BELL LABS

METRO NETWORK TRAFFIC GROWTH: AN ARCHITECTURE IMPACT STUDY

STRATEGIC WHITE PAPER

Like many studies before it, the Alcatel-Lucent Bell Labs Metro Network Traffic Growth Study provides evidence of an upward trend in IP traffic growth. However, this study is unique in that it takes the extra step to analyze the impact of that traffic growth on metro and backbone networks. The study analyzes the impact of the largest drivers on traffic growth: IP video content and data center proliferation within metro networks. The key take-away from this study is that metro networks face many changing dynamics that will impact the architecture and design of metro networks. Alcatel-Lucent understands the evolutionary phase that metro networks are currently in and offers a Cloud-Optimized Metro solution which delivers agility, scale and efficiency to meet growing traffic demand and the requirements of application-driven, on-demand cloud services.

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EXECUTIVE SUMMARY

Metro networks[1] are on the cusp of significant transformation, driven by the continuing growth of residential, mobile, business and cloud services. The Metro Network Traffic Growth Study, conducted by Alcatel-Lucent's Bell Labs, uses US end-user trends as a baseline to characterize traffic growth forecasts over 5 years (2012-2017). The end-user demand forecasts are then applied to a real-world reference network architecture to analyze the impact of traffic growth within metro and backbone networks. The reference architecture and traffic mix is representative of a converged services operator delivering residential (Internet and pay TV), mobile, business and cloud services.

End-user demand in this study is conservatively estimated at a 3.7 times increase in the combined residential fixed Internet, business fixed traffic and mobile traffic from 2012 levels. The traffic model also includes pay TV consumer traffic which is growing at an average rate of 2.3 times from 2012 levels. Pay TV includes traditional viewing and non-traditional viewing. Traditional viewing refers to linear TV to the set-top box while non-traditional viewing includes viewing of on-demand content (free or paid VoD, time-shifted TV, network PVR) and viewing on IP-connected devices (such as Smart TVs, PCs, smartphones, game consoles, and tablets). Non-traditional pay TV traffic is expected to grow 7.5 times by 2017.

As the demand for video content increases, there is a move towards caching video content closer to the end user. Video caching is now being implemented within metro networks, moving content caching deeper into the network. This approach ensures a superior quality of experience (QoE) as most popular content is now sourced from within the metro network and not uniquely from a national caching location.

The increasing importance of data centers (DCs) for cloud services and moving forward, advanced networking functions like Network Functions Virtualization (NFV), will result in significant proliferation of DCs within metro networks. The Metro Network Traffic Growth Study analyzes the impact of migrating DCs and content sources (currently located at a few national locations) to a metro or regional level. The Bell Labs study forecasts the following metro traffic growth trends.

Total metro traffic will increase 560% by 2017. The results indicate a significant increase in total metro traffic over the next five years. IP video and DC/cloud traffic are the largest drivers for growth. The Bell Labs study forecasts that traffic derived from video (pay TV and Internet video) will skyrocket by as much as 720 percent. Data center (user-to-DC and DC-interconnect) traffic is forecast to increase more than 440 percent during the same time period. Combined, video and data center traffic are the key drivers to an overall forecast growth of 560 percent increase in traffic in the metro by 2017. **Metro traffic will grow about two times faster than traffic going into the backbone by 2017.** This faster growth rate in conjunction with the projected traffic increase will require scaling of network nodes and links in the IP and Optics domains of the metro network.

1 While the term "metro network" is used in this paper, for some geographic regions, the term metro network may represent a single or multi-region network. In such cases, alternative terms like regional network or aggregation network may be used to represent a metro network.

By 2017, 75% of total metro traffic will be terminated within the metro network and 25% of traffic will traverse the backbone network. Due to the increased concentration of traffic sources within the metro network, more bandwidth will now stay local within the metro network. Until recently, metro traffic had a north-south flow from a content source to the end user with content sources (managed or over-the-top) typically located at a national central location and accessed via the backbone network. These north-south flows now see a shift in the location of content sources and end-user destinations: content sources will be concentrated within the metro network and end users are now increasingly accessing content via fixed as well as mobile devices. The metro network will also experience increasing east-west flows, as traffic flows from DC to DC for the delivery of cloud services. These shifts in traffic flows require network architectures that deliver scale and versatility to meet current and future needs.

Implementing video caching closer to the end user can result in a 41% bandwidth reduction within metro networks. Caching content centrally within the metro network results in bandwidth savings in the backbone network, since multiple end users requesting the same content are served from this cache instead of being served from a central storage accessible via the backbone network. If caching is extended even deeper (closer to the end user) into the metro network, the overall traffic can be reduced by 41%.

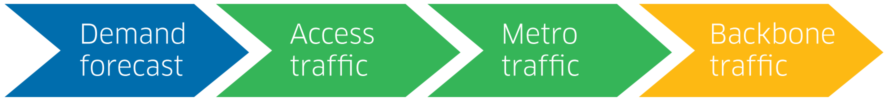
The Alcatel-Lucent Bell Labs Metro Network Traffic Growth Study validates that traffic within metro networks is poised for significant growth driven largely by IP video and DC/cloud traffic. Content sources will now be located within the metro network resulting in a change in network-wide traffic flows. Service providers understand that these trends will have an impact on how they evolve and architect their metro networks. Alcatel-Lucent offers service providers innovative, cost-effective solutions that enable agile, scalable and efficient cloud-optimized metro networks. See References at the end of this paper for further reading.

OBJECTIVES AND METHODOLOGY

The Metro Network Traffic Growth Study characterizes traffic growth within metro networks (using US end-user traffic trends as a baseline) and analyzes the impact of these trends on real-world service provider networks (based on a reference network architecture). This study develops a comprehensive traffic forecast for the metro area for both residential and business services that includes the impact of video, cloud and mobile data. It then analyzes the impact of the resulting traffic in the access, metro and backbone network. The impact analysis focuses on how the use of caching for optimized video content delivery and the introduction of DCs for cloud service delivery impacts the bandwidth and traffic within metro networks.

The Alcatel-Lucent Bell Labs metro study methodology (Figure 1) is based on in-depth analysis of traffic growth in the metro and backbone using a proprietary bottom-up approach. Bell Labs forecasted residential, business and mobile demand from end users and developed comprehensive traffic models through access, metro and backbone based on a typical network infrastructure and specific traffic distributions and patterns for each type of content and application in those domains. The study took into consideration the sensitivity of traffic growth against market trends, such as the proliferation of DCs and the migration to the cloud, and the use of caching for optimized video content delivery over 5 years (2012 -2017).

Figure 1. Metro Network Traffic Growth Study methodology

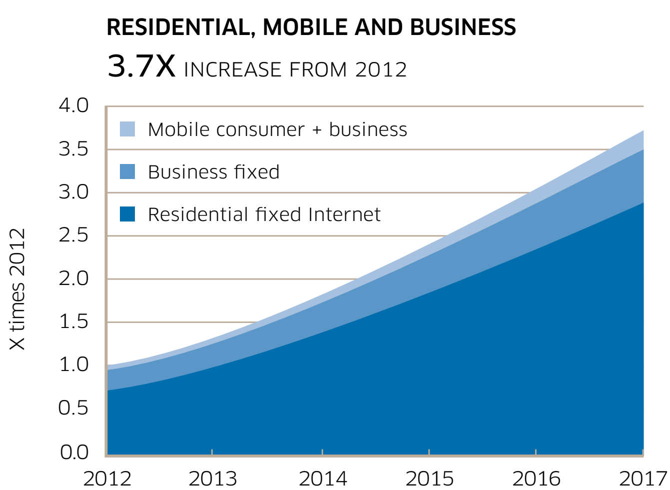


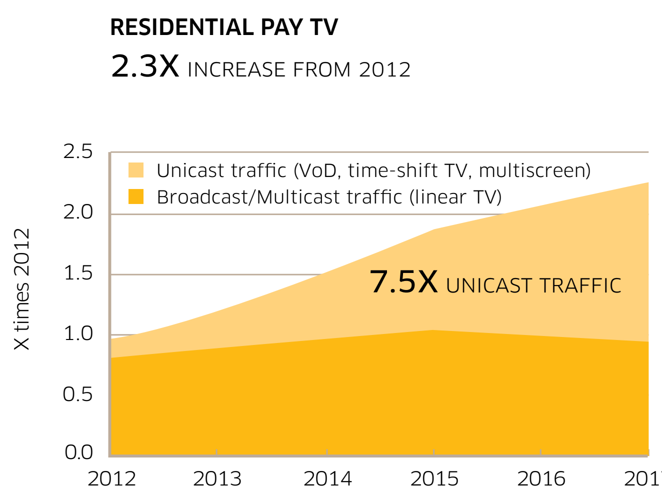
The assumptions for traffic growth are based on very realistic (conservative) demand-supply assumptions, since the primary focus of the study was to analyze the impact of metro traffic growth on real-world network architectures. The traffic study and reference architecture are representative of a converged services operator delivering residential (Internet, IPTV, VoD), mobile and business/cloud services.

Demand forecast

The study conservatively estimates that by 2017, end-user traffic demand will have increased 3.7 times from 2012 values for combined residential fixed Internet, business fixed traffic and mobile traffic (Figure 2). Residential services account for the largest share of total bandwidth. Mobile traffic makes up the smallest share of total bandwidth, but it has the highest growth. Video demand coming from mobile and portable devices on Wi-Fi® connections also impacts fixed traffic.

Figure 2. Residential, mobile and business traffic demand from 2012 to 2017



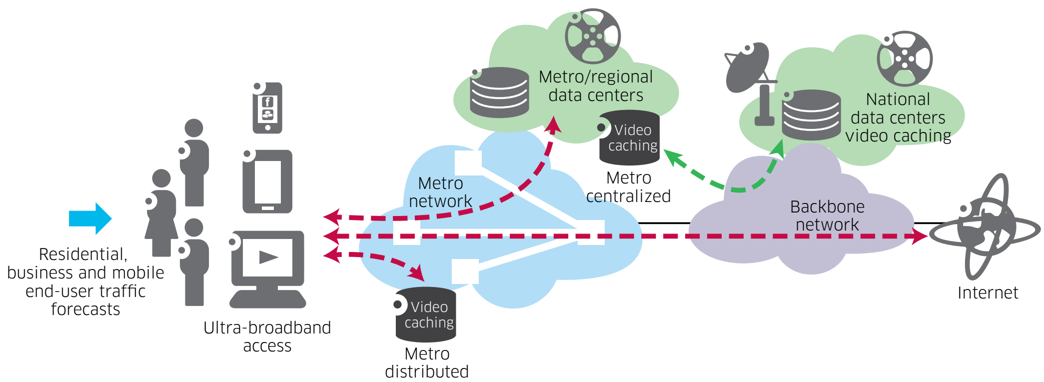


The traffic model also includes pay TV consumer traffic which is growing at an average rate of 2.3 times. Pay TV includes traditional viewing and non-traditional viewing. Traditional viewing refers to linear TV to the set-top box while non-traditional viewing includes viewing of on-demand content (free or paid VoD, time-shifted TV, network PVR) and viewing on IP-connected devices (such as Smart TVs, PCs, smartphones, game consoles, and tablets). Non-traditional pay TV traffic is expected to grow 7.5 times by 2017.

Reference network architecture

The Bell Labs study analyzed the impact of end-user traffic growth using a reference network architecture (see Figure 3) consisting of metro networks interconnected by a backbone network.

Figure 3. Reference network for metro/backbone traffic modeling and video caching/DC impact analysis



As the demand for video content increases, there is a move towards caching video content closer to the end user. Video caching is now being implemented within metro networks to complement national content caching. This approach ensures a superior quality of experience (QoE) as most popular content is now sourced from within the metro network and not uniquely from a single national caching location. The traffic model analyzed the impact of regional content caching and the proliferation of DCs within metro networks to support emerging cloud services. Two cases were analyzed:

1. **The metro centralized case**, where content caching and DCs are located centrally (closer to the core of the metro network) within the metro network
2. **The metro distributed case**, where content caching is further distributed very close to the end users (sometime referred to as deep caching)

Case 1 is the most likely starting point for most operators, as it provides a “build as you need” or “pay as you grow” approach for introducing content caching or DCs within the metro network. As unicast video traffic ramps up, some operators may choose to distribute the caches deeper in the metro (Case 2).

STUDY RESULTS

The results described below (unless stated otherwise) are based on the following assumptions:

- Video caching and DCs are deployed centrally within the metro network (metro centralized case).
- Based on industry research[2], Bell Labs modeling uses a 10% to 20% yearly growth rate for the number of metros that have deployed DCs; the results below are based on a 20% yearly growth estimate.
- The number of DCs deployed in the metro network will increased 60% (moderate growth) by 2017.

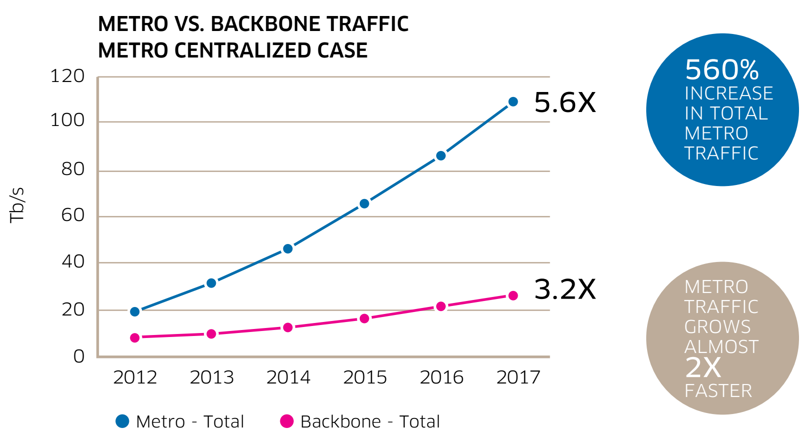
Refer to Appendix A of this white paper for additional details on assumptions and sensitivities related to the Bell Labs Metro Network Traffic Growth Study.

2 D. Cappuccio, “The Case for the Infinite Data Center”, Gartner Group, June 7, 2012

Metro traffic will grow faster than backbone traffic

Figure 4 illustrates metro and backbone traffic growth based on video caching and DCs being located centrally within the metro network (case 1, metro centralized). According to the study, metro traffic will grow by a factor of 5.6 times: "Metro traffic driven by all applications will increase 560% by 2017". In comparison, "backbone traffic will grow by a factor of 3.2X" and "metro traffic will grow almost twice as fast as backbone traffic by 2017". Metro traffic includes broadcast TV, time-shifted TV, VoD, Internet video, web data; mobile video and audio, communication (video, VoIP, e-mail, immersive), file sharing, residential cloud; and DC-to-DC interconnect. The Bell Labs study forecasts that traffic derived from video (pay TV and Internet video) will skyrocket by as much as 720 percent. Data center (user-to-DC and DC-interconnect) traffic is forecast to increase more than 440% during the same time period. Combined, video and data center traffic are the key drivers to an overall forecast growth of 560% increase in traffic in the metro by 2017.

Figure 4. Traffic growth in metro and backbone network with metro centralized video caching and DC deployment



Metro video traffic will increase 720% by 2017. Video traffic includes all of the following on any or multiple screens:

- Internet video (all categories of streamed, downloaded, progressively downloaded, free or paid, transaction or subscription, user-generated or professional content)
- Residential fixed-managed video (pay TV live/broadcast programs (standard, premium channels)
- VoD (paid or free)
- Time-shifted (cloud recorded, services allowing post-viewing of all aired programs)

Metro cloud and DC traffic will increase 440% by 2017. DC traffic includes DC-to-end-user and DC-to-DC (interconnect) traffic.

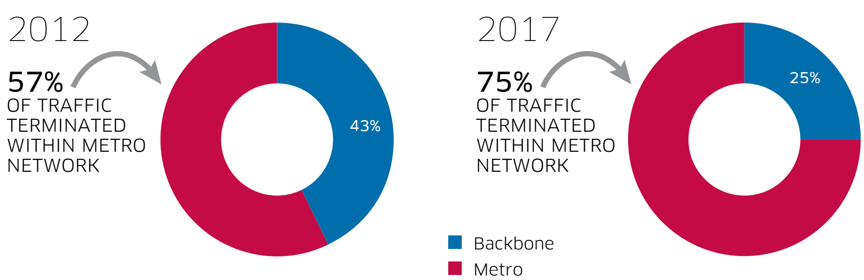
- DC-to-end-user traffic includes:
  - ¬ Business – video (communication and content), web, data, and file-sharing
  - ¬ Residential – cloud apps (desktop, content management), and Internet video that has moved to a cloud-based model (all categories of streamed, downloaded, progressively downloaded, free or paid, transaction or subscriptions, user-generated or professional content)
- DC-to-DC interconnect traffic consists of:
  - ¬ Virtual DC resources moving across DCs
  - ¬ Backup and disaster recovery operations between DCs

As more and more video, data and web content is sourced from within the metro, the growth rate for metro traffic is faster, compared to backbone traffic. This faster growth rate, in conjunction with the projected traffic increase within metro networks, calls for network-wide scaling of network nodes and links in the IP and Optics domains of the metro network.

Traffic distribution is changing

By 2017, 75% of total metro traffic will be terminated within the metro network and 25% of traffic will traverse the backbone network. This compares with 43% of metro traffic reaching the backbone while the remaining 57% terminated within the metro in 2012 (see Figure 5).

Figure 5. The changing distribution of traffic between metro and backbone



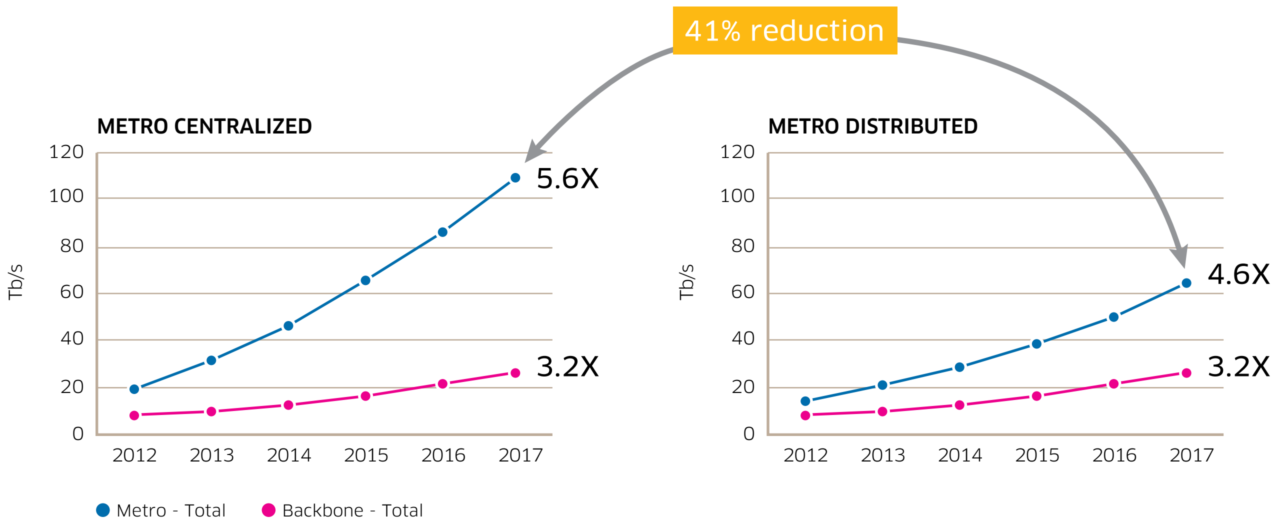
Due to the increased concentration of traffic sources within the metro network, more bandwidth will now stay local within the metro network. Until recently, metro traffic had a north-south flow from an end user to content sources that were solely accessed via the backbone network (such as the Internet or the service provider's managed content source). These north-south flows will now see a shift in the location of content sources (as they are increasingly concentrated within the metro network). In addition, there will be an increase in east-west traffic flows, with the increase in DC-to-DC traffic from cloud-based services. These shifts in traffic flows require network architectures that deliver scale and versatility to meet current and future needs.

Bandwidth optimization with distributed video caching (deep caching)

Caching content centrally within the metro network (case 1) results in bandwidth savings in the backbone network, since the backbone network does not have to send multiple copies of the content to multiple users.

With the metro distributed (case 2), where caching is extended even deeper into the metro network (and closer to the end user), metro traffic will grow by a factor of 4.6 times. Since a copy of the required content is available locally, less bandwidth is consumed within the metro network to deliver the same content, resulting in a reduction in total metro bandwidth for the metro distributed case. This architecture optimization for video caching can reduce the overall total traffic by 41% (see Figure 6). The distributed model of deployment for video caching (metro distributed) offers an evolutionary path to support increased demand for video services.

Figure 6. Metro distributed caching provides bandwidth savings



CONCLUSION

The Alcatel-Lucent Bell Labs Metro Network Traffic Growth Study validates that traffic within metro networks is poised for significant growth driven largely by IP video and the growth in DC/cloud traffic. Locating content sources within the metro will result in a change in traffic flows in the network. Service providers understand that these trends will have an impact on how they evolve and architect their metro networks. Alcatel-Lucent offers service providers innovative, cost-effective solutions that enable agile, scalable and efficient cloud-optimized metro networks.

REFERENCES

[1] *The Case for the Infinite Data Center*, D. Cappuccio, Gartner Group, June 7, 2012.

[2] *Semi-Empirical Description and Projections of Internet Traffic Trends Using a Hyperbolic Compound Annual Growth Rate*, S. Korotky, Bell Labs Technical Journal, 18:3, (2013).

[3] *Video Shakes Up the IP Edge, A Bell Labs Study on Rising Video Demand and its Impact on Broadband IP Networks*, Alcatel-Lucent Bell Labs Strategic White Paper, December 12, 2012. See also http://www2.alcatel-lucent.com/techzine/why-you-need-to-take-video-to-the-edge/

[4] *The LTE Imperative, Technology & Market Brief*, Corporate CTO Group White Paper, Corporate CTO Business Modeling Group and Bell Labs Enabling Computing Technologies Department, September 2013.

FURTHER READING

Application note: *Alcatel-Lucent Cloud-Optimized Metro Networks: Moving the metro forward with agile, scalable and efficient networks.*

Alcatel-Lucent Cloud-Optimized Metro solution: http://www.alcatel-lucent.com/solutions/cloud-optimized-metro

APPENDIX A — ASSUMPTIONS AND SENSITIVITIES

Detailed assumptions and sensitivities

Demand forecast is based on several Bell Labs developed models:

- All residential demand models track minutes of use and throughput FACING the network. The medium-growth demand scenario is a conservative forecast reflecting all trends, applications, and devices already visible in the market and historical measurements to 2017. Residential demand models start with current trends and baseline measurements and mix conventional forecasting methods with projections of user behavioral usage of the main and emerging applications, thus accounting for new devices and technologies, cloud services, and economical factors.
- The US forecasts include user segment, location, and time-of-day usage profiles, device availability and preference, impact of Wi-Fi, and technological trends. Minutes of use and bandwidth throughput requirements by app type, quality (HD/SD), screen size and type are used to calculate the final traffic demand. Busy-hour profiles by application type are used for further network engineering.
- Business demand forecast is based on a higher level model from Bell Labs, described in [2].

Demand forecasting domains:

- Business fixed Internet and managed network – video (communication and content), web and data, and file-sharing
- Business mobile – all video applications (communication and content), web and data, and file sharing
- Residential mobile – streaming video and audio, computer, gaming, storage and backup
- Residential fixed – Internet: video (all categories of streamed, downloaded, progressively downloaded, free or paid, transaction or subscriptions, user-generated or professional content), audio, communication (video, VoIP, email, immersive), cloud apps (desktop, content management), gaming, browsing, file-sharing, and storage/backup
- Residential fixed – managed: pay TV live/broadcast programs (standard, premium channels), VoD (paid or free), time-shifted (local/cloud recorded, services allowing post-viewing of all aired programs), on any or multiple screens

Demand forecast sensitivities:

- The medium-growth demand scenario used for this study is a conservative forecast reflecting all trends, apps and devices already visible in the market and historical measurements to 2013. A higher growth scenario will project more video and cloud apps, which will further increase the traffic growth, and the relatively higher growth of the metro compared to backbone.
- A more aggressive scenario on the fixed networks not only increases the time residential subscribers spend watching video, but also speeds up the new way they consume it: for example, on IP connected devices (such as smartphones, tablets, and PCs), and via on-demand services whenever they want. These new ways of consuming content require unicast traffic (each individual user is served by a unique stream), not broadcast or multicast (which distributes the same streams to all viewers at the same time). A Bell Labs study [3] of this behavior has shown that by 2022, unicast-type video will represent more than 90% of the demand.
- On the mobile network, a Bell Labs study [4] has also shown that if technology deployment of LTE and small cells is combined with Smart Loading optimization techniques and alternative business scenarios, network operators can profitably address a more than 14 times increase in traffic demand.

Network sensitivities:

- DC trends:
  - ¬ As the percentage of video and web/data traffic served by DCs increases and more and more DCs are deployed in metros, video and web/data traffic will be terminated locally within metro and not traverse the backbone, reducing traffic growth in the backbone.
    - Bell Labs modeling considers 20% to 60% of video and web/data content to be served by DCs a reasonable range and conducts traffic modeling based on 20% and 60% respectively.
    - Based on industry research [4], Bell Labs modeling uses a 10% to 20% yearly growth rate for the number of metros that have DCs deployed.
  - ¬ As cloud deployment becomes more mature and advanced, traffic exchanged between DCs will increase. For example, SDN (such as what is available from Alcatel-Lucent's Nuage Networks) solves the previous challenge of virtual machine movement and thus allows virtual resources to be more freely utilized among DCs. This will create more DC-interconnect traffic. Other contributors to DC-interconnect are backup and disaster recovery operations.
    - Bell Labs modeling assumes DC-interconnect traffic as a percentage of total traffic terminated by the DC to be 20% in 2012, 30% in 2013 and increasing linearly to 40% in 2017.
    - An 80/20 traffic distribution is applied to the DC-interconnect traffic. That is, 80% of DC-interconnect traffic remains within metro (between DCs located within the same metro) while 20% will go over the backbone (between DCs located within different metros). The same 80/20 rule is also applied to VoIP, video phone and file sharing which have a common meshed traffic pattern among the metros.
- Caching:
  - ¬ Initial year of study, caches were over-provisioned
    - VoD traffic assumed 100% cacheable; Internet traffic assumed 20% potentially cacheable
    - Cache size of 4 TB assumed over a five year period; priced at $3/GB
  - ¬ If the ability to cache Internet traffic increases, we expect metro traffic to decrease further.
- Impact of high demand:
  - ¬ More cloud demand will increase DC-interconnect traffic
  - ¬ More video demand will be handled by caches in metro

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