The Phone System

– Focus on the wires

• a call is a “circuit” not a “conversation”
• a phone number is a program to build the path not the callee address (**Revenue comes from path construction**)

Single basic service: two-way voice
– low end-to-end delay
– guarantee that an accepted call will run to completion

Endpoints connected by a circuit
– like an electrical circuit
– signals flow both ways (full duplex)
– associated with bandwidth and buffer resources

Synchronous transmission Multiplexing (STM)

- Neither multiplexor nor demultiplexor needs addressing information (why?). requires however accurate timing information.

ISSUE:
– idle users consume bandwidth (STM is inefficient)
– Arbitrary schedules result in complicated operation
– STM service is inflexible

Solution to ISSUE

- use packets instead
  – meta-data (header) indicates src/dest
  → **ATM and IP**

The ATM network

– Focus on virtual circuits (VCs)

Uses IDENTIFIER pre-enstablished, IDs must be switched in intermediate points (switcheswith translation table)

ISSUES

- All packets must follow the same path
- Switches store per-VC state (entry in translation table)
- separation of data and control (control in software over slow time scale, data transfer in hardware)
- Virtual circuits do not automatically guarantee reliability (packet loss)
- Small Identifiers can be looked up quickly in hardware (cant do it with IP)

PROs

- Simpler buffer hardware
  – Simpler line scheduling
  – Easier to build large parallel packet switches
- The smaller the packet, the larger the header overhead
  CONs
  – If the chosen size < ADU ⇒ overhead
  – segmentation and reassembly cost
  – last unfilled cell after segmentation wastes bandwidth

How do ATM networks allow for integrated service (voice, video, and data traffic on separete networks)?
– lots of (switching) capacity: hardware-oriented switching
– support for different traffic types
- signaling for call set-up
- admission control, Traffic descriptor, policing
- resource reservation
- requires intelligent link scheduling for voice/data integration
(more flexible than telephone because of headers)

The Internet today

– Focus on the endpoints

The future Internet

– Focus on the data

Two global namespaces: DNS and IP addresses

What holds the Internet together?
Addressing
– how to refer to a machine on the
Internet
Routing
– how to get there
Internet Protocol (IP)
– what to speak to be under

architectural problems
Hosts are tied to IP addresses
– Mobility and multi-homing pose problems
Services are tied to hosts
– A service is more than just one host: replication, migration, composition

Datagrams

– Fairly share the path
CONTS
– Using the wires differently from phone system
-- No set up phase

TCP/IP

- Reliability increases exponentially with the system size
- No call setup

When TCP was invented there were a lot of users per machine Now there is a lot of machines per user with data to be synchronized and shared

Content Centric Networking (CNN)

A **networking** paradigm that emphasizes **content** by making it directly addressable and routable.

There are two CCN packet types:
interest (similar to http “get”) and data (similar to http response). Both are encoded in an efficient binary XML.

Software Defined Networking

- • SDN comes from the IT world:

- – Separate the data and control layers, while centralizing the control
- – Deliver the ability to program network behavior using welldefined interfaces

Death to the Control Plane!
• Simpler management – No need to invert control-plane operations
• Faster pace of innovation – Less dependence on vendors and standards
• Easier interoperability – Compatibility only in wire protocols
• Simpler, cheaper equipment – Minimal software

Extreme: What if software decides whether to accept each flow, and how to route it?
How many $400 servers do we need for 35,000 users?
Answer: 15 less than one → If we can define network operation outside the datapath, then eventually we will. With replication for fault-tolerance and performance scaling.

With SDN it seems like we should be able to:

1. Formally verify that our networks are behaving correctly.
2. 2. Identify bugs, then systematically track down their root cause.

Why debugging networks is hard Complex interaction
– Between multiple protocols on a switch/router.
– Between state on different switches/routers.
Multiple uncoordinated writers of state. Operators can't…

- Observe all state.
  – Control all state.

Conclusion on SDN
– Open interfaces to the data plane
– Separation of control and data
– Leveraging techniques from distributed systems

OpenFlow Networks

NFV

A means to make the network more flexible and simple by minimising dependence on HW constraints

- implementing network functions in software
- allows use of a single physical platform for different applications
- Reduced equipment costs

- Improved operational efficiency
- Reduced (OPEX) operational costs: reduced power, reduced space, improved network monitoring

NFV challenges

- high performance virtualised network appliance
- Co-existence with bespoke HW based network platforms
- • Management and orchestration of virtual network appliances
- • Appropriate level of resilience to HW and SW failures

Service Fonctions Chaining (SFC)

• Set of network services, such as firewalls or application delivery controllers interconnected through the network to support an application