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RESEARCH ARTICLE

A SURVEY ON DATA FUSION AND AGGREGATION TECHNOLOGIES OF WIRELESS MULTIMEDIA SENSOR NETWORKS

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ABSTRACT

The availability of CMOS cameras and microphones of cheaper costs have lead in processing multimedia information along with regular scalar information in wireless sensor networks. In collaborative in-network processing especially in the application layer of wireless multimedia sensor networks (WMSN) , there exists data redundancy problem while gathering the information by neighbouring nodes, which can be overcome by using data fusion and aggregation technologies. The present study concentrated in providing the state of the art in data fusion and aggregation technologies of WMSN.

INTRODUCTION

The attention of research community for a long time now has been towards wireless sensor networks (WSN) which has a wide range of applications such as environment monitoring, industrial process control, millitary survillience, health care, traffic control and so on.Due to the advancement in micro electro mechanical systems(MEMS), the availability of CMOS cameras and microphones at low costs have lead in processing of multimedia information along with regular scalar information .Information in the form of audio, video and image constitute multimedia information. In wireless multimedia sensor networks (WMSN) , the parameters for processing multimedia information such as energy consumption, bandwidth requirement, throughput, delay, jitter etc., vary widely. Sensors are relatively smaller devices with low battery capacity and low bandwidth supporting characterstics and multimedia information processing is relatively larger than scalar data to be processed, which opens wide range of research challenges. One of the major aspects in processing the multimedia data is the data redundancy problem at the time of gathering information by neighbouring nodes, which can be overcome by using data fusion and aggregation technologies. As WMSNs are costlier than WSNs, wastage of data resources should be avoided and it should be made more reusable. Hence WMSNs should be of data-centric approach.Figure 1 shows three steps i.e., Acquistion of Data, In-network Processing of data and transmission of data for data aggregation.In the in-network processing of data section, different techniques and algorithms for data fusion are discussed. This paper concentrated on investigating current research in data fusion and aggregation technologies. Network architectures for WMSNs are discussed in section 2 of the paper, Acquisition of data is discussed in section 3, processing of data is discussed in section 4, Transmission of data is discussed in section 5 and in section 6 final conclusion is presented. Even though there are a few papers available in data aggregation technologies, in this paper we try to discuss the updated information about the new algorithms proposed for data fusion and aggregation technologies.

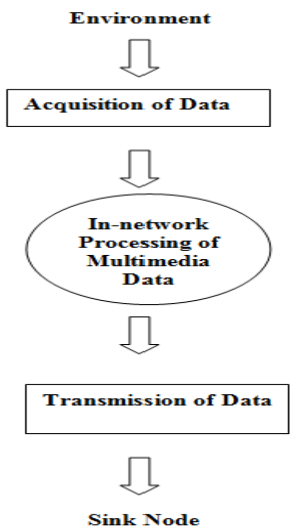

Fig. 1: Data Aggregation

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Network architectures for WMSN

In [1], three types of architectures for WMSN are discussed.They are:

1. Single-tier flat architecture
2. Single-tier clustered architechture
3. Multi-tier architechture

Figure 2 shows the three types of architectures.

Single-tier flat architecture

In Single-tier flat architecture, homogenous sensor nodes of similar functionalities and capabilities are deployed. In this architecture all nodes on multihop basis can perform all functions from acquisition of data, in-network processing to transmission of data towards sink.

Single-tier clustered architecture

In Single-tier clustered architecture, heterogenous sensor nodes such as scalar, audio and camera sensors are deployed which acquires data within each cluster and transmits it to cluster head. The cluster head which has more resources performs intensive data processing.

Multi-tier architecture

In Multi-tier architecture, heterogenous sensor nodes are deployed at different tiers. In the first tier, scalar sensors which perform motion detection are deployed; in the second tier, camera sensors that can perform object detection/ recognition may be deployed and in the third tier, more sophesticated cameras of high resolution that are capable of performing complex tasks like object tracking are deployed.

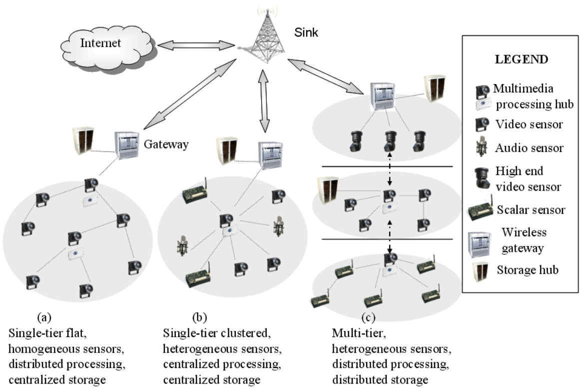


Fig. 2: WMSN Architecture (Courtesy Google Images)

(a) Single-tier flat Architecture
(b) Clustered Architecture
(C) Multi-tier Architecture

Acquisition of data in WMSN

In the acquisition of data, the sensors deployed should cover all the hot spots and all kinds of useful data need to be sensed.So, in data acquisition coverage becomes a key problem.Using appropriate architechure and algorithm, coverage problem can be solved and needed information can be acquired using less energy.In [2], the coverage problem in Video sensor networks has been preliminarily investigated.The camera's field of view (FOV) has replaced the concept of sensing range i.e., the maximum area that can be covered by the camera. In [3], Maximum Directional Area Coverage (MDAC) problem to maximize covered area by scheduling the working directions of the sensors in the network is proposed.Also distributed greedy algorithm is presented to deal with NP-Complete problem.In [4], rotatable directional sensing model is considered to estimate the amount of directional nodes for a given coverage rate.To divide a directional sensor in network into several parts in distributed environment Sensing Connected Sub Graph (SCSG). The coverage enhancing algorithm minimizes the overlapping sensing area of directional sensors only with local topology information. In the above said articles , directional sensors are deployed randomly in the sensor field, and the main concern is to organise the direction of the sensors.But, the deployment of visual sensors also need to be considered.In [5], to solve the directional sensor problem in 2D-direction a Integer Linear Programming model is proposed.

Processing of data in WMSN

Processing the acquired data is a very important phase. WMSN has certain other characteristics from that of traditional WSN such as: Larger data capacity, limitation on computation, storage, energy and quality of service during transmission. Hence collaborative in-network processing of redundant data is required in order to overcome redundancy. The amount of data which has to be transmitted is decreased by using different source coding techniques and algorithms.

In-network processing of data in WMSN

In WMSN, collected sensory data has relatively high redundancy and hence many WMSN applications use multimedia processing, such as feature extraction, data compression, data fusion and aggregation to decrease the amount of data while keeping important information. Reliability against packet loss becomes an issue in WMSN especially if these contain important original data such as Region of Interest (ROI).In order to perform the in-network functionalities with less execution time and minimum energy consumption. It is important to have efficient querring and distributed filtering in the in-network processing architectures.It is also necessary to develop algorithms that efficiently perform data fusion or other complex processing operations in-network. In [6], Internet – scale Resource-Intensive Sensor Network (IrisNET), a distributed filtering architecture for wide area sensor enriched services that supports scalable data collection from high bit-rate multimedia sensors by greatly reducing the bandwidth demands is proposed. The architecture makes a number of novel contributions. First, it enables the use of application-specific filtering of sensor feeds near their sources and provides interfaces that simplify the programming and manipulation of these widely distributed filters. Second, its sensor feed processing API, when used by multiple different services running on the same machine, automatically and transparently detects repeated computations among the services and eliminates as much of the redundancy as possible within the soft real-time constraints of the services. Third, IRISNET distinguishes trusted and untrusted services, and provides mechanisms to hide sensitive sensor data from untrusted services. In [7], a collaborative hybrid classifier learning algorithm is proposed to achieve online vector machine learning for target classification in WMSN. Distributed computing paradigm for in-network multimedia processing in each cluster, and peer-to-peer paradigm between the cluster heads is used in this algorithm. The collaborative hybrid classifier learning algorithm can effectively implement target classification in WMSN, and the ant colony optimization based routing and clustering method can largely decrease the energy consumption and time cost. In [8], an image recognition scheme called as Artificial Immune System (AIS) is proposed. The AIS algorithm within an environment of low cost computing and efficient data transmission among the wireless sensor nodes proposes an innovative approach for dimesion reduction,also a sleep control algorithm is proposed to reduce the image redundancies in order to achieve energy efficiency while guaranteeing the object recognition success rate in dynamic WMSN topology.

In [9], a Guassian Process classifier(GPC) is used for target classification. To improve the robustness and accuracy, it also proposes to fuse the local decisions of multiple sensor nodes running GPCs with different kernel functions, where committee based hybrid decision fusion strategy is employed to combine the local decisions with dynamically adjusted weights. The committee decision based hybrid decision fusion strategy can reduce the impact of the uncertainty of classification and improve the overall performance. In [10], a multi-agent architecture is used in structuring the process of fusing data in large networks of information sources. This model is based on the notion of negotiated cooperation between pairs of autonomous sensor agents. The sensor agents may communicate with each other , thus enabling them to fuse the information that they acquired.

Data association in video sensors

The Field of View (FOV) of each video sensors are restricted to certain range. At times, situations may arise such that the FOV of one video sensor does not overlap with the other. Hence during survilliance certain area may not be covered by any video sensors.Based on FOV, data association in video sensors can be categorised as FOV of video sensors overlapping and FOV of video sensors not overlapping.

FOV of video sensors overlapping

When Video sensor nodes are deployed densely, FOV of sensors overlap. In this situation shape recovery and image registration becomes a major concern. In [11], 2D view or 3D representation of images of same scene acquired with different view points is dealt with technology of image registration.
The registration method consists of feature detection, feature matching, transform model estimation and image resampling. As the FOV of different video sensors overlap implementation of image registration on parallel architecures of sensors to produce single data set is suggested. In [12], a method of partitioning the sensing task among highly correlated sensors and image fusion algorithm based on epipolar line is suggested to reduce the workload for each individual sensors.

FOV of video sensors not overlapping

Video sensors consists of appearence features like colour , outline etc., and time and space features. The appearence of object in one camera view is usually very different from its appearence in another camera view due to the differences in camera parameters. The above said problem can be stated as multi aspect target detection problem. To overcome the above said problem many data assosiative algorithms have been suggested. In [13] and [14], Baysean methodology has been suggested that enables direct tracking of objects from image sequences, eleminating any single frame image correlation or pattern recognition step and integrating detection and tracking.

Transmission of data in WMSN

In WMSN, once the data is acquired and processed, the processed data has to be transmitted to the sink node. The main concern at the transmission time is minimum energy consumption to ensure longivity of battery life. Hence routing algorithms need to be considered for shortest path and minimum muti hops in WMSNs. Secondly, reliability and security is also important during transmission of data.

Routing in WMSN

In WMSN, routing algorithm plays a very important role . Routing in WMSN can be of two types. They are traditional client/server computing mode and mobile agent mode.In client/server computing mode, service oriented sensor acctuator network (SOSANT) is described [15].To avoid aimless routing many heterogenous sensor nodes exists in SOSANT to provide different services, so that service oriented querry message should know exactly which node provides the service. For mobile agent mode in [16] , routing mechanism takes remaining energy of next node and the direction in which the target is moving into consideration.In [17], an assumption is made such that the sink node moves through the target area by sending several mobile agents called as TinyBees to gather data. In [18], cluster control algorithm is suggested for multilayered architecture where cluster head election method and multimedia data transmission in clusters are discussed

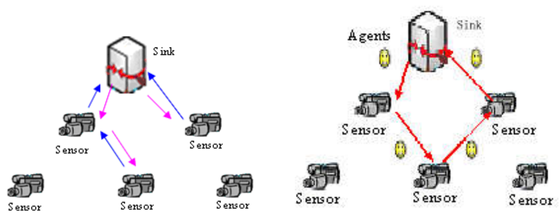
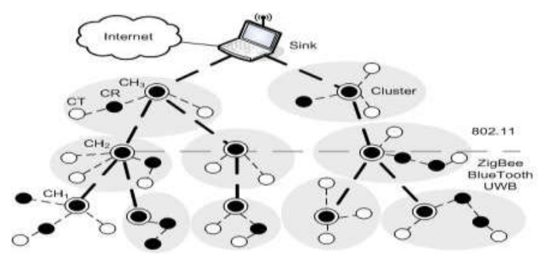


Fig. 3: Routing Mechanisms in WMSN
[a] Client-Server Mode [b] Agent Mode



[c] Cluster Mode
(Courtesy Google Images)

***Quality of service and security of data in* WMSN**

It is very important to develop effective security algorithms to protect multimedia information from attacks such as piracy, tampering, forgery and evesdropping. In [19], a video sensor survillience system requires in-network processing techniques to reduce the amount of information flowing in the network. At the aggregation point of incoming streams, the packets would have to be completely decoded and thus the computational complexity of security algorithms must be low to allow real-time processing.

CONCLUSION

WMSN when compared with wirless sensor networks pose many research challenges. As the data that has to be acquired, processed and transmitted are multimedia data, data redundancy should not occur. Hence to over come this problem different data fusion and aggregation techniques have been discussed in this paper. We believe that advancement in data fusion and aggregation technologies will lead to lot of new applications in WMSN and also the present study will throw light on the recent developments and trends in this area.

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