# Streaming Video and Wireless: A Fundamental Mismatch?

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SMARTER NETWORKS. BETTER VIDEO.™

# Executive Summary

Revenue growth for the wireless industry in the coming decade will continue to be driven by rich media and video based applications enabled through a plethora of new devices that today include Smartphones, Netbooks, Tablets, eReaders and in the future will include a wide spectrum of specific use wirelessly connected consumer devices. How will the networks survive under this continuing tsunami of video based data?

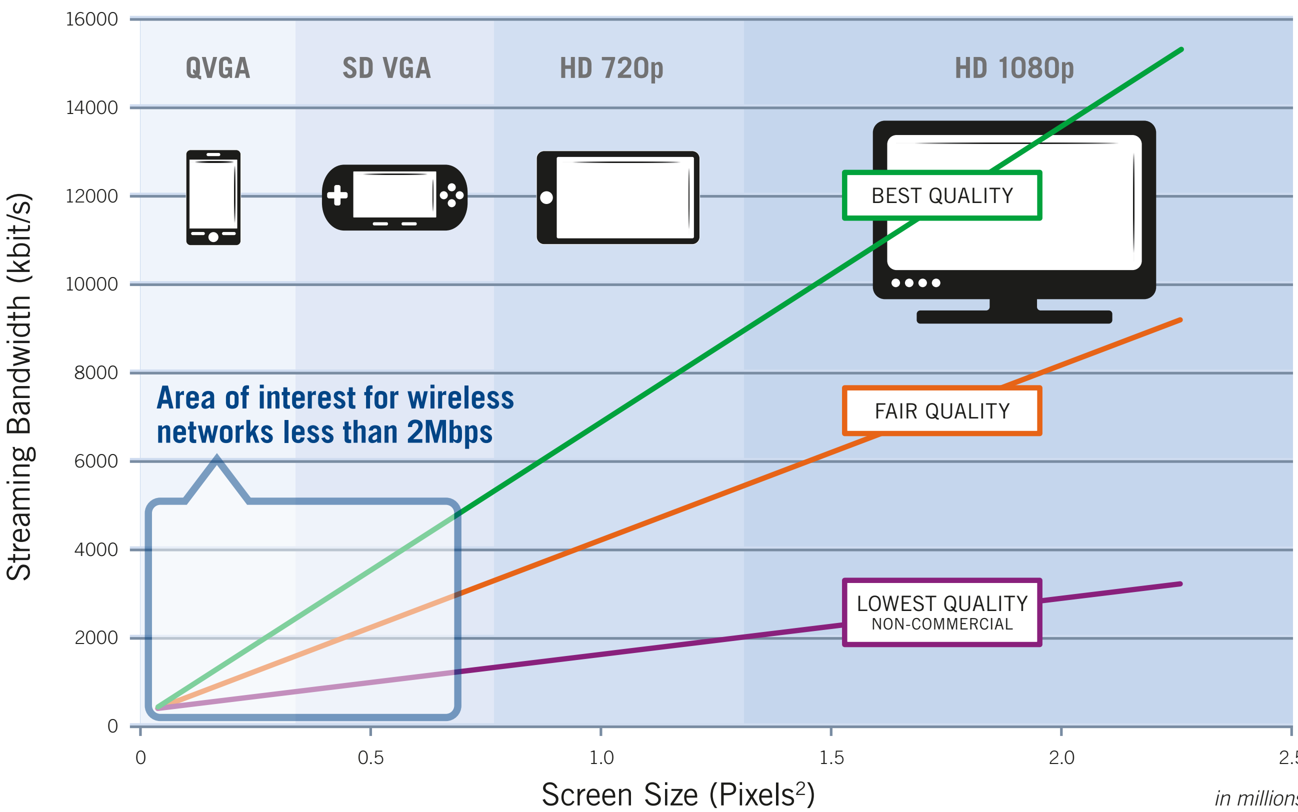
There is no question that video will drive innovation and revenue growth for wireless services in the future but with streaming video as the predominant distribution technology, these video applications lack the linear relationship between data consumption and revenue generation that has been critical to other profitable applications in the past; namely voice and SMS based services. Without question video applications will be a dominant part of our wireless future, but is streaming video a scalable and sustainable technology for the evolution of wireless applications and services?

Is there a fundamental mismatch between the amount of spectrum available on the planet and the demand that streaming video places on that spectrum? Are profoundly different video distribution technologies and consumption models required for mass adoption and profitable growth of video applications and services in the wireless industry? We think so.

This paper examines various solutions available to operators to handle the massive strain placed on their networks from video services and concludes that Content Prepositioning is an essential technology to augment 4G, Network Offload, Adaptive Streaming and QOS technologies.

# How Much Capacity Does Streaming Video Use?

The amount of capacity (the continuous bit rate) required for streaming video is determined by the quality of the video playback to be delivered and the size of the rendition – the screen size. A true HD stream to a large flat screen TV would require tens of megabits per second whereas a video stream to a small Smartphone screen with reasonable minimum playback quality can be as low as 300kbps. The graph below demonstrates the relationship between playback screen size and the bit rate required for delivery.



In contrast, voice services and SMS services use a fraction of the bandwidth consumed by streaming video. The table below compares the bandwidth consumption for various wireless applications averaged over a typical session duration.

**Table 1: Comparative Bandwidth Consumption**

| Service | Average Session Bit Rate | Typical Session Duration |
|---|---|---|
| **Voice** | ~12 kbps | ~5 minutes |
| **SMS** | ~10 kbps | ~1 minutes |
| **Web Page Download** | ~20 kbps | ~4 minutes |
| **Streaming Web Video** | ~300 kbps for Smartphone<br>~700 kbps for Netbook | ~2 minutes |
| **Streaming Premium Video** | ~700 kbps for Smartphone<br>~1500 kbps for Netbook | ~20 minutes |

Streaming video based TV shows over a 30 minute period consumes a total of 67.5MBytes. A typical 3 minute voice call will consume 270kBytes of available capacity. This means that a typical streaming mobile TV session will consume 250 times the capacity of a typical voice session. Does that TV show create 250 times the revenue?

A typical web video clip (for example a streaming CNN news clip or YouTube clip) consumes 4.5MBytes of available capacity which is 17 times the capacity consumption of a typical voice call - these web video sessions are 'over the top' and create no revenue for the operators beyond the basic data subscription revenue.

Content companies need to find ways to distribute their content over broadband wireless networks in a far more cost efficient way and using a technology that works with the network if they are to be sustainable in the long term. Streaming over wireless for content owners and operators alike is not a long term viable business proposition.

# How Much Spectrum is Available?

Analogies have been drawn comparing wireless spectrum to real estate. Without the land (spectrum) the most elegant building architecture (network/business plan) is worthless. It is easy then to understand why carriers spend billions of dollars to acquire scarce blocks of wireless spectrum in order to deploy their services. The winners and losers in spectrum holdings often determine the ultimate fate of the carrier's plans to compete in the market.

**Table 2 - USA Spectrum Holdings**[1]

| Top 100 Markets | Cellular | PCS | AWS | 700 | 2.5 GHz | Total (MHz) |
|---|---|---|---|---|---|---|
| **AT&T** | 25 | 34 | 12 | 20 | 0 | 91 |
| **Verizon** | 25 | 24 | 13 | 32 | 0 | 91 |
| **T-Mobile** | 0 | 27 | 27 | 0 | 0 | 54 |
| **Sprint** | 17 | 36 | 0 | 0 | 0 | 53 |
| **Cable Co's** | 0 | 0 | 19 | 0 | 0 | 19 |
| **Clearwire** | 0 | 0 | 0 | 0 | 150 | 150 |

The table shows a summary of the cellular spectrum holdings of the major US carriers. Equally important to the total extent of a carrier's total spectrum is how the spectrum will be deployed and reused. In today's 3G deployments, base station sectors (channels) are 5 MHz wide and voice and data traffic must be deployed and shared by users within these frequency slots. Carriers with more spectrum are better able to plan the spectral reuse within their networks in order to limit performance-sapping interference between network cells that operate on a common frequency. More spectrum also means that carriers are able to overlay or split cells in high use areas for additional network capacity.

It is also important to note that a carrier's spectrum holdings totals are summed across all national deployments. In a given market a carrier typically has a fraction of the indicated total spectrum available to deploy. For instance,

[1] Source: company data, Morgan Stanley Research

according to FCC filings,  in 70% of the markets AT&T only has enough spectrum for a single 5+5 MHz FDD channel allocation in the 700 MHz band.

To place this within the context of deploying data services, including video, a 5 MHz channel represents a certain aggregate bandwidth total. Industry marketing sources are fond of quoting peak throughput rates that in theory can be achieved under ideal conditions (stationary, idle channel, next to radio tower, etc.). A more meaningful real-world metric is the average spectral efficiency over the cell that is used to translate the channel size into the achievable shared throughput available to users.

The spectral efficiency of a 3G channel is quoted in terms of the throughput (bits-per-second, bps) that is achievable per Hz of spectrum. A reasonable currently achievable estimate for cell average is around 0.7 bps/Hz which allows a 5 MHz channel to deliver 5 MHz x 0.7 bps/Hz = 3.5 Mbps of aggregate downlink user throughput. This accounts for mobility, non-ideal radio conditions, protocol overhead, etc. Most deployed cellular architectures also take a portion of the channel and dedicate it to voice services.[2] Depending on network use patterns this voice/data split can be manipulated but may be estimated as taking 25% of the available channel. This further reduces the channel size for data services such as video to 75% x 3.5 Mbps = 2.6 Mbps average over the cell.

With the estimate of the total channel shared throughput in hand, the scenario of multiple streamed video sessions becomes starkly evident. Assuming a smart phone (e.g. iPhone) streaming at 700 kbps (QVGA resolution), fewer than four users completely consume the entire available sector capacity. From this perspective it is easy to understand why the advent of smart phones and streaming media is placing unsustainable pressure on the wireless networks while attempting to keep up with user traffic demands.

[2] Over time cell networks are evolving to so-called all-IP operation where voice-over-IP (VoIP) and packet data will all share common logical channels for improved efficiency. This transition will be gradual and tied to the next generation LTE deployments.

# Possible Solutions

**4G To The Rescue?**

The conventional wisdom concerning the traffic crunch on 3G networks is that things will get better as wireless capacity technology evolves to 4G OFDM.

Different standards bodies are pursuing separate competing technical tracks towards 4G. The 3GPP is developing long term evolution (LTE) which is the dominant standard adopted by most major wireless operators globally and will eventually be updated to LTE-Advanced starting with Release-10. The IEEE/WiMAX Forum is developing 802.16/WiMAX and expects to eventually replace the current version with an advanced version being developed by the IEEE in the 802.16m project. Both LTE and WiMAX are based on OFDM radio technology and both improve the efficiency of the radio channel allowing more capacity in the same amount of radio spectrum.

As larger carriers begin the infrastructure shift from 3G to 4G the trend in increasing peak rates will come in part because of more advanced OFDM based radios, but more fundamentally because of the larger blocks of spectrum specified for the channels in the new standards (e.g., up to 20 MHz instead of 5 MHz for 3G).

Ideal 4G peak rates tend to get talked about more than the average cell rate that applies across the entire cell in real-world mobility. Yet it is the average cell capacity that will determine the performance under load and consequently determine the user experience and also whether more than a handful of streaming video sessions can be supported at a time. The average cell capacity takes into account mobility and decreasing performance for users with lower radio path quality such as near the cell edges.

The critical metric is how much capacity can be carried by each Hertz of spectrum. Estimates of this metric vary but most conservative estimates[3] of real world average spectral efficiency are in the region of 1.3bits per second

[3] "IMT-Advanced: 4G Wireless Takes Shape in an Olympic Year", Moray Rumney, Agilent Measurement Journal, Issue-6, 2008.

per Hertz (1.3b/s/Hz). Certainly more spectrum as outlined in the prior section and a denser base station footprint (how often the spectrum is reused) will help add capacity but will not come close to solving the issue.

By 2015 with a 10 MHz LTE channel available to an operator, a typical cell capacity might be expected to be 13 Mbps; more than doubling the capacity available today with 3G. Unfortunately, the demand of video on the networks is 20 to 200 times greater than that of voice and with mass penetration of Smartphone devices and Netbooks to come there has to be more than just 4G in the operators' plans. Moreover, many carriers will not have the available spectrum to deploy wider channels in all markets. Spectrum will remain a scarce, expensive resource somewhat blunting the technological advantage of 4G.

Additionally, consideration must be given to the connectivity between the Base Stations and the network – the backhaul network. This too must scale to meet the demands of a video dominated application suite. Pico cell architectures in urban environments will rely on fiber networks and office Ethernet connectivity and coupled with Self Organizing Network technology will provide much greater capacity density in a given area (bps/Km2) – this will help.

So LTE will enable broader band OFDM devices, with denser self organized networks but that is not the whole answer. Much more will be required. New technologies, new consumption models and new billing models including data caps will be required to help manage through these challenges. Content companies and internet companies must embrace new technologies other than streaming for digital content distribution over wireless if they are to find compelling profitable applications in the future.

**Adaptive Video Compression To The Rescue?**

Adaptive video compression (AVC) is a now common technique used to try to mitigate the negative effects of all-too-frequent network congestion on video streaming delivery. There are many flavors in use of the technology but the basic concept is to adaptively reduce the streaming delivery rate whenever congestion is sensed by the receiving end. This results in trading reduced video playback quality against the worse alternative of starving the playback buffer (resulting in screen freezes).

Typically congestion is detected by monitoring the receiver playback buffer fill level and/or rate and the sending end is signaled to take action as the level falls below a critical threshold. The sending end responds by reducing the streaming rate, for example by switching to a previously encoded lower-rate content source. Of course if the congestion is persistent and AVC has already rolled back the picture quality to minimum, screen freeze will still happen. AVC does nothing to address the fundamental capacity problem of too many bandwidth hungry video streams in too small a wireless channel.

While AVC 'works' in that the dreaded screen freeze scenarios may be reduced in some scenarios, the significant negatives are fuzzy images and video artifacts that can intrude on the viewer's experience, devalue the content owners brand and add additional complexity and cost for the operator to support the substantially increased storage and compute power needed to pull off the behind the scenes tricks needed to switch video quality in mid-stream. In short, AVC is more of a band-aid to help disguise network congestion rather than a solution and even when operating at low or minimal quality, AVC streams still degrade the networks for all users.

**Core Network QoS?**

An alternative to flat best-effort content delivery is to install high performance gateway equipment at the carriers' network internet borders. The idea is to inspect each packet as it enters the network and make decisions as to the type of traffic and priority of the flow. Once sorted the packets are handled by the gateway according to priority which allows policies to be enforced during congestion to let high-priority traffic access the network ahead of low-priority traffic – providing differentiated quality of service (QoS).

In theory QoS is an effective tool in the carrier's arsenal to protect critical revenue services such as voice against video bandwidth heavyweights. There are however significant limitations to the approach.

Up front it should be recognized that QoS does not create any new capacity but simply acts as a traffic cop to let certain applications to have preferential access. This means that streaming video users still face exactly the same poor quality-of-experience issues during intervals when the network is congested. QoS in other words does nothing to help carriers promote new services relying on streaming video.

There is also a significant capital and operational cost that carriers must bear in order to establish core network QoS capability. The advanced mobile gateways that have the capacity to handle tens or even hundreds of thousands of concurrent QoS sessions are expensive and must provide additional computing capacity, availability and manageability. There is also a heavy operational cost to support the additional complexity needed to develop and maintain the policies required to implement QoS in order to avoid unintended consequences and consumer churn or sticky legal issues surrounding open-access.

Finally, there are a number of technical limitations that blunt the benefits of QoS. For example, QoS depends on the ability to sort packets according to which application they belong to. Unfortunately tech-savvy consumers can foil classification by encrypting their packets or misrepresenting the type of application which defeats the ability of gateways to sort the packets.

**Data Capacity Limits on Consumers and Network Offload Techniques?**

Operators are now beginning to issue capacity limits on their broadband consumers. By limiting the “all you can eat” plans, operators can now begin to manage the overall load placed on their networks. This initiative addresses well the issue of extreme users, those consumers who are overwhelming the network resources and degrading the communication platform for other users. However, operators are in the business of selling bandwidth to consumers, and much of the future revenue growth will be driven from rich media applications and the devices that enable these applications. Over-reaching limits on data caps could stifle these growth engines in the industry and must therefore be carefully applied. They are a useful tool to limit extreme users, but can only go so far.

An industry hot topic is the strategy of load-shedding data traffic to existing wired and fiber networks using either cellular indoor femto cell gateways connected to exiting broadband Internet cable/DSL connections or other radio networks such as WiFi with similar backhaul; a concept tagged as “offload” in the industry.

The managed offload strategy works to the extent that consumers can be coaxed to adopt service models and devices that “transparently” move traffic off the macro cellular network when alternatives exist. The challenge is that broadband mobile services are espoused as anywhere anytime. Not only when you happen to be in your home or office. Although offload will help it is only an incremental solution that can help address insufficient cellular capacity. It will not yield enough capacity relief to scale streaming video in wireless.

**Pre Positioning of Content?**

Streaming video is one mechanism to deliver video services in broadband networks, and to date is the predominant method. However, other, fundamentally different technologies and consumer behavior models must be considered and pursued in order for the industry to truly scale video based wireless applications. Streaming video is fundamentally mismatched with the spectrum available on Planet Earth.

Pre-positioning content in end devices offers an enormous potential for exciting new applications and business models, while at the same time guaranteeing very high quality and consistent playback – something worth paying for. Opanga's pre-positioning technology enables a fundamentally new world of network friendly video applications that can help save the operator's networks while providing a vastly superior consumer wireless video experience.

# Conclusions

1. **Streaming is not sustainable for scalable growth of video applications in wireless; not enough spectrum.**

Streaming video is enormously expensive for operators in terms of wireless resources consumed for the achieved revenue per user. A few smart phone users can exceed the entire channel capacity while streaming video and operators do not have sufficient spectrum or resources to build out sufficient new required infrastructure.

2. **4G is not enough. Other solutions are needed.**

Carriers gradual network upgrade from 3G to 4G will help but will not by itself solve the capacity crunch required to support mobile video applications. Increasing screen sizes and new user applications will continue to absorb and exceed all new capacity provisioned into the wireless networks.

3. **Data caps take us only so far and could backfire and stifle revenue growth if over-used.**

Carriers cannot simultaneously promote the vision of the open mobile internet while discouraging users to adopt new services and devices. Moreover, competition will force operators to adopt the most aggressive operator's policies in order to limit churn. Ultimately new solutions are needed to solve the bandwidth crunch.

4. **We need fundamentally more sustainable and scalable video distribution solutions for wireless and to enable new distribution solutions that improve network efficiency and consumer performance.**

What are required are fresh ways of approaching the problem of video content delivery that go beyond problematic streaming video. Encouraging consumers to adopt new models such as content pre-positioning will not only alleviate the bandwidth crunch but improve consumer experience and content owner brand protection at the same time – a win-win for service providers, studios and consumers.

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