On the Implementation of IP Video Surveillance Systems

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Abstract - Research breakthroughs in areas like the Integrated Circuits technology, Digital Signal Processing and the growing implications of the convergence of Information and Communications Technology (ICT) based on the Internet Protocol has in turn had a great effect on the trends in the video surveillance industry and market. With the rising spate of crime and security challenges all over the world, there is a very urgent need for comprehensive security and surveillance solutions to augment human resources and efforts. The traditional CCTV systems which are analog based are now being replaced by Internet Protocol (IP) cameras or network video surveillance systems due to the growing availability of faster and cheap broadband internet access. There is continuous activity in the industry as manufacturing companies introduce products with better functionalities to survive in the keenly competitive market. The implications of the implementation of network cameras are numerous to companies, business enterprises, government corporations and even individuals. This paper therefore focuses on reviewing past, present and future trends in the IP video surveillance world as regards to technology and market developments with the aim of recommending it as a tool for optimum efficiency for security agencies.

Index Terms – CCTV, DVR, IP Camera's, PoE, Surveillance, VCR

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1.0 Introduction

The geometric advancement in technology is increasingly causing a corresponding revolution in all area of human endeavors. More commonly in recent times, technology is used not only to proffer solutions to problems but also to improve pre-existing solutions to a problem. The world of technology is a very dynamic environment as a result of continuous research work embarked upon by researchers from both the university and the industry. Consequently, systems previously celebrated and highly instrumental in meeting human needs are fast becoming sunset technologies as they are being edged out by newer developments. For instance, just as the phonograph gave way to stereos which was later replaced by Compact Disc players, typewriters and fax machines have been replaced by computers and the old fashioned analog film cameras have almost been completely replaced by digital cameras. Such is the pace of technology that yesterday's latest and greatest may become old news today as not just analog but even digital systems struggle to remain relevant and significant.

As the world is rapidly changing therefore, security technology must therefore evolve to keep pace with the sophisticated threats. Most security agencies in developing nations still depend on human efforts and capabilities to combat crime. Reaction to crime is mostly reactive instead of proactive. However, with the rising spate of crime and security challenges, human resources and efforts must be augmented by security and surveillance solutions that leverage on technological advancements for effective deployment. Market trends and reports from the industry assert the fact that surveillance systems have moved from traditional analog into digital and IP-based technologies with access applications that are hard-ware independent and operate by mobile and wireless technologies [1], [2].The promised possibilities of IP network cameras are very enticing and the competition amongst manufacturers is helping to produced more advanced equipment's at affordable prices. IP video surveillance is undoubtedly a technology for the present and future. It is a very welcome technology that will redefine the order of the day. Its use will cut across not only security but will enhance optimum performance in transport, banking, sports, shopping malls and supermarkets, hoteling and many other sectors.

2.0 Technology Review

This section deals with issues like the overview of IP surveillance, history and principle of IP cameras, standardization and the contribution of the Internet Protocol. A comparative analysis of analog and IP surveillance systems is also presented therein.

2.1 Overview of IP- video Surveillance Systems

IP- Surveillance refers to a security system that presents a user the ability to monitor and record video/audio over an Internet Protocol-based computer network such as a local area network or the internet [3]. IP-Surveillance sometimes also known as network video or IP CCTV uses

the IP network technology as the backbone for transporting information.

As a result of the digital nature and method of video distribution, IP-based surveillance systems introduce a host of advanced functionalities that enhance greater control and management of live and recorded video data thereby making them highly suitable for security surveillance applications. Some of these include remote accessibility, high image quality, easy and future-proof integration, scalability, flexibility, cost-effectiveness, event management and intelligent video [3].

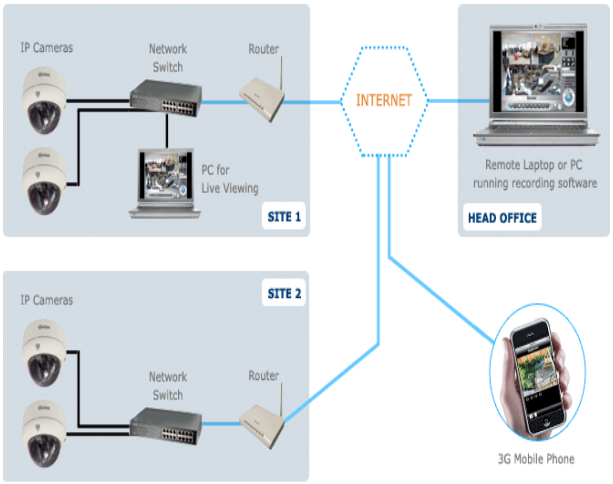

Figure 1: Illustrating setup of Multi cameras over multi sites [3]

IP based cameras are the future of surveillance systems. Although this technology has been available for over a decade, it has gained widespread attention in the last few years leading to the developments in Megapixel IP. Table 1 presents a summary of the benefits of using IP based systems over traditional analogue systems.

Scenario	IP CCTV	Analogue
Greater Flexibility	They do not require local recording as they can transmit their images across LAN, WAN and the Internet to a central location.	This system is designed to record security cameras locally only.
Better Performance	IP CCTV systems convert all images to data and have no theoretical limit to resolution, providing the relevant bandwidth to transmit the images	They are based on PAL analogue technology thus limiting the amount of quality images a single analogue camera can supply
	exists.	and reducing the area it can view.
Easier System Installation	Run over existing IP networks thus causing less disruption, reduction in installation time and minimize unsightly cables especially in the case of PoE IP cameras which are powered via the network cable.	They have their own proprietary cabling. Each camera has to be wired back to the DVR or Monitor and also has to be connected to a power source.
Better Value	With installation and setup requiring little time, IP Systems can work out to be far more economical than traditional Analogue solutions.	They are an excellent value for money. However, IP CCTV represents an investment in to a future technology whereas analogue CCTV systems are based on old technology.
Better System Integration	They communicate using IP, allowing them to integrate and co-exist on the same network/cabling as other IP based systems, such as Access Control and IP Phone Systems.	Designed to be closed circuit systems, hence they do not integrate easily with Access Control, Intruder Alarm or other systems that are found in buildings.

Table 2: Comparing IP and Analog Surveillance Systems

2.2 The History of Video Surveillance

The use of technology to aid surveillance is reported to have begun in the 1970s with the CCTV systems [4]. The major components of these analog-based systems include cameras, multiplexers, video camera recorders (VCR) and monitors. The limitations of these systems included the need for a lot of coaxial cable wiring to send and store the video onto video tapes, the tedious and labor-intensive routine in maintaining the VCR due to their low storage capacity, their need for frequent service checks and short life span of two years and finally the time-consuming and strenuous task of rewinding the tapes to trace evidence.
The Digital Video Recorder (DVR) technology was birthed in response to the shortcomings of the VCR. In a DVR, a digital storage media such as a computer hard drive is used for storing the video recordings and the recordings could be transferred to a tape for archiving if needed. However, a DVR also has its own limitations in that it is usually a local solution where at least one DVR unit is required per location.

Axis communications invented the first network camera in 1996 while IQinVision built on this feat to produce the first megapixel model in 1998 [4]. Milestone Systems contributed its quota by introducing the first open platform software for managing IP Camera-based video surveillance system. By 2003 there were more sophisticated computer-based DVRs on the market that could handle multi-camera input and provide additional functionality such as alarm handling, activity detection, alarm notification and remote access [4]. With the IP network approach, archiving and storage are more efficient and compression standards also improved for optimized system use.

In 2004 Axis released the first network camera with Power-over-Ethernet (POE) that significantly improved ease of hardware installations and the flexibility to add, move or change cameras on the network at any time [4].
Presently, IP cameras with network interfaces have become widely available from an increasing number of manufacturers, with high definition image quality and sophisticated camera functionalities. These cameras are directly attached to a data network, such as a local or wide area network from where the camera is then directly accessed and viewed from a computer on the network. As a result of the huge capital already spent to install the analog CCTV, network video servers also known as video encoders evolved to help convert traditional analog video camera output to digital data for connecting to the network thereby allowing seamless migration from existing analog or basic DVR systems to network-based digital solutions.

2.3 Principleof operation of IP cameras

Network cameras are widely described as a combination of a camera and computer into the same unit.

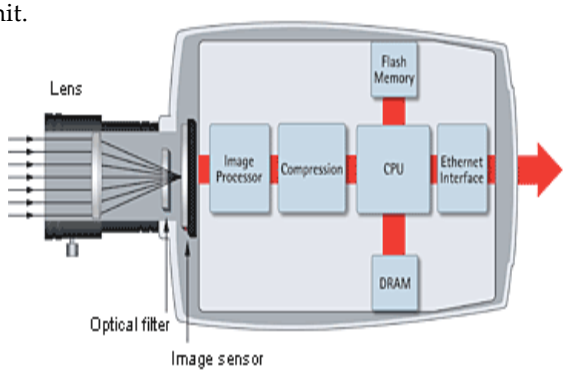

Figure 2: Building Blocks of an IP Camera [3]

The network camera usually has its own IP address with which it accesses the network directly just like any other network device. Everything needed for viewing images over the network is built into the unit. It also has in-built software for a Web server, FTP server, FTP client and e-mail client. Other features include alarm input and relay output functions. More advanced network cameras can also be equipped with many other value-added options such as motion detection and an analog video output.
The lens of the network camera's camera captures the image represented as light of different wavelengths and passes the image through the optical filter. The function of the optical filter is to ensure that infrared light is removed so that the necessary colors are displayed. The image sensor further converts the image, which is composed of light information, into electrical signals. These signals from the image sensor are then converted from analog to digital format making them now in a format that can be compressed and transferred over networks.
The CPU, Flash memory and DRAM memory perform the computing functions of the camera and are designed specifically for network applications. Together, they handle the communication with the network and the Web server. With the use of an Ethernet port or wireless antennae, images are sent to different devices on the network.

2.4 Standardization

Since the invention of the first network camera by Axis Communications, the market has become a cluster of activities with different manufacturers from different countries and continents. Each make of IP camera produced had its own features and functions, video encoding or compression schemes, supported network protocols and the API for use by the video management software of the manufacturer in question.
The need for standardization for the instilment of order and synergy in the industry birthed two groups namely Open Network Video Interface Alliance (ONVIF) and the Physical Security Interoperability Alliance (PSIA) both in 2008. These two groups have designed standards for the purposes of interoperability; thereby permitting users of existing equipment maintain functionality with new purchases from other members of the group.
ONVIF originated with three initial members namely AXIS communications, BOSCH and Sony. Presently, there are 438 members comprising of 18 full members, 22 contributing members and 398 user members [5]. The

PSIA on the other hand was formed by 20 member companies including Honeywell, GE security and Cisco [6]. A review of the membership of both groups reveals that some companies belong to. Furthermore, the ONVIF commands the major players in the industry while PSIA represents companies with lower IP camera share.

2.5 The Role of the Internet Protocol (IP)

The use of the Internet Protocol (IP) as the underlying platform for many recent technologies is gradually becoming the order of the day. For example, convergence of ICT has at its foundation the Internet Protocol. Voice-over-Internet-Protocol (VoIP) and Video-over-Internet-Protocol are areas that have transformed businesses and social networking. The IPTV is also growing at a very fast rate. This same success is being recorded in the IP surveillance market. It is therefore pertinent to review the features and characteristics of the internet protocol that are responsible for its widespread acceptance and performance.

An advantage of the Internet Protocol over traditional technologies like the Asynchronous Transfer Mode (ATM) is that it is packet-based. Furthermore, an IP-based network surpasses other 'connection-oriented' networkswith its ability to make the network itself determine the best path for transmitting traffic to its destination at any given moment, and routes traffic dynamically. Thisis referred to as a connection-less approach and has the benefit of guaranteeing easier provisioning, cost-efficiency and inherent resiliency. Such a network can better survive link and node failures as it can reroute around any link or router failure.

IP as an open standard has also contributed tremendously to fostering interoperability among vendors. This has ensured that various equipment from different vendors are able to relate over the same network and produce efficiency in terms of cost and time. This is as against vendor dependent platforms which are limited by rules regarding its use, deployment and modification.

IP-bases networks can also benefit from CoS differentiation and QoS-based routing. In other words, IP allows for the assignment of priority to certain services over the others so as to ensure or guarantee optimization. This leads to better utilization of resources and also allows for capacity redundancy to take care of an increase in the number of users. With many types of operations running simultaneously on a single network and with certain applications having varying tolerance for transit delays, dropped packets, and error rates, IP architecture comes to the rescue with the implementation of QoS reflecting the requirements of the different applications.

3.0 Analysis of Present and Future Trends for IP-based Video Surveillance Systems

The IP surveillance industry has grown in the last few years. This growth though affected by the economic downturn in Europe is on the increase especially as the year 2013 is expected to be a landmark year in the industry from various market forecasts.

3.1 Trend in Market Sales

Despite the attention drawn to IP-based video surveillance systems in recent years following the worldwide record market break in 2006 where there was a 41.9% growth [7],sales reviews for the years 2011 and 2012 show that contrary to expectations, it is yet to surpass the market sales figures for analog video surveillance equipment's. Precisely, as at 2011, it was reported that network cameras accounted for about 40% of global security camera sales [8]. The recent adverse economic condition in Europe is reported to be responsible for this development. The year 2012 however showed some signs of bounce-back in the market. Factors like new developments such as High Definition network security cameras and the introduction of intelligent cameras with the ability to make decisions further contribute to this trend. The development of Asian markets with China in particular has also displayed encouraging signs of increasing growth. The present year 2013 has been forecast as the year when sales in network video surveillance equipment will tip those that are analog based. The percentage share of IP cameras in the global CCTV market is expected to increase to approximately 60% by the year 2016.

Also, according to the 2012 edition of "The World Market for CCTV and Video Surveillance Equipment" report from IMS Research, Axis Communications is now the top global manufacturer of surveillance cameras, including providers of both IP-based and analog solutions [9]. It is therefore safe to conclude that since an all-IP camera manufacturer is now the leading producer of surveillance cameras worldwide; the analog to digital shift in video surveillance is fast becoming a practical reality.

3.2 Demand for better compression techniques

Transmission of video data over an IP network presents two major concerns to the network administrator. These include the need for greater storage requirements and higher consumption of network bandwidth for transmission. Bandwidth usage depends on criteria such as image resolution, compression type, compression ratio, frame rate and image complexity. To transmit images effectively over a network, data must be compressed to avoid consuming too much bandwidth. In a case where bandwidth is limited, lowering the frame rate or accepting a lower image quality can radically reduce the size of video files for storage purposes. A number of compression standards exist that deal with the tradeoff between frame rate and image quality in different ways, the most common being Motion JPEG, MPEG-4 and H.264 [10], [11]. H.264 is the latest compression standard that offers the most efficient format for compressing video and which enables great savings in bandwidth and storage. It has been proven that without compromising image quality, an H.264 encode can reduce the size of a digital video file by more than 80 percent compared with the Motion JPEG format and as much as 50 percent more than with MPEG-4 [3]. The implication of this figure is that lesser network bandwidth and storage space are required for an H.264 video file or put in another way, much higher video quality can be achieved for a given bit rate. Presently, there is a growing demand for higher resolution security cameras by users in order to experience greater clarity when viewing live video. This resulting high definition video as already highlighted implies greater storage costs due to the larger file sizes. Consequently, there is a need for the industry to transition to more efficient video compression codecs.Some of the potential compression formats include H.264 Scalable Video Coding (SVC), WebM and High Efficiency Video Coding (HEVC) [12].

Different research statements have suggested that video compression technology in the video surveillance industry can be improved. Despite the call for better compression formats, it is unfortunate to state that MPEG4, Wavelet and JPEG2000 are still widely used with H.264 still referred to as new. The case for H.264 SVC; an extension of H.264 is growing and is seen as the most worthwhile option in the short-term while HEVC might perhaps the most likely successor to H.264 in the long-term depending on its performance and suitability for video surveillance applications. Production of surveillance cameras using this format might grace the market in the year 2013.

3.3 The trend in different end customer segments

Aside from security installations, network video is expected to become widely applied in other fields. This is primarily because network video offers great freedom of movement as surveillance can take place via Smartphone's and notebook computers.

Sectors such as retail, transportation and healthcare have a huge potential to drive the growth of IP surveillance systems. The banking sector is reported to be the segment that first embraced video surveillance. However, while retail is the largest end customer segment within video surveillance, healthcare and education are presently the most penetrated end customer segments, a state of affairs that applies globally. Teachers, students and parents all have an interest in safety and security measures due to a rising spate of harassment, threats, violence, drug dealing, theft and other criminal activities [13]. Transport is the segment that has grown most rapidly in recent years. These systems play a vital role in container park, distribution center and warehouse security programs by enabling freight and warehousing companies to track warehouse deliveries and loading, certify that trailers are fully unloaded, document fraudulent worker compensation claims for accidents that never occurred amongst others [14]. Government initiatives in many countries are also expected to greatly enhance the market growth.

In summary, growth has been high virtually in all markets and this trend is expected to continue. Individuals are also expected to begin to install such systems in their homes to monitor kids and for other domestic uses.

3.4 Growth beyond the BRIC nations

The BRIC nations consisting of Brazil, Russia, India and China has been the hub of activities in present times. At a global level, growth within network video is predicted in all geographical regions. Growth varies depending on various factors in the individual markets, such as the need for surveillance, infrastructure and legal requirements. In Brazil, installations of network video are being prepared in airports, hotels, arenas and in critical urban environments ahead of the football World Cup in 2014 and the Olympics in 2016 [15]. India and China are upgrading their surveillance systems to IP surveillance systems.

In emerging markets in Latin America, Africa and Asia, areas with low digital surveillance penetration rates are expected to display higher growth than others, as people there will choose a digital system directly. Asia is expected to gain significant share in the global CCTV market by 2013 therefore accounting for about 34% of the total market [16]. India and China with huge population base will be joined by other 'Asian dragons' like Malaysia, Thailand and Taiwan to achieve this target. The CIVETS (Colombia, Indonesia, Vietnam, Egypt, Turkey and South Africa) are being touted as the next set of tiger economies due to their rapidly industrializing economies. The indicators appear promising as the current long term GDP rate for the CIVETS is in line with that for the BRICs.

4.0 Challenges to Wider Deployment of IP Surveillance Systems

A glaring challenge to the wide deployment of IP surveillance systems is low internet penetration and poor internet speed in most countries of the world. As of June 2012, 34.3% of the world's population had access to the internet (a great rise when compared to March 2008 when 20.3% of the world's population had access to the Internet)[17]. It is significant however to note that both Africa and the Mideast have experienced the most significant increase in access in recent years.

A region specific issue like poor power supply in developing nations is another major barrier to widespread deployment of IP-based surveillance systems. Since enterprises are already spending a lot of money to keep their businesses running due to the cost of running alternative power sources, they are hesitant in releasing extra funds for the implementation of surveillance systems.

Another issue of concern in the use of IP surveillance cameras is security flaws. It has been reported that the inherent design of web interface of the IP surveillance cameras is not robust and is therefore prone to security flaws. Network attacks such as the injection of video streams through ARP spoofing, Cross Site Scripting (XSS), Cross Site Request Forging (CSRF) and Cross Domain Image Streaming (CDIS) based on the concept of Remote File Inclusion (RFI) have been experienced. This is reported to be due to insecure Common Gateway Interface (CGI), factory defaults and undocumented credentials, insecure front end design in the web interfaces of IP surveillance cameras, invalidated entry points and unencrypted cameras [18].

These challenges are being eroded gradually as everyone want to leverage on the potentials of IP surveillance systems for efficiency.

5.0 Conclusion

In this paper, we have reviewed the past, present and future occurrences in the video surveillance industry. Video surveillance has become a foremost global strategic tool for fighting the war against terrorism, preventing crimes, protecting corporate assets and enhancing public safety. Since they serve the needs of military, government, utilities, corporate, medical, retail, hospitality, transportation and education, no individual can claim not to be affected by this trend. Despite the challenges to its widespread deployment in some regions, the future is very bright for this technology.

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