IMPLEMENTATION OF A WISN BASED ON THE WAVELET TRANSFORM AND A SMART ROUTING-TRANSMISSION PROTOCOL

THỰC THI MẠNG CẢM BIẾN TRUYỀN ẢNH SỬ DỤNG GIAO THỨC ĐỊNH TUYẾN THÔNG MINH VÀ BIẾN ĐỔI WAVELET

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ABSTRACT

In wireless image sensor networks, a multimedia sensor node equipped with a tiny camera will capture an image and send it to a sink via multiple wireless hops. The process has some stringent requirements such as reliability in data transmission, energy consumption of nodes, and end-to-end delay in image transmission. This paper proposes a smart routing-transmission protocol and the use of wavelet transform to deliver images fast and reliably on a sink-originating tree topology. In this approach, the source multimedia node utilizes the wavelet transform to compress the captured image, segments the image, and forwards all segments along the data path. Then, nodes on the data path will collaborate to improve the reliability of data transmission greatly without relying on retransmissions while making the packet move fast. The proposed approach is verified by analysis and experiment, showing that it far outperforms the recent approach in terms of end-to-end delay and packet delivery rate.

Keywords: *Smart routing protocol, wavelet transform, reliability, end-to-end delay.*

TÓM TẮT

Trong mạng cảm biến hình ảnh không dây, nút cảm biến đa phương tiện được trang bị một máy ảnh nhỏ sẽ chụp một hình ảnh và gửi nó đến nút chủ thông qua nhiều bước truyền. Quá trình này có một số yêu cầu nghiêm ngặt về độ tin cậy trong truyền dữ liệu, sự tiêu thụ năng lượng của các nút và độ trễ trong truyền hình ảnh. Bài báo này đề xuất một giao thức định tuyến thông minh và sử dụng biến Wavelet để truyền hình ảnh nhanh chóng và tin cậy cho mạng có cấy trúc cây. Trong phương pháp này, nút đa phương tiện sử dụng biến đổi Wavelet để nén hình ảnh đã chụp, chia nhỏ hình ảnh thành các gói tin và chuyển tiếp các gói theo đường truyền dữ liệu. Sau đó, các nút trên đường truyền sẽ hợp tác cùng nhau để cải thiện độ tin cậy của việc truyền dữ liệu mà không phụ thuộc vào việc gửi lại dữ liệu trong khi làm cho các gói tin được truyền một cách nhanh chóng. Giải pháp đề xuất cho quá trình truyền ảnh trong mạng cảm biến đã được đánh giá so sánh bằng phân tích và thực nghiệm. Các kết quả chỉ ra rằng giải pháp đưa ra vượt trội hơn các phương pháp gần đây về chỉ tiêu trễ truyền, năng lượng tiêu thụ và đạt được độ tin cậy cao của bản tin truyền đi.

Từ khóa: *Giao thức định tuyến, biến đổi wavelet, độ tin cậy, trễ truyền.*

1. INTRODUCTION

In wireless multimedia sensor networks (WISNs), multimedia sensor nodes transmit still images via multiple wireless hops to the sink. Before transmitting in WISN, images are compressed in order to reduce the number of transmitted bits by removing special and spectral redundancy, leading to save energy consumption. The images are also divided into a number of image packets so that the size of each packet can be fit into the medium access control protocol data unit (MPDU) of IEEE 802.15.4 of 127 bytes [1]. Then, the image packets are transmitted one by one to a sink that is responsible for decompressing and saving the reconstructed image. In transmission process, WISNs require a cross-layer protocol and that can transmit the image packets reliably with a constrained end-to-end delay.

Some research has been performed to evaluate the importance of image compression before sending it over WISNs. However, most of them focus on the multi-resolution levels and the embedded progressive characteristics of wavelet based image compression. In [2], the authors studied the trade-off between energy consumption and image quality. They have shown that energy-efficient transmission may be achieved by balancing computational energy consumption and transmission energy through image compression. In [3], authors used JPEG2000 standard and proposed the

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use of source channel coding protection to different levels of bit-streams for energy-efficient image transmission in WISNs. In [4], multiple bit-streams are created to constrain error propagation in a sub-tree, and hierarchical unequal error protections are applied. In two approaches, the unequal importance between structure information and magnitude information is not fully identified. In [5], the authors focused on the distributed image compression to overcome the computation and energy limitations of individual nodes by sharing the processing task between various nodes. This approaches can extend the lifetime of WISNs under a specific image quality requirement.

For image transmission in WISNs, many cross-layer protocols have been proposed [6-8], however, the studies were limited to the design of a new protocol and its evaluation based on simulation. In [9], the authors implemented a transmission control protocol that uses congestion control and error control to improve the reliability in data transmission. In [10], the authors implemented a simple transmission protocol in which a multimedia node transmits each image packet with a sufficient delay such that only one packet remains on the whole data path. In this way, the protocol excludes multiple concurrent transmissions, thereby avoiding collision and congestion. It also employs a hop-by-hop retransmission mechanism that is used to salvage the missing packets. According to experiments, the protocol could achieve packet delivery ratio (PDR) of 91.7% when a multimedia node is located two hops away from a sink and one-hop transmission time of a packet is given about 11 milliseconds. Consequently, it is easily conjectured that the protocol cannot achieve high reliability and low latency in image delivery as the distance between a sink and a multimedia node increases.

In the paper, we utilize the wavelet transform for image compression and we propose a smart routing-transmission protocol (SRP) for image transmission. The protocol establishes a data path in which every node on the path maintains a cooperating node that salvage lost packets by mean of overhearing and transmits packets in a pipelined manner. It was shown that this approach can deliver an image in a fast and reliable manner in spite of the high interference signals. Moreover, the *SRP* manages energy consumption of nodes efficiently by scheduling time slots for nodes on the data path and by turning off nodes outside the path.

The rest of this paper is organized as follows. In Section 2, the motivation is given and followed by the wireless image sensor network model in Section 3. In Section 4, the implementation of a WISN based on the wavelet transform and a smart routing-transmission protocol is described and followed by the performance evaluation in Section 5. Concluding remarks are given in Section 6.

2. MOTIVATION

In low-bandwidth and error-prone wireless sensor network, it is not easy for a multimedia node to send an image to a sink. Three critical requirements in sending an image are high reliability in data transmission, low latency in image delivery, and low energy consumption in a node. First, the high reliability of data transmission is the most important requirement because it directly affects the quality of a reconstructed image at the sink. For example, suppose that an image of 2.5 Kbyte's is divided into 25 packets to fit into IEEE 802.25.4 MPDU [1]. If one of those packets is lost, the server may fail to detect an event from the reconstructed image. Second, it is desirable to reduce image delivery latency to satisfy time constraints required by various real-time applications. For example, consider a fire detection system in which a server requests a still image from the target zone to make sure that a fire really occurred. Then, the image has to be delivered to the server in a timely manner. Third, the energy consumption of a node is another critical issue. In surveillance applications in which image transmission occurs frequently, a considerable amount of energy can be consumed during the transmission of images.

The discrete wavelet transform (DWT) based on the concept of multi-resolutions facilitates progressive transmission of images that decomposes a given image into a number of sets, where each set is a time series of coefficients describing the time evolution of the signal in the corresponding frequency band. This is achieved by first applying the low-pass filter (L) and a high-pass filter (H) to the lines of samples, row by-row, and then re-filtering the output to the columns by the same filters. As a result, the image is divided into 4 sub bands: low-low (LL), low-high (LH), high-low (HL) and high-high (HH). In [11], the authors shown that DWT is a low-complexity and energy efficient image compression scheme for wireless sensor networks. Moreover, to the best of our knowledge, none of dependable image transmission protocols has been successfully implemented so far such that it can satisfy the stringent above requirements of industry applications in delivering an image on WISNs.

In this paper, the soundness of using wavelet transform and a smart routing-transmission protocol in WISNs is verified in a testbed built in the building in terms of packet delivery ratio, image delivery ratio, and image transmission delay. The protocol is characterized by the use of a data path and the allocation of a distinct slot to each tree level to secure the reliability of data delivery. It employs the channel-assisted slot reuse technique [12] and spatial slot reuse technique [13] to enable parallel transmission, thereby increasing throughput and reducing transmission delay. Moreover, it manages energy consumption effectively by letting every node know whether it will take part in image transmission or not and when to wake up after sleeping.

3. WIRELESS IMAGE SENSOR NETWORKS

3.1. Tree topology

A considered WISN includes a sink node or server, scalar nodes (SNs), and multimedia nodes (MNs). The sink is wall-powered, whereas SNs and MNs are battery-powered. All nodes form a tree originating from the sink. A node is said to be a tree-node if it belongs to a tree, and a link between a tree-node and its parent is called a tree-link. Otherwise, it is an orphan-node. Two nodes that can directly communicate with each other are said to have an ordinary link. Data from a SN is delivered to a sink via multiple wireless hops and then a sink forwards it to the control system via a high-speed link, such as the internet connector.

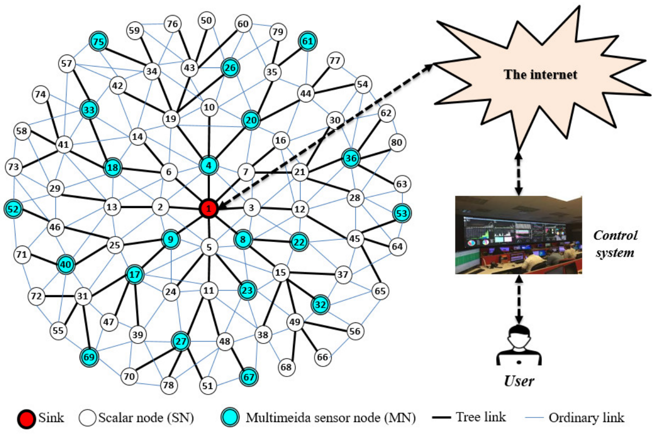


Figure 1. A wireless image sensor network with tree topology

Figure 1 shows a tree with five tree levels, which consists of one sink, 59 SNs, and 20 MNs. The thick solid lines and the thin dashed lines represent tree-links and ordinary links, respectively. A sink collects scalar data from SNs at regular intervals while it acquires an image from a MN in an event-driven manner. To prevent the interference of scalar data to the transmission of image, a sink does not collect scalar data from the participating nodes while an image is being transmitted. Since an image far exceeds the IEEE 802.15.4 MPDU of 127 bytes, it is to be segmented into a number of image packets before transmission.

3.2. Hardware

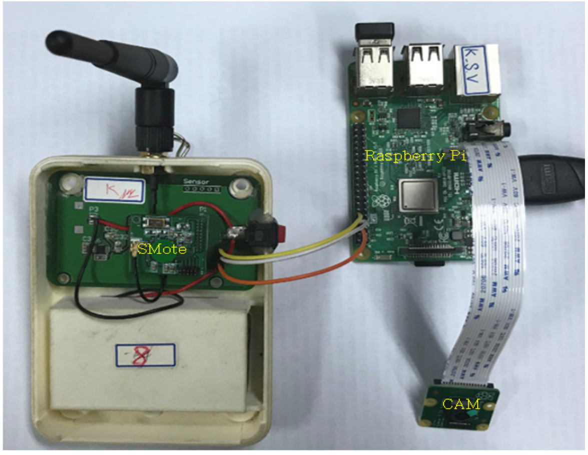


Figure 2. Multimedia node (MN)

A MN includes multimedia board, sensor mote (Smote), and camera module (CAM). The multimedia board captures an image from the CAM and forwards the image to Smote that in turn sends it towards a server using WISN. The multimedia board should have low power consumption and high-speed calculation. Thus, we selected Raspberry pi 3 model B (Rasp-Pi) that includes 1GB of RAM and a powerful 1.2GHz quad-core ARM Cortex-A53 (64Bit) CPU. It has a camera serial interface (CSI). The CAM uses Raspberry Pi Camera Module V2 and the Smote was implemented with the CC2630 chip that integrates ARM Cortex M3 and CC2420 radio chip. The CAM and Smote are connected to the multimedia board by a camera serial interface (CSI) port and universal asynchronous receiver-transmitter (UART), respectively. The Rasp-Pi uses Raspbian, a Debian-based operating system, and the Qt creator version 4.14.0 [14] to control the CAM module and process the image data. A multimedia node is shown in Figure 2.

The WISN consists of a number of Smotes that form a multi-hop transmission network based on the IEEE 802.15.4 standard [1]. Every node has a routing capability. A sink node that receives the image and then forwards it to a server. It reassembles the image packets to recover the original image.

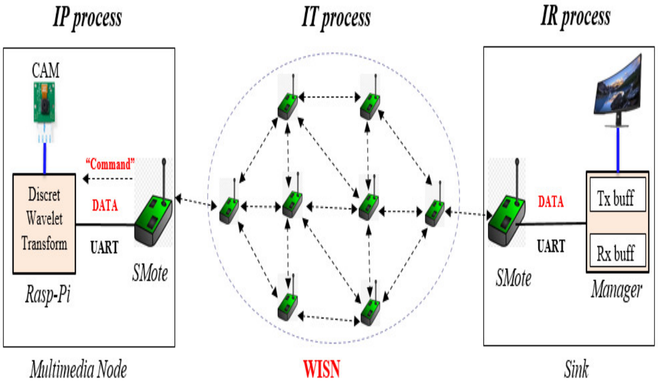


Figure 3. Image transmission procedure over WISN

As shown in Figure 3, the implementation of image transmission is divided into three functional parts: Image preparation (IP), image transmission (IT), and image reconstruction (IR). The IP process deal with image preprocessing that includes image capture, compression, and the generation of image packets. The IT process addresses data transmissions over WISN using the SRP. The IR process handles with image recovery.

4. IMPLEMENTATION

4.1. Image Preparation

A server collects data from scalar nodes in the target monitoring zone at regular intervals. If it judges that an abnormal situation has occurred in the target zone based on the analysis of collected scalar data, it requests a camera still image to the source multimedia node, srcMN, by sending an image request (IRQ) message. Upon receiving IRQ, the Smote in srcMN sends a command, such as AT01, to the multimedia board. Upon receiving the AT01 command from the Smote, the multimedia board captures an image using the CAM module. In our testbed, the image has a resolution of 150 pixels in width and 120 pixels in height (150 × 120 pixels).

4.1.1. Wavelet image compression

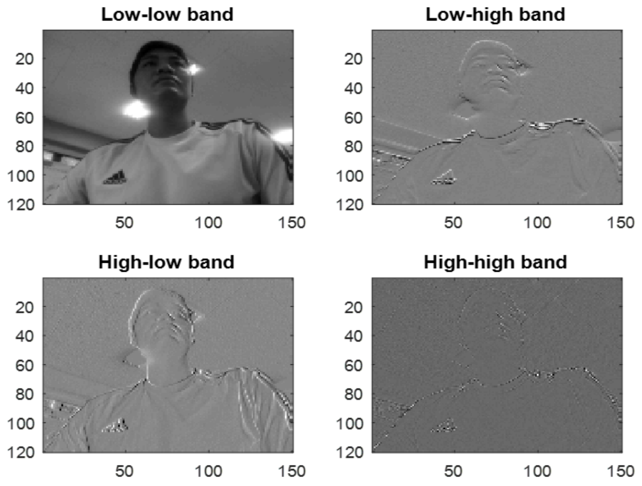


Figure 4. Applying the discrete wavelet transform to compress a still image

In this study, we have adopted the concept of multi-resolutions which divides an image into a number of sets, each of which is a time series of coefficients reflecting the time evolution of the signal in the corresponding frequency band: LL, LH, HL, HH. The LL sub-band coefficients are more are more important than the HL, HL, and HH sub-band coefficients because they represent the lowest image resolution. Figure 4 illustrates the distribution of wavelet coefficients after applying the DWT to compress the image from the CAM module.

4.1.2. The size of compressed images

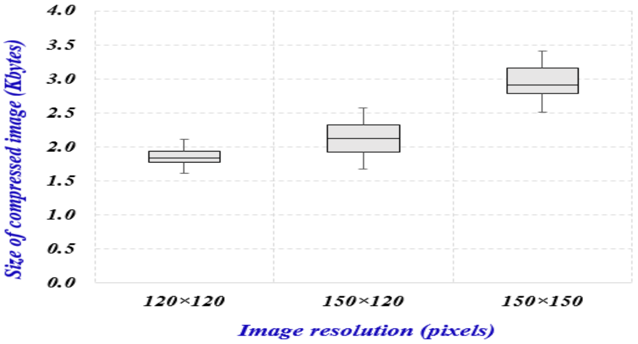


Figure 5. The sizes of the compressed images with the use of wavelet transform

The captured images are of an identical size; however, the compressed images are different in size. Thus, the image transmission period has to be adjusted according to the size of the compressed image. Figure 5 shows a variation in the sizes of compressed images I_1, I_2, I_3 with resolutions of (120 ×120 pixels), (150 × 120 pixels), and (150 × 150 pixels), respectively. The resolution of the captured image can be changed by setting image resolution. The multimedia board compresses and encodes the still image by using the DWT. The compression ratio achieves around 18:1 in our implementation. Thus, the compressed images with the resolution of 150 × 120 pixels range in size between 1.7 and 2.65 Kbytes and mostly between 1.9 Kbytes and 2.3 Kbytes. The median value of the sizes is 2.15 Kbytes.

4.1.3. The segment of compressed images

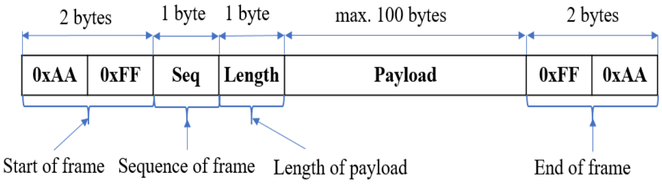


Figure 6. The format of a packet

The SrcMN saves compressed image in the buffer, segments the image, each segment being of 100 bytes, and then forwards all segments to the Smote. Then, the Smote formats each segment to have a packet for transmitting and decoding. The packet consists of the start of frame (2 bytes), sequence number (1 byte), length of data (1 byte), payload (100 bytes), and end of a frame (2 bytes), as shown in Figure 6.

4.2. Image Transmission

Upon receiving an image packet, the Smote transmits it towards the server over WISN using a smart routing-transmission protocol (SRP). The SRP has two important functions, which are to establish a data path for the transmission of packages and to satisfy the image transmission requirements. The operation of the SRP is described as follows. First, the SRP establishes a data path that consists of path nodes residing on the tree path and cooperating nodes that help the path nodes to improve reliability in data transmission. Each path node selects one cooperating node during path establishment. Then, a path node collaborates with its cooperating node to deliver packets reliably to nodes at one level lower within the distinct slot allocated to each tree level. Finally, two channels are used and scheduled to allow the transmission of packets in a pipelined manner. This section explains the establishment of a data path, the schedule of channels and slots, and the transmission of image.

4.2.1. Data path construction

In a tree structure, a multimedia node can send image packets along a tree path, defined by a sequence of tree-links, leading to a sink. However, a packet can be lost by an external interference such as WiFi and BlueTooth signals or a link breakage due to battery depletion, node failure, or node movement. Therefore, relying on a simple tree path is not sufficient to achieve high quality in image transmission. This section explains a method to build a data path in which a path node can select a cooperating node against the loss of data packet.

To establish a data path, a sink broadcasts an image request message, IRQ, towards the srcMN. Upon receiving IRQ, the srcMN sends an image reply message (IRP) that includes a set of secondary parents, SPS, to its primary parent on the tree. Upon receiving IRP, a path node selects one node that belongs to not only SPS in the IRP, but also its neighbour set, Nbrs, as a cooperating node, cn. Now, its upstream path node forwards IRP = (cn, SPS) to its parent to continue the construction of a data path. By overhearing IRP, a node can know that it was selected as a cooperating node. This process continues until the IRP reaches a sink. The algorithm to construct the data path is detailed in Algorithm 1.

Algorithm 1. The data path construction

```
// x.SPS: The SPS of a node x;
// x.Nbrs: The Nbrs of node x;
At multimedia node x that receives IRQ:
    send IRP = (0, x.SPS);
At node x that receives IREP = (z, y.SPS):
    node x becomes a path node
    if  y.SPS = $\phi$ then
        send IRP = (0, x.SPS);
    else
        select cn $\in$ y.SPS $\cap$ x.Nbrs;
        send IRP = (cn, x.SPS);
    endif
At node x that overhears IRP = (z, y.SPS):
    if x = z and level (x) = level (y) then
        node x is a cooperating node;
```

Note that the selected cooperating node connects to the path node at the same level and the path node one level higher, forming a stable triangle connection among the three nodes. The established data path allows the implicitly reconfigurable multiple paths, thereby increasing the reliability of data transmission. In other words, if packet transmission was not successful on one link, it was simultaneously tried along another link so that another secondary parent can continue data transmission. This makes a quick progress without requiring the sender to retransmit the same packet. In this way, this approach enables a multi-path mechanism adaptively without hindering the progress of data transmission.

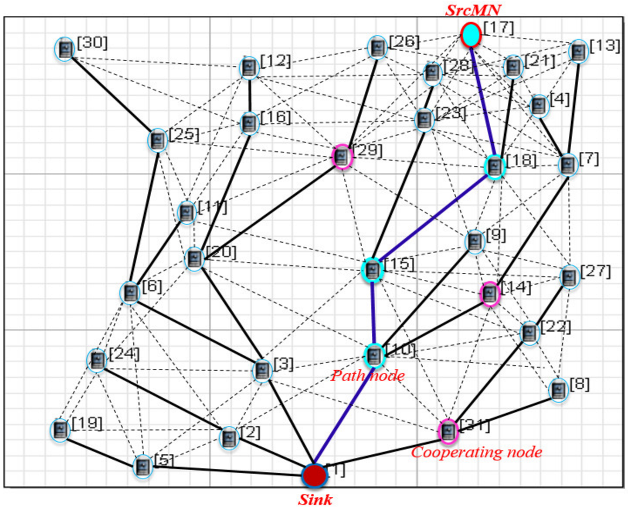


Figure 7. A real network link to verify the construction of data path (Network topology included a sink, 30 nodes, and random distribution in area of 30x30m^2)

Figure 7 shown the construction of data path from the SrcMN, 17, to the Sink in the commercial QualNet simulator of version 5.0.2. In fact, the probability that there are a path node and a cooperating node at same level on data path is very high because WSNs are deployed in some limited area for a special purpose.

4.2.2. Time slot scheduling

Along with building a data path, a distinct transmission slot is allocated to each tree level. The path node collaborates with its cooperating node at the same level in forwarding packets to the nodes one level lower within the allocated slot. Suppose that the srcMN locates at tree level L, and an image is divided into a number of packets, nPackets.

Upon receiving IRQ, a node x located at level l set a time out interval, T_{out}, to wait IRP and to decide node's status belong to sleeping node, path node, or cooperating as follows:

$$T_{out} = \begin{cases} 0 & \text{if } l \geq L \\ (L-l)\times(T_{IRP}+T_{IRQ})+T_{IRP} & \text{if } l \leq L \end{cases} \tag{1}$$

where T_{IRP} and T_{IRQ} are time to transmit a IRP and IRQ message in one hop, respectively.

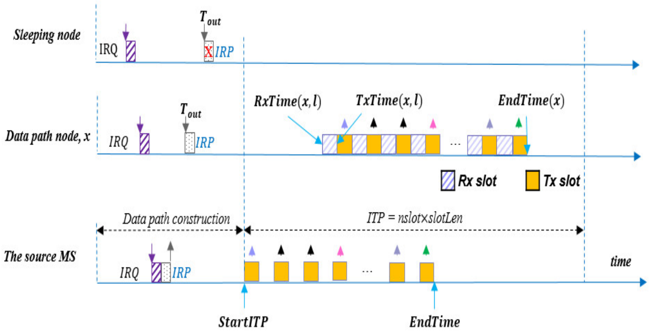


Figure 8. Time slot scheduling for image transmission

Then, the parameters nSlots as the number of slots, ITP as the length of image transmission period, RxTime(x, l) as receiving time of the first packet of node x, TxTime(x, l) as sending time, and EndTime(x) as ending time of image transmission can be calculated as follow:

$$\begin{aligned} &\text{nslots} = 2\times \text{nPcakets} + L - 3 \\ &\text{ITP} = \text{nslots}\times \text{slotLen} \\ &\text{RxTime}(x,l) = \text{StartITP} + (L-l-1)\times \text{slotLen} \\ &\text{TxTime}(x,l) = \text{StartITP} + (L-l)\times \text{slotLen} \\ &\text{EndTime}(x,k) = \text{StartITP} + (L-l-1)\times \text{slotLen} \\ &\qquad + (2\times \text{nPackets})\times \text{slotLen} \end{aligned} \tag{2}$$

where StartITP is the starting time of image transmission and it can be calculated as follows:

$$\text{StartITP} = (L-1)\times(T_{IRP}+T_{IRQ}) \tag{3}$$

Let a path node or a cooperating node be a data path node. Since every data path node can predict the time when it will receive IRP, it can go to sleep unless it receives IRQ within the predicted time out interval, T_{out}. This implies that every node except the node goes to sleep during the transmission interval of an image as shown in Figure 8.

4.2.3. Transceiver channel scheduling

It was studied in [15] that the signal interference range is approximately twice the transmission range. Thus, if two nodes are four-hop away from each other, it is possible to reuse the same channel. Thus, with the use of two channels, the following formulas can be derived to determine Ch_l^{Tx} and Ch_l^{Rx} that indicate a sending channel and a receiving channel at level l, respectively [16]:

$$\begin{aligned} Ch_l^{Rx} &= ((Q(l)+R(l)) \text{ MOD } 2 \;+\; 1 \\ Ch_l^{Tx} &= ((Q(l-1)+R(l-1)) \text{ MOD } 2 \;+\; 1, l \neq 1 \end{aligned} \tag{4}$$

where $Q(l) = l \text{ DIV } 2$ and $R(l) = l \text{ MOD } 2$.

Table 1. The channel allocation according to level of a node

Level (l)	Ch_l^{Tx}	Ch_l^{Rx}
4k + 1	1	2
4k + 2	2	2
4k + 3	2	1
4k + 4	1	1

Consider the channel allocation for four adjacent levels, 4k+1, 4k+2, 4k+3, 4k+4. According to Eq. (1), the resulting channel allocations are summarized in Table 1. Note that the channel allocations are repeated for different k values. Nodes at two adjacent level use the same channel for transmitting and receiving as underlined in the table.

4.2.4. Image transmission

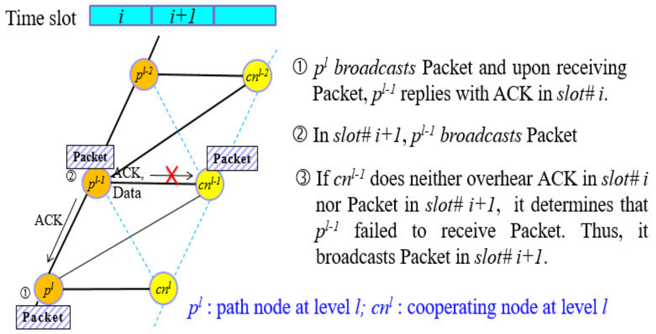


Figure 9. The collaborative transmission to improve reliability

The packet transmission in ITP is performed by mean of broadcasting as illustrated in Figure 9. Upon receiving a packet, a path node and a cooperating node both save the received packet, and only the path node responds with ACK to the sender. In transmission time slot, Tx slot, a path node rebroadcasts the received packet. This implies that a path node always takes a priority over a cooperating node in data transmission. On the contrary, the cooperating node broadcasts the saved packet with a time delay if it does not overhear either ACK that the path node responds to or a packet that the path node forwards to its parent. Note that a path node has priority over a cooperating node because it always has a connection to path node and cooperating node one level lower.

By the overhearing activity of ACK, a cooperating node can know whether a path node at the same level has received a packet successfully or not. If the cooperating node fails to overhear ACK with which its counterpart path node replies, it determines that its counterpart path node has failed to receive a packet. Thus, it salvages the packet by broadcasting the saved packet towards the nodes one level lower.

The advantages of using a data path are three-fold. First, the protocol improves the reliability of data transmission between two adjacent tree levels by salvaging the lost packet with no retransmission. Second, it can reduce image transmission time by employing the pipelined transmission technique using two channels and by disallowing packet retransmission in the way that if a path node failed to receive a packet from its child node, its counterpart cooperating node forwards the saved packet. This enables a fast-forwarding of packets. Third, it manages energy consumption effectively by having every node know whether it will take part in image transmission or not and when to wake up after sleeping.

4.3. Image reconstruction

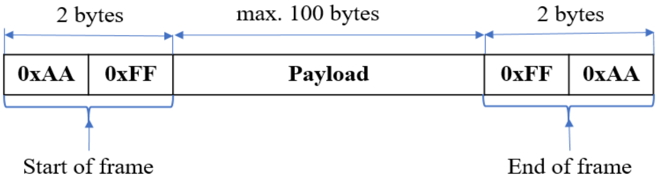


Figure 10. A packet that is reformatted by a sink

When a sink receives a packet, it saves only the payload of the packet on its buffer, and reformats the payload as shown in Figure 10. The format includes the start of a frame, payload, and the end of the frame. Then, the sink forwards each packet to the server that decompresses and saves the reconstructed image.

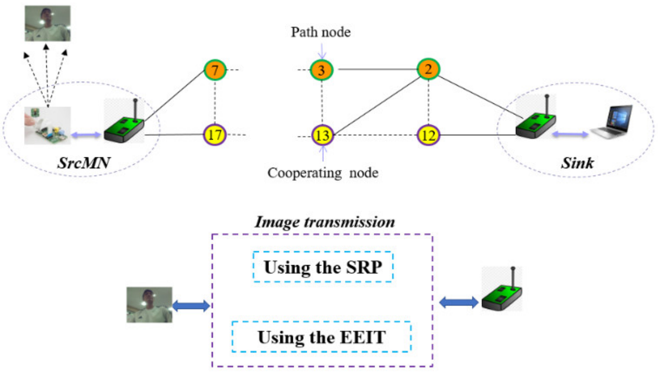
5. EVALUATION

5.1. Experiment setup

A number of sensor nodes were manually deployed along the corridor of the Radio-Electronic faculty (17th floor). An MN is located in a room, #1, while a sink is located in other Room, #4, as shown in Figure 11. The distance of two rooms is about 70m. Note that WiFi access points located along the corridor and in other rooms can interfere with image delivery.

Three metrics were used for evaluation. Firstly, the packet delivery ratio (PDR) indicates the ratio of the number of packets received at a sink to the total number of packets transmitted by the MN. Second, the image delivery ratio (IDR) is the ratio of the number of lossless reconstructed images at the server to the total number of images transmitted by the MN. Third, the end-to-end delay (E2ED) of an image includes the time span to compress a captured image at a multimedia node, deliver an image from the source multimedia node to a sink, and reconstruct the image at a server. The time to turn on CAM and capture an image is deliberately ignored since it varies largely according to the quality of a camera module.

(a) Deployment of network



(b) The testbed of WISN

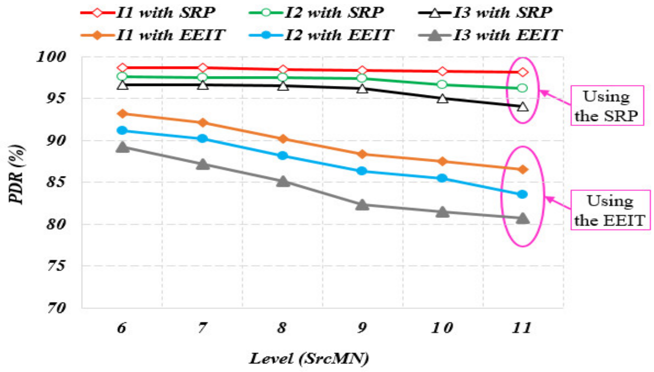
Figure 11. Experimental environments

In this section, the PDR, IDR, and E2ED of two approaches from the experiments in the testbed are compared: SRP that employs a smart routing-transmission protocol, and the EEIT protocol [10] that uses a simple path and allows the transmission of a packet in every transmission interval (TxInt). It should be mentioned that, the three original images I_1, I_2, I_3 with a resolution of 120×120 pixels, 150×120 pixels, and 150×150 pixels, respectively, were compressed to images of median values of 1.85, 2.15, and 2.8 Kbytes for testing purposes. The images are divided into 19 packets, 22 packets, and 28 packets of 100 bytes for testing.

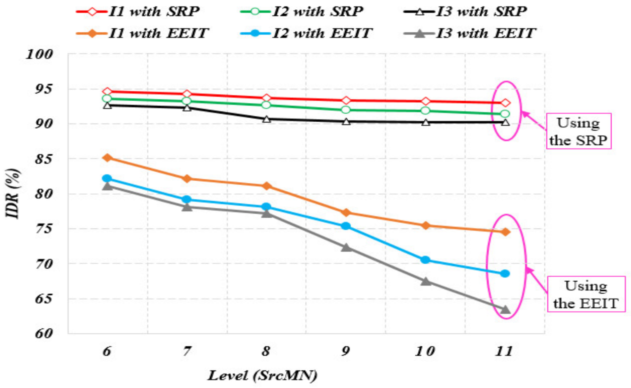
5.2. Experiment results

5.2.1. Packet and image delivery ratio

In our evaluation, IDR does not count any blurred images reconstructed with the loss of any packets since the blurred images may not be used to identify an object. Figure 12 shows the PDR and IDR of two approaches SRP and EEIT protocol from the experiments in the testbed as the hop distance of source MN rises. Figure 12a compares the PDRs of two protocol. It is shown that when the hop distance of MN increase, the performance gap between SRP and EEIT increases gradually. When the source MN is located at the tree level of 11, the PDR of SRP improves that of EEIT by 14%. Figure 12b compares the IDRs of the two approaches. In this comparison, the image with a single loss of packet is disposed without counting and the source MN 300 images totally. By experiments, a sink with the SRP could receive over 93% of images with I_1, 91,7% of images with I_2, and 90.3% of images with I_3. On the contrary, the IDR of EEIT decreases sharply as the tree level of the MN increases, down to 74,3% of images with I_1, 68% of images with I_2 and, 64,7% of images with I_3 at the tree level of 11. In summary, the SRP is highly reliable in delivering images even with the harsh environment with several interfering WiFi APs.



a) Packet delivery ratio



b) Image delivery ratio

Figure 12. The reliability of data transmission according to the hop distance of the MN

5.2.2. End-to-end delay

In this section, the E2ED of image transmission over a WISN using SRP and EEIT protocol is evaluated. The SRP could transmit images I_1, I_2, and I_3 in 0.23 seconds, 0.27 seconds, and 0.34 seconds on average, and slightly increasing delays as the hop distance of source MN increases as shown in Figure 13. This is the reason that the pipelined transmission just increases the latency of one hop by the increase of one level. So, the graph pattern looks like a flat. On the contrary, EEIT increases the E2ED linearly to the number of hops since the intervals of two consecutive data packets increase.

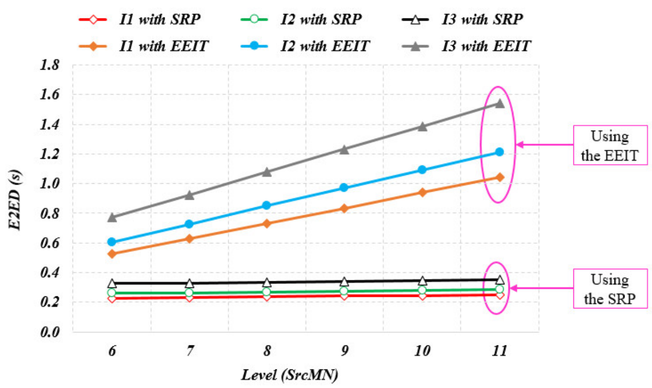


Figure 13. The time of image transmission according to the hop distance of the MN

6. CONCLUSIONS

This paper discusses the implementation and experiments of the image delivery network using the DWT for image compression and using the SRP for image transmission. From this study, it was shown that the SRP is highly dependable to meet the requirements to deliver images in harsh environment, in terms of the packet transmission reliability and the end-to-end delay of image delivery. According to experiments, the SRP could deliver images regardless of the hop distance of MN in an almost constant delay and a reliable manner by applying the pipelined and collaborative transmission.

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