MSN and Its Applications

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Abstract – The multimedia sensor network (MSN) is gaining its fame due to the availability of low-cost hardware i.e., networks of resource- constrained wireless devices that can retrieve multimedia content such as video and audio streams, still images, and scalar sensor data from the environment Recent years have witnessed tremendous advances in the design and applications of wirelessly networked and embedded sensors. They leverage the concept of wireless sensor networks (WSNs), in which a large (possibly huge) number of collaborative sensor nodes could be deployed. As an outcome of the convergence of micro-electro-mechanical systems (MEMS) technology, wireless communications, and digital electronics, MSNs represent a significant improvement over traditional sensors. The integration of telemedicine with medical micro sensor technology (Mobile Sensor Networks for Telemedicine applications - MSNT) provides a promising approach to improve the quality of people's lives. This type of network & can truly implement the goal of providing health-care services anytime and anywhere.

Index Terms — Multimedia sensor networks, video sensor networks, wireless sensor networks, System architecture, Sensor network, Remote medical applications, Multimedia Communications, Sensor networks, Mobile Networks, Telemedicine.

1. INTRODUCTION

The state-of-the-art and research challenges characterize the wireless multimedia sensor networks (WMSNs), that is, networks of wireless embedded devices that allow retrieving video and audio streams, stilt images, and scalar sensor data from the physical environment With rapid improvements and miniaturization in hardware, a single embedded device can be equipped with audio and visual information collection modules.[l] In addition to the ability to retrieve multimedia data, WMSNs will also be able to store, process in real-time, correlate, and fuse multimedia data originated from heterogeneous sources.

The main unique characteristics of WMSN can be outlined as follows.

- Resource Constraints. Embedded sensing devices are constrained in terms of processing capability, and achievable data rate.
- Application-Specific QoS Requirements. In addition to data delivery modes, typical of scalar sensor Networks, multimedia data include snapshot and streaming multimedia content. Snapshot-type multimedia data contain event triggered observations obtained in a short time period (e.g., a still image). Streaming multimedia content is generated over longer time periods, requires sustained information delivery, and typically needs to be delivered in real time.
- High Bandwidth Demand. Multimedia contents, especially video streams, require data rates that are orders of magnitude higher than that supported by commercial off-the-shelf (COTS) sensors. Hence, transmission techniques for high data rate and low power consumption need to be leveraged.
- Variable Channel Capacity. Capacity and delay attainable on each link are location dependent, vary continuously, and may be bursty in nature, thus, making quality of service (QoS) provisioning a challenging task.
- Cross-Layer Coupling of Functionalities. Because of the shared nature of the wireless communication channel, there is a strict interdependence among functions handled at all layers of the communication protocol stack. This has to be explicitly considered when designing communication protocols aimed at Q0S provisioning on resource constrained devices.
- Multimedia Source Coding Techniques. State-of-the- art video encoders rely on intraframe compression techniques to reduce redundancy within one frame, and on interframe compression (also predictive encoding or motion estimation) to exploit redundancy among subsequent

frames. Since predictive encoding requires complex encoders, powerful processing algorithms, and high energy consumption, it may not be suited for low-cost multimedia sensors. However, it has recently been shown [2] that the traditional balance of complex encoder and simple decoder can be reversed within the framework of so-called distributed source coding. These techniques exploit the source statistics at the decoder and by shifting the complexity at this end,

- It enable the design of simple encoders. Clearly, such algorithms are very promising for WMSNs.
- Multimedia In-Network Processing. Processing of multimedia content has-mostly been approached as a problem isolated from the network-design problem. Similarly, research that addressed the can1ent delivery aspects has typically not considered the characteristic of the source content and has primarily studied cross- layer interactions among lower layers of the protocol stack. However, processing and delivery of multimedia content are not independent, and their interaction has a major impact on the achievable QoS. The QoS required by the application will be provided by means of a combination of cross-layer optimization of the communication process and in-network processing of raw data streams that describe the phenomenon of interest from multiple views, with different media, and on multiple resolutions.[3]
- Power consumption: Power consumption is a fundamental concern in WMSNs, even more than in traditional wireless sensor networks. In fact, sensors are battery-constrained devices, while multimedia applications produce high volumes of data, which require high transmission rates, and extensive processing. While the energy consumption of traditional sensor nodes is known to be dominated by the communication functionalities, this may not necessarily be true in WMSNs. Therefore, protocols, algorithms and architectures to maximize the network lifetime while providing the Q0S -required by the application are a critical issue.
- Flexible architecture to support heterogeneous applications. WMSN architectures will support several heterogeneous and independent applications with different requirements. It is necessary to develop flexible, hierarchical architectures that can accommodate the requirements of all these applications in the same infrastructure.
- Multimedia coverage. Some multimedia sensors, in particular video sensors, have larger sensing radii and are sensitive to direction of acquisition (directivity). Furthermore, video sensors can capture images only when there is unobstructed line of sight between the event and the sensor. Hence, coverage models developed for traditional wireless sensor networks are not sufficient for redeployment planning of a multimedia sensor network.
- Integration with Internet (IP) architecture. It is of fundamental importance for the commercial development of sensor networks to provide services that allow querying the network to retrieve useful information from anywhere and at any time. For this reason, future WMSNs will be remotely accessible from the Internet, and will therefore need to be integrated with the IP architecture. The characteristics of WSNs rule out the possibility of all-IP sensor networks and recommend the use of application level - gateways or overlay IP networks as the best approach for integration between WSNs and the Internet [4].

Integration with other wireless technologies Large-scale sensor networks may be created by interconnecting local "islands" of sensors through other wireless technologies. This needs to be achieved without sacrificing on the efficiency of the operation within each individual technology.

2. WIRELESS SENSOR ARCHITECTURE

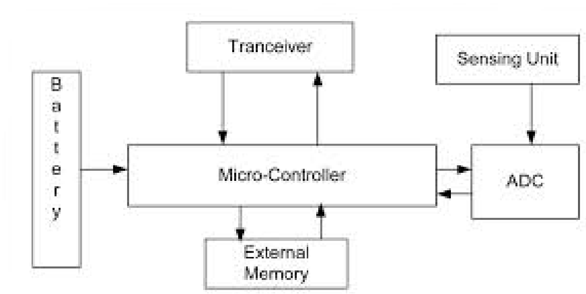

Fig. 1 Wireless sensor Architecture

There are typically four main components in a sensor node [5], i.e., a sensing unit, processing unit, a communication unit, and power supply. The sensing may be composed of one or more sensors and Analog-to-Digital Converters (ADCs). Sensors are hardware devices that measure some physical data of the monitored system's state such as temperature, humidity, pressure, or speed. The analog signals produced by the sensors are digitized by ADCs and sent to the processing unit for further processing. Within the processing unit, there is a microcontroller associated with a small storage unit including on-chip memory and flash memory. The processing unit is responsible for performing tasks, processing data, and controlling the functionality of other components of the sensor node. A wireless sensor connects with other nodes via the communication unit, where a transceiver encompasses the functionality of both transmitter and receiver. The wireless transmission media may be radio frequency, optical (laser), or infrared. At present, the main types of power supply for wireless sensor node are batteries, rechargeable or nonrechargeable. Energy is consumed for sensing, data processing, and communication. For small wireless sensor nodes (with limited computing capacity), data communication will expand the majority of energy, while sensing and data processing are much less energy-consuming. In the past one and a half decades, a number of prototype and commercial wireless sensor nodes have been made available by research institutions and companies from around the world Although these sensor nodes often differ in capacity and feature, most (if not all) of them have been built upon the architecture given in Figure 1 Table 1 gives a list of some available wireless sensor nodes.

Table 1 some available wireless sensor nodes.

Node	Sensing Unit	Microcontroller	Memory	Transceiver
BT Node	UART,SPL,12C, GPIO,ADC	AT mega 128L	4KB EEPROM,64 KB SRAM,128KB FLASH	CC1000, ZV4002, Bluetooth
Firefly	Sensor expansion card: temp, light, acoustic	AT mega128I	8KB RAM,128KB ROM	CC 2420
IMote2	UART, SPL, 12C, SDIO,GPIO	Intel PXA 271	256KB SRAM,32MB FLASH,32MB SDRAM	CC2420
Mica Z	Expansion connector for light, pressure, acceleration	AT mega 128L	4KB RAM,128KB FLASH	CC2420
Sun SPOT	Temp, light, acceleration	ARM 920 T	512KB RAM,4MB Flash	CC2420
Tiny Node 584	On board temperature sensor	TI MSP 430	10KB SRAM,48KB FLASH	XE1205
T mote Sky	On board humidity ,temp, light sensor	TI MSP 430	10KB RAM,48KB FLASH	CC2420

The proliferation of these products opens up unprecedented opportunities for a wide variety of scientific, industrial, agricultural, commercial and military applications, such as health care. smart transportation, emergency response, home automation, social studies, critical infrastructure protection, and target tracking, just to mention a few. In particular, wireless sensor and actuator networks are a key enabling technology for cyber-physical systems [6, 7], which will ultimately improve the quality of our lives.

3. WMSNS (WIRELESS MULTIMEDIA SENSOR NETWORKS) ARCHITECTURE

A typical WMSN architecture is depicted in Fig. 3, where users connect through the Internet and issue queries to a deployed sensor network. We introduce reference architecture for WMSNs, where three sensor networks with different characteristics are shown, possibly deployed in different physical locations. The first cloud on the left shows a single-tier network of homogeneous video sensors. A subset of the deployed sensors has higher processing capabilities, and is thus referred to as processing hubs. The union of the processing hubs constitutes a distributed processing architecture. The multimedia content gathered is relayed to a wireless gateway through a multi-hop path. The gateway is interconnected to a storage hub,that is in charge of storing multimedia content locally for subsequent retrieval. Clearly, more complex architectures for distributed storage can be implemented when allowed by the environment and the application needs, which may result in energy savings since by storing it locally, the multimedia content does not need to be wirelessly relayed to remote locations. The wireless gateway is also connected to a central link, which implements the software front-end for network querying and tasking. The second cloud represents a single-tiered clustered architecture of heterogeneous sensors (only one cluster is depicted). Video, audio, and scalar sensors relay data to a central cluster head, which is also in charge of performing intensive multimedia processing on the data (processing hub). The cluster head relays the gathered content to the wireless gateway and to the storage hub. The last cloud on the right represents a multi-tiered network, with heterogeneous sensors. Each tier is in charge of a subset of the functionalities. Resource-constrained, low-power scalar sensors are in charge of performing simpler tasks, such as detecting scalar physical measurements, while resource-rich, high-power devices are responsible for more complex tasks. Data processing and storage can be performed in a distributed fashion at each different tier 8].

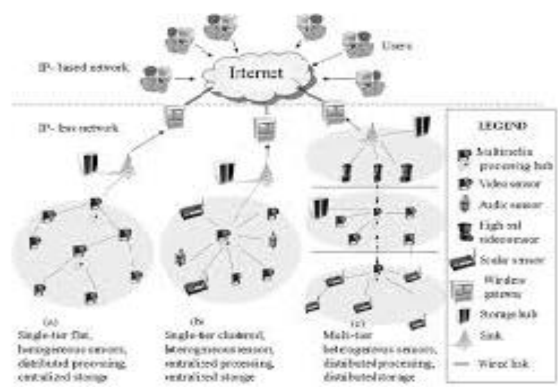

Fig. 2 Single-tier v/s multitier sensor deployment

One possible approach for designing a multimedia sensor application is to deploy homogeneous sensors and program each sensor to perform all possible application tasks. Such an approach yields a fiat, single-tier network of homogeneous sensor nodes. An alternative, multi-tier approach is to use heterogeneous elements [9]. In this approach, resource-constrained, low-power elements are in charge of performing simpler tasks, such as detecting scalar physical measurements, while resource rich, high-power devices take on more complex tasks. For instance, a surveillance application can rely on low-fidelity cameras or scalar acoustic sensors to perform motion or intrusion detection, while high-fidelity cameras can be woken up on-demand for object recognition and tracking. In [10], a multi-tier architecture is advocated for video sensor networks for surveillance applications. The architecture is based on multiple tiers of cameras with different functionalities, with the lower tier constituted of low-resolution imaging sensors, and the higher tier composed of high-end pan-tilt-zoom cameras. It is argued, and shown by means of experiments, that such architecture offers considerable advantages with respect to single-tier architecture in terms of scalability, lower cost, better coverage, higher functionality, and better reliability.

Coverage: In traditional WSNs, sensor nodes collect information from the environment within a predefined sensing range, i.e., a roughly circular area defined by the type of sensor being used. Multimedia sensors generally have larger sensing radii and are also sensitive to the direction of data acquisition. In particular, cameras can capture images, of objects or parts of regions that are not necessarily close to the camera itself. However, the image can obviously be captured only when there is an unobstructed line-of sight between the event and the sensor. Furthermore, each multimedia sensor/camera perceives the environment or the observed object from a different and unique viewpoint, given the different orientations and positions of the cameras relative to the observed event or region. In [11], a preliminary investigation of the coverage problem for video sensor networks is conducted. The concept of sensing range is replaced with the camera's field of view, i.e., the maximum volume visible from the camera. It is also shown how an algorithm designed for traditional sensor networks does not perform well with video sensors in terms of coverage preservation of the monitored area.

4. NETWORK CODING FOR MULTIMEDIA. STREAMING

A lot of attention has been devoted to applications such as peer-to-peer (P2P) and wireless mesh networks, in which peer nodes can self-organize in order to exploit more efficiently the network infrastructure. A significant advantage of these networks lies in the multiple paths and the multiple forwarding peers between servers and clients. The network diversity can be used to enhance the quality of service in video communication systems with increased bandwidth throughput or improved resilience to packet loss. However, this requires the development of appropriate streaming mechanisms, so that the network resources are exploited and redundancy avoided. In many cases, it has been found that optimal communication of information over networks requires the intermediate network nodes to perform coding operations. In particular, "network coding" (NC) [12] is a new paradigm that significantly innovates the prevalent model in which the role of intermediate network nodes is only to forward the incoming messages towards the appropriate destination. NC brings the main novelty of allowing "processing" of messages at each hop in the network. Each intermediate node is allowed to mix incoming messages and then to forward the combined packets towards the destination nodes. The encoding ensures that any destination node can receive with high probability enough combinations to recover the original messages. NC has been shown to generally improve throughput, achieving network capacity for single source multicasting. While most NC research has been carried out in the field of information theory, its potential benefits for media streaming applications have spurred a lot of interest in the multimedia community. NC multimedia applications however require to overcome the simplistic network models employed in information theory and to deal with the requirements specific to multimedia streaming, most notably the delay constraints.

5. BASIC CONCEPT OF NETWORK CODING

Network coding benefits can be exemplified through the two scenarios depicted in Fig. 3. The first one (Fig. 3-a) considers a multicast setting in which two sources SI and S2 want to transmit packets a and b, containing binary information symbols, to receivers X and Y. The intermediate node R does not simply relay a and b. Rather, it creates a new packet a XOR b and forwards it to X and Y. As a consequence, using only once the outgoing link of R, X can recover b as b = a XOR (a XOR b) and Y can similarly recover a. In a non-coded network R should have made two individual transmissions of a and b. Therefore, as can be seen, coding in the network allows increasing the throughput and reducing the delay and also the energy consumption. In the second example (Fig. 3b), wireless nodes X and Y in the range of a base station S. but cannot communicate directly; they want to exchange information packets a and b - First X sends a to S, and then Y sends b to S. The base station creates a new packet a XOR band broadcasts it to X and Y. As in the previous example, coding allows to save a transmission slot by sending only the "difference" information with respect to what already is in the buffer of each node. These two toy examples illustrate-the potential of coding operations in the network nodes.

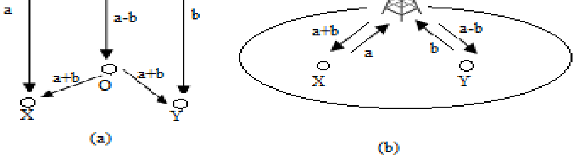

Fig. 3 (a) Multicast with two sources and two receivers (b) Wireless point-to-point communication

We now formalize NC by looking at the operation of a given node X of the network. We assume that X has M incoming and Q outgoing connections; for simplicity, we assume that each link can transport one packet per instant of the time scale and that nodes are able to perform linear coding operations. At a given instant, node X receives a set of M packets denoted as r j,j=1,2…..M, and combines them to produce Q output packets as

$\rho 1 = \sum_{j=1}^{M} \alpha j\ j\ rj$, l=1,……Q. This is a symbol by symbol linear combination of co-located symbols of all incoming packets using coefficients $^{\alpha j,j}$, with all operations performed on a finite field F of given size. That is, for every output link, a set of M coefficients are chosen and used to compute the symbol-by- symbol combinations. In general, the input packets are not I the original information packets, but packet combinations themselves. Therefore, each packet typically contains information about all original packets, but is not sufficient to decode any of them. Received packets are of the form

$rj = \sum_{i=1}^{N} \beta i, j\ pi$. That is, each of the M received packets are a linear combination, over finite field F, of the set of N original source packets pi. The final combination coefficients $^{\beta i,j}$ are assumed to be known, and depend on the various $^{\alpha jt,}$ that have been used by each intermediate node of the network. This can be conveniently written in matrix notation as r= Gp where r = $[r_1 \ldots.. r_M]^T$, p = $[p_1 \ldots pN]^T$ and G the matrix of coefficient $^{\beta i,j}$. The set of original packets can be recovered if G is invertible over F. information theoretic results have shown that NC can increase network throughput compared to traditional networks in both point-to-point and multicast scenarios. The linear NC scheme described above achieves network capacity for multicasting from a single source [13]. Linear coding is however not optimal in general communication settings, in particular when several sessions are transmitted jointly. While coefficients $^{\alpha j,j}$ can be chosen optimally when the network if fully characterized, they are in practice picked randomly from a uniform distribution over F. This has been shown [14] to be asymptotically optimal as the finite field size becomes large.NC principles have been used recently in multimedia streaming applications, targeting efficient resource allocation, increased throughput and resiliency to transmission errors. NC has been mostly applied in peer-to-peer or wireless broadcast scenarios, under different forms. Extensions have recently been proposed that account for the different packet importance in media streams. In a first attempt of pushing channel coding into network nodes, Reed- Solomon codes or digital fountain codes have been implemented in network-embedded FEC nodes [15] and in network peers [16]. Both schemes show that the network, throughput can be significantly improved with NC. However, in both cases, the packets are decoded and encoded in the network nodes, before transmission towards the streaming client. Decoding employed in information theory, and to deal with the requirements specific to multimedia streaming, most notably the delay constraints and re-coding operations in network nodes unfortunately augments the latency of the streaming system. A new streaming algorithm called R2 [17] incorporates random NC along with a random pushing algorithm to smooth the latency problems, and enable live peer-to-peer streaming. Alternatively, the latency could also be reduced by avoiding the decoding in the network nodes. Packet re-encoding with rate less codes has been proposed in [18], which has been shown to be robust to erroneous channel estimations, especially at high loss rates and with limited network diversity. NC has also been proposed as an efficient algorithm for multicasting multimedia streaming in overlay or peer-to peer networks [19-21], where it can take advantage of path diversity. The benefit of NC in such scenarios has been analyzed in, which shows that NC is very useful in peer to- peer networks, since it provides resiliency to network dynamics and leads to better bandwidth exploitation. Research has been also conducted in the application of NC to wireless broadcast scenarios. Once losses happen in this context, one could rapidly face a feedback implosion effect if all the receivers expect to receive missing packets by retransmission. NC has been shown to efficiently combat the implosion problem [22]. One of the important characteristics of multimedia data lies in the unequal importance of the packets with respect to the quality of the decoded information. Typically, the multimedia information is organized hierarchically by the source coding algorithm, such that it is crucial for the decoder to receive at least the most important packets. This property has to be included in the NC algorithm, in order to ensure an efficient use of the bandwidth resources, and maximize the quality of the decoded stream. The significance of each packets can be considered in the selection of the packet to be encoded in the network, as proposed in [23] and [24] for effective video streaming over wireless mesh networks or broadcasting from a WLAN access points, respectively. The construction of the network codes could also be optimized in order to prioritize the delivery of the most important video frames when the bandwidth or transmission energy is constrained [25].

6. APPLICATIONS

- Surveillance. Video and audio sensors will be used to enhance and complement existing surveillance systems against crime and terrorist attacks. Large scale networks of video sensors can extend the ability of law-enforcement agencies to monitor areas, public events, private properties, and borders. Multimedia sensors could infer and record potentially relevant activities (thefts, car accidents, traffic violations) and make video/audio streams or reports available for future query. Multimedia content such as video streams and still images, along with advanced signal processing techniques, will be used to locate missing persons or to identify criminals or terrorists.

- Traffic Monitoring and Enforcement. It will be possible to monitor car traffic in big cities or highways and deploy services that offer traffic routing advice to avoid congestion. Multimedia sensors may also monitor the flow of vehicular traffic on highways and retrieve aggregate information such as average speed and number of cars. Sensors could also detect violations and transmit video streams to law enforcement agencies to identify the violator, or buffer images and streams in case of accidents for subsequent accident scene analysis. In addition, smart parking advice systems based on WMSNs [26] will allow monitoring available parking spaces and provide drivers with automated parking advice, thus improving mobility in urban areas.

- Personal and Health Care. Multimedia sensor networks can be used to monitor and study the behaviour of elderly people as a means to identify the causes of illnesses that affect them such as dementia [27]. Networks of wearable or video and audio sensors can infer emergency situations and immediately connect elderly patients with remote assistance services or with relatives. Telemedicine sensor networks [28] can be integrated with third generation multimedia networks to provide ubiquitous health care services. The main features of the proposed "30 Mobile Telemedicine based on Sensor networks" are as follows:

1) We utilize the infrastructure of CDMA2000-based 3G wideband wireless cellular networks.

2) To implement 'communication anywhere', we assume a multi-layer hierarchical structure that includes the following cell-sizes: pico-cell, micro-cell, macro-cell and satellite-cell (Fig.l). A mobile user can use soft handoff to contact the base station with the strongest communication signal strength.

3) Sensor Telemedicine Networks are seamlessly integrated with the aforementioned 3G mobile networks. In the future telemedicine systems, patients will carry medical sensors that sense the health parameters, such as body temperature, blood pressure, pulse oxymetry, ECG, breathing activity, and so on. In addition, serious patients can also carry other sensors that help the medical centre carry out remote monitoring. Typical examples are location sensor, motion or activity sensor, microphone sensor, and camera sensor. Typically a patient will carry a wrist- device (called as super-sensor in this paper) with a stronger battery and higher memory compared to the other medical sensors, to perform multiple-hop ad hoc communication. Super-sensors will be used to collect sensing data from body sensors and communicate with other super-sensors. However, these tiny wrist- devices will not have as much power as today's cell phone, to perform two-way communication with the base stations. They therefore transmit data through multi-hop routing algorithm [E29].

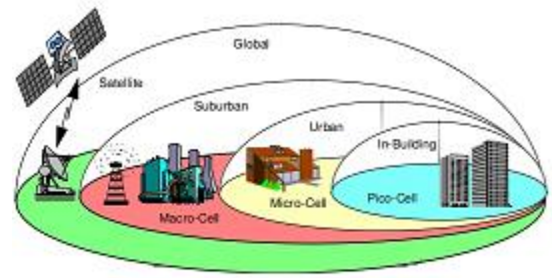

Fig.4 Hierarchical mobile network structure

1. Real-time calls from Ambulance Patients using the video (camera) sensors, 61'S system, and other advanced medical sensors to establish a rate-guaranteed connection with the medical centre. We treat them as "handoff-guaranteed" calls since we should reserve wireless bandwidth in the next cell to guarantee their on-going connections when they move through different cells. These calls are given the highest priority.

2. Handoff-prioritized calls from serum patients or elder people The serious patients can use a high-power back pack computer or medical cell phone (Fig.5) to perform two- way communication with the medical centre. We give the second highest priority to these calls when they need to hand over to a new cell.

3. Non-real-time calls from Cluster-heads who collect medical data from wrist-worn super sensors of average patients or normal people. These super sensors can aggregate all kinds of medical data and locally perform some preprocessing such as filtering and compression. Please note that they cannot communicate with the medical center directly since they do not have enough power. Actually they would "wake up" periodically or when urgent medical conditions, are detected by the body sensors. They could transmit data, using multi-hop communication, to the cluster-head who could be a cell-phone of a nearby person/patient or a specialized facility driving around and collecting medical data from these sensors, and then communicate with the medical centre. We provide their communication the best-effort services when the command centre sends out a query to a certain cell to collect medical data. These super-sensors utilize "ad hoc multi-hop transmissions" to relay query results[30].

- Gaming. Networked gaming is emerging as a popular recreational activity. WMSNs will find applications in future prototypes that enhance the effect of the game environment on the game player. As an example, virtual reality games that assimilate touch and sight inputs of the user as part of the player response [31], [32] need to return multimedia data under strict time constraints. In addition, WMSN application in gaming systems will be closely associated with sensor placement and the ease in which they can be carried on the person of the player. An interesting integration of online and physical gaming is seen in the game, Can You See Me Now (CYSMN) [33], wherein players logging onto an online server are pursued on a virtual representation of the streets of a city. The pursuers are real street players who are equipped with digital cameras, location identification, and communication equipment. The feedback from the devices on the body of the street players is used to mark their position and their perception of the environment The online players attempt to avoid detection by keeping at least 5m away from the true locations of the street players. The growing popularity of such games will undoubtedly propel WMSN research in the design and deployment of pervasive systems involving a rich interaction between the game players and the environment.

- Environmental and Industrial Several projects on habitat monitoring that use acoustic and video feeds are being envisaged, in which information has to be conveyed in a time-Critical fashion. For example, arrays of video sensors are already used by oceanographers to determine the evolution of sandbars via image processing techniques [34]. Multimedia content such as imaging, temperature, or pressure, among others, may be used for time critical industrial process control. For example, in quality control of manufacturing processes, final products are automatically inspected to find defects. In addition, machine vision systems can detect the position and orientation of parts of the product to be picked up by a robotic arm. The integration of machine vision systems with WMSNs can simplify and add flexibility to systems for visual inspections and automated actions that require high speed, high magnification, and continuous operation.

7. CONCLUSIONS

This motivated the need for experimental research on wireless multimedia sensor networks to provide credible performance evaluation of existing architecture for wireless multimedia sensor networks. NC is a new networking paradigm with many prospective streaming applications. Then, whave discussed and classified existing applications for wireless multimedia sensor networks. The local personal area network is scalable depending on the medical applications and the number of physiological sensors involved. And the communication between local personal server and remote hospital server uses commercially available 3G communication networks. However, there are several research problems that warrant further investigation.

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