Charting a Future Internet Infrastructure for Bhutan

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Technologies

- IPv6 deployment to end users
  - Required to carry on scaling the Internet
- NAT does not scale
  - Lack of IPv4 addresses for NAT translations
  - Latency introduced into network
  - Exceptional cost of devices vs deploying IPv6
- A network with IPv6 fully deployed to consumers will likely see >80% traffic on IPv6
  - <20% traffic accessing legacy IPv4 via NAT

Content is the future

- Internet usage in Bhutan (5th June: 9am to 2pm)

Network Operator	ASN	Traffic %
Google	15169	43.7
Facebook	32934	28.6
Akamai	20940	5.7
Apple	6185	3.3
Microsoft	8068	2.7
Level3	3356	1.9
Amazon	38895	1.5
Akamai	16625	1.4
Limelight	22822	0.7

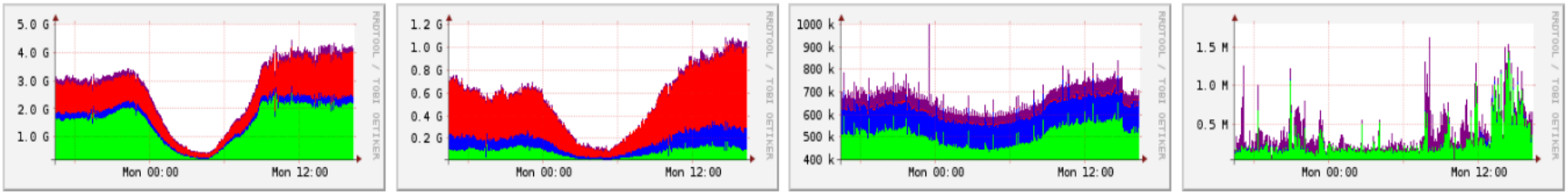
Content is the future

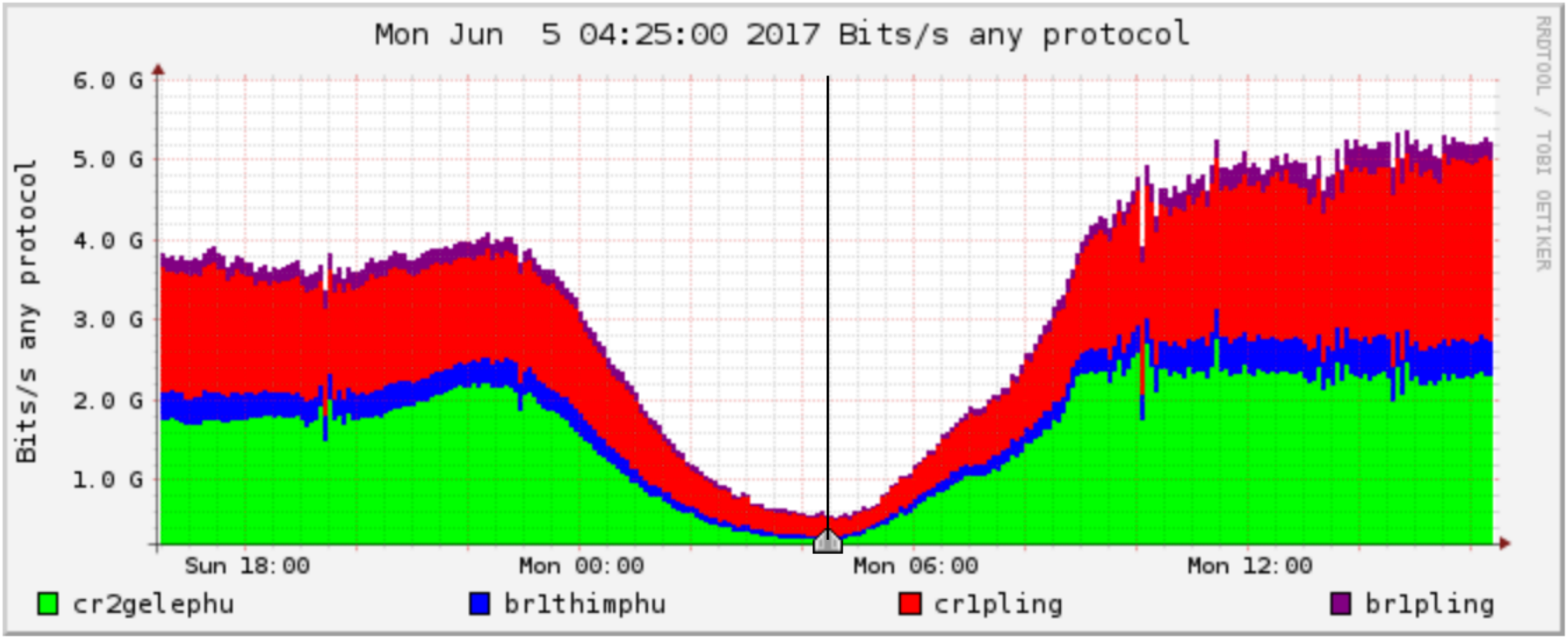
- Internet is now a big content network
  - Google and Facebook dominate (traffic!)

- Challenges:
  - How to get content to the users efficiently and at least cost
  - Content Caching in Bhutan
    - (in addition to Google Global Cache)
  - How to scale the access network

DrukNET – traffic profile

TCP **UDP** **ICMP** **other**





Consumer Access

- Future of Internet access is Mobile
  - Desktop PC sales declining sharply
  - Laptop sales not increasing
  - Tablet and Smartphone sales increasing
  - Fibre to the Home is expensive/impractical outside built up areas
- Copper access
  - Dialup obsolete long ago
  - ADSL depends on copper quality and distance from exchange
  - 24Mbps theoretical, 10Mbps “realistic”, often only a few Mbps is possible
  - LTE seems to be replacing ADSL/Cable access in places

Consumer Access

- 4G/LTE is the global norm now
  - 100Mbps to the handset (theoretical)
  - 5G (1Gbps to handset) promised for early 2020s
- 3G & 2G are outdated technologies
  - Too slow (<2Mbps to handset)
  - Too expensive to operate and maintain
- Operator priority is deploying LTE network
  - With full IPv6 support (IPv6 is part of LTE standard)
  - (With access to legacy IPv4 – 464XLAT & NAT64)

Consumer Access

- Challenges:
  - How to provide LTE density to meet user demands?
  - Spectrum choices *versus* handset availability *versus* roaming capability for foreign visitors?
  - How to provide support for IPv6 as well as for legacy IPv4?
  - Profusion of mobile towers, or shared infrastructure?

Enterprise Access

- Access for:
  - Small enterprise
  - Large enterprise
  - Town/City apartment living
- Copper access
  - Now obsolete – 1980s and 1990s technology
  - TDM networks are expensive to operate and maintain
  - Low bandwidths: 64kbps to 2Mbps only

Enterprise Access

- Fibre is the future
  - Fibre to the kerb/front door
  - Access speeds at 1Gbps (or parts there of) or even 10Gbps (or parts there of)

- Challenges:
  - Who deploys fibre to the building?
  - How to deploy fibre to the building?
  - How to allow Internet Service Providers access to it
    - Fibre pairs?
    - Wavelengths?
    - Who runs the fibre backbone?

Enterprise Networks

- Core network:
  - Single-mode fibre
    - Multi-mode is expensive and very limited
  - 10Gbps is de facto standard
    - Managed 10Gbps switches are inexpensive
- Access network:
  - 1Gbps to the desktop (copper)
  - 10Gbps fibre uplinks to the Core
    - Switches with 10/100/1000 and 10Gbps uplink are inexpensive
- Dual stack (IPv4 & IPv6) essential
  - Reduces the dependency on NAT

International Connectivity

- Content providers route by round trip time
  - BGP used to inform about content caching only
  - Totally changes the BGP redundancy model we are accustomed to
- Bhutan content fed from Singapore & Mumbai datacentres
- Challenges
  - Redundancy?
  - Landlocked country / diverse paths / transit costs
  - Phuentsholing/Gelephu/Samdrup Jongkhar to Chennai/ Mumbai/Dhaka ?

Recommendations

- Service Providers:
  - Mobile: 4G is a priority (MUST be with IPv6)
    - 3G is heading to obsolescence
  - Consumer access: fibre (affordable?) or 4G
  - Business access: fibre

- Businesses:
  - Campus backbone – 10G fibre is cheap, pointless doing less