NETWORK TECHNOLOGY REVIEW

Henning Schulzrinne

material drawn from various online sources, reports & author

DIVIDING THE PROBLEM
Broadband, Internet, communications

What do communications networks do that’s different?

- Any-to-any: multiparty, coordination & cooperation, conflict
  - less of a concern in (say) civil engineering
- Economics: network effect, scale effects
- Challenges:
  - geographic distribution
  - long-lived
  - different industries participating
What problems do networks solve?

- Diversity in technologies
  - wired vs. terrestrial wireless vs. satellite
  - trade-off capacity vs. cost vs. distance
- Variation in load
  - intermittent demand → shared networks
  - cannot design capacity for top 5 minutes of load
- "Noise"
  - electric noise
  - radio interference
- Human adversaries
  - denial-of-service attacks
  - information theft
  - impersonation

Network trade-offs

* incremental cost assuming legacy networks; "green field" cost is roughly the same
A bit of (US) history

- 1895-1901: G. Marconi demonstrates wireless communications
- 1912: Titanic
- Radio Act of 1912
  - all radio stations licensed
  - monitor distress channel (500 kHz)
- Radio Act of 1927
  - deal with AM ("medium wave")
  - chaos → licensing "in the public interest"

Communications as a regulated industry

- free-market economies, subject to government regulation
  - "why" (and objections) later
- telephony: federally regulated since 1910
- broadcasting: 1927
- telecommunications: 1934
  - but dates back to Interstate Commerce Act of 1887 (railroads)
  - cousins: railroads, electricity, air service, …
  - specialized administrative agency for sector-specific regulation
    - vs. general regulation (environmental, safety, employment, contracts, consumer protection, …)
The great infrastructure

- Technical structures that support a society → “civil infrastructure”
  - Large
  - Constructed over generations
  - Not often replaced as a whole system
  - Continual refurbishment of components
  - Interdependent components with well-defined interfaces
  - High initial cost

water   energy   transportation   communication

The Internet as core civil infrastructure

For Immediate Release  February 12, 2013

Executive Order -- Improving Critical Infrastructure Cybersecurity

EXECUTIVE ORDER

Improving Critical Infrastructure Cybersecurity

By the authority vested in me as President by the Constitution and the laws of the United States of America, it is hereby ordered as follows:

Section 1. Policy. Repeated cyber intrusions into critical infrastructures demonstrate the need for improved cybersecurity. The threat of both physical and cyber-attacks to our national security and economic security continues to grow and represents one of the most serious national security challenges we must confront. The national and economic security of the United States depends on the reliable functioning of the nation’s critical infrastructure in the face of such threats. It is the policy of the

THE INTERNET

A series of takes.
The Internet as core civil infrastructure

- Involved in all information exchange
  - (in a few years)
- Crucial to
  - commerce
  - governance
  - coordination
  - inter-personal communication
- Assumed to just be there
  - "plumbing", "pipes", ...

Interfaces: Energy

- 110/220V
- Lots of other (niche) interfaces
- Replaced in a few applications
Other long-lived interfaces

- Cigarette lighter (1956) - 1993
- Fuel nozzle - 1878
- SQL - 1974

Interfaces: Paper-based information

- 1798, 1922 (DIN)
- A0, A1, A2, A3, A4
Interfaces: Transportation

About 60% of world railroad mileage

1435 mm
1830 (Stephenson)
1846 UK Gauge Act

The two-layer model

content
apps & software
services

copyright
patents

"Lower layers"
infrastructure
"the network"

universal service
data privacy
disability access
disruption

investment
data theft
resource scarcity
technology innovation
Why layering?

- Perform functions once
  - upper layers rely on lower layers
  - in theory (see: “end-to-end principle”)
- Common in engineering and society
  - postal system, operating systems & other APIs, buildings, …
  - but not always formal or deep
  - model of a (legal) contract
- Change implementation without affecting relying parties
  - minimize communications, “information hiding”, “isolation”
  - "black box"
- Topological and administrative scoping
  - single physical connection technology
  - single vs. multiple administrative domains

OSI model background

- Introduced in 1978 and revised in 1984
  - first formal attempt to codify engineering practice
  - slice big problem into manageable areas of concern
- Formulates the communication process into structured layers
- There are seven layers in the model → the 7-Layer model
The function of a layer

- Each layer deals with a subset of aspects of networking
  - e.g., Layer 1 deals with the communication media
- Each layer communicates with the adjacent layers
  - In both directions
  - Example: Network layer communicates with:
    - transport layer
    - data link layer
- Each layer formats the data packet
  - Example: adds or deletes addresses

Layers ➔ wrapping
The (theoretical) layered approach to communication

“OSI model”

7. Application
message format, human-machine interface

6. Presentation
serialization, encryption, compression

5. Session
authentication, permissions, restoration, state

4. Transport
ded-to-end error, flow & congestion control

3. Network
network addressing, routing

2. Data Link
link flow control, error detection, framing

1. Physical
analog-digital (bit stream)

Division of layers

Upper Layers

Middle Layer

Lower Layers
The real model

The Internet Protocol Hourglass

small number of long-term stable interfaces

email  WWW  phone...
SMTP  HTTP  RTP...
TCP  UDP...
ethernet  PPP...
CSMA  async  sonet...
copper  fiber  radio...

S. Deering
**Why four (core) layers?**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Colloquial name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PHY</td>
<td>photons &amp; electrons $\rightarrow$ bits</td>
</tr>
<tr>
<td>2</td>
<td>MAC</td>
<td>bits $\rightarrow$ packets on one technology</td>
</tr>
<tr>
<td>3</td>
<td>L3</td>
<td>packets \textit{end-to-end}, on heterogeneous technologies, to interface</td>
</tr>
<tr>
<td>4</td>
<td>L4</td>
<td>unreliable $\rightarrow$ reliable host/interface $\rightarrow$ application</td>
</tr>
<tr>
<td>(5)</td>
<td>Presentation, data</td>
<td>application data structure encoding</td>
</tr>
<tr>
<td>7</td>
<td>Application</td>
<td>Application behavior (email, web)</td>
</tr>
</tbody>
</table>

**Internet layer functions**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Key protocols</th>
<th>Control protocol</th>
<th>Transmission technologies</th>
<th>Administrative domains</th>
<th>Main function</th>
<th>Addresses</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHY</td>
<td>Ethernet, 4G</td>
<td></td>
<td>single, but may be diverse (fiber, copper)</td>
<td>1</td>
<td>analog-to-digital</td>
<td>none</td>
</tr>
<tr>
<td>MAC</td>
<td>Ethernet</td>
<td>3GPP</td>
<td>same</td>
<td>1</td>
<td>framing</td>
<td>MAC address</td>
</tr>
<tr>
<td>network</td>
<td>IPv4, IPv6</td>
<td>DHCP, OSPF, BGP</td>
<td>agnostic</td>
<td>many</td>
<td>end-to-end delivery</td>
<td>IP addresses</td>
</tr>
<tr>
<td>transport</td>
<td>UDP, TCP</td>
<td>built-in</td>
<td>agnostic</td>
<td>2 (ends)</td>
<td>reliability, congestion control</td>
<td>ports</td>
</tr>
<tr>
<td>application</td>
<td>HTTP, RTP</td>
<td>SIP</td>
<td>agnostic (except for properties)</td>
<td>2 (ends)</td>
<td>framing, description, sessions</td>
<td>URLs, email addresses</td>
</tr>
</tbody>
</table>
Node functions

- Error detection
  - bit errors are detected with high probability
- Error correction
  - bit errors are repaired via redundancy ("forward error correction")
- ARQ
  - lost or corrupted packets are re-transmitted
- Flow control
  - prevent fast sender overwhelming slow receiver
- Congestion control
  - prevent fast sender overwhelming slower network

“Algorithms + Data Structures = Programs”

human protocols:
- “what’s the time?”
- “I have a question”
- air traffic control
- introductions
... specific messages sent
... specific actions taken when message received, or other events

network protocols:
- machines rather than humans
- all communication activity in Internet governed by protocols
Protocols

- Protocols define format & order of messages sent and received among network entities
  - and actions taken on message transmission or receipt
- Often includes notions of time
  - what happens if there is no response?
- Similar to Application Programming Interfaces (APIs)
  - size_t fwrite ( const void *ptr, size_t size, size_t count, FILE *stream );
  - differences?
- Can also consider a “contract”
  - “if I provide you X, you will provide Y”

What’s a protocol?

a human protocol and a computer network protocol:

Q: other human protocols?
Serialization: ASN.1

```
FooProtocol DEFINITIONS ::= BEGIN
  FooQuestion ::= SEQUENCE {
    trackingNumber INTEGER,
    question IA5String
  }
  FooAnswer ::= SEQUENCE {
    questionNumber INTEGER,
    answer BOOLEAN
  }
END

myQuestion FooQuestion ::= {
  trackingNumber 5,
  question "Anybody there?"
}
```

Serialization = convert data structure into (linear) byte stream

like C, without pointers...

Serialization: RFC 822

Delivered-To: hgs10@lionmailmx.cc.columbia.edu
Received: by 10.140.158.132 with SMTP id e126csp131562qhe;
    Thu, 28 Aug 2014 14:01:48 -0700 (PDT)
Return-Path: etickets@amtrak.com
Return-Path: etickets@amtrak.com
Received: from unknown (HELO etvswas01p) ([10.14.128.202])
    by phlsmtprelay01.amtrak.com with ESMTP; 28 Aug 2014 16:55:42 -0400
Date: Thu, 28 Aug 2014 17:01:30 -0400 (EDT)
From: etickets@amtrak.com
To: HGS@cs.columbia.edu, HENNING.SCHULZRINNE@FCC.GOV
Message-ID: <633700356.JavaMail.TDDServerProd@amtrak.com>
Subject: Amtrak: eTicket and Receipt for Your 09/10/2014 Trip
MIME-Version: 1.0
Content-Type: multipart/mixed;
    boundary="-----=_Part.1409259690306"
MIME-Version: 1.0
Content-Type: multipart/mixed;
Serialization: converting data structures into a byte stream

XML

```
<root>
  <user>
    <firstName>John</firstName>
    <lastName>Smith</lastName>
    <isalive>true</isalive>
    <age>25</age>
    <height_cm>167.6</height_cm>
    <address>
      <streetAddress>21 2nd Street</streetAddress>
      <city>New York</city>
      <state>NY</state>
      <postalCode>10021-3100</postalCode>
    </address>
    <phoneNumbers>
      <type>home</type>
      <number>212 555-1234</number>
    </phoneNumbers>
  </user>
</root>
```

JSON

```
{
  "firstName": "John",
  "lastName": "Smith",
  "isalive": true,
  "age": 25,
  "height_cm": 167.6,
  "address": {
    "streetAddress": "21 2nd Street",
    "city": "New York",
    "state": "NY",
    "postalCode": "10021-3100"
  },
  "phoneNumbers": [
    {
      "type": "home",
      "number": "212 555-1234"
    },
    {
      "type": "office",
      "number": "646 555-4547"
    }
  ],
  "children": []
}
```

The problems with layering

- Doesn’t capture whole story
  - control protocols
- Information hiding
  - inefficiency: more than needed
- Information and implementation leakage
- Ossification
- Duplication
  - “If you want it done right, you have to do it yourself”
What’s the Internet: “nuts and bolts” view

- millions of connected computing devices: *hosts*
  - running *network apps*

- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate: *bandwidth*

- *routers*: forward packets (chunks of data)

J. Kurose (Ch. 1)
Internet: “Nuts & bolts” view

- **protocols** control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, Skype, Ethernet
- **Internet: “network of networks”**
  - loosely hierarchical
  - public Internet versus private intranet
- Internet standards
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force

J. Kurose (Ch. 1)

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Internet traffic flows today

- content server farm
- backbone (transit)
- CDN
- eyeball ISP
- Level3 Cogent
- Google
- Facebook
- YouTube
- Yahoo
- Live
- Baidu
- Level3
- Cogent
- Netflix
- Akamai
- Comcast
- video conferencing
Network types

- Access
  - "last mile"
- Regional or metro
  - "metro fiber", “metro Ethernet”
- Wholesale
  - connect points-of-presence across
  - may also provide access to commercial buildings & data centers
- Trans-oceanic
  - often, owned separately (consortium), but integrated into wholesale networks

A backbone network
1901 “data” backbone

Submarine cable map
Wireline & wireless

"almost all networks are 99% wired" exceptions?

It’s all spectrum - phone
It’s all spectrum - wires

4 kHz

10 MHz

1 GHz

200 - 347 THz

copper

It’s all spectrum - modem
Fundamental limit to channel capacity

\[ C = B \log_2 \left( 1 + \frac{S}{N} \right) \]

channel capacity (bits/second)  bandwidth (Hz)  signal-to-noise ratio (typically, dB)

Shannon-Hartley limit

Shannon examples

- SNR (dB) = 10 \log_{10} (S/N)
- Telephone modem: SNR = 20 dB (1:100); frequency 4 kHz → 4,000 \log_2 (101) = 26.63 kb/s
- Noise can be larger than signal!
  - → negative SNR
- Less noise → higher signal power
- Only true for simple channel models
  - “additive Gaussian white noise” (AWGN)
- Spectral efficiency: bits per second per Hz
  - often, around 1-2 b/s/Hz, but can be much higher
It’s all spectrum - radio

FM radio: 100 kHz
Long wave radio
Medium wave radio
FM radio
Satellite broadcasting
TV

VLF LF MF HF VHF UHF SHF EHF FHF

Increasing range
Decreasing bandwidth

AM radio: 9 or 10 kHz
TV: 5 or 6 MHz

Typical cell channel: 5-10 MHz

Circuit switching: FDM versus TDM

Example:

4 users

FDM

TDM
All networks are similar

- packets
- time-division multiplexing
- modulation
- frequency division
- medium = spectrum

Reference architecture

- Internet Peering
- Other Communications Networks
- Users
- ISP
- Access Network
- Regional Broadband Network
- Transport Core
- Interconnected Networks
- Local Video Feeds
- Other Cores Within the Network
- Video Feeds and 3rd Party CONs
- L3 Router
- SBC/SS
- L3 Router
- Set top box commands and control
- Video Cache
**Broadband Access Technologies**

- FBWA or 4G
- BPL
- DSL
- HFC
- 4G
- Fiber PON

**Digital Subscriber Line**
- Telco or ILEC
- 10s of Mbps
- Entertainment, data, voice

**Hybrid Fiber Coax**
- CableCo (MSO)
- Entertainment, data, voice
- 10s of Mbps

**Fiber -- Passive Optical Network**
- Telco or ILEC
- ~75 Mbps
- Futureproof?

**Fixed Broadband Wireless Access**
- Wireless ISP
- WiMAX or LTE:
- -10s of Mbps
- Satellite: few Mbps

**4G/LTE**
- Cellular operators
- 5-10 Mbps (100 kph)

**Local loop**

Paul Henry (AT&T), FCC 2009
Physical architecture

- **Feeder Cables**
  - Carries traffic serving multiple endpoints from an “office” to a neighborhood (local convergence point, LCP, or serving area interface, SAI)

- **Distribution Cables**
  - Carry traffic for one or more households from LCP to the curb (network access point)

- **Drop Cables** (above ground) or service wire (underground)
  - Carry traffic from curb to dwelling unit

- Depending upon the architecture
  - Cables may be fiber, twisted pair or coax
  - Local convergence point and/or network access point could host a patch panel, a DSLAM, an optical splitter, an Ethernet switch, or a fiber/coax interface.

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Broadband access

Architectures Offered Today – Illustrative

![Diagram of broadband architecture](image-url)
Logical architecture

- Access network extends from Residential Gateway (RG) to Broadband Network Gateway (BNG)
- Flow management between AN and RG depends upon the architecture
- Flow management in the Ethernet Aggregation Network similar across architectures but may differ from how flows are managed between the AN and the RG
- In Metro Network flows are typically distinguished by layer 3 QoS tags and/or separate VPNs


xDSSL logical architecture

**ADSL (ITU G.992.1)**

ADSL spectral power repartition (PSTN)

<table>
<thead>
<tr>
<th>Power</th>
<th>POTS</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 Hz</td>
<td>3.4 kHz</td>
<td>22 kHz</td>
</tr>
</tbody>
</table>

**FDD:** Frequency Division Duplexing

→ no interference between up and down

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**Access net: cable network**

- **HFC:** hybrid fiber coax
  - asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate
- **network** of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend
  - unlike DSL, which has dedicated access to central office
**Simplified access network diagram**

- Logical Channel Bonding Technology
- 152 Mbps
- 38 Mbps
- 38 Mbps
- 38 Mbps
- 38 Mbps
- 38 Mbps
- 38 Mbps

**DOCSIS 3.0 Channel Bonding**

- DOCSIS 2.0 is limited to single channel's capacity
- DOCSIS 3.0 employs packet bonding across multiple channels
  - Initially will bond 4 channels
  - 8 channel-capable silicon coming soon
  - Upstream bonding in 2010
  - Increased speeds 100Mbps+
Typology of FTTH

- P2P: Point-to-point (individual links from CO to premises)
- P2MP: Point-to-multipoint (feeder to neighborhood, then branching)
- PON: Passive Optical Network (optical signal on feeder passively split)
- TDMA-PON: PON where traffic to multiple households multiplexed in time
- (T)WDM-PON: PON using combination of Wavelength Division Multiplexing and TDMA
- EPON: Ethernet Passive Optical Network
- DPOE: DOCSIS Provisioning over EPON
- BPON: Broadband Passive Optical Network (ATM based)
- GPON: Gigabit Passive Optical Network (Generic Framing)
- NG-PON: Next Generation PON
**Verizon’s FTTP Architecture**

- **OLT (Optical Line Terminal)**
- **ONT (Optical Network Terminal)**
- **Optical Couplers (WDM)**
- **EDFA (Erbium Doped Fiber Amplifier)**

**Bandwidth & Services**

- **Upstream**: 1310 nm
  - Voice & Data at 1.55 to 622 Mbps
- **Downstream**
  - **1490 nm**: Voice, Data & Video at 622 Mbps
  - **1550 nm**: Broadcast Video

**Active Ethernet**

- Active Ethernet uses single fiber from CO to neighborhood where there is an active Ethernet Switch.
- Variant of P2P because there is a direct link (P2P) from the neighborhood Ethernet switch to the premise.

http://www.glits.biz/graphics/Nov2011/active-ethernet.png
PON standards

- Two different families of standards for PON networks
- IEEE standards
  - EPON or Ethernet in the First Mile (EFM)
    - Based on Ethernet framing over fiber
    - Flow management similar to xDSL using VLAN tagging
    - Video carried as IPTV
- ITU Standards
  - ATM-based *(deprecated but significant installed base)*
    - BPON (G.983)
      - 622 Mbps down/155 Mbps up
  - Packet based
    - GPON (G.984) *(Most common in the U.S. today)*
      - 1.2 Gbps and 2.4 Gbps down/155 Mbps, 622 Mbps, 1.2 Gbps and 2.4 Gbps up
    - XG-PON (10G-PON) (G.987)
      - 10 Gbps down/2.5 Gbps up
    - NG-PON2 (G.989) *emerging standard*
      - Combines WDM and TDMA to support both P2P and P2MP

Typical Fiber GPON Access Architecture for providing voice, data and video

- OLT (Data) and EDFA (Video) output are combined using a WDM in the Fiber Distribution Frame (FDF) and transmitted to the Outside Plant over a feeder fiber
- A splitter located at the Fiber Distribution Hub (FDH) splits the optical power evenly to be shared between 32 or 64 customers
- Each 1x32(64) splitter feeds 32(64) distribution fibers to serve 32(64) homes in a neighborhood. The drop fiber connects the ONT to the distribution fiber at the Fiber Distribution Terminal (FDT)
- Separate wavelength for linear video (1550 nm)
- Voice and data carried as cells/packets (1490 nm down/1310 nm up)
PON architecture

Communication Satellites

Communication satellites, some properties, including: altitude above earth, round-trip delay time, number of satellites for global coverage.

Geostationary Satellites (1)

<table>
<thead>
<tr>
<th>Band</th>
<th>Downlink</th>
<th>Uplink</th>
<th>Bandwidth</th>
<th>Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>1.5 GHz</td>
<td>1.6 GHz</td>
<td>15 MHz</td>
<td>Low bandwidth; crowded</td>
</tr>
<tr>
<td>S</td>
<td>1.9 GHz</td>
<td>2.2 GHz</td>
<td>70 MHz</td>
<td>Low bandwidth; crowded</td>
</tr>
<tr>
<td>C</td>
<td>4.0 GHz</td>
<td>6.0 GHz</td>
<td>500 MHz</td>
<td>Terrestrial interference</td>
</tr>
<tr>
<td>Ku</td>
<td>11 GHz</td>
<td>14 GHz</td>
<td>500 MHz</td>
<td>Rain</td>
</tr>
<tr>
<td>Ka</td>
<td>20 GHz</td>
<td>30 GHz</td>
<td>3500 MHz</td>
<td>Rain, equipment cost</td>
</tr>
</tbody>
</table>

The principal satellite bands

Geostationary Satellites (2)

VSATs using a hub.

"bent pipe"
HTS launches per year

<table>
<thead>
<tr>
<th>Dedicated HTS</th>
<th>Hybrid Payload HTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thaicom 4</td>
<td>Anik F2</td>
</tr>
<tr>
<td>WildBlue 1</td>
<td>AMC-16</td>
</tr>
<tr>
<td>Spaceway 3</td>
<td>AMC-16</td>
</tr>
<tr>
<td>Ka-Satt</td>
<td>Ciel-2</td>
</tr>
<tr>
<td>ViaSat-1</td>
<td>Hylas 1</td>
</tr>
<tr>
<td>Jupiter-1</td>
<td>Arabsat 5C</td>
</tr>
<tr>
<td>Inmarsat SF2</td>
<td>YahSat-1B</td>
</tr>
<tr>
<td>Inmarsat SF1</td>
<td>Hylas 2</td>
</tr>
<tr>
<td>Inmarsat SF3</td>
<td>Hispasat A21</td>
</tr>
<tr>
<td>NBN Co 1A</td>
<td>Express AM6</td>
</tr>
<tr>
<td>NBN Co 1B</td>
<td>Astra 2F</td>
</tr>
<tr>
<td>GSAT-11</td>
<td>Express AM6</td>
</tr>
<tr>
<td>GSAT-11</td>
<td>Amazonas 3</td>
</tr>
<tr>
<td>NBN Co 1B</td>
<td>Astra 2E</td>
</tr>
<tr>
<td>NBN Co 1B</td>
<td>Thur 7</td>
</tr>
<tr>
<td>NBN Co 1B</td>
<td>Astra 2G</td>
</tr>
<tr>
<td>NBN Co 1B</td>
<td>Jabiru-1</td>
</tr>
</tbody>
</table>

HTS Capacity Launches (Gbps)

Low-Earth Orbit Satellites (1)

The Iridium satellites form six necklaces around the earth.

Satellite

### Advantages
- Near-universal geographic availability
- Low incremental cost
  - Satellite terminal + installation
- Resilient after natural disasters
  - Often used as backup

### Disadvantages
- Latency
  - MBA 2014: RTT 671 ms
- Temporary disruptions
  - Sun alignment
  - Rain fade
- Capacity
  - Viasat-1: 140 Gb/s (for 300,000 customers)
  - Usually, usage-capped
# Example: Exede

<table>
<thead>
<tr>
<th>Evolution</th>
<th>Freedom</th>
<th>Freedom</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>$49.99</strong></td>
<td><strong>$69.99</strong></td>
<td><strong>$99.99</strong></td>
</tr>
<tr>
<td><strong>LIMITED TIME OFFER</strong></td>
<td><strong>OUR BEST OFFER EVER!</strong></td>
<td><strong>Virtually UNLIMITED</strong></td>
</tr>
<tr>
<td>Unlimited Access*</td>
<td>Unlimited Access*</td>
<td>Virtually UNLIMITED* access to everything all the time</td>
</tr>
<tr>
<td>+15 GB/mo</td>
<td>+20 GB/mo</td>
<td>for everything all the time</td>
</tr>
<tr>
<td>for everything else</td>
<td>for everything else</td>
<td></td>
</tr>
<tr>
<td>12/3 Mbps</td>
<td>12/3 Mbps</td>
<td>12/3 Mbps</td>
</tr>
<tr>
<td><strong>Early Bird Free Zone</strong></td>
<td><strong>Early Bird Free Zone</strong></td>
<td><strong>Plan description:</strong></td>
</tr>
<tr>
<td>Unlimited access to everything 1 am to 6 am, every day</td>
<td>Unlimited access to everything 1 am to 6 am, every day</td>
<td>You want to try a virtually unlimited plan for 6 months to do whatever you want online, whenever you want (including plenty of HD video).</td>
</tr>
<tr>
<td><strong>Plan description:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You want an unlimited plan for browsing web pages and using email, and you're a light user of online video.</td>
<td>You want to try a virtually unlimited plan for 6 months to do whatever you want online, whenever you want (including plenty of HD video).</td>
<td></td>
</tr>
</tbody>
</table>

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*Note: Plans and pricing may change.*