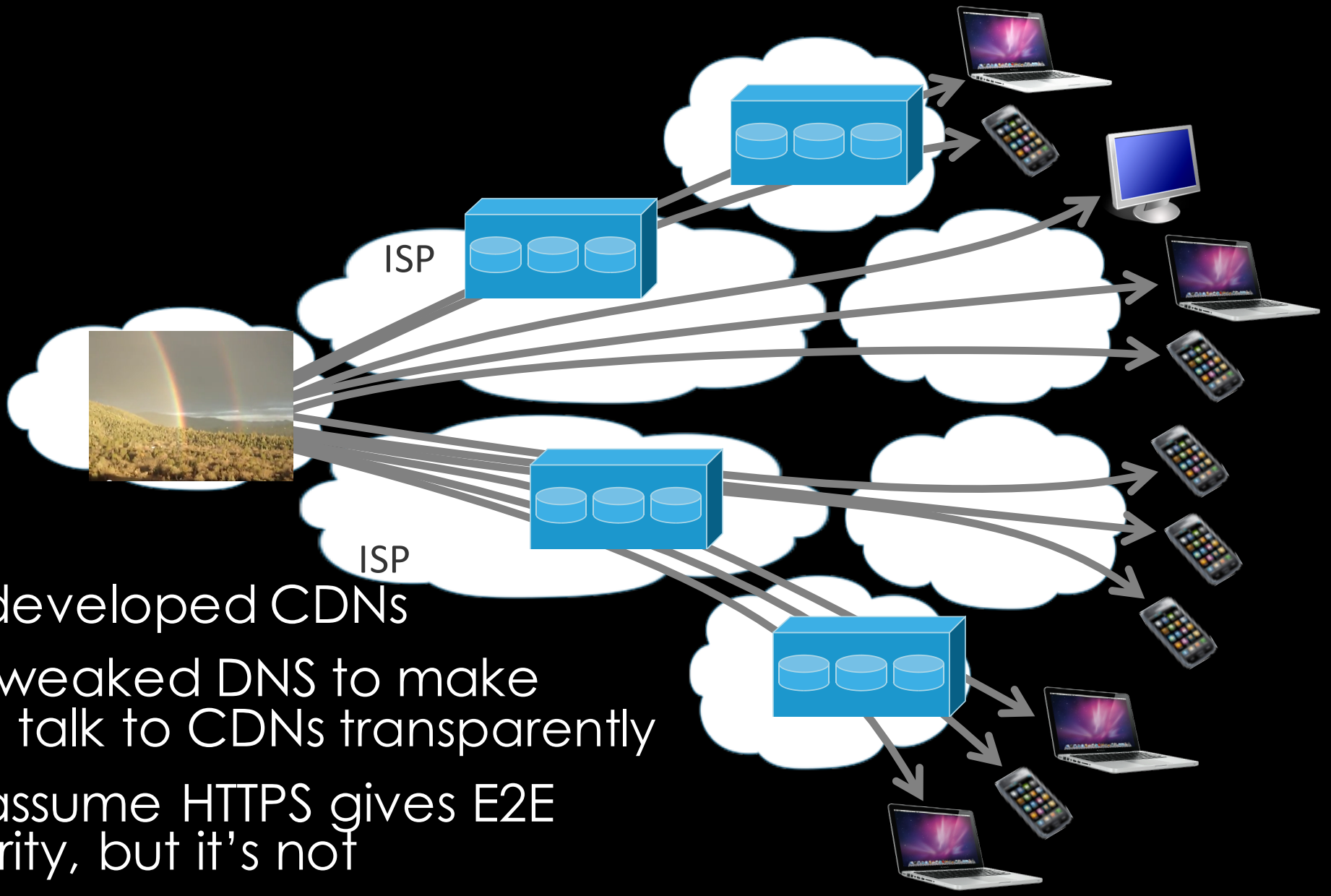
- Moore's Law empowered users: affordable, ever powerful computer in everyone's hand
- Internet protocols offered *robust* end-to-end reachability from anyone to anyone else

Since 1981 the world has changed in fundamental ways

- The technology
- The applications

The Internet protocol stack has not

To support new apps with TCP/IP protocol stack



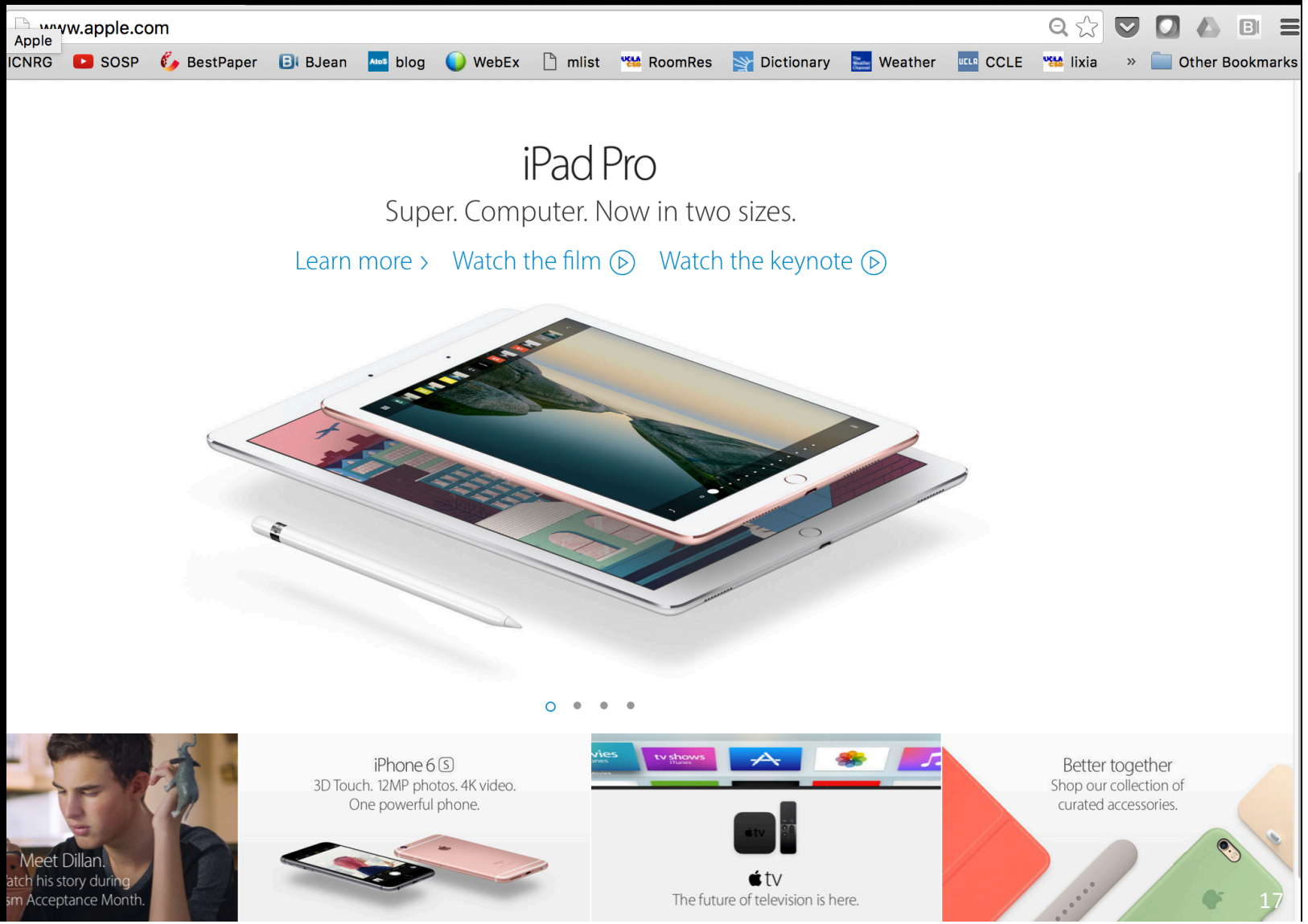
We developed CDNs

We tweaked DNS to make hosts talk to CDNs transparently

We assume HTTPS gives E2E security, but it's not

Data naming

- Applications fetch data by names
  - example: www.apple.com

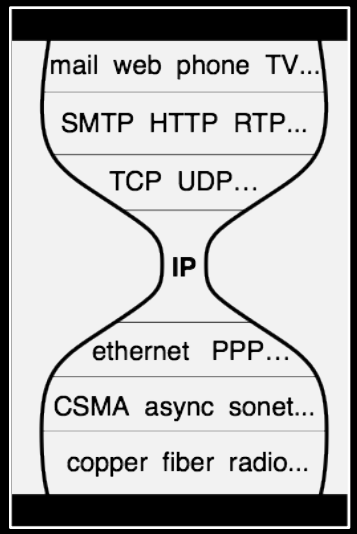


```
[Cs-211-104:~] lixia% dig www.apple.com

; <<>> DiG 9.8.3-P1 <<>> www.apple.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 41991
;; flags: qr rd ra; QUERY: 1, ANSWER: 4, AUTHORITY: 9, ADDITIONAL: 8

;; QUESTION SECTION:
;www.apple.com.                 IN      A

;; ANSWER SECTION:
www.apple.com.                  1004    IN      CNAME   www.apple.com.edgekey.net.
www.apple.com.edgekey.net.      4400    IN      CNAME   www.apple.com.edgekey.net.globalredir.akadns.net.
www.apple.com.edgekey.net.globalredir.akadns.net. 1994 IN CNAME e6858.dscc.akamaiedge.net.
e6858.dscc.akamaiedge.net.      20      IN      A       23.74.131.14

;; AUTHORITY SECTION:
dscc.akamaiedge.net.    250     IN      NS      n6dscc.akamaiedge.net.
dscc.akamaiedge.net.    250     IN      NS      n7dscc.akamaiedge.net.
dscc.akamaiedge.net.    250     IN      NS      a0dscc.akamaiedge.net.
dscc.akamaiedge.net.    250     IN      NS      n0dscc.akamaiedge.net.
dscc.akamaiedge.net.    250     IN      NS      n1dscc.akamaiedge.net.
dscc.akamaiedge.net.    250     IN      NS      n2dscc.akamaiedge.net.
dscc.akamaiedge.net.    250     IN      NS      n3dscc.akamaiedge.net.
dscc.akamaiedge.net.    250     IN      NS      n4dscc.akamaiedge.net.
dscc.akamaiedge.net.    250     IN      NS      n5dscc.akamaiedge.net.
```

Incongruity of today's Internet

- Protocol architecture views IP address as its namespace
  - The network delivers packets based on IP addresses
- The applications view DNS names as the namespace
- DNS Name ≠ IP Address

Internet applications built on names



Incongruity → System Complexity

- DNS Name ≠ IP Address:
  - tweaking DNS resolution to mend the disconnect
  - tweaking IP address semantics
    - Anycast address,
    - multicast address,
    - logical address, or virtual address
- Also lead to implications on communication security

Incongruity → fail to communicate

- Infrastructure first, communicating after
  - build topology
  - nail down IP addresses

"What's going on in front of the queue?"

Google Maps can't answer that question for you

- Need local comm. between cars

IETF has been working hard to tweak IPv6 & conventional protocols to fit into IoT, with ever increasing complexity

Deployed IoT systems largely rely on datacenters

Another example

DHCP service
- IP address allocation
- Subnetting
- Default router

DNS service

My slide file: /ucla.edu/lixia/talks/1606CFI-key

A means-ends confusion?

Recall the 3 observations of Internet's success so far

1. The success of Internet = the success of Internet applications
2. The success of Internet applications: Innovations from the global user community
3. Innovations from the global user community: fueled by two enablers
   - Moore's Law empowered users: affordable, ever powerful computer in everyone's hand
   - Internet protocols offered *robust* end-to-end reachability from anyone to anyone else

To take Internet into the future with even greater success

3. accelerate innovations of the global user community by:
   - Continued computing technology advances to empowered user community
   - A new Internet protocol stack that facilitates, instead of impeding, new application development in the era of
     - Unlimited number of devices
     - Unbounded amount of information
     - Unprecedented importance of system security

Insights accumulated over the years

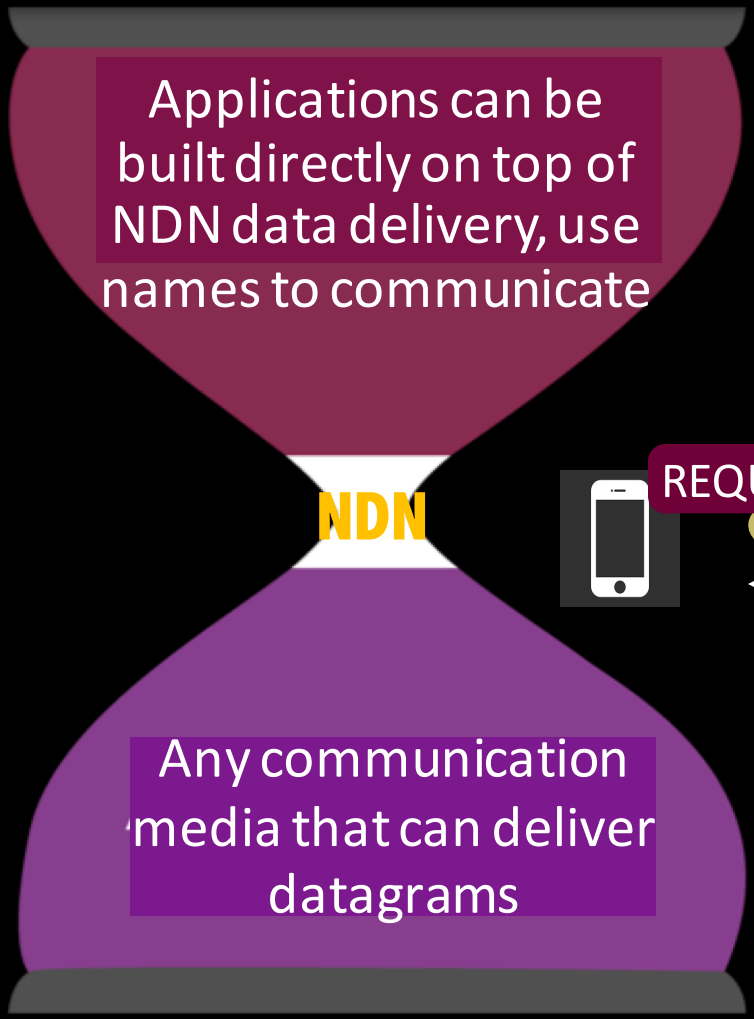
- "Multicast Routing in Internetworks and Extended LANs" SIGCOMM 1988
- "Architectural Considerations for a New Generation of Protocols" SIGCOMM 1990
- "RSVP: A New Resource ReSerVation Protocol" 1993
- "A Reliable Multicast Framework for Light-weight Sessions and Application Level Framing" SIGCOMM 1995
- "Adaptive web caching: towards a new global caching architecture" 1998
- "Building Efficient Wireless Sensor Networks with Low-Level Naming" (SOSP2001)
- World Wide Web: the foundation of all modern applications
- BitTorrent: naming and securing data blocks directly, to enable peer-to-peer data exchanges

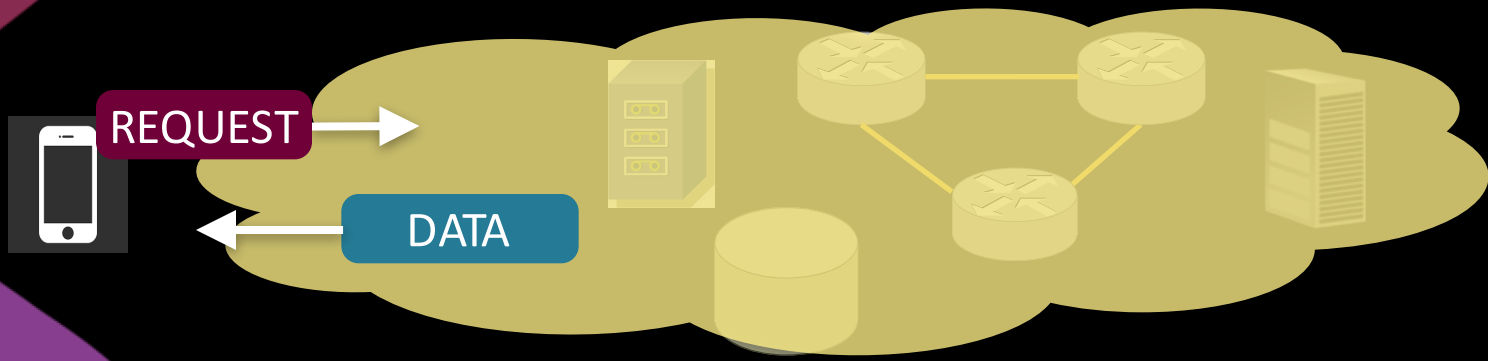
A New Way to look at Networking

Van Jacobson

August 30, 2006

Named Data Networking





- consumers request data
- *Leave to the network* to figure out where/how to find requested data
- Every data packet carries a crypto signature so it can be validated independent from where it comes

Naming Data

- Names are expressive
- Data is immutable
- Crypto signature binds the name to the data
- Requested data may come from anywhere
  - Wireless, wire, storage, or processing unit all look the same in terms of bringing back requested data

Interest packet

Data name
(may carry a few optional parameters)

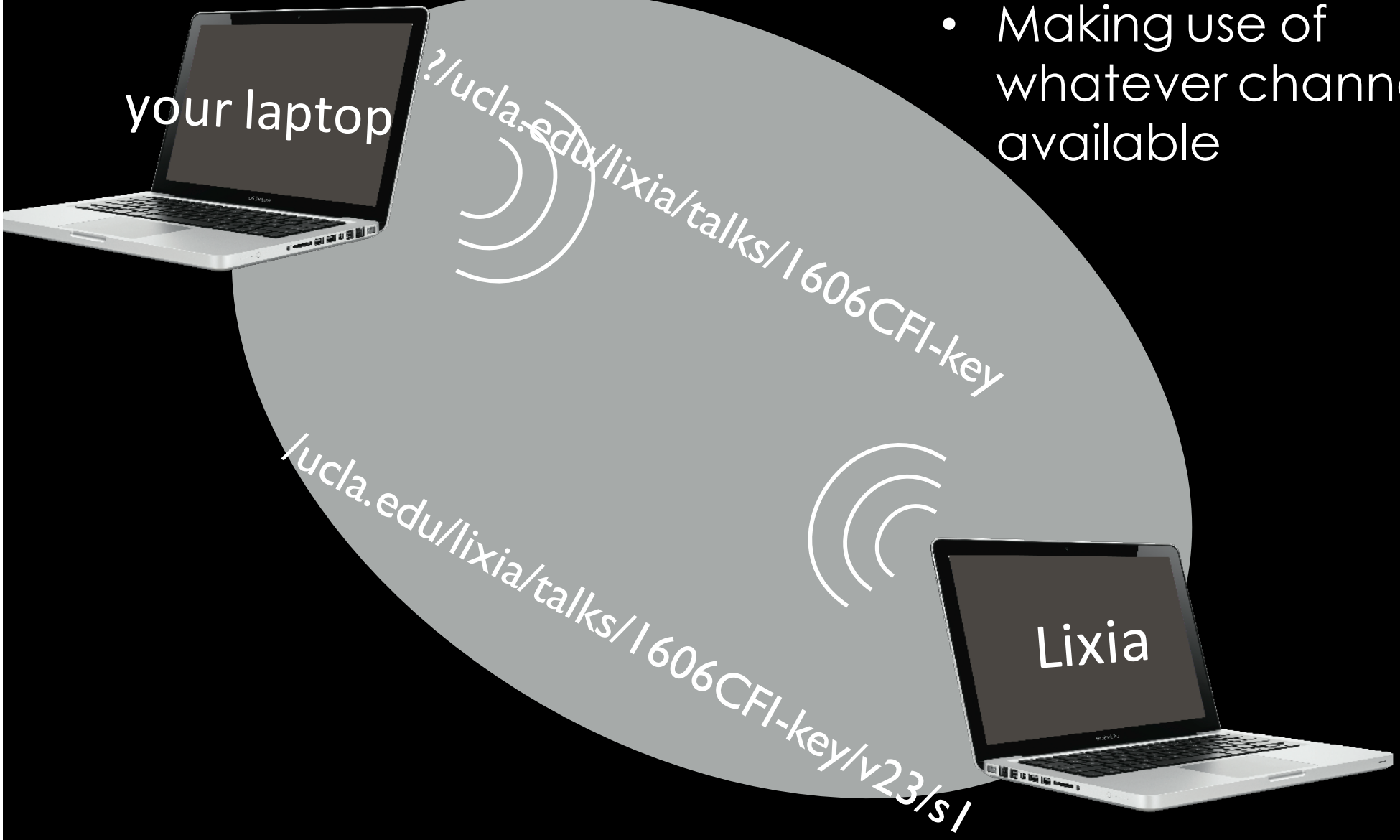
data packet

Data name
Data
Crypto signature

What naming data enables

Applications driven communication

- Making use of whatever channels available



What naming data enables:

"What's going on in front of the queue?"

- Request a photo using the name of intersection (assuming cars with maps)

- Name "things" and operate on "things"
- Focus on data associated with things instead of worrying about managing the addresses
- Secure IoT data directly

Please see "Named Data Network of Things"

What naming data enables:

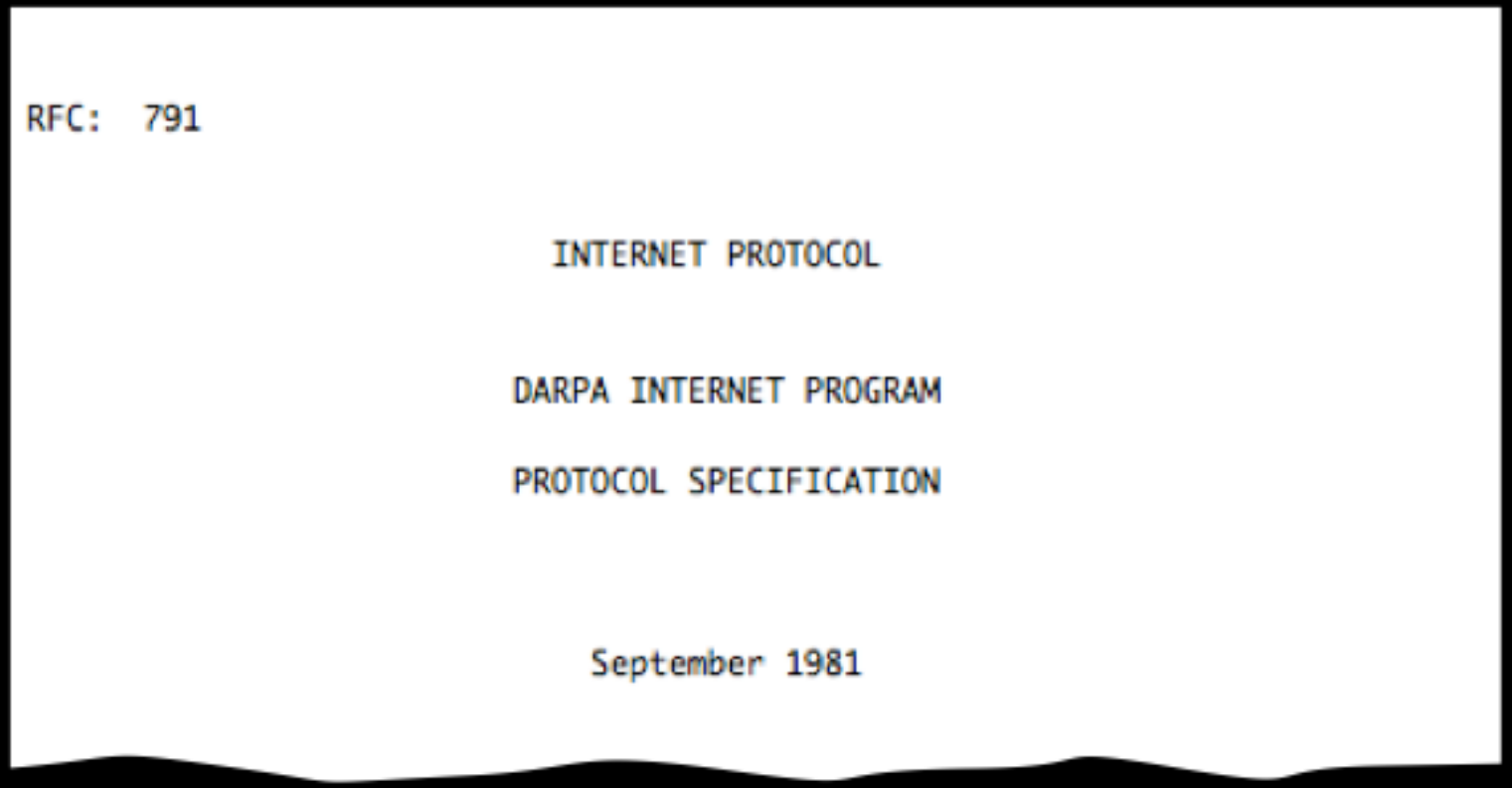
Most efficient data dissemination

- Names enable in-network storage
- Signed content ensures consumers are getting what they asked for

Our On-going Efforts

- Applying NDN to solve *real application problems*
  - *Today's apps are already information-centric*
    - youtube, netflix, facebook
    - new generations of apps: IoT, V2V, mobile health
  - Supporting new apps via IP's point-to-point communication, as we do today, is complex & error-prone
- NDN team: developing a diverse range of apps
  - Which drives the development of congestion control, mobility support, autoconfiguration, forwarding, routing, and (automated) security support

Expected End Product



RFC: 791

INTERNET PROTOCOL

DARPA INTERNET PROGRAM

PROTOCOL SPECIFICATION

September 1981

A NDN protocol spec equivalent to RFC791

Research challenge: verification and validation of the exact functions that must be supported by the narrow waist.

Analogy: consider TCP/IP in early 80's

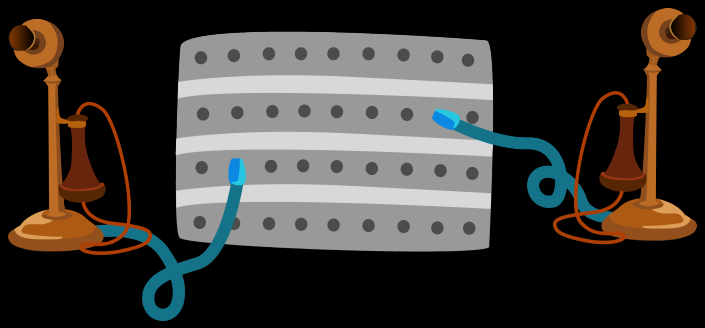
- Promising new networking technology
- Largely unknown outside its small community
- Research funding led TCP/IP to its success
  - BSD development, NSFnet
- A number of problems exposed and resolved through larger scale experimentation
  - DNS development
  - Congestion control
  - Evolution of the routing system
  - and a long list of other things

The road to a new architecture

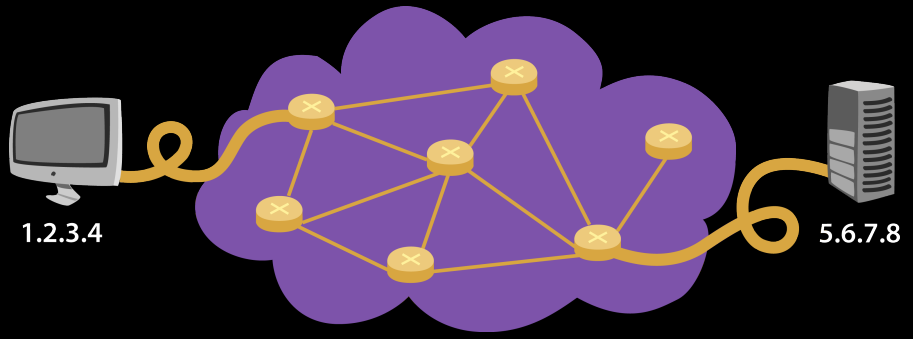
- Application-driven development
  - Running code, useful applications
  - tackling emerging environments/applications where no good IP-based solutions
- Open source development, global community engagement
- Grassroots growth from edges, *the same way as IP did*
  - NDN can run over everything: WiFi, Bluetooth, Ethernet, IP, TCP/UDP tunnels

Take Away

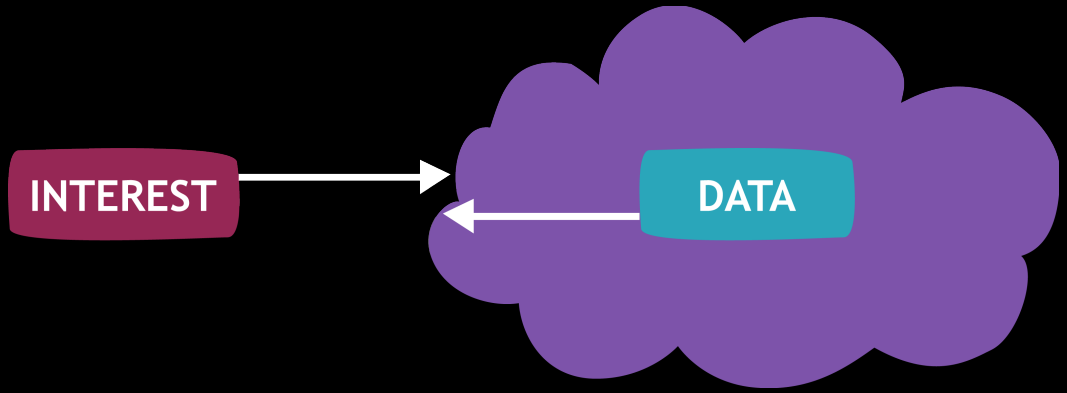
- Future of networking lies in *recognizing the right communication abstraction*



Telephone Network:
Focused on building the *wires*



Internet Protocol (RFC791): Focused on delivering packets to destination *node*



NDN: Focusing on retrieving *data*

You can help!

NDN research: still in early stage

- NDN architecture design: needs a global collaborative effort
  - Mailing list ndn-interest@lists.cs.ucla.edu
- NDN prototype development: a global open source effort
  - https://github.com/named-data
  - http://redmine.named-data.net/projects
- NDN testbed: open to all interested parties