WHITE PAPER

Wireless Mobile Video Transfer and Storage by the Numbers:

An Examination of the Current State of In-Car Video Wireless Technology for Law Enforcement

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Part 1: Wireless Mobile Video

It's hot, everyone wants it, it makes in-car video simple and easy, and everyone knows the benefits and advantages. But it's also complex, demanding, poorly understood, poorly explained and expensive. And that's the problem…

In this series of articles, we will attempt to address some of the things that a department should consider when investigating any wireless system or technology, to guarantee that expectations are reasonable, affordable and practical, given the current state of wireless video transmission.

At Apollo Video Technology, like others in the mobile video industry, we recognize and embrace wireless and remote video technology. When properly designed and implemented it is a very useful tool that can provide many options for remote viewing, control and storage. It can carry data, voice, video and audio, and make it feasible to send and receive information to and from remote locations.

With wireless networking, we can download video clips remotely, watch events as they happen, transmit data, monitor multiple patrol cars at the same time, automate notification of certain events from the car to the dispatcher… even turn things around and give a department remote control of some of the vehicles functions.

For instance, a dispatcher can connect to a patrol car and see what an officer is dealing with as it is actually happening… and even remotely do things like turn on a cars siren or lights, or disable the ignition on a stolen cruiser.

Wireless video transfer is the "Holy Grail" for in-car video systems, but it may prove to be as elusive as the cup itself.

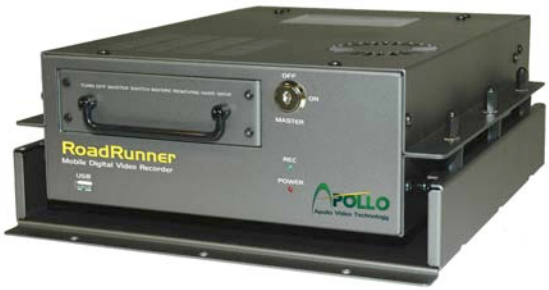
Because the demand for these benefits is so strong, there are many instances of wireless technology being vastly oversold; of promises being made that sometimes stretch the limits of practicality far beyond the breaking point.

Here's another way to look at it: A budget that supports 10 cars with wireless transfer might purchase enough systems for 30 cars or more with removable hard drives.

In the rush to accept new technology for it's perceived benefits, there can sometimes be a tendency to push the boundaries until what is possible may not also be practical; witness the *$1.6 Million Mobile Command Vehicle that had to be taken out of service in Washington DC, "mechanically and structurally unsound for service," apparently burdened with too much equipment.* (http://www.policeone.com/police-products/vehicles/articles/94391/)

Of course, there are many different methods of recording and storing video. It is not so much a matter of what is right or wrong, as it is a matter of what will honestly meet departmental requirements, and do so in the most efficient and cost effective manner. The solution that is right for one department can easily be wrong for another, based on available budget, familiarity with technology, size of the staff, and many other factors.

In an interesting twist, it appears that in many cases a wireless network is much more practical for a small department than it is for a large department, because of the incredibly massive amount of data that video recording can generate.



Apollo Video's RoadRunner Mobile Digital Video Recorder

Generally speaking, a new product or system has a 3 to 5 year useful lifespan before it becomes obsolete, too expensive to maintain, or incompatible with newer technology. But that lifespan can be shortened further if the system is operating near its full capacity as soon as it is turned on, or as in the case of any developing technology, users ask it to do things that were not anticipated by the designers, loading the system down even more.

At the end of each section we will suggest some questions that should be asked before committing to any wireless video system. While it is impossible to anticipate every combination of equipment and technology, asking these questions will go a long way towards designing a system that meets the current and future needs of a department.

As we will see, in-car video systems create a lot of data. The real issue here is this: how do we get the part we want, the video clips for evidentiary purposes, from the car to the office?

Links in a chain
Each part of any system has its own requirements and capabilities, and the limits of one part can limit the effectiveness of the entire system, so each segment must be examined twice: first independently, then again to judge it's impact on the overall system.

For our purposes here, we will break it down into these parts:

- The in-car equipment: cameras, DVR, router/access point, etc.
- The wireless network equipment and management software.
- The Department LAN, Support staff, Video Management Software
- Storage drives and RAID arrays
- Video Storage Cost comparisons

In addition, each segment will have its own support costs, which may or may not cross over from one segment to another. In other words, the IT person who supports the building network, or LAN, may not be the same person who supports the equipment in the car.

"Do the math!"
There are only 24 hours in a day. A fleet of cars could very well generate more video than can be transferred in this time, in which case something has to give somewhere else in the system. It is virtually impossible to judge the effectiveness and total cost of a system until each segment of the system has been investigated. Fortunately, many of the requirements are quantifiable, meaning that a lot of this is basic math… nothing more than a numbers game, just with very large numbers!

It sounds very complicated, but it isn't. The amount of data to be transmitted can be calculated fairly closely and accurately. This in turn determines the network requirements, and the time needed to transfer the video evidence from a patrol car to an internal network server. The results make it easy to figure out what size department a particular system will support.

Possible Vs. Practical Vs. Affordable
It is important to realize that something that is *possible*, especially on a small scale, may not be *practical* or *cost effective* on a large scale. It's one thing to connect to one or two patrol cars and download two or three hours of video/audio files and store it on a computer somewhere on a network. It is quite another matter to manage the daily downloading and archiving of several hours of data from 20, 50 or 100 cars. Every variable must be considered, from the file size, to the number of cars, to the number of shifts, to the average hours of video recorded each day…the list goes on.

Another thing to remember is that the efficiency of the entire system is limited by the weakest part of the system. For example, if the image file sizes are large and the video is recorded in real-time, it will take a lot of bandwidth to transfer the data. If there is a lot of radio interference in the area, a wireless system's

performance can be severely downgraded. In addition, an existing network may be at its capacity for bandwidth and storage already, and may be inadequate for the additional duties of managing video downloading and archiving. These are only a few of the possible issues.

Also, scaling up all of this for large departments can be very costly when compared to other methods of recording, storing and playing back video evidence, such as in-car storage with a removable hard drive. By some estimates, wireless downloading and storage of in-car video can *cost as much as 3 to 5 times as much per patrol car when compared to removable media based systems.*

As you can see there is a lot to consider. Let's examine each segment separately first, then we'll try to put it all together.

Part 2: The Patrol Car

In part 1 of this series, we stated that a wireless video transfer system really consists of many parts, and that the only way to predict the usefulness of a given system is to break it down and look at each part separately, then put it all back together again. The place to begin is the patrol car.

Here's where it all starts, and of course, this video is the reason for everything to follow, so let's look at it closely. Inside each car there will be anywhere from one to four cameras. There will also be a wireless microphone on the officer, and possibly another mic in the car. There may be a GPS receiver, text insertion from a radar gun, etc. All of these devices are creating data, which is stored in some digital format on some type of media, usually a hard drive.

We really don't want to get too bogged down with numbers, but a little simple math is the only way to answer our questions.

For our calculations here, we will assume only a single camera, a single microphone, and a DVR recording at real-time, but only when there are "events" like traffic stops.

1 camera = 30 images per second = 1800 images per minute

Let's say a typical traffic stop is 5 minutes;

5 minutes times 1800 images per minute = 9000 images

If the image quality and compression equal a file size of 5 kilobytes per image, then:

5000 bytes X 9000 images = 45,000,000 or 42.9 megabytes

Audio will add another 5 to 10 megabytes of data to store, so let's round it off to 50 megabytes of data for every 5 minute traffic stop.

If we assume 20 stops per shift, we arrive at 1000 megabytes of data. A gigabyte, or Gb, of data is actually 1024 Mb, but our estimate is more than close enough for our purposes here, so we'll call it like this:

One camera, recording 20 five-minute traffic stops per shift, with 5 Kb file sizes, will create around 1 Gb of video data per car per shift.

Ten cars using the same numbers will create around 10 Gb's of video data
Twenty cars = **20 Gb's**
One hundred cars = **100 Gb's or .1 terabytes of data daily.**

Two cameras in the car? Multiply these number by two.

Three cameras? Multiply by three…

Then multiply that number by the number of shifts that each car is on patrol each day.

As we stated earlier, this is strictly a numbers game, and the numbers can get very large, very quickly! All this video evidence may be "virtual" but it has very real consequences for storage and transmission.

The basic formula looks something like this:

File size
times recording rate
times number of cameras
times daily recording amount per officer
times number of cars
times number of shifts for each car
equals Amount of data to be transferred across the network each day for storage.

Here are a couple of samples at two extremes, to illustrate how this adds up…

1 Patrol Car X 1 Shift X **1 Camera** X 30 ips (images per second) X **3 Kb file size** X 3 Hours video (average per shift) **= 2.0 Gb / per shift / per day**	50 Patrol Cars X 1 Shift X **2 Cameras** X 30 ips (images per second) X **10 Kb file size** X 3 Hours video (average per shift) **620 Gb / per shift / per day**

Here's another way to look at this situation: a 100 car department can easily generate **50 terabytes or more of data**… *every 4 to 6 months*!

We'll come back to these numbers later when we talk about Storage Server requirements.

Questions to ask:

- What is the image file size of the video to be stored?
- What is the video quality at that file size? *(VHS? S-VHS? Better?)*
- How many ips, or images per second, will the unit be recording at for each camera?
- How many cameras will be in each car?
- How many hours of video will be generated each day?
- How many cars will be equipped?
- How many shifts will each car be on patrol?
- How many hours will the entire fleet require to download all video? More than 24?
- If software is required, is there a licensing fee?
- What is the total cost per patrol car?

Next, we'll look at the wireless part of this system.

Part 3: The Wireless Connection

In the first part of this series, we looked at the process of recording video using the example of a number of traffic stops, and calculated an estimate of the amount of data that would be created by this recording. Once all this data has been collected, at some point it must be moved from all the various patrol cars to the department network. There are various methods for this such as removable hard drives or some other type of media like Compact Flash, a hard-wired network connection, or a wireless connection. Here we will take a look at the wireless option in more detail.

We will assume that we are discussing the most common type of wireless connection, 802.11. There are two major varieties of this protocol currently in use; 802.11b and 802.11g. The main difference between the two is speed.

802.11b is rated to transmit data at 11 Mbps.
802.11g is rated to transmit data at 54 Mbps.

> *Technical note: transmission speed, or bandwidth, is measured in megabits per second, or Mbps, while our earlier calculation of file sizes were done using megabytes, or Mb.*
>
> *The actual unit of measurement is 1024 per kilo in the binary system, and 1000 per kilo in the decimal system, but the numbers used here are more than adequate for our purpose of estimating system bandwidth and storage capacity.*
>
> *One megabyte = 8.3 megabits*
>
> *8,388,608 bits*
> *1048576 bytes*
> *1024 kilobytes (abbreviated as KB or Kb*)*
> *Now, back to important stuff…*

However, in the real world these speeds are rarely, if ever, attained. Actual *throughput* testing, which measures the real rate of data that is moved across a wireless network when subject to conditions outside of a test lab, and disregarding the manufacturers claims, has shown that average speeds on the 802.11g network are only around 18 to 20 Mbps, and can be as low as 1 Mbps on some networks.

There are a number of reasons for this:

- **Overhead**: A certain percentage of the networks capacity is reserved for it's own use.
- **Interference**: This can be caused by things like microwave ovens, wireless keyboards and mice, and some cellular phones.
- **Shared Frequencies**: 802.11 uses the unregulated 2.4 GHz frequency range, along with cordless telephones and many other wireless devices.
- **Antennas**: Corroded or aging connectors can severely degrade service.
- **Obstructions**: Brick or concrete walls, trees, etc. This can cause multipath signals, which means simply that the signals arrive at the antenna at slightly different times, resulting in a slow down.
- **Distance**: Range is typically around 150 feet from Access Points.
- **Conflicts:** Other wireless networks.
- **Security:** Aside from the obvious issues in securing any network, the very act of turning on security protocols will cause the network to slow down by a significant amount.

In a crowded urban environment, even if a network tests and performs as expected, there is no guarantee that another network will not be created that overlaps, with the potential for creating havoc on the existing network.

It would be a great help if the patrol car can be brought into a secure and controlled area, such as a sally port or fueling station while video is being transferred, but that can create the issue of only being able to download a single car's video at a time, and it might tie up that area while the transfer is taking place. This may be impractical with a larger department, or impossible if the cars are used on succeeding shifts.

At this point, the patrol cars on-board storage capacity becomes an issue, since any video that has not been transferred risks being lost if it is overwritten by new video before it can be archived. If the car's storage limits have been reached, that car might not be placed back into service until the data has been retrieved.

In the worst case, evidentiary video is at risk of being overwritten and lost forever..

The longer a DVR can store data on-board, even with network data transfer, the less chance of this ever becoming a problem. Once again, this is where image file size and on-board storage capacity become important issues.

Questions to ask:

- Has the area been tested for interference from sources like microwaves, radios, etc.?
- Has the area been tested for other wireless networks?
- Is this to be a dedicated connection, used only for video evidence transfer?
- How many simultaneous users must it support?
- Is this connection ever likely to be used for any other purpose?
- Is there enough actual throughput to leave room for future expansion?
- What is the total cost of the wireless connection equipment?

Now, on to the building LAN….

Part 4: The Department LAN or Local Area Network

In part 1 of this series we looked at the process of recording the video, then in part 2 we examined the real-world operability of an 802.11 wireless network to get the video evidence from the patrol car to the department's internal network. Now let's look at the internal network itself.

A local area network, or LAN, consists of cabling, servers, routers, hubs, switches and other pieces of equipment, along with all the other computers that are connected to it. It can be as small as two or three computers linked together, or as large as hundreds of computers, printers, scanners, data servers, etc. It may also run the building phone system and other things not directly involved with law enforcement or mobile video.

The network may also be the connection to the internet, and may even host the departments intranet – its own internal data network..

There might be a dedicated staff of IT (Information Technology) professionals monitoring the systems every move, or there may be an officer with an interest in computer technology who baby-sits the network as a sort of hobby. Most likely there will be something in between these two extremes.

First obvious question: your department probably already has a LAN. Can it handle the additional duties of transferring video data from the fleet of patrol cars? Or will a wireless connection for downloading the video evidence from each car require creating a separate network that is secure, dedicated and reliable?

Typical wired LANs are 100 Mbit networks, meaning they theoretically support up to 100 megabit per second transmission speeds. But by now it should come as no surprise to learn that this speed is never really achieved.

Here's an excerpt from Tech Target's Expert Answer Center:

Actual throughput on Ethernet is NEVER 100Mbps if you are looking at data transfer by trying to carve up a file and assume what is being carried. There is overhead associated with Ethernet including framing, acknowledgements, etc. Typically one can expect about 1/3-2/3 of the actual speed based on several factors such as traffic. Also, if there are problems in your physical layer causing retransmissions, your throughput will suffer as well.
http://expertanswercenter.techtarget.com/eac/knowledgebaseAnswer/0,295199,sid63_gci976342,00.html

Most hardwired LANs are pretty robust, which means that they can handle a fair amount of traffic, and store a large amount of data. Most are also secure, but extra care should be taken to monitor and verify that the network cannot be compromised by expanding it to include wireless connections. There are many programs running on the internet that are constantly "sniffing", looking for an opening to private networks so they can steal data, or plant a malicious virus.

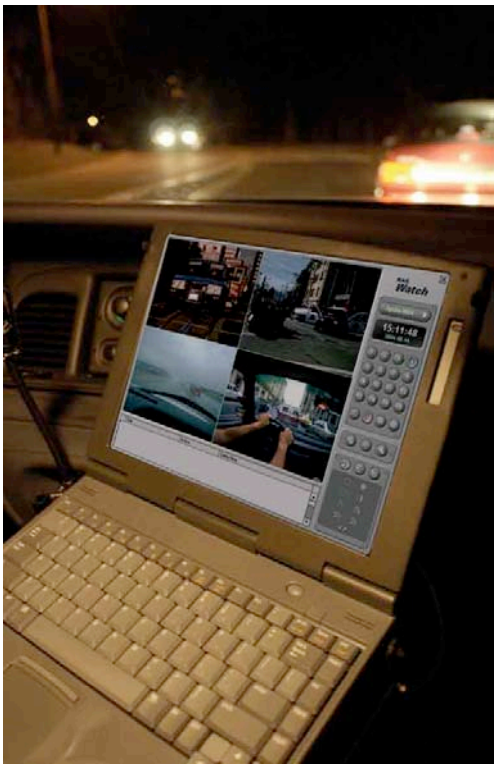
When considering adding video transfer and storage, the departments IT staff should be brought in early in the process for best results. In a small department there may be enough storage space to handle a small amount of additional video data, but most likely more storage in the form of dedicated servers will have to be added.

As we saw in Part 1 of this series, the amount of video data generated can increase dramatically and quickly. A properly planned system should be able to grow with a department and not put the network at maximum capacity "right out of the box".

Video Management software

After transferring video data to an internal LAN, it will be necessary to keep it organized, and provide some easy means of searching through the data to create a video clip when needed. This is where the digital video management software (sometimes referred to as DVMS) comes in. Each of these programs will have to be examined on their own merits to see if they meet the departments needs. The software should be intuitive and easy to use, stable and robust enough to not cause problems on the network.

Who will have access? Who will manage the video? Who will create the clips for trial when needed? Will this be a responsibility of the IT staff?



RoadRunner MR4 Remote Access Software shown at a Traffic Stop

Also, be sure to verify any licensing fees and how many users are supported per license. In other words, are there limits to the number of downloads, or the number of people who can log in to the software without purchasing more "seats"?

Questions to ask:

- How much of the existing network bandwidth is already spoken for?
- Will using the same network to support video transfer slow it down unacceptably?
- Does the department have sufficient trained IT support staff, or will it have to hire someone?
- Software: How much does it cost per user? *(licenses per seat)*
- Does the software have an expiration date, after which you must renew the license?

Next we'll look at storage requirements, and summarize all the sections of this series.

Part 5: When is enough storage enough?

As we have seen in the previous installments of this series, video generates a very large amount of data. It is very conceivable that a department could generate terabytes of data *every few days*. Factor in state and local requirements for length of time for storing video evidence, and it becomes apparent that data storage will be a major consideration.

Apart from Law Enforcement video storage, there is this report from entrepreneur.com: *"Companies are finding that they have to double their storage capacities every six to 12 months, according to industry studies. And the government isn't helping. Recent regulations, such as Sarbanes-Oxley, HIPAA and the USA Patriot Act, require businesses to accurately record and report more and more data."* And this is not considering video, only raw data, which takes up much less storage space.
(http://www.entrepreneur.com/article/0,4621,314051,00.html)

In addition, since we are talking about video as evidence, it is critical that it be stored securely, and access is controlled to maintain Chain of Evidence.

So what will a department do with all this data?

Once you have done the calculations in Part 2 of this series to arrive at an estimate of the amount of data that will be stored on your network (based on everything from the original image file size to the number of cars, cameras and shifts) you will probably find it necessary to add more storage servers.

This can take the form of an additional large hard drive on an existing server, or more likely, adding dedicated storage such as RAID arrays, NAS (Network Attached Storage), SAN (Storage Area Network) or a Managed Storage Network.

There are also other options such as digital tape drive storage devices, which are very efficient at storing vast amounts of data, but may not be the best choice where highly reliable, low-maintenance, fast access to video is important.

What is a RAID array? Originally it stood for Redundant Array of *Inexpensive* Disks, but it didn't take long for this to be changed to Redundant Array of *Independent* Disks. The idea is straightforward enough: copy the data to more than one hard drive at a time. If one drive is good, two is better. That way if a drive is lost, damaged or corrupted, the information can be retrieved from the other drive or drives, hence the "Redundant" description.

Need help figuring out how long you can record on a HDD? Go to www.avt-usa.com and click on "HDD Calculator" for a quick estimate!

RAID storage devices start at around $3000 for each terabyte of storage. A medium sized police department could potentially generate that much data every few days, so you can see that storage very quickly becomes an issue, both in expense and maintenance. Once again, proper system planning from start to finish is critical.

Let's look at an alternative for a moment… standard hard drives are continually increasing in size while at the same time, they are falling in price. This means in-car DVR's with good compression and large hard drives can easily store *months* of video on board. If they also have an effective way to preserve video clips as needed, such as a docking station, or in-car laptop computer, and include their own software, this eliminates the expense, complexity and support of a wireless network storage infrastructure, while drastically reducing overall system cost.

Of course, any method of recording, storing and administering in-car video systems will require some level of support over not having video at all. However, this method assumes the officer or another designated employee will only have take a few minutes as needed to download and archive the video, either as raw data or video clips, as opposed to a full-time network support staff.

Cost Comparisons

Since there are so many variables in the equipment, departments and infrastructure required for an effective video recording and storage system, it is impossible to give more than a very rough estimate. In addition, some parts of the infrastructure may already be in place, but will most likely require upgrading.

However, this should serve as a general indication of the types of expense associated with the different systems.

drive based in-car video system		**Wireless network based storage in-car video**	
Equipment per car	$4000 to $6000	**Equipment per car**	$7000 to $10,000
Offloading Station	$400 to $1000	**Offloading network**	$2000
Building LAN	N/A	**Building LAN**	$10,000
Storage (CD's, DVD's)	$1000	**Storage Servers**	$3000 to $10,000
Support Personnel	*Officer or assistant*	**Support Personnel**	*IT person or IT Department*

Questions to ask:

- How long will the video need to be stored? Three months? Twelve months? Two years?
- Is the existing network infrastructure and storage adequate?
- What is the additional cost of each component?
- Can current staff manage the new requirements, or will IT staff need to be hired?
- Is there a budget for additional support staff?

Summary:

At Apollo Video Technology, we enthusiastically support many applications of wireless networking, when it is properly presented, implemented and supported. But again, we also see it being oversold and not properly explained *in detail* to prospective customers.

As stated earlier, wireless downloading and storage of in-car video can cost as much as three to five times more per patrol car compared to removable media based systems, when all the factors are considered. The increased costs in equipment and support personnel are difficult to predict exactly, but are very real none the less.

As stated at the beginning of this series of articles: a budget that supports 10 cars with wireless transfer might purchase enough systems for 30 cars or more with removable hard drives… when all the facts are presented.

In this series of articles, we could not explore every possible consideration and requirement, but hopefully we have presented enough basic information to give any department some idea of what is required to make an informed decision. Hardware cost must be balanced against support and licensing fees, but fortunately, these are almost all things that can be assigned values and reduced to hard numbers.

Both removable hard-drive based and wireless storage in-car video systems have a place and purpose in Law Enforcement. Indeed, hard drive based systems should be expected to also support wireless technology.

Ultimately, each part of the system must be considered on it's own merits and requirements. The video recording technology, the size of the department, the number of cars to be equipped, the support staff, the existing infrastructure, all this and more must be taken into consideration when designing an effective system that meets requirements and expectations.

Ultimately, the common goal is good quality video evidence to protect officers from false accusations, and to prosecute defendants. There are various ways of getting this result, at various levels of cost and complexity. And as we have seen, there are very real calculations that must be made to avoid problems, additional expense and disappointed customers after the installation.

In the end, it is simply a matter of asking the right questions!

The complete White Paper is available from our web site: www.avt-usa.com

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