Boundless Security Systems, Inc.
the communications bandwidth experts

WHITE PAPER:

Wireless ISPs' *Fair Usage* Bandwidth Policies and How Boundless Can Help the Public Safety Sector Avoid Violating Them for Mobile, Outdoor, and Temporary Digital Video Surveillance

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Summary

Public wireless networks are getting faster, even rivaling speeds from wired ISPs, but the amount of data one may transfer per day or month is *decreasing*. Most ISPs, both wired and wireless, are switching from "unlimited" broadband to "fair usage" broadband. This makes sense in today's world of increasing Internet usage, and provides a better online experience for everyone. The amount of data that one may transfer over time, rather than the speed of the wireless uplink, is now a limiting factor on the performance of outdoor digital video surveillance systems.

It is becoming increasingly popular in the public safety sector to connect a digital, IP-camera to a cellular modem and continuously stream live video at as high a data rate as possible to a distant monitoring and recording station. However, bandwidth on public wireless networks is limited. Wireless ISPs have Fair Use / Fair Usage / Acceptable Use / Acceptable Usage Policies in their service agreements to help ensure that a few customers do not use excessive bandwidth at the expense of quality of service for most customers. Users of IP cameras can consume their entire monthly bandwidth limit in a few days, or in a few hours a day. Users of excessive bandwidth can have their service restricted or terminated, and this is occurring *more often* as public wireless networks become faster since outdoor video surveillance using IP-cameras is increasing.

This White Paper gives examples of wireless ISPs' fair usage policies, and data rates for digital video surveillance. It explains how the ultra low bandwidth, ***Boundless Security System™,*** when used optimally, with its bandwidth-saving, video on demand, many different video streams per camera, and continuous, near-camera recording, can provide live and recorded, outdoor video surveillance via the Internet, with better quality recorded video than can be sent live, with many more cameras per square mile than otherwise possible, in remote locations with poor cellular service and in moving vehicles, and without violating ISPs' fair usage policies.

Update

Sprint discontinued its so-called "unlimited" data transfer policy in August 2008. The major US cellular carriers, VerizonWireless, AT&T, and Sprint, now have similar cellular data policies. The price for the first 5 GB/month of traffic is now about $60/month, with additional data being

priced at 5c/MB, although Sprint provides for a base transfer of up to 10 GB/month at a higher price, while others may discontinue service when monthly traffic exceeds 5 GB/month. To put this into perspective, using a conventional IP camera and cellular data modem with continuous video surveillance traffic of 256 Kbps would transfer 80 GB/month, which, if the traffic were allowed to continue to the detriment of other nearby users, would cost $3,810/month. However, when used optimally, Boundless' ultra low bandwidth equipment using video-on-demand and near-camera recording enables users to avoid such large communications costs, and to operate more cameras in a neighborhood simultaneously while recording better quality video than can be sent live.

Introduction

This White Paper focuses on the use of public wireless IP-data networks, particularly cellular networks, for remote access via the Internet to outdoor digital video surveillance systems. This paper focuses on uploads from these mobile and stationary, video cameras and video camera systems in the field, rather than on video surveillance downloads to handheld devices. It is not concerned with consumer applications such as web cameras, VoIP, downloading motion pictures, or peer-to-peer file sharing.

It is becoming increasingly popular in the public safety sector to connect a digital, IP-camera to a cellular modem in the field, and continuously stream live video at as high a data rate and image quality as possible to a central monitoring and recording station. Cellular ISPs' marketing statements that the latest generation, cellular data networks are becoming as fast, or even faster than, wired Internet connections have encouraged many video surveillance users, especially government agencies, to send large amounts of video surveillance over public wireless networks.

However, bandwidth on public wireless networks is limited – much more so than for landline communications. To keep equipment costs manageable with wired networks, Internet access in each neighborhood is *contended*, or shared with other users. Wired networks are relatively simple and typically share a certain amount of bandwidth among as many as 50 customer accounts. Cellular networks are far more complex since a cellular modem is a mobile radio transmitter/receiver, and radio waves are hard to control. With cellular networks, the amount of data bandwidth available to users, the amount of contention, and sharing of bandwidth can't be controlled well since there's a limited number of cellular frequencies, limited backhaul between towers, and mobile users constantly move in and out of cells, with signal levels and data rates that constantly vary with the distance from the nearest tower and affect the network's efficiency.

Wireless Internet data access is intended for burst use, such as downloading pages from a web site, not high, sustained traffic from uploading, or streaming, video from web cameras or IP cameras, or downloading full length movies. Many Cellular ISPs have a Fair Use / Fair Usage / Acceptable Use / Acceptable Usage Policy in their terms and conditions of service that aims to ensure that a few customers do not use an excessive amount of bandwidth at the expense of quality of service for most customers. Users of IP cameras can consume their entire monthly bandwidth limit in a few days a month, or a few hours a day. Customers who use too much bandwidth can have their service restricted or terminated. Internet Service Providers that use satellite communications have a similar clause except that the bandwidth limits are monitored

much more closely, the limits are lower and there's an explicit cost per megabyte of traffic that exceeds a specified monthly amount.

Some Cellular ISPs have looked the other way, allowing very large customers, such as state and federal government, to violate the ISP's Fair Usage Policy, at the expense of the quality of service for the ISP's other customers. *Yet, even when looking the other way, even after installing additional capacity at particular cell phone towers, and even after improving the backhaul communications network from towers to the Internet, the wireless capacity often simply has not been enough to enable the public safety sector to conduct outdoor, temporary, digital video surveillance everywhere they want it, with the desired image quality, and with the desired number of cameras per square mile.*

This White Paper gives examples of Wireless ISPs' fair usage policies, and data rates for digital video surveillance using the two most popular forms of compression. It explains how the ultra low bandwidth, ***Boundless Security System™,*** when used optimally, with its bandwidth-saving video on demand, many different digital video streams per camera, and continuous near-camera recording, can enable the public safety sector to conduct outdoor digital video surveillance via the Internet with many cameras per square mile, with better recorded video than can be sent live, even in remote areas, and without violating Wireless ISPs' fair usage bandwidth policies.

Examples of Wireless ISPs' Fair Usage / Fair Use Policies

A few examples of data transfer limits using IP-data plans are:

Cellular

USA: VerizonWireless, AT&T, Sprint – 5 GB/month

UK: Orange – 1 GB/day and 3 GB/month

Satellite

USA: WildBlue – 2.3, 3.0 or 5.0 GB/month, depending on service plan

World: Inmarsat – various plans with various amounts of traffic per month, generally in the range of a few 100 MB/month to a few GB/month, with explicit charges for each MB of traffic beyond the amount specified in the plan

NOTE: This list is not intended to be exhaustive. Check with carriers for current plans. This information is believed to be correct as of July 2009, but Boundless is not responsible for any errors or omissions. Also see Disclaimer at the end of this document.

Data Rates for Video Surveillance

To put these data transfer limits into perspective, consider the following data rates, which include all overheads and protocols (adding a total of about 10% to the amount of data transferred), not

just payload data, and which, if made continuously, regardless of content, would transfer the following amounts of data:

10 Kbps = 100 MB/day = 3.3 GB/month

16 Kbps = 160 MB/day = 5.3 GB/month = *VerizonWireless', At&T's and Sprint's monthly limit*

64 Kbps = 640 MB/day = 21 GB/month

100 Kbps = 1,000 MB/day = 33 GB/month = *Orange's daily limit, and 11 x Orange's monthly limit*

128 Kbps = 1,280 MB/day = 42 GB/month

256 Kbps = 2,560 MB/day = 84 GB/month

1 Mbps = 11,000 MB/day = 330 GB/month

To put these data rates into perspective for video surveillance, which has much less motion and requires less data than entertainment video, except for mobile cameras, consider the following video resolutions, types of compression and amounts of compression for video surveillance.

Even low resolution video of 160x120 at the low frame rate of 1 fps, when run continuously at the extremely low data rate of 8 Kbps, consumes a large amount of bandwidth over time, 5 GB/month. The amount of data that one may transfer per month, which is the subject of ISPs' Fair Usage Policies, rather than the instantaneous speed of the wireless uplink, is now a limiting factor on the performance of conventional, outdoor, IP-based, digital video surveillance systems. The ultra low bandwidth, Boundless Security System™, used optimally, is compatible with these limits and provides better performance than conventional, IP-based systems.

JPEG Compression

JPEG compresses each video frame in isolation. Data rate is directly proportional to resolution and frame rate. There is no inherent mechanism to capture frame rate or time period between frames. M-JPEG offers only a tiny improvement and lacks standardization, allowing one set of compression parameters to be shared among multiple image frames in a single file, but still compressing each frame in isolation and not including any temporal information.

Brightness information is handled with higher resolution than color information due to the fact that the eye is more sensitive to brightness than color. In other words, an image with 640x480 resolution is generally compressed with 640x480 resolution of the brightness information but only 320x240 resolution of the color information. JPEG, unlike MPEG-4, allows three choices for the resolution with which color information is compressed. The figures below assume color information has ¼ the resolution of brightness information, the same as MPEG-4, in which case the number of raw bytes per frame is 1.5 x number of 8-bit pixels, instead of 3 x.

JPEG compression is available on most digital IP-cameras, including the Sony SNC-RZ30N IP-PTZ camera that is popular with law enforcement agencies in the USA. This camera has an analog composite video output that can be connected to Boundless' ***Multi-Stream Video Server*** so Boundless can provide live video from the camera via the Internet at far lower bandwidth than the camera can provide, with better quality recorded video than can be sent live. Boundless' ***Control Panel*** viewing client software also supports IP-based PTZ, used by this camera.

MPEG-4 Compression

Video frames are compressed relative to one another, starting from a periodic key frame. There is an inherent mechanism to capture frame rate or time period between frames. Motion estimation, based on pixel changes, not on the motion of objects, may or may not be used to provide additional compression. Data rate is directly proportional to resolution and is often seen in surveillance applications to be 2/3 to frame rate. In other words, the data rate for 15 fps is only about 2x, not 3x, the data rate for 5 fps, for low to medium subject motion, for a stationary camera that is not panning, tilting or zooming. At low frame rates, the frequency of key frames is significant. *The calculations below assume that bandwidth needed for key frames is insignificant; this is reasonably accurate for frame rates that are many times the rate of key frames, e.g., for frame rates of 5 fps and higher, and with only one key frame every 5 seconds.*

Brightness information is handled with higher resolution than color information due to the fact that the eye is more sensitive to brightness than color. In other words, an image with 640x480 resolution is generally compressed with 640x480 resolution of the brightness information but only 320x240 resolution of the color information.

The amount of compression can be varied dynamically to give relatively constant data rates (constant bit rate) regardless of the amount of motion, or to allow data rates to be much lower during periods of low motion but to spike when there's a burst of motion (variable data rate). Boundless uses a number of techniques together to control data rates dynamically, resulting in data rates that do not spike excessively when a burst of motion occurs, and that often enable much lower data rates than shown in the table below to occur. *Except as noted, the data rates given below should not be taken as the data rates that Boundless produces (Boundless' data rates are generally lower).*

To provide a fair comparison, the amount of compression used in the table below for MPEG-4 gives image quality comparable to video compressed with JPEG.

Table of Compressed Video Data Rates

Video Specs	JPEG	MPEG-4	Comments
Note: These figures are only for video, not including transmission overheads and reverse traffic for packet confirmation, which, in total, add about 15% to the total size of transfers as measured by ISPs.	Using 10:1 compression and 1.5 bytes / raw pixel. Much higher compression is often used at the expense of image quality. Note: This calculation uses 1.5 bytes / pixel instead of 3, so many would call this 20:1 compression.	Using 30:1 compression and 1.5 bytes / raw pixel Note: This calculation uses 1.5 bytes / pixel instead of 3, so many would call this 60:1 compression.	MPEG-4 can give 3+ x better compression than JPEG for comparable image quality for moderate amounts of motion for a stationary camera. The improvement is much more for low motion, except when frame rates are very low because of MPEG-4's key frames.
Standard Definition Video resolution or less			
160x120 @ 1 fps (19,200 pixels = 28,800 bytes per raw frame at 1.5 bytes / pixel)	23,040 bps = 7 GB / month (gigabytes per month)	7,680 bps = 2.25 GB / month [4.5 GB / month] NOTE: Actual figure for 1 fps is 2+ x, shown in [ ]. due to need to have at least 1 key frame / 5 sec.	Continuous lowest resolution and frame rate JPEG exceeds all Fair Usage limits given above. The same specification MPEG-4 is compatible with some of the Fair Usage limits given above.
160x120 @ 5 fps	115,200 bps = 35 GB / month	38,400 bps = 11 GB / month	
160x120 @ 15 fps	345,600 bps = 105 GB / month	76,800 bps = 22 GB / month	Boundless often uses 32 Kbps for this live video
320x240 @ 1 fps (76,800 pixels = 115,200 bytes per raw frame at 1.5 bytes / pixel)	92,160 bps = 28 GB / month	30,720 bps = 9 GB / month [18 GB / month] NOTE: Actual figure for 1 fps is 2+ x, shown in [ ], due to need to have at least 1 key frame / 5 sec.	
320x240 @ 5 fps	460,800 bps = 112 GB / month	153,600 bps = 45 GB / month	
320x240 @ 15 fps	1,382,400 bps = 336 GB / month	307,200 bps = 90 GB / month	Boundless often uses 128 Kbps for this live video

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Video Specs	JPEG	MPEG-4	Comments
640x480 @ 1 fps (307,200 pixels = 460,800 bytes per raw frame at 1.5 bytes / pixel)	368,640 bps = 110 GB / month	122,880 bps = 36 GB / month [72 GB / month] NOTE: Actual figure for 1 fps is 2+ x, shown in [ ], due to need to have at least 1 key frame / 5 sec.	
640x480 @ 5 fps	1,843,200 bps = 550 GB / month	614,400 bps = 180 GB / month	
640x480 @ 15 fps	5,529,600 bps = 1,650 GB / month	1,228,800 bps = 360 GB / month	
High Definition Video			
1280x960 @ 1 fps (1,228,800 pixels = 1,843,200 bytes per raw frame at 1.5 bytes / pixel)	1,474,560 bps = 440 GB / month	491,520 bps = 144 GB / month [288 GB / month] NOTE: Actual figure for 1 fps is 2+ x, shown in [ ], due to need to have at least 1 key frame / 5 sec.	
1280x960 @ 5 fps	7,372,800 bps = 2,200 GB / month	2,457,600 bps = 720 GB / month	
1280x960 @ 15 fps	22,118,400 bps = 6,600 GB / month	4,915,200 bps = 1,420 GB / month	

Using Boundless to Improve Performance, Minimize Bandwidth and Help Avoid Violating Wireless ISPs' Fair Usage Policies

> **NOTE:** The ***Boundless Security System™,*** when used optimally and when a wireless link does not have any other sources of traffic, can help users improve performance while minimizing their uplink bandwidth usage and thus helping them avoid violating their Wireless ISP's Fair Usage Bandwidth Policy. However, Boundless Security Systems, Inc., cannot and does not guarantee or make any assurances of any kind that users will not violate their ISP's Fair Usage Policy by using the ***Boundless Security System™***. In fact, users can violate their ISP's Fair Usage Policy if they do not use the ***Boundless Security System™*** in an optimum manner that maximally limits bandwidth usage.

ISPs' Fair Usage Policies limit total bandwidth, which is the sum of both uplink and downlink bandwidth. Boundless' ***Multi-Stream Video Server,*** the video acquisition portion of the ***Boundless Security System™,*** uses TCP/IP and only requires about 5% of the downlink bandwidth as it does for uplink bandwidth, thus the downlink contribution is negligible.

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The highest speeds of wireless networks should be used sparingly, in short bursts, not continuously. The ***Boundless Security System***™ takes full advantages of this high burst capability and can help users improve performance and minimize their uplink bandwidth if they:

1) only remotely view live video on occasion by using its video on demand capability that produces negligible network traffic except when the user chooses to remotely view live or recorded video using Boundless' ***Control Panel*** live and recorded viewing, and searching, client software, or using Boundless' ***Broadcast Control Panel*** live and recorded viewing, searching and transcoding, client software

2) use Boundless' default, hybrid method of MPEG-4 video compression that combines the best features of both constant bit rate encoding, to avoid saturating bandwidth-limited communications links during spikes of activity, and also variable bit rate encoding, to reduce the amount of data produced when images are static; in many cases, the data rate produced by Boundless' video encoder for a given video stream is only 25% to 35% of the specified "nominal not to exceed" data rate, but can exceed this value during bursts of activity

3) minimize the number of cameras viewed remotely simultaneously from a given ***Multi-Stream Video Server***

4) remotely view as low a frame rate live video stream as possible, and then manually switch to viewing recorded video with higher resolution, frame rate and/or clarity

5) remotely view as low a resolution live video stream as possible, and then manually switch to viewing recorded video with higher resolution, frame rate and/or clarity

6) remotely view video streams that have been optimized and configured for live viewing not recorded viewing

7) remotely view video streams that have been optimized and configured for use with stationary cameras not moving cameras

8) configure Boundless' ***Multi-Stream Video Server***, on a camera by camera basis, for wide-screen format video instead of full-screen format video to reduce the number of top and bottom lines of pixels to avoid useless sky and foreground information

9) remotely review motion search results using the lowest resolution, frame rate and clarity recorded video stream available to determine whether or not a particular point in time merits further investigation, then click over to a higher quality recorded video stream for further investigation; this two-stage process also has the benefit of speeding up remote access to recorded video, and all motion searching is done by a search engine inside the ***Multi-Stream Video Server*** so no video has to travel over the wireless connection to be searched; hours of recorded video can be searched in seconds

10) use Boundless' ***Broadcast Control Panel***, under control of a dispatcher, to select a live or recorded video stream from a ***Multi-Stream Video Server***, and make it available to many users simultaneously in a Windows Media Player format from a central server without placing any additional load on the wireless uplink from the ***Multi-Stream Video Server***

11) use Boundless' optional ***VPN & Tunneling Broadcast Server***, and optional tunneling in the ***Multi-Stream Video Server***, when multiple users want to view the same video stream at the same time using Boundless' ***Control Panel,*** where only a single load on the ***Multi-Stream***

Video Server wireless uplink is required when multiple users view the same video stream simultaneously

12) use Boundless' optional ***VPN & Tunneling Broadcast Server***, optional tunneling in the ***Multi-Stream Video Server***, and optional ***Live Alerts***, to remotely display a recorded video clip from a few seconds earlier that shows the remotely programmable, zoned motion event that triggered the alert, and then manually switch to viewing live video, where only a single load on the ***Multi-Stream Video Server*** wireless uplink is required even when multiple users view the same video stream simultaneously, and where there's negligible load on the wireless uplink while live video is not being viewed and the system is waiting for a motion event to occur

13) do not use the ability of Boundless' ***Multi-Stream Video Server*** to store a video stream externally, and do not use its ability to simultaneously store the same video stream redundantly, i.e., both internally and externally

Conclusion

Public wireless networks are getting faster, even rivaling speeds from wired ISPs, but the amount of data one may transfer per day or month is *decreasing*. Most ISPs, both wired and wireless, are switching from "unlimited" broadband to "fair usage" broadband. This makes sense in today's world of increasing Internet usage, and provides a better online experience for everyone. The amount of data that one may transfer over time, rather than the speed of the wireless uplink, is now a limiting factor on the performance of outdoor digital video surveillance systems.

It is becoming increasingly popular in the public safety sector to connect a digital, IP-camera to a cellular modem, and continuously stream live video at a high data rate to a distant monitoring and recording station. However, bandwidth on public wireless networks is limited. Wireless ISPs have Fair Use / Fair Usage / Acceptable Use / Acceptable Usage Policies in their service agreements to help ensure that a few customers do not use excessive bandwidth at the expense of quality of service for most customers. Users of IP cameras can consume their entire monthly bandwidth in a few days a month, or a few hours a day. Users of excessive bandwidth can have their service restricted or terminated, and this is occurring *more often* as public wireless networks become faster, since outdoor digital video surveillance using IP-cameras is increasing.

The ultra low bandwidth, ***Boundless Security System™,*** with its bandwidth-saving, video on demand, many different video streams per camera, and continuous, near-camera recording, when used optimally, can provide live and recorded, outdoor video surveillance via the Internet, with many more cameras per square mile than otherwise possible, with better quality recorded video than can be sent live, in remote locations with poor cellular service and from moving vehicles, and without users' violating their ISPs' fair usage bandwidth policies.

References

Malaysia

Mavis (**cellular** – CDMA)

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http://www.maxis.com.my/personal/broadband/termncon.asp

UK

FSN (wired – ADSL):

https://www.ukfsn.org/home/internet/adsl/maxallowance.html

Karoo (wired):

http://www.karoo.co.uk/broadband/fair-usage_policy.asp

Namesco (wired – ADSL) – "unlimited" but considers 60 GB/month as excessive:

http://www.names.co.uk/usage-policy.html

Orange (**cellular** – GPRS):

http://www.orange.co.uk/terms/7094.htm

Orpheus Internet (wired – ADSL):

http://www.orpheusinternet.co.uk/products/fairuse.html

T-Mobile UK (**cellular** – GPRS):

http://www.t-mobile.co.uk/services/uk/fairuse/

Virgin Media (wired):

http://www.virgin.net/allyours/faqs/traffic_faqs.html

http://www.virgin.net/terms/broadband_tc.html

USA

VerizonWireless data plans (**cellular** – CDMA):

http://b2b.vzw.com/broadband/bba_terms.html

World

SATLink (VSAT satellite):

http://www.satlink.it/?action=pg_static&page=fup

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Author and Company Background

Boundless Security Systems, Inc., www.BoundlessSecurity.com, is a privately held, woman-owned, small business. Boundless specializes in outdoor digital video surveillance, where communications bandwidth is precious. Boundless was formed in response to the 9-11 terrorist attacks. Steve Morton, Boundless' CEO and CTO, used his telecommunications background from ITT and MIT to assess the ability of public wireless data networks to carry digital video surveillance for outdoor, mobile and temporary applications. He concluded that conventional "low bandwidth" surveillance video, that requires several million bits per second -- albeit only a small fraction of the data rate of raw standard definition digital video, was still 10 to 100 times faster than could reasonably be carried by those networks, and that those networks were intended only for short bursts of data, not massive continuous video streams. He then architected and developed the ultra low bandwidth, ***Boundless Security System***™ that requires only a few percent of the bandwidth of others' so-called "low bandwidth" systems.

Steve Morton is a serial entrepreneur and has a BSEE '71 and MSEE '72 from MIT. He has 35 years' experience developing computer systems, 20 years' experience in digital imaging, and 15 years' experience developing mission-critical communications systems. He has been awarded more than 20 patents and has a special interest in digital imaging for public safety.

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