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Visualization of Various Aspects of Wireless Multimedia Sensor Network: A Review

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Abstract: With technological advancements, real-time automation systems now require flawless data flow over wireless sensor networks. In the future, it appears that wireless sensor networks, or WSN, will cover the entire earth's surface. WSN currently plays a dominating role in the IoT for primary data gathering. But the focus now has shifted from typical scalar wireless sensors to Wireless Multimedia Sensor Networks (WMSNs), which consist of various multimedia devices that can extract scalar sensor data along with video, audio, and image data. WMSNs are designed to provide multimedia content due to the accessibility of low-cost CMOS cameras and microphones, as well as the substantial advancements in distributed signal processing and multimedia source coding techniques. This paper has been proposed to complete a thorough survey of WMSNs from different aspects. The detailed survey present in this work will be useful for researchers working in this area for future development in the given area.

Keywords: Wireless Multimedia Sensor Networks, Protocols, Medium Access Control, QoS.

1. Introduction

In today world, WSN has been emerging its applications in various files including plant monitoring, industrial automation systems, and farming automation etc. [1]. In all such application, it has been employed in order to measure, monitor and store the information related to real quantities such as atmospheric pressure, moisture, motion, humidity, vibration, light and temperature etc. In general, WSN comprises of big amount of sensor nodes that are installed at target places in order to form a network. Figure 1.1, given below has been showing a wireless sensor network.

But the research focus now has shifted from typical scalar wireless sensors to Wireless Multimedia Sensor Networks (WMSNs), which consist of various multimedia devices that can extract scalar sensor data along with video, audio, and image data. WMSNs are designed to provide multimedia content due to the accessibility of low-cost CMOS cameras and microphones, as well as the substantial advancements in distributed signal processing and multimedia source coding techniques.

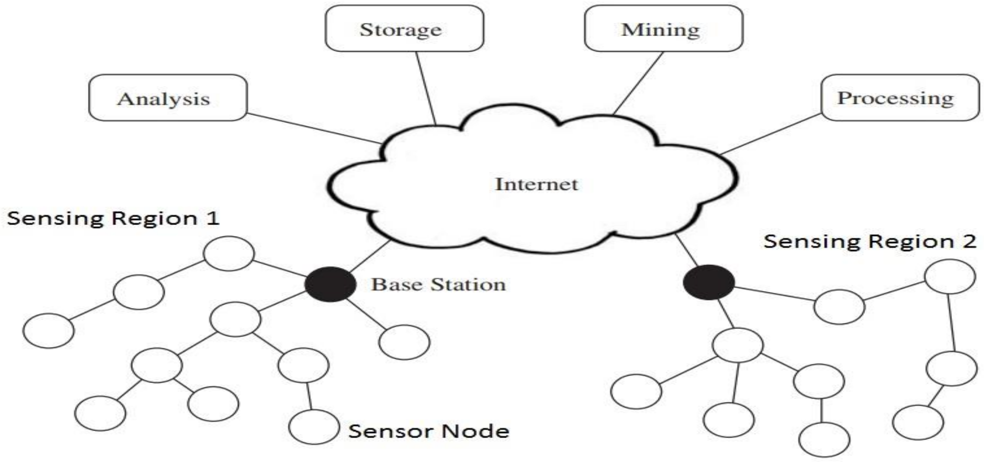

Figure 1: Structure of General WSN [2]

WMSNs hold promising responses for numerous potential applications in civilian and non-civilian (military contexts) areas that call for visual and aural data. For example, surveillance sensing devices, traffic control networks, systems for managing industrial processes, telemedicine, automated senior care, and improved delivery of health care, etc. Such applications can increase the amount of information collected, expanded coverage area, and offer multiple resolution views by integrating multimedia network.

Due to the inherent nature of real-time multimedia data, WMSNs have various specific properties as well as difficulties beyond those of general Wireless Sensor Networks (WSNs). All such specific properties include demands for higher bandwidth, real-time response, delay tolerance, and facing appropriate jitter and frame loss rates. In addition to this, because of the small physical sensor sizes and the demand of multimedia applications, which often create a large amount of data, WMSNs have several issues associated with them, such as energy constraints, bandwidth, throughput rate, storage, buffer size, and computational complexity, etc. Hence, the properties of WMSNs together with various aspects need to be visualised thoroughly in order to achieve the quality of service (QoS) standards and to use the network's finite resources in a fair and efficient manner.

With the same objective, the current work has been begin by reviewing recent publications that span every facet of WMSN research, including network architecture, communication layer stacks, cross-layer design, challenge issues including security and coverage, hardware etc.

2. Architecture of WMSN

A major challenge while designing a wireless multimedia sensor network is creating a scalable network. The majority of wireless sensor networks that have been designed conventionally are built on a flat, homogenous architecture in which each and every sensor has the same physical capabilities and can only communicate with other sensors that are nearby. But when it comes to having to deal with the volume of traffic produced by multimedia applications like audio and video, flat topologies may not always be the best choice. Similarly, not all nodes may have the processing capacity needed for data processing and communications, as well as the power needed to run them.

Figure 1, given below represents reference architecture for WMSN. In figure 1 three sensor networks with various features are displayed and may be installed in various places.

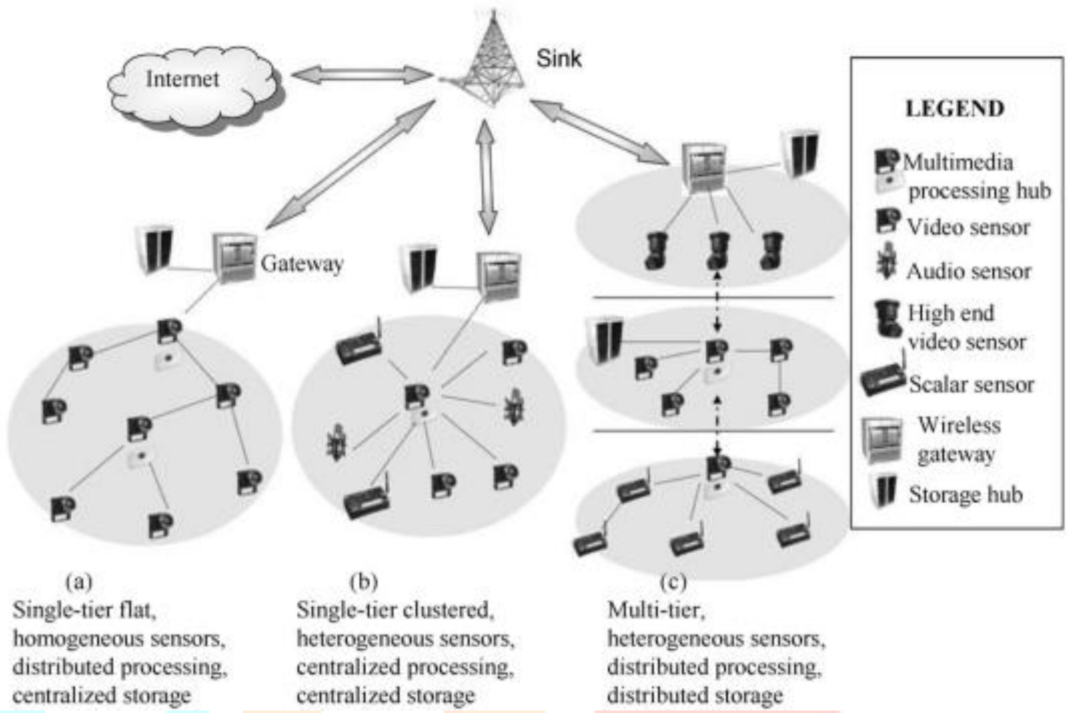

Figure 1: Reference Architecture of WMSN [3]

A single-tier network of uniform video sensors may be seen in the first cloud from the left. Processing hubs are a subset of the distributed sensors that have more powerful processing abilities. A distributed processing architecture is made up of the processing hubs combined. A multi-hop path is used to transmit the acquired multimedia data to a wireless gateway. The storage hub, which is responsible for storing multimedia information locally for later retrieval, is connected to the gateway. A network of more complex nature can be developed when the context and the technology permit.

Architecture for WMSN can be of single tier or multi tier network. A flat, single-tier network of uniform sensor nodes is deploying homogenous sensors and programming each sensor to carry out every potential application function. On the other hand, multi tier network is an approach consisting of heterogeneous elements [4]. This method assigns easier jobs, like sensing scalar physical measurements, to resource-constrained, limited-power elements, whereas more difficult tasks are handled by resource-rich, high-power components. For example [5] promotes a multi-tier framework for video sensing devices for use in surveillance systems. The system developed in this is built on a hierarchy of functionally distinct camera tiers, including low-resolution image sensors making up the lower tier and greater pan-tilt-zoom cameras making up the upper tier.

The radius of sense around multimedia sensors is often bigger, and they are also responsive to the orientation of data collection. In particular, cameras in WMSN are capable of taking pictures of things or areas that are not immediately in front of the device. Nevertheless, it is obvious that the picture can only be taken when there is a clear sight line seen between the incident and the sensor. In addition to this, in WMSN, the various angles and placements of the cameras in relation to the event of interest or area also observe the surroundings or the viewed thing from a unique and distinct viewpoint. For example a rough estimate of the coverage issue for video sensor networks is done in [6]. The camera's scope of view, or the largest area that can be seen from the camera, takes the role of the sensor field. Additionally, it is demonstrated how a video sensor-based algorithm created for traditional sensor networks struggles to maintain penetration of the observed region.

3. Layers description of WMSN

In this section, various layers and their descriptions have been given for WMSN.

3.1 WMSN's physical layer

The Physical Layer in WMSNs describes how to send raw bits over the wireless link interconnecting the entire network instead of logical packets of data. The layer has been made of the fundamental hardware communication system of a network. Additionally, it is in charge of modulating, channel encoding, and frequency selection. The physical layer in WMSNs should be developed so that it supports all activities related to higher-layer communication and adheres to the unique specifications and features of WMSNs. Depending on the modulation technique and bandwidth considerations, physical layer technologies can be divided into three groups. These three groups of physical layers are Narrow band based physical layers, Spread spectrum based physical layers, and Ultra-Wide band (UWB) based physical layers [7].

Further it can also be classified based on various standard protocols such as IEEE 802.15.1 Bluetooth, IEEE 802.11WiFi, 802.15.3a UWB Zig- Bee and IEEE 802.15.4 ZigBee etc[8]. For wireless connection in WMSN, Bluetooth has been used in [9] [10], although WiFi has been used with Stargate devices in numerous applications as well.

As compared to the narrow band based physical layers and spread spectrum based physical layers, the strategy of Ultra-Wide band (UWB) based physical layers has the ability to facilitate low energy consumption, greater throughput rate, short-range wireless communication, and has carrying potential candidature to the physical layer standard of WMSN if it is designed with a coding efficiency of around 97.94% and a throughput rate of up to 250 Mbps for a nominal range of 10 meters along with its immunity to multipath propagation and precise positioning capabilities [11][12].

Further in order to increase the system's capacity and to reduce the system's degradation multi-antenna systems, such as antennas diversity, smart antenna, and MIMO systems, can be used with UWB. Short-range networks with multiple gigabit rates might be possible when used in conjunction with multiple antenna techniques like MIMO systems because of UWB's practically impulse-like channel response. These physical-layer techniques must address a number of challenging problems before they can be developed for WMSNs. Despite the fact that UWB has a number of enticing features and appears to be a potential alternative physical layer technology, it is still in its infancy and has a lot of issues that need to be resolved and are not fully understood.

3.2 WMSN's MAC Layer

In WSN, the development of extremely effective and trustworthy medium access (MAC) protocols is crucial. Conventionally, the objective was to offer adequate data transmission at the lowest possible energy cost under a modest network load state. A cursory examination of the existing MAC protocols for WSNs, as reviewed in [13], demonstrates that WSNs are currently without a single de-facto standard MAC protocol due to a lack of standardization and application-specific unique requirements.

MAC is crucial to synchronizing channel access between competing devices in WMSNs. The Mac protocol should be dependable, error-free transfer of data with a minimal level of retransmissions while meeting the QoS requirements with effective resource utilization given the energy constraints of the small, battery-powered sensor devices.

3.3 WMSN's routing layer

In WSN, the routing layer's goal is to transmit detected information from the sources to a sink node while taking into consideration a number of design factors, including scalability, fault tolerance, energy efficiency, and link quality. The routing layer's design for WMSN remains an active research area even though numerous routing methods for the standard WSN have been proposed.

In WMSN, to satisfy the area-specific service quality needs and network circumstances, the multimodal nature of the information retrieved imposes additional constraints on the design of the routing protocols. Numerous routing protocols have been developed previously, such as [14]'s proposed Ant-based Service-aware Routing Algorithm (ASAR). This is a wireless multimedia sensor network QoS routing model that selects the best paths for various QoS criteria from various types of services. Similarly, [15] has proposed Two-Phase Greedy Forwarding (TPGF), a technique that is basically a geographic routing approach.

Further, having a small count of mobile swarms deployed, the study in [16] suggested using the landmark ad hoc routing protocol (LANMAR). In this, the network is divided into groups, and each group includes a landmark node that is dynamically elected. The suggested non-interfering disjoint multipath routing for WMSN has been proposed by [17]. Other than this various routing methods such as Direct Diffusion [18], Improved Adaptive Routing (M-IAR) [19] etc has been also present in state of art.

3.4 WMSN's Transport Layer

In order to allow an end-to-end communication process, a set of protocols known as the transport layer are applied over the network layer. Many services, including same-day delivery, data dependability and loss restoration, flow and congestion control, and possibly Qos, is provided by this layer. Examples of common transport protocols presently used on the Internet include TCP and UDP. These traditional transport protocols, however, cannot be used in a wireless sensor network [20][21] as WSNs in general, and WMSNs in particular, have distinct characteristics that distinguish them from traditional Internet networks and a wide range of applications that necessitate specialized criteria.

3.5 WMSN's application layer

The WMSN application layer offers a variety of functions and supports a wide range of services, including multimedia processing and source coding methods that rely on the hardware's capabilities and needs for a certain application, strong network connectivity with other application programmes to support in-network multimedia processing techniques for collaboration and admissions and traffic control etc.

The application layer in WMSNs allows multimedia coding methods that adhere to the hardware-posed limitations and application-specific needs. Since multimedia data is by its very nature, source code ought to be simple and highly compressible without lowering the application quality of service. Less complexity allows for more energy-efficient source code design. These programmers' ability to reliably interact over unreliable links is another important characteristic. Numerous methods, such as intra-or interframe, also known as predictive coding or motion estimation methods, are sophisticated in nature and inefficient in terms of power [22]. Another suggestion [23] is to move the difficulty from the node end to the sink end. This method, known as Wyner-Ziv coding, is a part of dispersed source coding and produces results that are comparable to those of predictive motion estimation, which uses complicated encoders at the node's end.

3.3 Technical challenge to WMSN

Throughout this section, various technological difficulties faced by WMSNs has been discussed. It has been observed that the layout of video sensor networks is influenced by a variety of factors, including the need for QoS, flexible and scalable configurations and protocols to support heterogeneous requirements, fast broadband demand, localized data processing and fusion, energy efficiency, serviceability, and incorporation with IP and numerous other wireless devices.

3.3.1 QoS

Meeting the QoS constraints unique to each application is one of the WMSN's design's most significant challenges. The WMSNs are made to handle a wide range of application situations, from straightforward scalar operations to multi-tier support incorporating heterogeneous sensors and support for multimedia sensors in addition to scalar sensor usage. In the first scenario, capacity is not a significant problem and can be readily managed while adhering to application-specific QoS criteria. The incorporation of multimedia content, such as snapshots (event-based) or video streaming (potentially extended duration) in the latter situation, however, may place stringent restrictions on QoS needed in addition to the high bandwidth demand. In order to achieve the application-specific QoS requirements, this necessitates proper cooperation between the application-specific algorithms and protocols of the communication protocol layers.

3.3.2 Bandwidth

The bandwidth needed for multimedia data communication in WMSNs is a magnitude of more than that needed for the current WSNs. For instance, the scalar WSN design using TelosB or Micaz, among other motes, offers the Zigbee/802.15.4 radio protocol, which allows for a maximum data rate of 250Kbps.

3.3.4 Processing and data fusion

In WMSNs, sending multimedia data demands a lot of bandwidth, and sending it unprocessed would result in an extremely high operational cost. Due to this, network computing became necessary. Due to the WMSN node's great computing capacity, efficient application-level multimedia processing and data fusion methods may help to both minimize communication costs as well as meet the fast broadband requirement. Therefore, the concept of distributed coding that uses basic encoders appears viable for energy-constrained WMSNs instead of employing the more complicated and energy-intensive standard predictive encoders [25-26].

3.3.5 Energy Efficient

WMSNs are thought to operate under stricter power constraints than conventional WSNs. The most energy-intensive operations in WMSNs are the techniques for analysing multimedia information and their rapid communication. To maximise network life while adhering to framework QoS requirements, this necessitates the creation of energy-aware multimedia processing algorithms [27].

Other than the various technological challenges in WMSN, there is various security challenges associated with WMSNs. A literature review on the same has been integrated in the next section.

3.4 Security issues associated with WMSN

In this section, various issues associated with WMSN security and challenges have been reviewed along with the latest solution provided. In WMSN, data gathered from the target region is not just scalar in form, such as heat, lighting, pressure, moisture, and seismology, but also more complex, such as image and streaming video data. As a result, computation energy instead of communication energy dominates the power dissipation in multimedia sensor nodes.

The author in [28] performed an assessment and analysis of the various security concerns that must be taken into consideration when designing the platforms and protocol for WMSNs. [29] gives a summary of the key conclusions on secure WMSNs and predicts the potential of this technology in the near future.

In this work, the four major security issues such as Quality of Service (QoS) and authentication, node localization have been considered for the review for it latest solution.

Table 1 given below has been demonstrating the various security issues along with their solution.

Table 1: Reviewed article on security challenges

Reference no	Year	Author	Type of security issues	Proposed Approach	Results
[30]	2013	Hamid and Bashir	Quality of service	XL-WMSN: (cross-layer QoS protocol	Simulation investigation demonstrates that XL-WMSN is more effective than existing alternatives and enhances the likelihood of providing multimedia information before the date specified.
[31]	2015	Magaia et al.	Quality of service	Multi-objective technique to routing problem	Simulation has shown that the delay has been reduced.
[32]	2018	Nguyen et al.	Quality of service	Reinforcement learning	The suggested eqCC is contrasted to Flush,

					another congestion management technique for Wireless Sensor Networks, and standard TCP as well as being validated through simulations (WSN). The outcomes demonstrate how eqCC beats the competition in both high and low network demand scenarios.
[33]	2018	Wu et al.	authentication	Two three-factor user authentication schemes	The findings show that the proposed strategy is reliable enough to guard against numerous security flaws.
[34]	2019	Trinh et al.	Quality of service	Multi-path TCP	The effectiveness of eqCCMP is assessed in relation to other methods, such as the standard MPTCP and ecMTCP. The suggested eqCCMP surpasses the alternative solutions in a simulation setting in terms of capacity and energy efficiency by taking an additional element into account for congestion window adjustment during the congestion control phase.
[35]	2021	Benmansour,	Quality of	Swarm	The idea is to offer the

		and Labraoui	service	Intelligence-Based Routing Protocols	best route options. In this study, a details on how to establish and construct smart routes to satisfy applications that take into account QoS.
[36]	2021	Goyat et al	Authentication	Blockchain technology	The proposed method has been gives more accuracte localization accuracy and detection of malicious activities.
[37]	2022	Priyanka and Reddy	Authentication	Greedy algorithm	For safe wireless sensor network localization and routing (WSN), an intrusion protection architecture is offered. The proposed method has promote data dependability, prolong network life, and safeguard the network against malicious attacks.

Conclusion

A detailed review of various aspects of wireless multimedia sensor networks has been given in this paper given in this paper. The detailed review has demonstrated the reference article framework, layer descriptions,, technical as well as security challenges in wireless multimedia sensor networks have been given. It has been discovered that there are numerous design restrictions when designing wireless multimedia sensor networks. Due to the nature of real-time multimedia content, WMSNs additionally face additional features and difficulties, such as high bandwidth demands, real-time transmission, acceptable end-to-end delays, and appropriate jitter and frame loss rates. In addition to this, due to the tiny size of the sensor and the nature of the multimedia application, which often produces a large quantity of data, WMSNs have several distinct resource constraints concerning energy, bandwidth, throughput rate, etc. Other than this there are numerous security issues associated with WMSN for which various solutions have solutions have been reviewed in this article.

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