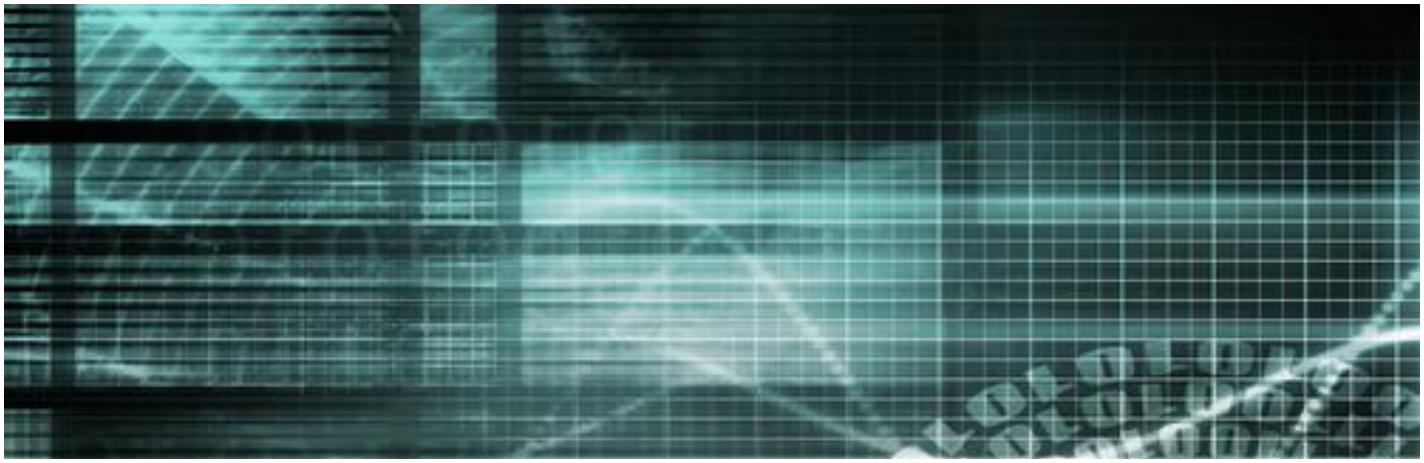

Executive Summary

The consumption of video content is creating a shift from use in the home to mobile devices. This is driving exponential increases in mobile bandwidth demand. This changing viewing habit, furthermore, is highly leveraged in that mobile video streams are unicast so that the shift of small amounts of residential broadcast TV traffic to mobile produces many hundreds or even thousands of new video streams on the mobile backhaul network. New mobile device types, applications, and larger screen sizes also are contributing to very high mobile broadband demand growth rates.

This exponential growth in mobile broadband demand has the potential to create a bottleneck at the fiber backhaul network. This paper estimates the combined impact of all bandwidth demand drivers as they affect mobile network backhaul capacity. The forecast is unique in that it predicts bandwidth requirements (bits per second) during the busy period while other published forecasts predict total mobile data usage (bytes per month).

ACG Research projects most likely peak period bandwidth requirements to increase at 52 percent compound annual growth rate (CAGR) through 2018. A sensitivity study predicts the probable CAGR range to be from 33 to 78 percent. The root causes of this bandwidth growth are separately analyzed and include video content increases, device market penetration, and increased on-net usage (reduced Wi-Fi offloading).

The forecast is used to model engineered backhaul capacity requirements for a 1,200 square kilometer metro area with a population of 2.5 million. This case study finds that the cell site backhaul bandwidth requirement will range between 0.4 Gbps and 2.5 Gbps in 2018. The odds favor the high end of this range. 10 Gbps Ethernet links in the access network and 10 Gbps rings will be needed to meet the demand requirement, support growth, and maximize load sharing. Agile network architectures will reduce the cost of supporting the expected rapid and volatile increases in mobile bandwidth demand.

KEY FINDINGS

ACG Research projects peak period bandwidth requirements to grow at a 52% CAGR through the next five years. Forecast details include:

- Entertainment apps account for 59% of smartphone 2018 bandwidth demand.
- Tablet and M2M device penetration increase at 20% CAGR.
- Mobile device media data rates increase at 30% annually.
- Smartphone and tablet peak period usage doubles within five years.
- 10 Gbps links to cell sites will be needed to support the expected bandwidth demand increases.

Introduction

The widespread move from viewing TV broadcast programs on home TVs to viewing content as unicast video streams on mobile devices is the most important driver of mobile bandwidth demand. This shift in content consumption has tremendous leverage because one broadcast channel of 2 Mbps bandwidth would be multiplied by millions of times more bandwidth if everyone were to switch to consuming video content over mobile devices.

New mobile device types and applications will put additional pressure on bandwidth demand. New devices include wearables such as Google Glass and Apple Watch, and Internet of Things or Machine-to-Machine (M2M) devices. New device size categories with larger screen sizes and movement to more bandwidth-intensive digital video formats also are driving bandwidth demand increases. For example, the recent iPhone 6 Plus introduction increased awareness of the "phablet," a device bigger than a smartphone but smaller than a tablet, which offer more screen pixels that translate into increased bandwidth requirements.

Network innovations will facilitate bandwidth increases by expanding the capacity of the access network, reducing service providers' costs, and creating new incentives for subscribers to stay on-net. For example, the benefits of LTE-Advanced include optimized heterogeneous networks with a mix of macro cells and small cells to improve coverage and reduce costs and use of multicarrier to support higher data rates. Policy-based pricing schemes enable service providers to offer custom-pricing plans that precisely match subscribers' needs and therefore motivate subscribers to stay on-net. Facebook usage, for example, may not be charged against the monthly data usage limit when a pricing strategy called zero-rate pricing is used.

This paper links users' bandwidth demand to service providers' engineered mobile network backhaul capacity. The forecast is unique in that it predicts mobile users' bandwidth (bits per second) during the busy period versus other published forecasts that predict total mobile data usage (bytes per month). Peak bandwidth projections are needed to plan network capacity; monthly data usage bears more directly on revenue projections.

Methodology

The projections are made on a per person basis and on a per connected device basis. Bandwidth per person is used to model the effect of increased subscriber penetration on the bandwidth requirement. Bandwidth per connected device is used to plan backhaul capacity where the number of each device type carried by the backhaul link is known. In each case bandwidth is defined to be the average bandwidth required over the busy period[1].

The forecast projections are built bottom up by projecting the bandwidth requirements for each application and mobile device type as shown in Figure 1.

[1] Average bandwidth over the busy period = bandwidth when application is active X percent of busy period when application is active. The percentage of activity during the busy period is called concurrency. For example, if Netflix is viewed for 30 minutes during a one-hour busy period then concurrency is 50 percent.

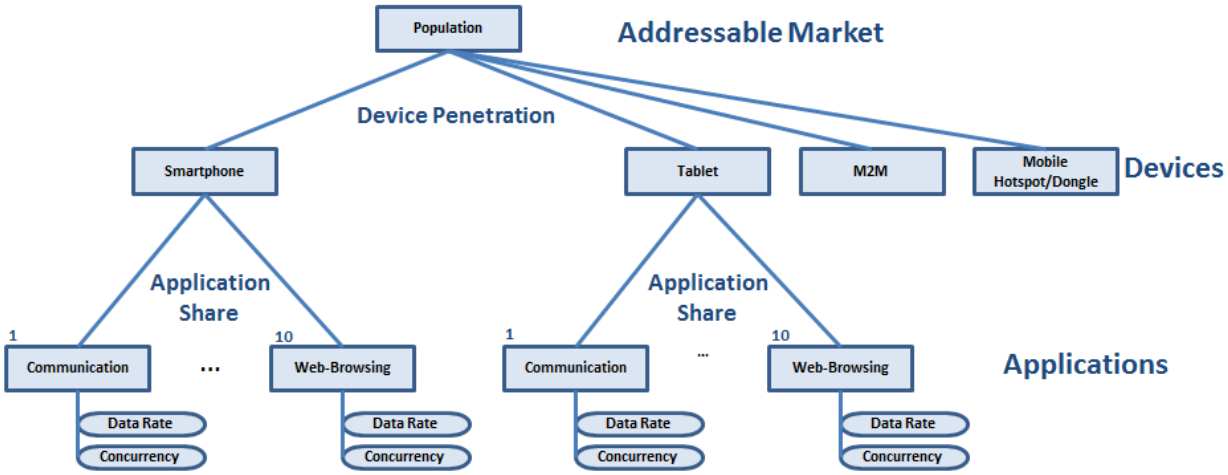

Figure 1 – Bottom-up Forecasting Method

Total bandwidth demand is estimated by determining the bandwidth contribution incurred from each application when active on each type of mobile device and then analyzing the device penetration[2] for the entire population[3]. The total per person demand projection is then made by combining the trends in the following factors:

1. Device penetration
2. Application-specific bandwidth requirements
3. Peak usage time (concurrency)
4. Wi-Fi offloading

Each of these factors is analyzed in the following sections.

Once the per person demand projection is made then it must be aggregated to requirements for engineered backhaul capacity. The factors used to aggregate per person requirements to an estimate of engineered backhaul capacity include:

1. Population covered by backhaul network segment
2. Per person bandwidth demand
3. Signaling traffic per unit of bandwidth demand
4. Spare capacity to protect against forecasting errors
5. Capacity for future growth (This is determined by the optimal capacity addition interval)

Aggregation of the backhaul capacity requirement is presented after the per person bandwidth demand projection.

[2] Penetration = Devices/Population.

[3] Most population measures are for the U.S. or North America markets.

Device Penetration Trends

Figure 2 shows projected trends in mobile device penetration.

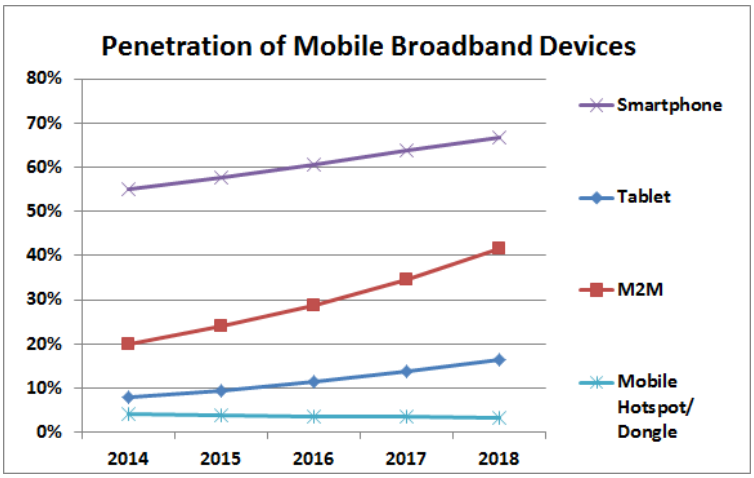

Figure 2 – Penetration of Mobile Broadband Devices

Though more than one-half of the U.S. population uses smartphones today, demand is expected to grow as many industries are incorporating smartphone interfaces into their product and service offerings. The penetration rate is projected to grow at five percent CAGR during the next five years. The IoT, which includes body telemetry, automated car systems, and home energy management applications, typically uses a mobile broadband communications link. The IoT devices are typically small, low cost, and send short packet bursts at infrequent time intervals; in other words, data payloads are small and concurrency is very low. M2M penetration[4] is expected to grow at 20 percent CAGR during the next five years.

Today, tablets are primarily connected via Wi-Fi. Recent initiatives, such as virtualization, Small Cells, and LTE multicast, to reduce mobile network costs should provide service providers with the cost relief to raise subscribers' monthly data usage limits. New policy-based pricing schemes also should increase subscribers' willingness to use tablets via mobile broadband services. Mobile-equipped tablet penetration is projected to grow at 20 percent CAGR during the next five years. A small number (4 percent penetration) of PCs, including laptops and notebooks, are connected to mobile broadband services via dongles (UCB mobile broadband transponders) or via mobile hotspots (mobile phone, tablet or other mobile device tethered to PCs via Wi-Fi.) Though PCs are losing market share to tablets worldwide, shipments are projected to maintain a 300 million run rate for a number of years[5]. This large installed base ensures that PCs will continue to contribute to mobile broadband bandwidth requirements.

[4] Penetration of M2M devices per person is number of M2M devices in covered area/population in covered area. This includes personal devices such as biometrics as well as M2M devices such as those used on the electric power grid.

[5] IDC March 4, 2014.

Application-Specific Bandwidth Requirements and Trends

Application-specific bandwidth requirements are grouped into 10 categories (See Figure 3 for the categories). The bandwidth required for each category when used on each device type is the percentage of the time that this application is used on each device type in the busy period. These factors are combined to estimate the share of each application category of total busy period bandwidth requirement as shown in Figure 3.

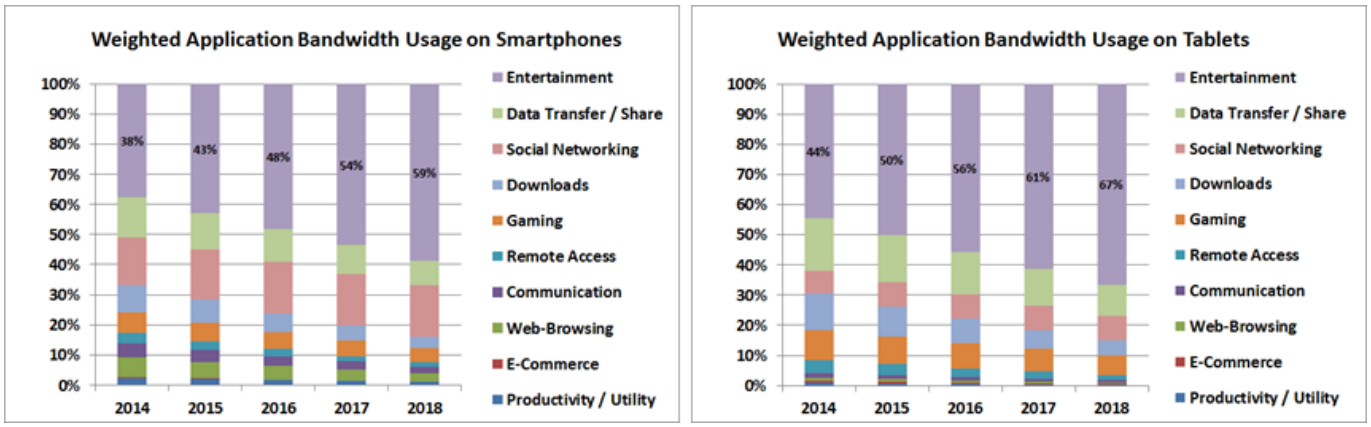

Figure 3 – Relative Bandwidth Shares for Smartphones and Tablets

The entertainment and social networking applications have the largest bandwidth shares for both devices. This is caused by a combination of their average minutes of use during the busy hour and their data rate when active.

Tablet leisure applications such as entertainment, social networking, and gaming consume a greater bandwidth share than they do for smartphones. This reflects the more generalized use of smartphones for work and leisure; tablet usage is heavily weighted to leisure activities.

How Video Streaming Drives Bandwidth Demand

The shift in viewing video content on TV sets to viewing it on mobile devices has a significant effect on mobile broadband bandwidth requirements. Several factors combine to increase mobile backhaul bandwidth capacity requirements.

- Subscribers' quality expectations are influenced by their experience of watching traditional TV. This will drive up the media rate.
- Entertainment applications have long session times. This increases the share of peak usage time (concurrency).
- The shift of a small quantity traditional TV viewing produces huge traffic volumes on the mobile backhaul network because the video streams are unicast. For example, top U.S. TV dramas are one-hour programs with prime-time viewership of about 18 million. If all viewers watched these

programs using mobile broadband then 18 million one-hour video streams would be created in the peak period[6].

Peak Usage Time Trends

Figure 4 shows the peak activity time for each mobile device type expressed as a percentage of the peak period (concurrency).

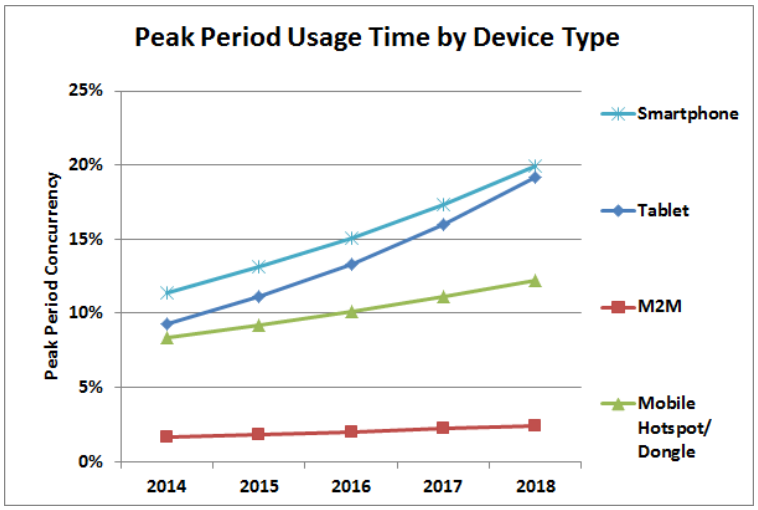

Figure 4 – Device Usage Trends during the Peak Period

Smartphone peak usage time increases by 75 percent in five years; tablet peak usage time more than doubles during the five-year study. The usage increases are caused by the large and growing number of available applications, the constant flow nature of video streaming traffic, and viewing of longer format videos, TV programs, and movies. Mobile tablet peak usage time increases more than smartphone usage because its larger screen is more conducive to long-format video. Mobile hotspot/dongle usage time increases by 50 percent in five years, which is caused by increased viewing of longer video formats. The growth is less than that of smartphones and tablets because PCs are already well established as the primary device used for video streaming. M2M devices by their very nature have very low active usage times. They send short bursts of data spaced between long periods of inactivity.

[6] LTE broadcast, which is emerging from the trial stage, now has the potential to ameliorate the expected surge of in video traffic. The role of the technology in service providers' business models has not yet been defined. For example, will it be used to limit traffic volumes or will be packaged as a value added broadcast service offering?

Wi-Fi Offload Impact on Mobile Bandwidth Requirements

Figure 5 shows the on-net share of total mobile device traffic. The remaining traffic is offloaded to Wi-Fi, which includes home Wi-Fi, public Wi-Fi, and business WLAN.

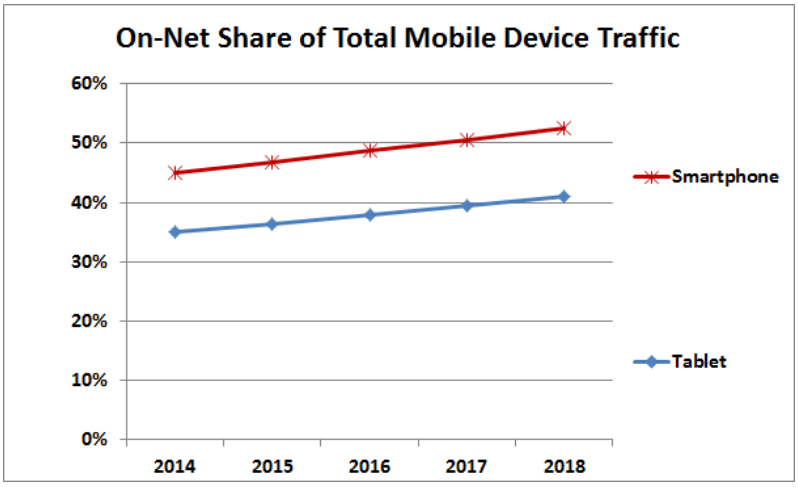

Figure 5 – Mobile Network Share of Total Traffic

Wi-Fi alternatives carry a larger share of mobile device traffic than mobile networks because fixed Internet access networks have monthly data usage limits that are significantly above current mobile usage limits.

Steady increases in the share of total traffic for mobile networks are projected because of initiatives that will lower mobile operators' unit costs and make higher data limits financially viable. Pricing plans are being introduced that will increase mobile subscribers' incentives to stay on-net. The initiatives include:

- Movement of content closer to users to reduce backhaul network costs.
- Introduction of LTE-Advanced to enable optimized heterogeneous networks with a mix of macro cells and low power nodes such as pico cells, femto cells, and new relay nodes. This will boost mobile network coverage and performance while decreasing unit costs[7]. The on-net share of total traffic will be increased by reducing the need to seek an alternative network and enable mobile operators to profitably raise their monthly usage limits.

[7] Real Wireless found an 82 percent TCO savings for small cells compared to macro cells when deployed to cover the same urban area. "Small Cell Business Cases: Urban and Enterprise" on behalf of the Small Cell Forum, February 24, 2014.

Mobile Bandwidth Requirements 2014–2018

Figure 6 summarizes peak period bandwidth requirement per person[8].

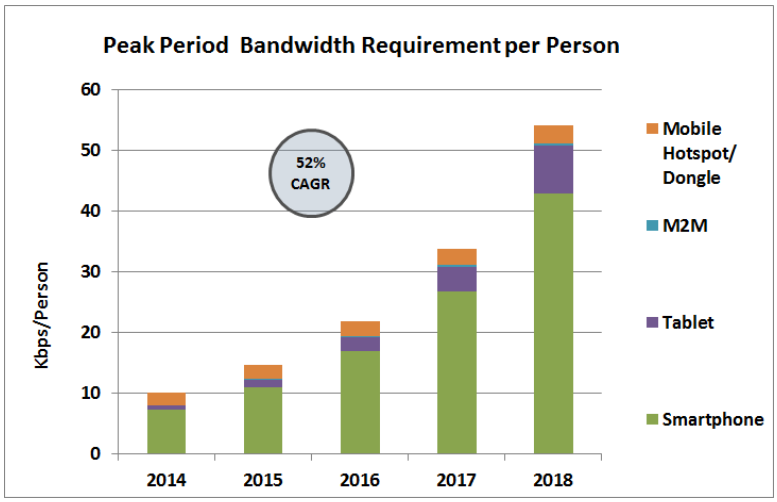

Figure 6 – Peak Period Bandwidth Requirement per Person

Peak period bandwidth requirements per person are projected to increase from 10.1 kbps per person in 2014 to 54.1 kbps per person in 2018, a 52 percent CAGR. Smartphone traffic accounts for the majority of the bandwidth requirement. Tablets also steadily increase their bandwidth share during these five years. Mobile hotspot/dongle devices have very low market penetration and as mature technology have limited future growth potential. M2M based devices have very strong growth potential but their traffic characteristics (short messages with long inter-arrival times) are not likely to make a significant contribution to demand requirements during peak period.

Smartphone and tablet increasing bandwidth requirements are caused by:

- Increasing use of video content: Video content is embedded across all application categories and its use is increasing. OTT video entertainment with its high bandwidth requirements, long session times, and continuous stream traffic characteristic accounts for a large share of the total bandwidth requirement. More OTT video content is becoming available with services such as HBO and CBS following the OTT streaming video model.
- Increases in device market penetration: Though 55 percent of the U.S. population currently has a smartphone the penetration rate is projected to continue increasing at five percent annually. Tablet penetration rates are projected to grow at 20 percent annually. This growth is fueled by adoption by new users and by substitution of tablets for laptops, notebooks, and other PCs.
- Increased on-net usage: Higher mobile broadband data monthly use caps and more attractive mobile service pricing plans will increase the incentives to stay on the mobile network versus using Wi-Fi services.

[8] Person means the total population within the covered area, including those who do not use mobile devices. Population statistics are as per the U.S. census.

Bandwidth Requirements per Average Connected Device

Figure 7 shows the average busy period bandwidth requirement per connected device.

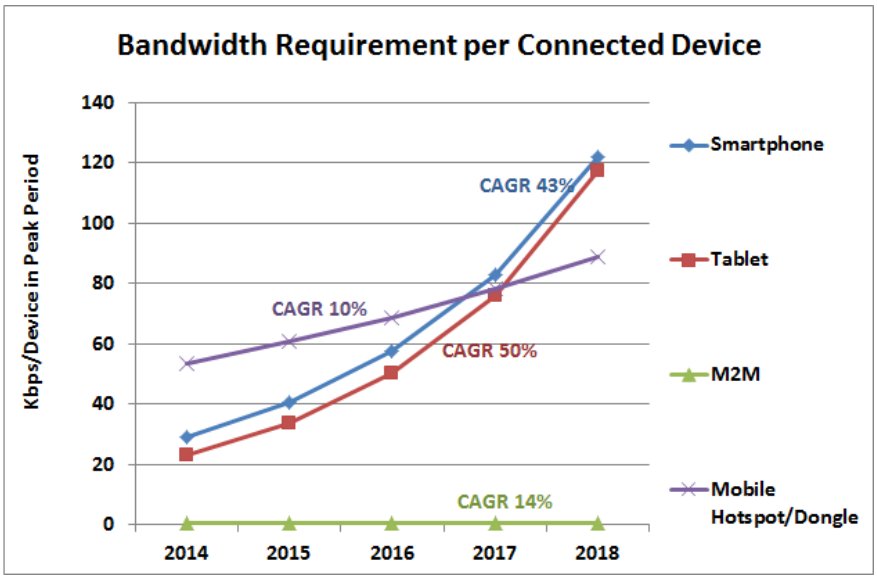

Figure 7 – Bandwidth Requirement per Connected Device

The total backhaul bandwidth requirement is calculated by multiplying the data rates shown in Figure 7 by the number of devices of each type expected to be connected to the backhaul network in each year. Smartphone and tablet per device bandwidth requirements are expected to exceed that of mobile hotspot/dongles by 2018 (Future smartphones and tablets will require more bandwidth than PCs used today).

Forecast Sensitivity

Bandwidth projections are subject to many uncertainties. Modeling assumptions that have the highest uncertainty levels include:

- Share of total device usage time by each application category.
- Increases in smartphone and tablet usage times during the busy period.
- Increases in tablet market penetration.
- The on-net usage trend for smartphones and tablets.

Three scenarios, optimistic, most likely (presented previously), and pessimistic, have been created by making assumptions for each of the modeling assumptions with highest uncertainty. Figure 8 shows the range of possible outcomes.

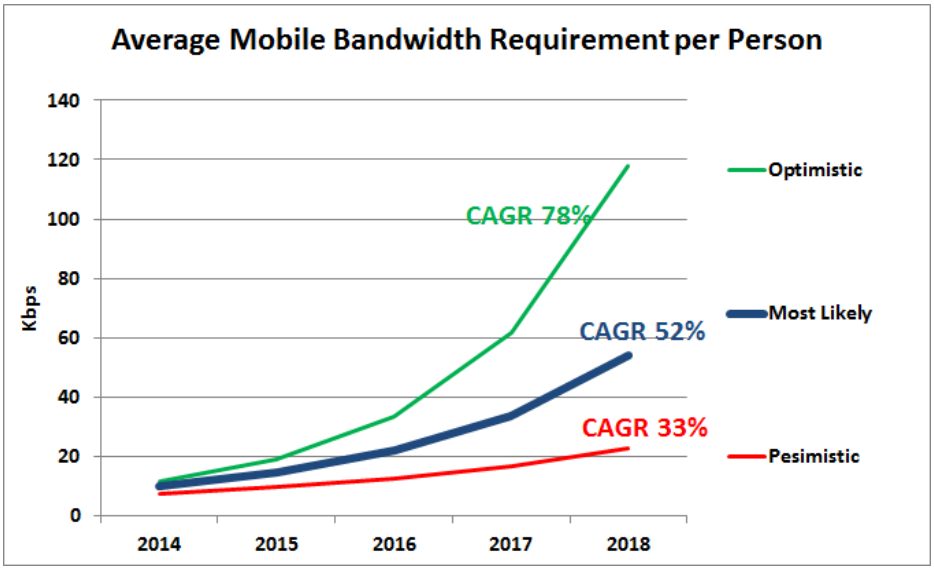

Figure 8 – Sensitivity of Bandwidth Requirement Projection

All three scenarios have robust double-digit CAGR. The greatest projection uncertainty is on the upside. The share of total device usage time and the closely related minutes of use during the busy hour of the entertainment category are the primary sources of forecast uncertainty. The leverage that this application category has is seen in reports of current network usage where 33 minutes per day of entertainment usage consumes 36 percent of the peak period bandwidth requirement.

Estimating Engineered Backhaul Bandwidth Capacity Requirements

The use of the mobile demand forecast in calculating engineered backhaul bandwidth capacity requirements is illustrated for a metro area characterized by:

- Metro area = 1,200 sq. km
- Cell site coverage = 2 sq. km
- Metro population = 2.5 million

This yields 600 cell sites in the metro area and 4,167 people per cell site. The engineered bandwidth capacity consists of:

- Payload: This is bandwidth requirement projection per person (Figure 8) multiplied by the population within the coverage area, for example, the cell site.
- Signaling traffic: This is control and administrative traffic used to set up/tear down sessions, provide administrative data to network operators, manage applications, and invoke security, privacy, quality of service, and service policies. Its volume is 25 percent of the payload traffic.
- Spare capacity: This is extra capacity to protect against forecasting errors. Current practice sets this amount at 35 percent of the projected payload.
- Future growth: There is an optimal capacity addition time interval that minimizes the present value of backhaul capacity additions. The optimal time interval is a function of the cost of capital, price inflation, and the ratio of fixed and variable capital expense. A two-year optimal capacity addition time interval is used in this analysis.

Figure 9 shows the engineered backhaul bandwidth capacity requirement for this example cell site that provides radio coverage for a population of 4,167.

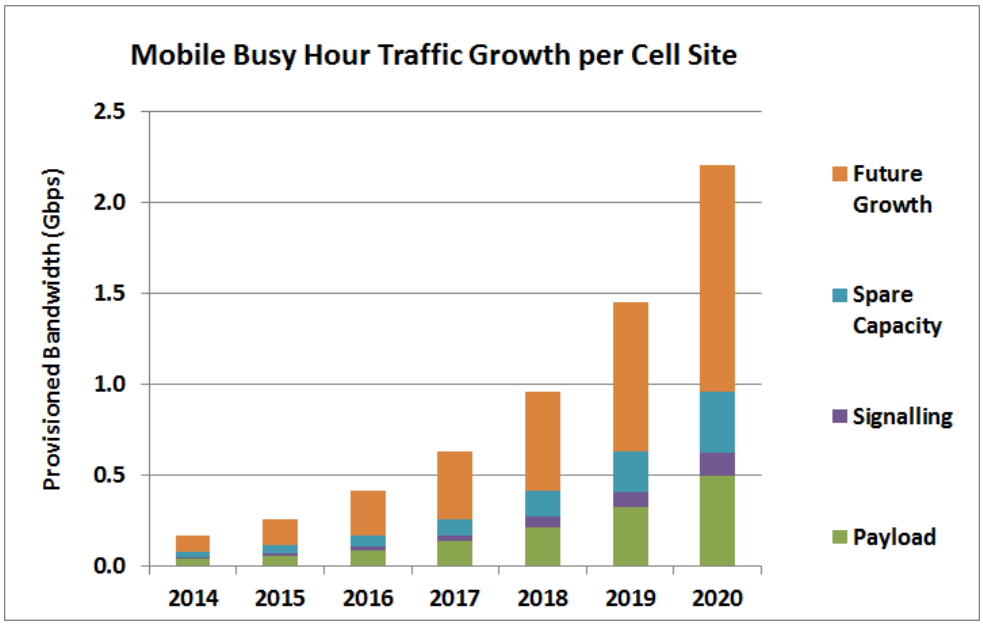

Figure 9 – Engineered Backhaul Bandwidth Capacity for Example Cell Site

The projection shows that the engineered bandwidth capacity requirement will soon reach the gigabit per second range. Today, 4G LTE macro cells currently support one Gbps; however, that capacity will be increased as small cells, multiple carriers, and other LTE-Advanced features are deployed. This creates a potential bottleneck at the fiber backhaul network. 10 Gbps Ethernet to the access network will be required to meet this projected bandwidth increase. Also, the introduction of 10 Gbps rings will provide easy support for growth and maximize load sharing.

The chart shows that a large quantity of bandwidth capacity is required to support two years of projected 52 percent CAGR growth. This capacity cushion is tied to current capacity addition processes. New agile backhaul network architectures provide the means to reduce spare and future growth capacity requirements.

Conclusion

Mobile broadband bandwidth demand, which is being driven by continuing increases in device penetration, hours of use, more applications, and the increased bandwidth capacity of mobile devices, is creating a potential bottleneck at the fiber backhaul network. A forecast of peak period mobile broadband demand projects backhaul network bandwidth capacity requirements.

The forecast projects:

- Peak period bandwidth requirements per person increasing from 10 kbps in 2014 to 54 kbps in 2018, a 52 percent CAGR.

- Smartphone usage accounts for the majority of the bandwidth demand with smaller contributions being made by tablets and mobile hotspots/dongles attached to PCs. M2M based devices are not projected to have a material impact on bandwidth demand.
- Cell site engineered backhaul capacity requirements will increase above the 1 Gbps level soon and10 Gbps backhaul links will be required.
- Agile network architectures will reduce the costs of meeting rapidly growing and volatile mobile network bandwidth requirements.

Primary demand drivers include:

- Increasing availability and consumption of OTT video content.
- Increases in mobile device market penetration.
- Increased on-net usage (decrease in the amount of Wi-Fi offloading).

Forecast sensitivity was tested against the input assumptions with the highest uncertainty, including the mix of application usage, device usage time during the busy period, mobile equipped tablet penetration, and the Wi-Fi offloading trend. Although the most likely five-year CAGR is 52 percent, there exists an upside CAGR potential as high as 78 percent and a downside CAGR potential of 33 percent. All expected growth rates are in the double-digit range with more upside potential growth than downside potential growth.

The sensitivity study finds that the example cell site backhaul requirement in 2018 will be in a range from 0.4 Gbps to 2.5 Gbps. The odds favor the most likely 1.0 Gbps projection being exceeded. Deployment of 10 Gbps backhaul links will lower investment risks.