Agent based Video Fusion in Wireless Multimedia Sensor Networks

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***Abstract*—Wireless Sensor Networks (WSN) has several limitations, which may not support information communication because of energy constraints. Information sensed by the sensor nodes in WSN is scalar, which can't be used in some of the applications involving video surveillance like traffic monitoring, defense applications, seashore monitoring, etc. To overcome these limitations, Wireless Multimedia Sensor Networks (WMSN) which consists of video sensors can be used for such applications. As WMSN supports sensing of videos, the amount of data to be transmitted wirelessly in multihop communication raises a challenge. To overcome this issue, this paper proposes an agent based video fusion in Wireless Multimedia Sensor Networks. The video sensors transmit sensed videos to the respective cluster head node. Cluster head node exploits the spatial and temporal redundancy using multi sensor video fusion using wavelet transform. Fused video is in turn transmitted to sink node using multi-hop communication. To evaluate the performance of the proposed scheme, this work is simulated using MATLAB.**

***Keywords*— Wireless Multimedia Sensor Networks (WMSN), Software Agent, Video Fusion**

I. INTRODUCTION

WSN comprises of group of sensor nodes that sense scalar data. Wireless multimedia sensor network (WMSN) is a network of sensor nodes enabled with multimedia devices such as microphone and camera that can sense multimedia data and communicate the same on multi-hop basis. Multimedia information consists of various forms of information such as audio, video, still images, scalar data. WMSN enable a wide range of surveillance applications such as health care monitoring, assisted living, smart home, infrastructure monitoring, environment monitoring, precision farming, vehicle monitoring, sea shore monitoring, etc. The characteristics of WMSN are: it is distributed in nature due to the geographical range of deployment, collaborative that comprises of redundant data, self-organized, application specific, which requires in-network processing of information. It is mainly resource constrained as it has limited bandwidth, memory, power source and computing capabilities.

The availability of low cost CMOS camera enabled sensors has led to WMSN. The amount of data generated by video sensor is much higher than all other types of sensors. Video can be considered as continuous form of image data called as video frames. Videos collected by video sensors are rich in information and are of complicated forms. It cannot be processed by means of recognition, compression, fusion, etc. in order to meet the requirements of diverse applications. Some of the constraints of WMSN are: (1) Energy conservation: Battery change cannot be allowed due to the environment in which, video sensor nodes have been deployed and its energy consumption is relatively high when compared to other sensor nodes. (2) Deployment and coverage: In order to have reliable monitoring, deployment of video sensor nodes and optimization of its coverage is very much essential. (3) Real-time transmission: Video information has high requirements of delay and synchronization for real-time transmission. Hence video sensors should be enabled with strong media transmission capabilities. (4) Storing and searching: Sensor nodes in WMSN continuously perceive and collect information from the environment. Information so collected is very huge for storage as WMSN is memory constrained. Searching for interested information from the collected massive data is great challenge due to computing capability constraints.
The information sensed by multimedia sensors, especially the videos are huge to be transmitted in raw form over the WMSN as it consumes more energy and the bandwidth in sensor nodes. Video fusion should be considered in order to overcome this issue in WMSN.

Agents are software programs, which can be employed for information fusion to prolong the network lifetime by identifying the redundancy in information and aggregation. It is very much essential to use agent technology in WMSN as they can potentially reduce bandwidth consumption by moving the data processing elements to the location of the sensed data. Transmission of raw data would be costly with respect to energy consumption by the sensor nodes in WMSN. Large amounts of data are collected by multimedia sensors and the same must be disseminated to the sink.

A. Related Works

The applications of tiny sensor nodes capable of sensing the environment it is deployed in, along with the review of factors influencing the design of these sensor networks, communication architecture, algorithms and protocols developed for each layer in the literature is discussed in [1]. Sensor network paradigm to enable delivery of multimedia content, such as audio and video streams and still images, as well as scalar data, resulting in distributed, networked systems, referred to as wireless multimedia sensor networks (WMSNs) are discussed in [2]. In [3], a method for cooperative video processing in video sensor networks based on senor correlations is discussed. Scalable, low-power video sensor networking technologies is given in [4] and [5]. The suitability of a feature-level based video fusion technique that overcomes the drawback of pixel-based fusion techniques for object detection is explained in [6]. Mobile agent systems employ migrating codes to facilitate flexible application re-tasking, local processing, and collaborative signal and information processing in wireless sensor networks is given in [7]. In [8], author focuses on the challenges involved in supporting fusion applications in wireless ad-hoc sensor networks (WASN). In [9], filtered frames from the captured video are fused into a single video by using the video fusion technique, which is based on the quality assessment in spatial domain. The temporal continuity in an iris video to improve matching performance using signal-level fusion from multiple frames of a liris video, to create a single average image is discussed in [10]. To overcome the limitations in WMSN this work proposes the agent based video fusion in WMSN.

B. *Our Contributions*

This work proposes an agent based scheme for video fusion in WMSN. The proposed scheme works as follows: (1) Video information sensed periodically by the video sensors is updated to the video node black board. (2) Cluster head initiates the clones of video migration agent which is used to collect the sensed video from the video sensor node and fuse the video with the previously collected video from the previous node visited, before returning back to the cluster head in the assigned path. (3) Cluster head processes all the videos received from VMA of various paths. A single video which provides the information of the whole scenario is then transmitted to the sink node. (4) Sink node interprets the scenario and takes necessary action.

The rest of the paper is organized as follows: Section II presents video fusion in WMSN. Section III explains agent technology for video fusion. Section IV gives details of simulation model and Section V discusses the results. Finally Section VI concludes the paper.

II. VIDEO FUSION IN WMSN

This section presents the network environment, Video fusion scheme at node level and cluster head level.

A. *Network Environment*

Figure 1 shows the network environment. Video sensor nodes are randomly deployed in predefined area. Each node has capability to capture the video periodically. Every node self organizes to connect in WMSN, which forms the cluster and in turn communicate to the sink node using multihop communication. Each video sensor node has full energy at the time of deployment

Every sensor node is enabled with agent platform. Each agent has its responsibilities and coordinates with each other for processing the video and communicates the same with sink node. Static agents that reside in sensor node assist in processing and communication. Mobile agents migrate from one node to the other for transmission of the processed video to the sink node.

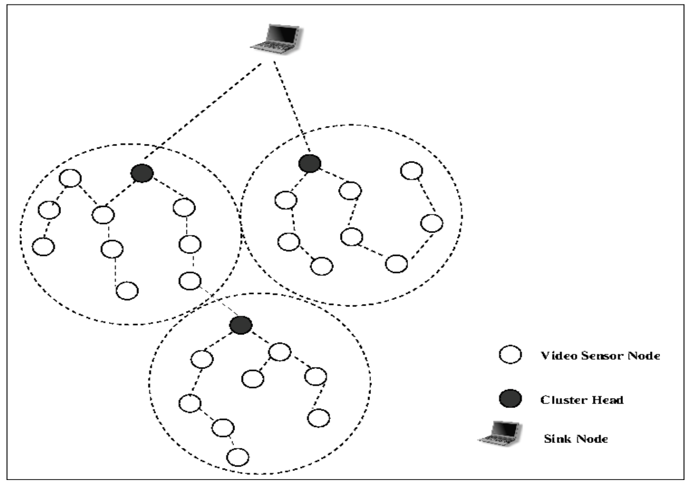

Fig. 1 Network Environment

B. *Video Fusion Scheme*

WMSN sends the sensed videos to the cluster head through the intermittent nodes. While transmitting from one node to the other node in the path, mobile agent gets the video from the current node and fuses it with the existing video before migrating to the next node. It continues till it reaches the cluster head. The videos collected in the cluster head are fused to integrate to a single video so as to give a complete view of the scenario, which in turn consumes less energy and bandwidth while transmitting from cluster head to sink node.

1. *Video Fusion at Sensor Node Level*

Every videos sensor nodes deployed in WMSN records the video for the specified interval of time‘t’. Let VS_1, VS2, VS_3, ……..VS_n, be video sensor nodes deployed in WMSN. Let F_1, F_2, F_3…F_n be the video frames of the respective video sensor nodes as shown in figure 2. Neighbor sensor nodes have highly correlated data due to the overlapping of field of view of both the video nodes, which leads to lots of redundancy. Videos recoded from the sensor nodes have to be transmitted to sink node using multi-hop communication. As the sensor nodes have limited energy, the conservation of the sensor node energy is one of the main objectives, which prolongs the network lifetime of WMSN. As the neighbor video sensor nodes have highly correlated data, sending the videos without eliminating the redundant data consumes lots of energy as well as suffers with maximum delay. In order to tackle this problem, the neighboring sensor node video can be compared for their similar data. To eliminate the redundant video frames, in this work we propose video fusion in WMSN. Figure 2 gives an overview of the proposed video fusion scheme.

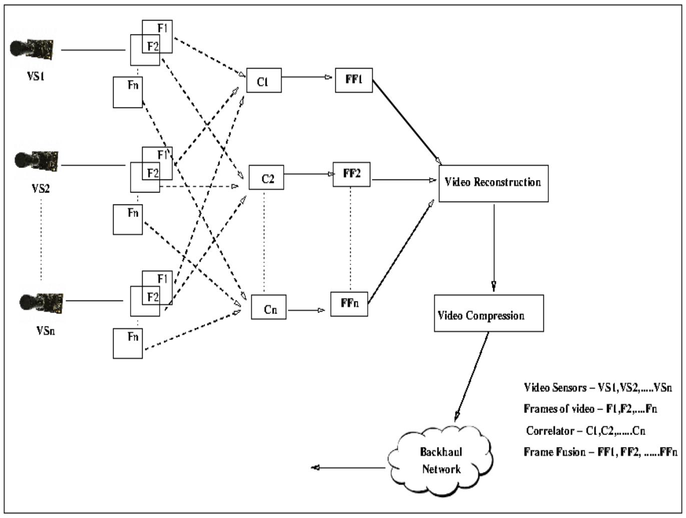

Fig. 2 Video Fusion in WMSN

Elimination of redundancy involves two steps, namely within the frame and between the corresponding frames. Within the frames the redundancy can be eliminated using lossy image compression techniques and between the correlated frames redundancy can be eliminated using the fusion techniques. In this work, highly correlated frames are fused using the wavelet based fusion techniques and fused frame is compressed and transmitted using multi-hop communication. Figure 3 presents the wavelet based sub band coding for video frame fusion.

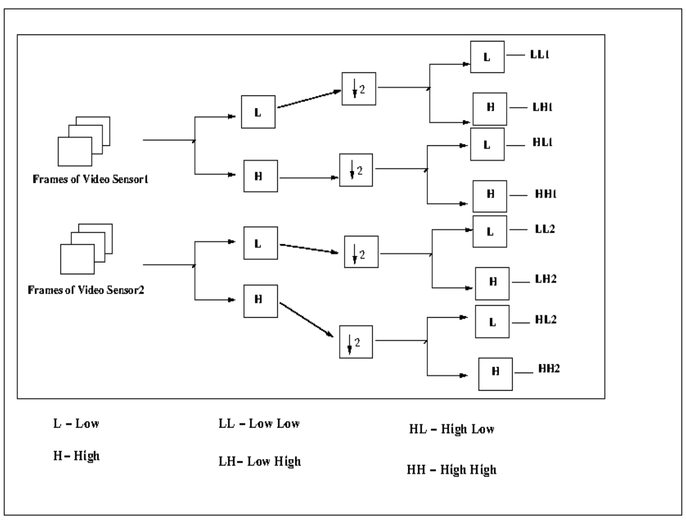

Fig 3 Frame Fusion using wavelet transformation

For video frame fusion the corresponding LL, LH, HL and HH bands are applied with fusion rules. In this work the fusion rules are averaging of the corresponding values. This process facilitates the fused video frames.

2. Video Fusion at Cluster Head Node

The following steps are performed in respective cluster head nodes to perform video fusion. The cluster head node is selected using leach protocol as given in [11]. Figure 4 shows the flow of video fusion process in cluster head node.

- Extract video frames from individual video and update the node black board with time of sensing, node id, and frame sequence number.
- Compares the previously sensed videos, if change is detected in the video then such video can be considered for the video fusion.
- Computation of correlation between the video frames to be fused. If the temporal correlation is above the predetermined value then the frames are extracted from the videos and object displacement vector is updated in the Video node black board.
- Video frames are fused using wavelet based image fusion. Using the fused video frames the video is reconstructed.
- In cluster head all the videos collected from mobile agents of different paths are again fused using the same procedure. The fused video is compressed and sent to the sink node on predetermined path.

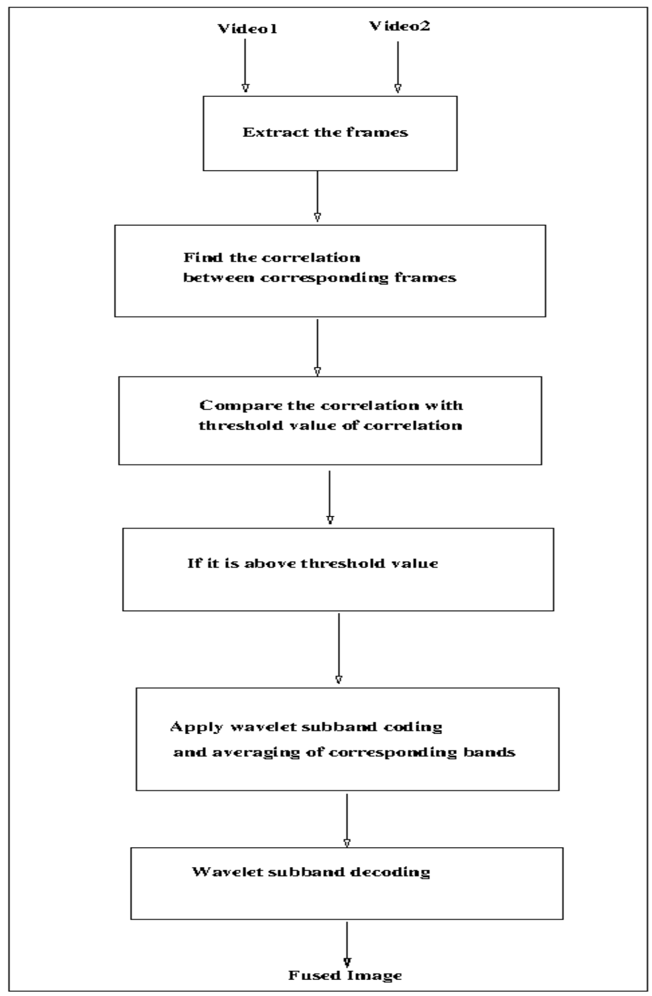

Fig 4 Video Fusion flow diagram

3. Proposed Algorithm

Nomenclature:

$V_1f_1, V_1f_2, V_1f_3 \ldots V_1f_n$: Video frames of sensor 1, $V_2f_1, V_2f_2, V_2f_3 \ldots V_2f_n$: Video frames of sensor 2, $V_nf_1, V_nf_2, V_nf_3 \ldots V_nf_n$: Video frames of sensor n, Vcorr : Correlation of corresponding video frames, th : Threshold, CH : Cluster Head, DWT: Discrete Wavelet Transformation, FV: Fused Video

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Algorithm 1: Video Fusion

```
Begin
    Step 1: Extraction of video frames
    Step 2: Compare correlation between the respective
            video frames
    Step 3: if (Vcorr > th) then
                FV=Video_framefusion(Videoframes)
            else
                Retain frame
            end if
    Step 6: Transmit FV to the sink node
End

Begin Video_framefusion
Input Videoframes
    Step 1: Apply DWT based video frame fusion
    Step 2: Get all the fused frames and reconstruct the video
Output fused video
End Video_framefusion
```

III. AGENT TECHNOLOGY FOR VIDEO FUSION

The proposed agency comprises of Video Node Agency (VNA), Cluster Head Agency (CHA) and Video Sink Agency (VSA).

A. *Video Node Agency*

Video Node Agency comprises of Video Node Manager Agent (VNMA), Video Processing Agent (VPA) and Video Node Black Board (VNBB), which are described below. Figure 5 explains the agent interactions of video node agency.

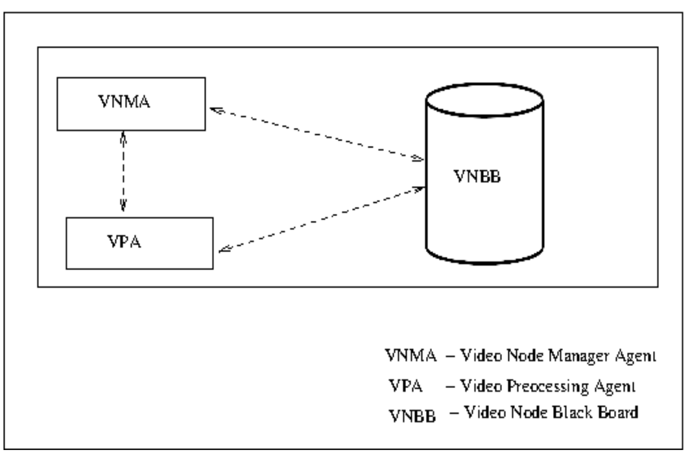

Fig. 5 Video Node Agency

1. *Video Node Manager Agent*

It is the static agent that resides in the all the video sensor nodes, which is responsible for the creation of VPA and VNBB. This agent facilitates sensing configuration such as low resolution, medium resolution and high resolution. It mainly wraps sensing (camera) and software component. It updates the sensed information to VNBB and also coordinates the communication between the other static agents, mobile agents and VNBB. It is also responsible for comparing the previous video and current video and estimates the temporal and frequency difference between those two videos and updates the VNBB.

2. *Video Processing Agent*

It is the static agent, which gets the information from the VNBB such as time of sensing, field of view, bits per pixel, and video. It extracts the video frame and enhances the video and updates the VNBB. VPA gets the video frames that are stored in VNBB and fuses. Fused frames are updated in the VNBB.

3. *Video Node Black Board*

It is the knowledge base, which can be read and updated by various static and mobile agents. VNBB data base comprises of the node id, residual energy, video, field of view, time of sensing, previous videos, critical videos, non-critical videos, neighboring node ids, and their location information, network bandwidth, predetermined path to reach sink node, fused video and time of fusion, freshness of the video data etc.

B. *Cluster Head Agency*

Cluster Head Agency consists of Cluster Head Manager Agent (CHMA), Video Migration Agent (VMA), Cluster Video Processing Agent (CVPA) and Cluster Head Black Board (CHBB). Figure 6 explains the agent interactions in cluster head agency.

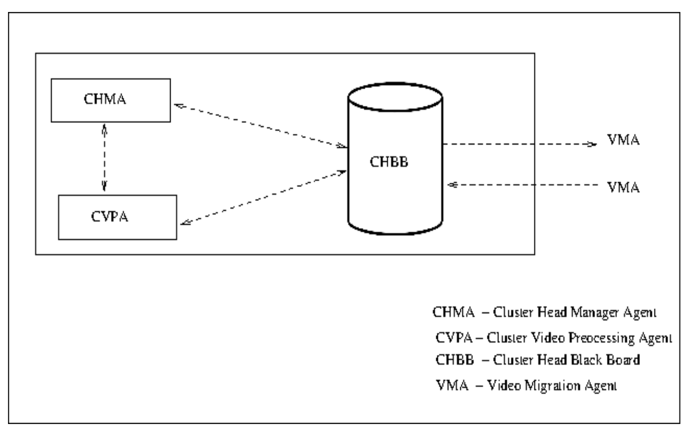

Fig. 6 Cluster Head Agency

1. *Cluster Head Manager Agent*

It is a static agent that resides in all the cluster head sensor nodes, which is responsible for the creation of CVPA, VMA and CHBB. It generates many clones of VMA and sends it over all the paths in the cluster to collect the videos and fuse it if correlation is more. It updates the CHBB with the fused and integrated video. It also helps in transmitting the fused video to the sink node.

2. Cluster Video Processing Agent

It is a static agent, which gets the videos from VMA. If the correlations among any of the videos received are more then, those videos are fused otherwise all the videos are stitched to provide a single view of the scenario. Transmitting this single video consumes less energy and bandwidth than sending all the received videos to the sink node.

3. Video Migration Agent

It is a mobile agent that is initiated by the CHMA in order to get the sensed videos from the sensor node and move to next node on the path by fusing the video with the previously visited node. This process is repeated until it reaches back to the cluster head node. This agent works in coordination with CVPA agent.

4. Cluster Node Black Board

It is the knowledge base that comprises of node id, time of sensing, sequence number, path information, bandwidth, node location information, node residual energy, previous video information. It is periodically updated by the information from every sensor node through VMA.

C. Video Sink Agency

This section presents the various agent components of video sink agency that facilitate inter-agent communication for video fusion in WMSN. The video sink agency interactions can be explained as shown in figure 7.

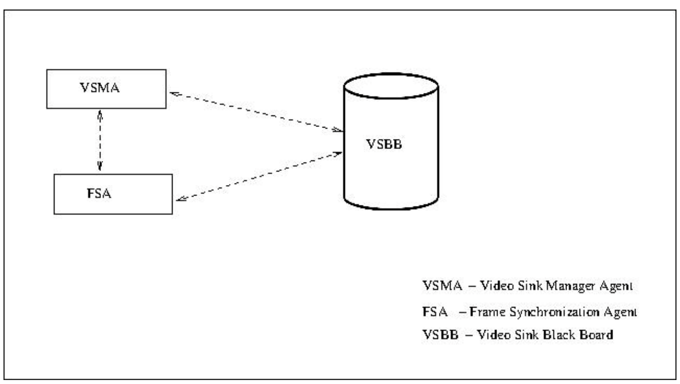

Fig. 7 Video Sink Agency

1. Video Sink Manager Agent

It is a static agent that resides in the sink node, which is responsible for the creation of FSA and VSBB. It is also responsible for computing the path information and facilitating the route information. It is also responsible for monitoring the previous information. If the user needs the information at particular time, this agent is responsible for sending the request message to all the cluster head for gathering the information of particular time. It is also responsible for taking the decisions like the quality of video required to collect from the WMSN based on the available network resources.

2. Frame Synchronization Agent

It is the static agent that gets the node id, frames sequence number, time of sensing, etc., from the VSBB. It synchronizes all the nodes frame for fusing the video. FSA gets the frames from the VSBB, synchronizes and computes the correlation between the corresponding frames. The corresponding nodes which have better correlation are fused for the better analysis.

3. Video Sink Black Board

It is the knowledge base that comprises of node id, time of sensing, sequence number, path information, bandwidth, node location information, node residual energy, previous video information. It is periodically updated by the information from every cluster head node.

IV. SIMULATION MODEL

The simulation of the proposed model is done using MATLAB. We discuss a generalized simulation model, simulation procedure and some of performance parameters.

A. Simulation Inputs

In the simulation model we consider “N” number of nodes in the area of length “L” and breadth “B”. A network consists of N static nodes that are randomly placed within a given area. We find some static and mobile agents between sensor nodes and sink node.

The transmission of packets is assumed to occur in discrete time. A node receives all packets heading to it during receiving interval unless the sender node is in non-active state. For simplicity, we have considered the channel to be error free.

Table 1: Simulation Inputs

Parameter	Notation	Value
Length	L	5000m
Breadth	B	5000m
Number of nodes	N	1-20
Transmission range	Rx	300m-500m
Sensing Range	Sr	5-15 meters
No. of bits per pixel	Bits/Pixel	8, 12 and 16 bits

The simulation procedure involves following steps:

Begin
1. Generate sensor network environment.
2. Formation of cluster and selection of cluster head.
3. The sensor node sends video from node to cluster head.
4. Apply the proposed scheme.
5. Compute performance parameters of the system.

End

B. Performace Parameters

Some of the performances considered to evaluate the proposed scheme are as follows:

- **Processing Time:** it is the total time required to fuse and reconstruct the fused video, which is measured in terms of milliseconds.
- **Mean Square Error:** It is quality measure of reconstructed video.
- **Throughput**: It is the ratio of total number of packets received to total number of packets sent.
- **Network lifetime**: It is the amount of time that the WMSN would be fully operative
- **Energy Consumption**: It is the total energy consumed for transmission of fused video from cluster head to sink node.
- **Delay:** It is the total amount of time taken for transmitting video from source node to sink node. Delay= Processing Time + Transmission Time

V. RESULTS

A. Energy Consumption based on Communication Range and Number of Nodes

Figure 8 shows the energy consumption increases as the the number of nodes increases. As the number of nodes increases the total of number of videos also increases. Hence there is increase in the energy consumption. If there is increase in the communication range number of of nodes within the cluster head increases hence there is increase in the energy consumption.

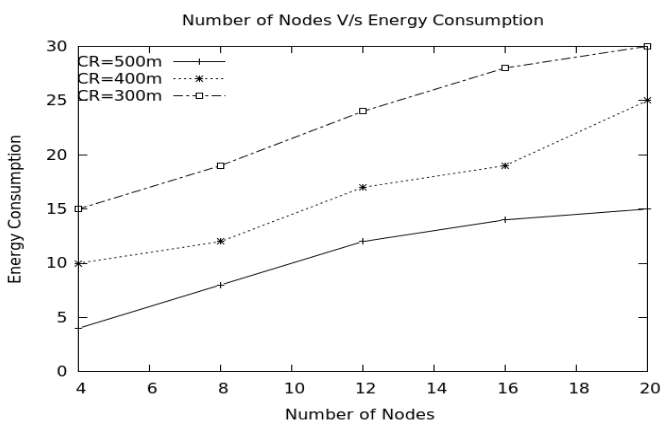

Fig. 8 Number of Nodes V/S Energy Consumption in millijoules

B. Processing Time based on Communication Range and Number of Nodes

Figure 9 shows the processing time versus the number of nodes. If there is increase in the number of nodes then there is increase in the number of video frames to be fused. If the amount of data increases there is increase in the processing time.

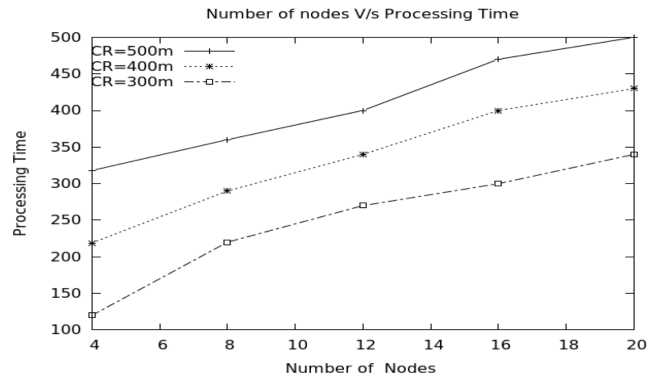

Fig. 9 Number of Nodes V/S Processing Time in milliseconds

C. Delay based on Communication Range and Number of Nodes

From the figure 10 we can notice that if there is increase in the number of nodes, the total amount of data also increases and there is decrease in the correlation between the frames and hence it takes more time for the transmission of the data from the cluster head node to the sink node.

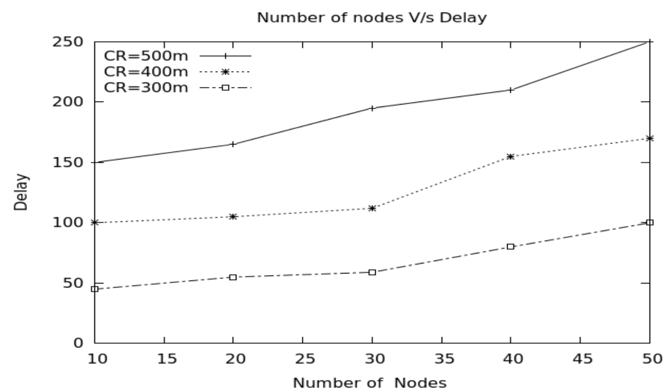

Fig. 10 Number of Nodes V/S Delay in milliseconds

D. Bandwidth required based on Communication Range and Correlation between Frames

From figure 11 we can notice that as there is increase in the correlation between the frames of the fused video, the size of the video decreases and hence it takes less time as well the bandwidth required for the transmission of the fused video from the cluster head node to the sink node is reduced.

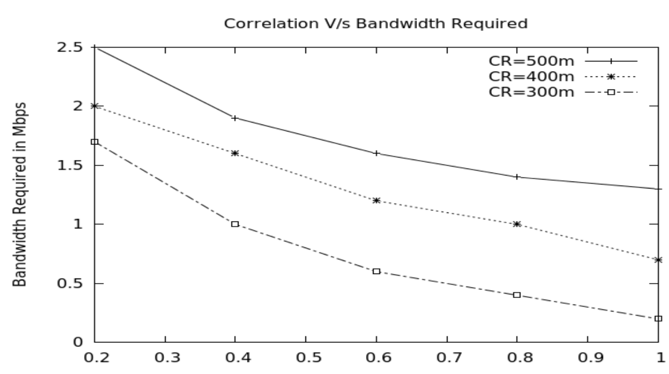

Fig. 11 Correlation between frames V/S Bandwidth required in Mbps

VI. CONCLUSION

Wireless networks have several limitations where huge amount of data cannot be transmitted using multi-hop communication. WMSN needs to transmit huge amount of data as multimedia type of data consists of videos, audios, images along with scalar data to be transmitted. A software agent based video fusion scheme for WMSN is proposed in this work. Videos sensed by the video sensors are collected by a mobile agent initiated by the cluster head node, which fuses the present collected video with that of the previously collected fused video in the assigned path before returning to the cluster head node. Cluster head processes the videos received by all the mobile agents and integrates them to send a single video which can be used to analyze the scenario. Software agents used in this work for video fusion, processing and transmission, performed better in conserving the bandwidth and energy of nodes, thereby conserving the network lifetime.

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