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Prioritized Multipath Video Forwarding in WSN

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Abstract—The realization of Wireless Multimedia Sensor Networks (WMSNs) has been fostered by the availability of low cost and low power CMOS devices. However, the transmission of bulk video data requires adequate bandwidth, which cannot be promised by single path communication on an intrinsically low resourced sensor network. Moreover, the distortion or artifacts in the video data and the adherence to delay threshold adds to the challenge. In this paper, we propose a two stage Quality of Service (QoS) guaranteeing scheme called Prioritized Multipath WMSN (PMW) for transmitting H.264 encoded video. Multipath selection based on QoS metrics is done in the first stage, while the second stage further prioritizes the paths for sending H.264 encoded video frames on the best available path. PMW uses two composite metrics that are comprised of hop-count, path energy, BER, and end-to-end delay. A color-coded assisted network maintenance and failure recovery scheme has also been proposed using (a) smart greedy mode, (b) walking back mode, and (c) path switchover. Moreover, feedback controlled adaptive video encoding can smartly tune the encoding parameters based on the perceived video quality. Computer simulation using OPNET validates that the proposed scheme significantly outperforms the conventional approaches on human eye perception and delay.

Keywords—WMSN, H.264, Multiple Paths, Quality of Service

1. INTRODUCTION

1.1 Background

The availability of low-cost hardware, such as CMOS cameras and microphones, has fostered the development of Wireless Multimedia Sensor Networks (WMSNs). In WMSNs, wirelessly interconnected devices ubiquitously retrieve multimedia content, such as audio/video streams and still images, from the environment. Despite the intrinsic limitation of communication, computation, and energy resources, the use of multimedia sensors has significantly progressed and they are now used in numerous areas, ranging from video surveillance to location-based services [1].

WMSNs not only enhance existing sensor network applications, such as tracking, home automation, and environmental monitoring, but can also enable several new applications such as: a) Multimedia Surveillance Sensor Networks - to enhance existing surveillance systems against

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crime and terrorist attacks; b) Traffic Congestion Avoidance Systems - to monitor road traffic and to deploy services that offer traffic routing advices to avoid congestion; c) Advanced Health Care Delivery – providing ubiquitous health care services by integrating telemedicine sensor networks; and d) Industrial Process Control - multimedia content such as imaging, temperature, or pressure, along with other items, may be used for time-critical industrial process control.

1.2 Motivation

Since WMSNs have some distinct differences from conventional data sensor networks, the sensor network paradigm has to be re-thought so that we are able to deliver multimedia content with a certain level of quality of service (QoS). The data generation rate of a video sensor is quite high, resulting in much higher network bandwidth requirement and power consumption. This issue is especially aggravated when no efficient compression scheme is employed before transmission. Thus, the transmission of huge amounts of multimedia data, particularly video data, over bandwidth-constrained sensor networks is a big challenge.

Since the need to minimize the energy consumption has driven most of the research in sensor networks so far, mechanisms to efficiently deliver application-level QoS, and to map these requirements to network-layer metrics, such as latency or delay, have been primary concerns in mainstream research on sensor networks. As WMSNs are envisioned to have no additional resources other than the inclusion of multimedia sensors, new approaches for multimedia processing, communication, and resource allocation must be proposed.

1.3 Contribution

Video data encoded with H.264 protocol is inherently composed of prioritized data. Each group of pictures in a H.264 video sequence consists of I, P, and B frames in a repeating pattern. The I-frames are intra-coded (i.e., coded independent of any other frames), and serve as a reference for the prediction of the subsequent P and B frames [2]. For this reason, the data pertaining to an I-frame is very important to video data quality. In this paper, we propose a composite QoS metric-controlled video transmission scheme for WMSN. It is called the Prioritized Multipath WMSN (PMW) scheme. It uses a two-stage process to find the two best paths towards the gateway, and the H.264 encoded video is intelligently transmitted in such a way that the important video part (I-Frames) is transmitted over the best path. In the first stage of the proposed PMW scheme, the two best paths are selected along with the recovery path, which is used as a backup if any of the links goes down during the video transmission. The better of these two paths is selected for I-frame transmission in the second stage. The link failure scenario has also been catered to using color code assisted failure recovery and link maintenance mechanisms.

We validated our work by simulating the WMSN environment on the OPNET Modeler 14. We not only relied on PSNR (Peak Signal to Noise Ratio) to measure the video quality but also used the Structural SIMilarity index (SSIM) [3] to measure the similarity between sent and received videos. SSIM is a recent emerging simple metric and in comparison to PSNR, it is a better representative measure of human visual perception. Apart from quality representative metrics, we also studied end-to-end delay to evaluate performance measures.

1.4 Organization

The rest of the paper is organized as follows: the next section discusses some existing work related to the paper that has been categorized into multipath routing and multimedia communication on WSNs. In Section 3, we discussed the basic requirement for video transmission on WSN and described the H.264 video encoding scheme. A detailed explanation of the proposed PMW scheme is presented in Section 4. Section 5 explains the metric calculation formulas used in both stages of the PMW scheme. The detailed analysis and graphical insight of our PMW scheme has been done in Section 6, while Section 7 concludes the paper.

2. RELATED WORK

During our survey of different WMSN algorithms and schemes, we observed that most of the proposed ideas use multiple paths with a single metric to make a QoS-oriented decision. Also, they do not include efficient video transmission approaches in their proposal. Thus, it is necessary to develop a scheme that uses multiple QoS metrics in making a decision and that intelligently schedule the video towards the gateway. The two research domains in the field of sensor networking that partially cover the main theme of the presented work are Multipath routing in WSN and Multimedia communication in WSN.

2.1 Multipath Routing in WSN

Although this paper deals mainly with efficient video delivery over WSN, the proposal is centered around multipath routing. Nasser and Chen [4] have proposed the Secure and Energy-Efficient Multipath Routing (SEEM) Protocol. SEEM consists of three phases: topology construction, data transfer, and topology maintenance. SEEM uses a multi-path alternately as the path for sharing betw een two nodes. The Quality of Service Multipath Routing (QOSMR) Protocol provides QoS guarantees that have a potential impact on the performance of the network in terms of throughput and network lifetime.

The Multipath Multi-SPEED (MMSPEED) protocol [5] uses multipath forwarding by transmitting duplicate copies of the packets, and uses a detour path as well. It offers QoS guarantees in the timeliness and reliability domains. MMSPEED can guarantee end-to-end requirements in a localized way, which is desirable for large-scale dynamic sensor networks with respect to scalability and adaptability.

Bhatnagar et al. has classified different paths based on their route lengths in [6]. The traffic is organized in such a way that all the critical queries go through the paths of minimum route lengths, and the rest of the traffic is distributed uniformly in the network to extend the network lifetime. The algorithm proposed by Das et al. [7] adaptively discovers the routes before the occurrence of route errors. It does so by distributing a large volume of data in an attempt to reduce congestion and end-to-end delay.

A novel approach called Label-based Multipath Routing (LMR) has been proposed in [8]. It can efficiently find a disjointed or segmented backup path to protect the working path. Disjointedness [9] allows for a better balance of traffic in the network. However, it does not deal with interference.

Wang et al. [10] presented a data gathering model by using agent mobility, where the station is stable and the agents distributed among the stations move around the circle. However, this method cannot balance the load among the nodes over two hops. Lin et al. [11] proposed a clustering hierarchy based on cellular topology for WSN. The remaining energy and position of sensor nodes are simultaneously considered when the clusters are constructed, and the desired cluster structure is obtained even when the nodes have no locating devices.

2.2 Multimedia Communication in WSN

Multimedia communication in WSN requires delay-tolerant transmission and hence, should recover quickly in case of a path down scenario. Multimedia transmission is not very well explained in the domain of WSN. Most of the proposed ideas focus on higher layer issues and neglect the more important lower layer issues. Thus, there is a lot of room for improvement in this domain.

The Delay-Constrained High-Throughput Protocol for Multipath Transmission (DCHT) [12] is the modified version of Directed Diffusion [13] that propounds the idea of using the multipath routing approach to support high-quality video streaming in low-power WSN. DCHT introduces a novel path reinforcement method and uses a routing cost function. However, due to the random topology of the WSN, constructing a sufficient number of node-disjoint paths to support high-rate multimedia streaming is not feasible.

The Energy-Efficient Protocol and the QoS-based Multipath Routing Protocol (EQSR) [14] are one of the recently proposed protocols designed to satisfy the reliability and delay requirements of real-time applications. EQSR improves reliability by using a lightweight Forward Error Correction (FEC) mechanism that introduces data redundancy in the data transmission process. However, it imposes high control overhead.

Maximally Radio-Disjoint Multipath Routing (MR2) [15] utilizes an adaptive incremental technique to construct minimum-interfering paths to satisfy the bandwidth requirements of multimedia applications. Additional paths are constructed whenever the active paths cannot provide the bandwidth requirements of the available network traffic. However, it has two main drawbacks: first, MR2 is only suitable for query-driven applications; second, the utilized flooding strategy for constructing non-interfering paths imposes a high control overhead.

In [16], the authors have presented the MPMPS scheme in the transport layer, which is based on the TPGF multipath routing protocol [17]. MPMPS supports multiple priorities and chooses the maximum number of paths to maximize the throughput of the streaming data transmission. However, this node-disjoint scheme results in a single point of failure.

A similar approach has been given in [18] by the name of MCMP (Multi-Channel Multi-Path) scheme. It uses multiple stages for path selection and uses a composite metric, but path sharing is strictly prohibited and does not include route maintenance either.

3. An Essential Requirement for Video Transmission

Compressing the video data prior to transmission on a physical medium is an essential requirement without which video transmission cannot be realized under normal conditions. There are various compression techniques of video whose purpose is to keep the number of bits as low as possible, while at the same time maintaining the quality of video as close to the

original (format as possible).

3.1 Why Compression is Necessary

The high bit rates that result from the various types of digital video make their transmission through their intended channels very difficult. This is analogous to an envelope being too large to fit into a letterbox. The biggest reason why video compression is necessary is for storage and transportation. However, even if the storage and transportation problems of digital video were overcome, the processing power needed to manage such volumes of data would make the receiver hardware very expensive. The power issue is a much bigger point of concern when using sensor nodes with limited resources. This reduction of bandwidth has been made possible by advances in compression technology, which has led to the arrival of video to TVs, desktops, mobiles, and ultimately the sensor network [19].

3.2 Overview of H.264

H.264, which is also known as MPEG-4 (Part 10) or AVC [8], is a next-generation video compression format that offers better compression efficiency than its predecessor techniques and provides greater flexibility in compressing, transmitting, and storing video [20].

The H.264 encoder carries out prediction, transform, and the encoding process to produce a compressed H.264 bitstream. The output of this video coding process is a periodic combination of I-frames (Intra frames) with P-frames (Predicted frames) and B-frames (Bi-directional frames) in between them.

Fig. 1. Typical IBP-based video frames

A reverse process occurs at the decoder [21]. The decoding of the I-frame is independent of any other frames. The decoding of the P-frame depends on the successful decoding of the I-frame and/or P-frame, while the decoding of B-frame depends on the decoding of both the I and P frames and the succeeding P-frames (Figure 1).

4. PMW Scheme Description

PMW, as the name suggests, divides video into multiple priorities that are later send on different paths in such a way that the high priority data is sent through the most reliable and healthy link. Multipath transmission helps to overcome the limited bandwidth issue, while intelligent path selection fulfills the essential QoS requirements. Employing a simple and smart

color coding technique also supports path sharing and the path recovery feature. In our proposed scheme, we make certain assumptions: i) sensor nodes can measure their remaining power; ii) in order to transmit huge video data, WMSN nodes have some additional power as compared to traditional WSN nodes; iii) the source video cameras are equipped with a small microprocessor to encode the captured video into H.264 format frames; iv) the header of all video frame packets are appended with a frame number and source camera ID for identification purposes; and v) the gateway has a buffer of considerable size to accommodate out-of-order frame packets.

The PMW scheme considers channel diversity and space diversity to obtain the maximum data rate and efficient transmission. A composite QoS metric calculation helps in priority path selection, while color coding is used for recovery and maintenance. At the time of deployment, every sensor node is assigned a unique ID for identification. We have divided the description of the PMW scheme into two parts. The first part is comprised of multipath selection, which is further categorized into two stages, while the second part addresses the network recovery and maintenance mechanism.

4.1 Multipath Selection

Multipath selection in PMW is a two-stage process. In the first stage, hop-count and energy metrics are used to select three basic paths for each camera. Two of the paths will be active paths and will be used for video transmission, while the third path is a passive path and will be marked as a backup path. In the second stage, the best of the paths selected in the first stage is selected. The subsections below describe both stages in detail.

4.1.1 Stage-I: Selection of Elementary Paths

At the time of deployment, all nodes are white. The path finder algorithm runs initially and the source camera broadcasts a Gateway Search Message (GSM) with a pre-assigned TTL. Every recipient node broadcasts it further to their neighboring nodes after appending its ID and energy level to the GSM packet. Thus, the GSMs carry QoS-related information as they are flooded throughout the network and ultimately reach the gateway after traversing multiple paths where all the processing occurs. Here, the hop-count (known by IDs) and the energy-level enclosed in each GSM are used in selecting the paths.

Based on the remaining energy and hop-count of each path, the gateway decides on three elementary paths. Two of the paths will be candidate paths and will compete for the transmission of I-frames. In Stage-II, the remaining third path will be marked as a recovery path that will be used as a backup if any of the active links fail. The formula used for selecting the paths based on the two metrics is presented in Section V.

$$\text{Elementary Paths} = \begin{cases} \text{Candidate Path 1} \\ \text{Candidate Path 2} \\ \text{Recovery Path} \end{cases} \tag{1}$$

Prior to the measurement of the QoS attributes, the following conditions are applied: a) if the hop-count is equal to or greater than a predefined threshold, then it is ignored so as to limit the transmission path and to avoid extra computation; b) disjointed paths are preferred, even though there is no compulsion; and c) paths with the same distance (hop-count) are preferred.

Fig. 2. The PMM updating the color code, distance parameter, & path-index to the intermediate nodes of the selected elementary paths

After selecting three paths, the gateway sends a Preferred Multipath Message (PMM) back to the source camera on the reverse path, so that the source camera can identify the path on which it can transmit the video frames (Figure 2). The PMM serves to change the color code of the intermediate nodes of the two candidate paths to black and to assign the distance (from gateway node) and the path-index. However, the PMM is sent on the recovery path to only change the color of intermediate nodes to grey.

If the source camera does not receive the PMM within time "T," or if it receives an Inadequate Information Message (IIM) from the gateway, it resends the GSM message with an increased TTL. The gateway now gets a larger picture of the network topology, and can make a better decision based on the current network scenario. Figure 3 comprehensively describes Stage-I.

Fig. 3. Stage-I flow of control packets

4.1.2 Stage-II: Selection of the Primary Path

Stage-II involves determining the primary path from the two candidate paths selected in Stage-I. The source camera simultaneously sends multiple copies of the same RAW (predefined) data to the gateway on both paths. From the reception of, the Bit Error Rate (BER) and delay of both the paths are approximated and are later assigned a particular weight for the best path selection.

Fig. 4. Primary path selection in Stage-II

If the quality is more important than delay, more weight is given to the BER. However, for time-sensitive applications, such as real-time display, delay is given preference. Based on the composite metric later described in Section V, the primary path is declared and conveyed back to the source camera through the Best Path Notification (BPN). This primary path is used for sending I-frames, while the other candidate path becomes the secondary path and it is used for sending both B-frames and P-frames. Stage-II has been summarized in Figure 4.

4.2 Sending Video Data

When video is to be transmitted in the case of any event or in response to any query, the source camera first sends activation messages towards the gateway on both primary and secondary paths. Upon receiving the activation message, nodes that were previously black are turned red for a limited period of time. Figure 5 depicts the scenario.

Fig. 5. Active video transmission

4.3 Intelligent Feedback Mechanism

The degree of required decoder performance in the H.264 standard is specified as a level. The levels of QCIF (176*144) format videos that are suitable for WMSNs are highlighted in Table 1. Adaptive H.264 encoding gives support for an intelligent feedback mechanism in PMW. If the Signal to Noise Ratio (SNR) of the decoded video deteriorates below a certain level, intelligent feedback can be provided to the source camera to lower the encoding level. Similarly, the current H.264 level is elevated if the gateway local conditions improve (there is enough space in the gateway buffer and more data can be received). Feedback information is sent by the gateway to the camera through the recovery path in a reverse direction.

Table 1. H.264 levels for the QCIF format

Levels	Max bit rate kbit/s	Highest frame rate/max # frames
1	64	15/4
1b	128	15/4
1.1	192	30.3/9

Path sharing has also been incorporated in PMW. PMW prefers to the disjoint node selection when discovering the paths for each video source, but if the disjointed paths are not found, the video from different cameras will engage in path sharing. Since IEEE 802.15.4 supports a maximum bit rate of 250kbps on a 2.4GHz channel, a single node can accommodate transit traffic from: a) 3 video cameras using Level 1 or b) 2 video cameras using Level 1b or c) 1 video camera using Level 1 and 1 video camera using Level 1.

4.4 Failure Recovery and Network Maintenance

Each sensor node periodically sends beacon messages every 5-10 minutes to neighboring nodes to deal with the failure recovery and network maintenance tasks. Beacon messages act as heartbeat messages and carry the following information: a) Remaining Energy, b) Node Color, c) Distance, d) Path-index (if assigned), and e) Advertised Distance (distance from neighboring node to any other path). From this information, every node maintains a neighbor table. An exemplary scenario and neighbor table is shown in Figure 6 and Table 2, respectively.

Fig. 6. Exemplary network scenario

Table 2. Neighbor table of node n_p

Node ID	Energy	Node Color	Distance	Path-index
nm	Em	Black	7	i
nq	Eq	Black	5	i
nw	Ew	Black	7	j
ny	Ey	Black	8	j
nx	Ex	White	9	i
nz	Ez	White	6	i
nz	Ez	White	8	j

If a black node does not receive any beacon message from the next black node in the path for five consecutive periods, it will consider the link as being down (dead interval = 5 * beacon message intervals). In that case, it will follow the infamous smart greedy mode. The node will check the local list of neighboring nodes and using the same path-index it will forward the packet to the neighboring node that is white, has adequate energy, and the shortest distance from the GW.

However, if a reasonable node is not found, the walking back mode will be enabled. In the walking back mode, the node preceding the path will try to find a path in order to restore the downed link. Finally, the path will be updated and the new node will be colored black. Later, Stage-2 will be executed to check if the primary path has been changed. Figure 7 shows the complete process.

Fig. 7. Walking back mode

Network recovery occurs in a somewhat different manner when video is being transmitted through the path. If a link goes down, the node prior (that is next to/the node that precedes the down(ed) node) to the downed node will find a suitable neighboring node according to the smart greedy approach. However, there will be no compulsion to select only the white node, rather the black and grey node will be preferred as they have already been qualified as nodes with better video forwarding metrics towards the gateway.

If no preferred path is found, the walking back mode will not be initiated; rather, a path-switchover will occur. If the primary path goes down and the gateway receives δBP frames on

secondary path or if the secondary path goes down and the gateway receives δI frames on the primary path, then the gateway declares the respective path as down and sends a Recovery Active Message (RAM) through the recovery path in the reverse direction. (δI and δBP are threshold numbers set by the administrator, and they are dependent on H.264 encoding parameters). The purpose of RAM is to:

- Inform the respective source video camera of the failed path.
- Perform a switchover from the failed path to the recovery path.
- Change the color code of the intermediate nodes of the recovery path to red.

Fig. 8. Path switchover scenario

Finally, a switchover is performed, as shown in Figure 8. When the transmission finishes, the failed path is verified and if it is found to be connected, then future transmissions will be done through it. Otherwise, Stage-II is applied to the recovery path and the already connected path, and the better path from among them is chosen based on BER and delay. In addition, the intermediate nodes of the failed path are also reverted to the color white.

5. PMW METRIC CALCULATION

In terms of the performance of in Stage-I, several GSM packets reach the gateway after traversing multiple paths, which then uses hop-count and the remaining energy to select the three best paths between the source camera and gateway. As described in the previous section, one path from among the three is marked as a recovery path, while the remaining two paths are used for video frame transmission that is scheduled as per the decision made later in Stage-II. The selection of the three paths is done in Stage-I using the metric (M1) that is calculated by:

$$M1(j) = \begin{cases} \left[\sum_{n \in N(j)} (100 - E_n)\right] * e^{\frac{\square_j}{\left|\square_{t\square r} - \square_j\right|}}, & \square_j < \square_{t\square r} \\ \infty & , \square_j \geq \square_{t\square r} \end{cases} \quad (2)$$

Where:

M1: Stage-I metric
j: Path-index
N(j): Set of nodes in path-j

h_j: Hop-count of path-j
E_n: Remaining energy of node-n (pct)

Metric M1 is evaluated using the energy and hop-count metric that have been collected by the GSM packets. Three disjointed paths with the lowest M1 metric are selected. If PI is the set of three selected paths, then:

PI = { j | three smallest M1(j) }
& |PI| = 3

Fig. 9. Stage-I metric (M1) calculated with the different energy levels of the immediate path nodes

Figure 9 shows the possible value of the Stage-I metric (M1) as drawn against the number of hops. Nodes are assigned a uniform distribution of remaining energy levels with the mean values (μ) of 35pct, 55pct, and 75pct, respectively. In order to make a fair comparison, we set the variance (σ2) value to be 20 in all three cases.

As discussed previously, the two paths selected in Stage-I are further prioritized in terms of BER and delay so that the vital I-frames are transmitted through the better path. Inspired by the EIGRP metric formula with default k values [15], the M2 metric formula (Equation 3) is derived with the BER and delay as the constituent parameters in Stage II.

$$M2\ (j) = (W_{BER} * BER_{scaled}) + (W_{Delay} * Delay) \tag{3}$$

Where:

BER_{scaled}: Scaled BER ($BER_{scaled} = BER * 10^4$)
W_{BER}: Weight assigned to BER
W_{Delay}: Weight assigned to delay
$0 \leq W_{BER}, W_{Delay} \leq 1$
$W_{BER} + W_{Delay} = 1$

The reason for scaling BER is to map the values that are close enough to the range of the delay metric, which is in microseconds. Since the values of BER are quite low (between 0 and 1), BER would have a negligible impact on the M2 metric even if the weight assigned to it were to be quite high. Mathematically, the primary and secondary paths can be expressed as:

Primary Path = arg M2(i) ≜ S1
Secondary Path = arg M2(i) ≜ S2

Fig. 10. Stage-II metric (M2) with a weight of 15:85 assigned to W_{BER} & W_{Delay}

Figure 10 shows the possible values of the Stage-II metric (M2) as calculated by Equation 2 with different values of BER and delay. Delay and BER are given a weight of 15% and 85%, respectively. If we focus on a particular delay value in the graph, we can infer that the metric M2 changes slightly, even when the value of the relative BER varies from 0 to 1. This is because the weight assigned to the BER metric is quite low, and therefore, has less of an effect on the overall Stage-II metric. (Figure 10).

6. PMW Performance Evaluation & Analysis

An analysis and evaluation of the performance of PMW scheme was done using an OPNET Modeler 14.5 simulator. We simulated a WMSN of 50 nodes using the built-in ZigBee model in a series of steps: a) encoding the sample video, b) generating a traffic file, c) mapping the traffic file as an input to the Opnet 14.5 simulator, and d) running the simulation and obtaining the results.

Fig. 11. End-to-end Delay measurement for all frames (I/B/P)

We first encoded 300 frames of the famous foreman_qcif.yuv video file using the FFMPEG encoder on a Fedora 16.1 operating system. FFMPEG is software that is widely used by researchers and programmers to efficiently encode/decode video. We initially encoded the video

with 20 frames/second and with a Group of Picture (GOP) size of 10.

Our next step was to packetize the encoded video bytes to be able to transmit it over any transport layer protocol. The Mp4BOX module converted the encoded video to real time packets. This type of module is used to send video through RTP and we could use the resultant file on any platform.

Thus, we had our final encoded video file, which could be transmitted through the IEEE802.15.4 based ZigBee network on our OPNET modeler 15.4. We then input the video to the OPNET network model. We fed the traffic file into the coordinator node, which emulated a video camera, in our network layout. We ran the simulation several times for 100 seconds each time and came up with a thorough analysis.

For comparison we also sent the video without considering prioritization like in conventional approaches. We sent the H.264 video frames haphazardly towards the destination on both paths and compared the performance parameters with our proposed scheme. The PSNR calculated during all 100 seconds was calculated with the Quantization Parameter (QP) of 26 and 30 respectively. The QP regulates how much spatial detail has been saved and is directly proportional to distortion. Our simulation result clearly illustrates that our scheme outperformed in terms of PSNR. There was a prominent improvement of 3dB and 4dB on average, as shown in Figure 11.

Fig. 12. SSIM vs. traffic load comparison

SSIM was employed to actually model human visual perception. SSIM takes luminance, contrast, and the structure difference into account to measure the similarity of two images. The value of SSIM falls in between 0 and 1. With a value closer to value 1, images x and y are more similar in terms of human visual perception. SSIM is measured by gradually increasing the traffic load. As shown in Figure 12, the SSIM of the video transmitted by our scheme was always greater than 0.9. In spite of the limited bandwidth and bulk data in the WMSN, our scheme works well in sending good quality, visually perceivable video towards the gateway.

Next, we studied the end-to-end delay of our proposed video transfer scheme. In our scheme, video bytes are later sent onto different paths, after going through categorization. We had to make sure that for a successful operation, that the end to end delay was within a certain limit, so that the gateway node would not have to wait too long for all the relevant frames to be received before starting the decoding process. As shown in Figure 13, the delay was normally between 20ms and 25ms, which is quite acceptable.

5. CONCLUSION

Unlike traditional sensor networks whose sole purpose is to transmit a few bits for reporting simple events, WMSN has to transmit a huge amount of data. Therefore, the WMSN needs a lot of resources, especially in terms of bandwidth and processing capability, so that they can successfully serve their purpose of efficiently transmitting video to the gateway node.

In this paper we have presented the PMW scheme by which H.264 encoded video can be effectively transmitted through the sensor network by considering multiple QoS parameters in two stages. In the first stage, the three best paths are identified based on the hop-count and remaining energy. In the second stage, the primary path is identified from among the two paths on the basis of BER and delay, so that the vital I-frames can be transmitted through it. The transmission of I-frames over the low BER and low delay path increases the transmission efficiency. This is because the I-frames play a vital role in fetching good quality video with high SNR at the receiver end. We also incorporated a failover scenario into the proposed scheme. The third path selected in Stage-I is called a “recovery path,” which takes over a failed path during transmission. Moreover, periodic maintenance is also carried out in which the QoS metrics are recalculated and the choice of best paths is updated based on the current status. Our detailed performance evaluation using the OPNET simulator showed that better visually perceivable video is received and that our scheme provides better result in terms of PSNR and SSIM.

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