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Multi-priority Multi-path Selection for Video Streaming in Wireless Multimedia Sensor Networks

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Abstract. Video sensors are used in wireless multimedia sensor networks (WMSNs) to enhance the capability for event description. Due to the limited transmission capacity of sensor nodes, a single path often cannot meet the requirement of video transmission. Consequently, multi-path transmission is needed. However, not every path found by multi-path routing algorithms may be suitable for transmitting video, because a long routing path with a long end to end transmission delay may not satisfy the time constraint of the video. Furthermore, each video stream includes two kinds of information: image and audio streams. In different applications, image and audio streams play different roles, and the importance levels are different. Higher priority should be given to the more important stream (either the image stream or the audio stream) to guarantee the using of limited bandwidth and energy in WMSNs. In this paper, we propose a Multi-priority Multi-path Selection (MPMPS) scheme in transport layer to choose the maximum number of paths from all found node-disjoint routing paths for maximizing the throughput of streaming data transmission. Simulation results show that MPMPS can effectively choose the maximum number of paths for video transmission.

1 Introduction

Using video sensors in wireless sensor networks (WSNs) [1, 2, 3, 4, and 5] can dramatically enhance the capability of WSNs for event description. Efficiently gathering and transmitting video streaming data in WSNs is necessary when the underlying infrastructure, e.g. 3G cellular networks or WLANs, does not exist. Real time video streaming in WSNs [6, 7] generally poses two requirements: 1) *Guaranteed end to end transmission delay*: Real time video streaming applications generally have a soft deadline which requires that the video streaming in WSNs should always use the shortest routing path with the minimum end to end

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transmission delay; 2) *Using multiple routing paths for transmission*: Packets of streaming video data generally are large in size and the transmission requirements can be several times higher than the maximum transmission capacity (bandwidth) of sensor nodes. This requires that multi-path transmission should be used to increase transmission performance in WSNs. Many multi-path routing protocols have been studied in the field of WSNs [8 □ 9]. However, most of the multi-path routing protocols focus on energy efficiency, load balance, and fault tolerance, and are the extended versions of DSR [10] and AODV [11]. These multi-path routing protocols do not provide a powerful searching mechanism to find out the multiple optimized routing paths in terms of minimizing the path length and the end to end transmission delay as well as taking the limited energy of WSNs into consideration.

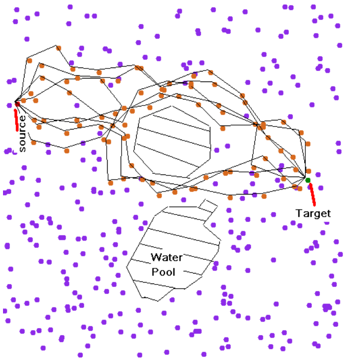


Fig. 1. An example of TPGF multi-path routing: Eight paths are found for transmission

TPGF [12] is the first multi-path routing protocol in the wireless multimedia sensor networks (WMSNs) field. It focuses on exploring the maximum number of optimal node-disjoint routing paths in network layer in terms of minimizing the path length and the end to end transmission delay as well as taking the limited energy of WSNs into consideration. The TPGF routing algorithm includes two phases: Phase 1 is responsible for exploring the possible routing path. Phase 2 is responsible for optimizing the found routing path with the least number of hops. The TPGF routing algorithm finds one path per execution and can be executed repeatedly to find more node-disjoint routing paths. It successfully addressed four important issues: 1) *Hole-bypassing*; 2) *Guarantee path exploration result*; 3) *Routing path optimization*; 4) *Node-Disjoint Multi-path transmission*. The Figure 1 shows an example of TPGF multi-path routing in a WSN with two holes. These found routing paths have varying numbers of hops. However, not every path found by TPGF can be used for transmitting video, because a long routing path with a long end to end transmission delay may not satisfy the time constraint of the video streaming data.

Furthermore, a video stream includes two kinds of information: image and audio streams. In different applications, image and audio streams play different roles, and the importance levels may be different. For example, in the applications of fire monitoring, image stream is more important than audio stream because it can directly reflect the fire event. But in the applications of Deep Ocean monitoring, the audio stream is more important than image stream, since the visibility in Deep Ocean is very low and the environment is extremely quiet. Therefore, instead of transmitting a video stream back to the base station by using fewer routing paths with a stricter real time constraint, it is better to split the video stream into image and audio streams and give higher priority to the more important stream (either the image stream or the audio stream) to guarantee the using of the suitable paths, as shown in Figure 2. The less important stream can be transmitted with a relatively looser real time constraint. Consequently, the routing paths with the longer end to end transmission delay can be used, which can increase the total received data in the base station, where the received data can be joined again or processed separately.

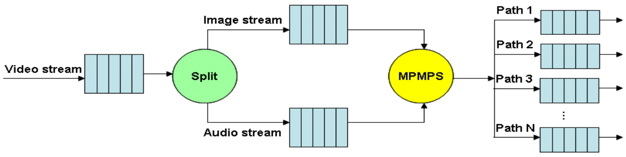


Fig. 2. The general model for multi-priority multi-path transmission

How to split a video stream into an image stream and an audio stream has been widely solved by many programs [13], which is not the focus of this paper. In this paper, we proposed a new Multi-priority Multi-path Selection (MPMPS) scheme to ***choose the maximum number of paths from all found node-disjoint routing paths for maximizing multimedia streaming data transmission and guaranteeing the end-to-end transmission delay*** in WMSNs. This scheme makes two contributions on: 1) supporting multiple priorities; 2) choosing the maximum number of paths to maximize the throughput of the streaming data transmission.

The rest of this paper is organized as follows. In section 2, we discuss the related work. In section 3, we present the network model and discuss the multiple priorities in section 4. In section 5, we formulate and analyze the problem. In section 6, we present the Multi-priority Multi-path Selection (MPMPS) algorithm. In section 7, we present the simulation and comparison work, and we conclude this paper in section 8.

2 Related Work

Surveys on WMSNs [14] have shown that transmitting multimedia streaming data in WSNs is still a relatively new research topic compared with other research topics in WSNs such as energy efficient routing, query processing, etc. In [15], another survey work on multimedia communication in WSNs also analyzed and discussed the existing research work from both the mobile multimedia and the WSNs fields in application, transport and network layers. Both surveys show that current existing protocols from both mobile multimedia and WSNs fields are not suitable for multimedia communication in WSNs, because they did not consider the characteristics of multimedia streaming data transmission and the natural constraints of WSNs at the same time. There exists a clear need for a research effort focusing on developing efficient communication protocols and algorithms in order to realize WMSNs applications.

To the best of our knowledge, no research has been done for multi-path selection in WMSNs. Although multi-path selection algorithms have not been studied in WSNs yet, there still are some research works that have been done for multi-path selection in other networks. In [16], the authors proposed an Energy Aware Source Routing algorithm to choose the multiple routing paths in wireless ad hoc networks, the goal of this research work is to maximize the network lifetime by minimizing the *overhearing ratio*. In [17], the authors considered the *concurrent packet drop probability* of multi-path in wireless ad hoc network, and proposed a path selection algorithm to minimize the *concurrent packet drop probability*. In [18], the authors investigated the problem of selecting multiple routing paths to provide better reliability in multi-radio, multi-channel wireless mesh networks with stationary nodes. In [19], a multi-path selection algorithm is proposed in an overlay network which focuses on minimizing the correlation of multiple paths. None of these above mentioned multi-path selection algorithms has a similar research goal as ours which is to choose the maximum number of paths from all found node-disjoint routing paths for maximizing multimedia streaming data transmission as well as guaranteeing the end-to-end transmission delay.

Therefore, to propose a new multi-path selection scheme for multimedia streaming in WMSNs is the key focus of this paper.

3 Network Model

In this paper, we consider a homogeneous geographic WSN. The locations of sensor nodes and the base station are fixed and can be obtained by using GPS. Each sensor node has the knowledge of its own geographic location and the locations of its 1-hop neighbor nodes. All sensor nodes have the same maximum transmission capacity (bandwidth) TC. Each source node, for example, a video sensor node, continuously produces sensed video stream S_V with a data generation rate R_V kbps. Source nodes can dynamically adjust (increase or decrease) their data generation rate by changing the sampling frequency. The video stream from the source node is sent to the base station for further processing. We assume that only source nodes know the location of the base station and other sensor nodes can only know the location of the base station by receiving the packet from source nodes. Video stream can be splitted into image stream S_I with data generation rate R_I kbps and audio stream S_A with data generation rate R_A kbps ($R_I + R_A = R_V$). The soft real time deadline of the image stream is T_I and the soft real time deadline of the audio stream is T_A.

After repeatedly executing the TPGF routing algorithm N number of node-disjoint routing paths $P = \{p_1, \ldots, p_n\}$ are found. Each routing path p_i has its own end to end transmission delay d_i based on the routing hops in the path. Only M_I number of routing paths $P_{Satisfy\_Image} = \{p_{SI1}, \ldots, p_{SImi}\}$ with transmission delay $D_{Satisfy\_Image} = \{d_{SI1}, \ldots, d_{SImi}\}$ can satisfy the soft real time deadline T_I, and only M_A number of routing paths $P_{Satisfy\_Audio} = \{p_{SA1}, \ldots, p_{SAma}\}$ with transmission delay $D_{Satisfy\_Audio} = \{d_{SA1}, \ldots, d_{SAma}\}$ can satisfy the soft real time deadline T_A. Here, we assume that a source node only tries to use an additional transmission path when all its currently using transmission paths meet the maximum transmission capacity, and a routing path cannot be used for transmitting two different multimedia streams at the same time. Thus, the total number of chosen paths is M ($M = M_I + M_A$).

4 Multiple Priorities

Supporting multiple priorities is a key feature of our MPMPS scheme. In this section, we present our multiple priorities in two aspects: 1) End to end transmission delay based priority; 2) Context aware multimedia content based priority.

Definition 1. End to end transmission delay based priority. *For any two paths p_i and p_j within the N number of node-disjoint routing paths $P = \{p_1, \ldots, p_n\}$ that are found by repeatedly executing the TPGF routing algorithm, if their end to end transmission delays meet $d_i < d_j$, we assign the higher priority to path p_i.*

Theorem 1. *For any stream S, choosing one routing path with the higher priority from any two path p_i and p_j can let it reach the base station faster than choosing another routing path with the lower priority.*

Proof: Let p_i denote the routing path with the higher priority and p_j denote the routing path with the lower priority. According to Definition 1, the end to end transmission delay d_i of path p_i is smaller than the end to end transmission delay d_j of path p_j. Thus, if the stream S chooses the routing path p_i, it can reach the base station faster than choosing the routing path p_j. □

It is clear that in MPMPS scheme, the routing path with the higher priority should always be chosen first to reduce the end to end transmission delay.

Definition 2. Context aware multimedia content based priority. *In any situation where the video sensor nodes are deployed for gathering information, for both image stream and audio stream, if the image stream is more important for reflecting the event and describing the phenomenon, we assign higher priority to the image stream. On the other hand, if the audio stream is more important for reflecting the event and describing the phenomenon, we assign higher priority to the audio stream.*

Theorem 2. *For any two given streams S_I and S_A, sending the stream with the higher priority first can reflect and describe the event better than sending the stream with the lower priority first.*

Proof: We can consider a fire monitoring application in a forest. Let S_I denote the image stream with the higher priority and S_A denote the sound stream with the lower priority. According to Definition 2, the image stream S_I is more important for reflecting the event and describing the phenomenon. Thus, sending the stream with the higher priority first can reflect and describe the event better than sending the stream with the lower priority first. □

According to Theorem 2, in MPMPS scheme, the stream with the higher priority should always be sent first to reflect the events.

Here, we want to clearly mention that dynamically assigning different priorities to image and audio streams based on the surrounding situation of the WSNs is another research issue, which is defined as "Situation Awareness in wireless sensor networks". For example, the video sensor node can use the sensor data gathered by attached light and sound sensors. When the light intensity is higher than a certain value and the sound intensity is lower than a certain value, then the higher priority is assigned to the image stream. Likewise, when the light intensity is lower than a certain value and the sound intensity is higher than a certain value, then the lower priority is assigned to the image stream. In this paper, we assume the priorities of image stream and audio stream is pre-assigned by using a certain situation awareness algorithm [20].

5 Problem Statement and Analysis

The problem of choosing the maximum number of paths M from all N node-disjoint routing paths for maximizing the throughput of video streaming data transmission and guaranteeing the end-to-end transmission delay can be formulized as:

$$\text{Maximize:} \quad M, (M = M_I + M_A) \tag{1}$$

Subject to:

$$P_{Satisfy\_Image} \cup P_{Satisfy\_Audio} \subseteq P \tag{2}$$

$$P_{Satisfy\_Image} \cap P_{Satisfy\_Audio} = \emptyset \tag{3}$$

$$M \leq N \tag{4}$$

$$P \neq \emptyset \tag{5}$$

$$N \neq 0 \tag{6}$$

$$D_{Satisfy\_Image} \neq \emptyset \tag{7}$$

$$D_{Satisfy\_Audio} \neq \emptyset \tag{8}$$

$$M \leq \lceil R_I / TC \rceil + \lceil R_A / TC \rceil \tag{9}$$

Equation (9) reflects that a routing path cannot be used for transmitting two different multimedia streams at the same time.

Based on equation (4), it is clear that the maximum number of paths M is bounded by the found node-disjoint routing paths N. However, the found routing paths N is also bounded by two factors as following presented Theorem 3 and Theorem 4.

Definition 3. Node-disjoint routing path. *A node-disjoint routing path is defined as a routing path which consists of a set of sensor nodes, and excluding the source node and the base station none of these sensor nodes can be reused for building another routing path.*

Theorem 3. *For any given source node* S_{Source_Node} *with* $N_{Neighbor\_Node}$ *number of 1-hop neighbor nodes within its transmission radius, it can have maximum* $N_{Neighbor\_Node}$ *number of possible node-disjoint routing paths for transmitting data.*

Proof: Assume that there are $N_{Neighbor\_Node}$ number of routing paths for a source node S_{Source_Node}. Let the source node S_{Source_Node} tries to find the ($N_{Neighbor\_Node}$ + 1) number of node-disjoint routing paths. According to Definition 3, it will try to explore every its 1-hop neighbor node to build up a routing path and every used neighbor node cannot be used twice. When the source node S_{Source_Node} tries to find the ($N_{Neighbor\_Node}$ + 1)th routing path after finding $N_{Neighbor\_Node}$ number of paths, there is no more 1-hop neighbor nodes available. Thus, for this source node S_{Source_Node}, the maximum number of possible node-disjoint routing paths is $N_{Neighbor\_Node}$. □

Theorem 4. *For any given source node* S_{Source_Node}*, the maximum number of possible node-disjoint routing paths is affected by using different routing algorithms.*

Proof: For example in Figure 3, if using the greedy forwarding routing algorithm (GPSR) [21], the number of routing paths can be only one (black color path) but with the shorter end to end transmission delay. However, if using the label-based multi-path routing (LMR) [22], the number of routing path can be two (green color path) but with relative longer end to end transmission delay. □

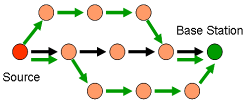


Fig. 3. Multi-path GPSR vs. LMR

Based on Theorem 4, it is not hard to draw the conclusion that the goal of exploring more routing paths contradicts the goal of using the approximately shortest routing paths with the minimized end to end transmission delay. It is worth noting that TPGF also sets using the shortest transmission path as the basic criteria, and then explores the possible number of node-disjoint routing paths. The key motivation for using this basic criteria is that the shortest transmission path generally has the shortest end to end transmission delay which may satisfy the time constraint of multimedia stream.

Corollary 1. *For any given source node* S_{Source_Node}*, the maximum number of final chosen paths M has the upper bound*

$$Min(N, \lceil R_I / TC \rceil + \lceil R_A / TC \rceil), \qquad (10)$$

where Min(para1, para2) is the function which returns the smaller value.

Proof: When the end to end transmission delays of all node-disjoint routing paths satisfy the real time constraints of image and audio streams, all these node-disjoint routing paths can be chosen for transmitting data. However, the actually required number of routing paths is decided by the $\lceil R_I / TC \rceil + \lceil R_A / TC \rceil$. When $N \geq \lceil R_I / TC \rceil + \lceil R_A / TC \rceil$, the final number of chosen paths is $\lceil R_I / TC \rceil + \lceil R_A / TC \rceil$. When $N < \lceil R_I / TC \rceil + \lceil R_A / TC \rceil$, although more routing paths are required for transmitting data, but only N number of routing paths can be used. Thus, the upper bound on the maximum number of final chosen paths M is Min(N, $\lceil R_I / TC \rceil + \lceil R_A / TC \rceil$). □

Corollary 2. *For any given source node S_{Source_Node}, the maximum number of final chosen paths M has the lower bound 0.*

Proof: When the end to end transmission delays of all node-disjoint routing paths are longer than the real time constraints of both image and audio streams, none of these routing paths can be chosen for transmitting data. Thus, the lower bound on the maximum number of final chosen paths M is 0. □

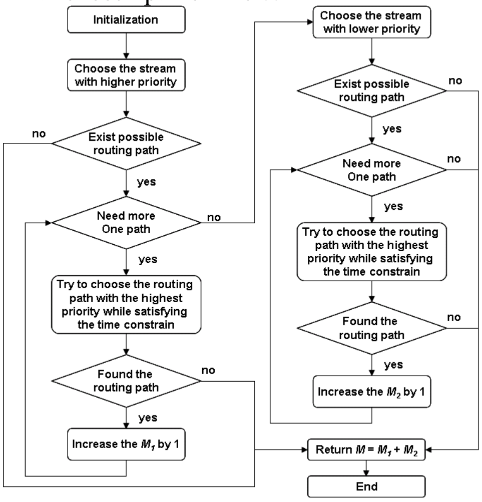


Fig. 4. The workflow of MPMPS algorithm

After having all these analysis, we propose the following Multi-priority Multi-path selection (MPMPS) scheme to solve the problem described in equations (1) – (9).

6 Multi-priority Multi-path Selection Scheme

The MPMPS algorithm should be executed after the TPGF explored all the node-disjoint routing paths. In MPMPS, the more important multimedia stream always chooses the routing path with the higher priority to transmit. The workflow of

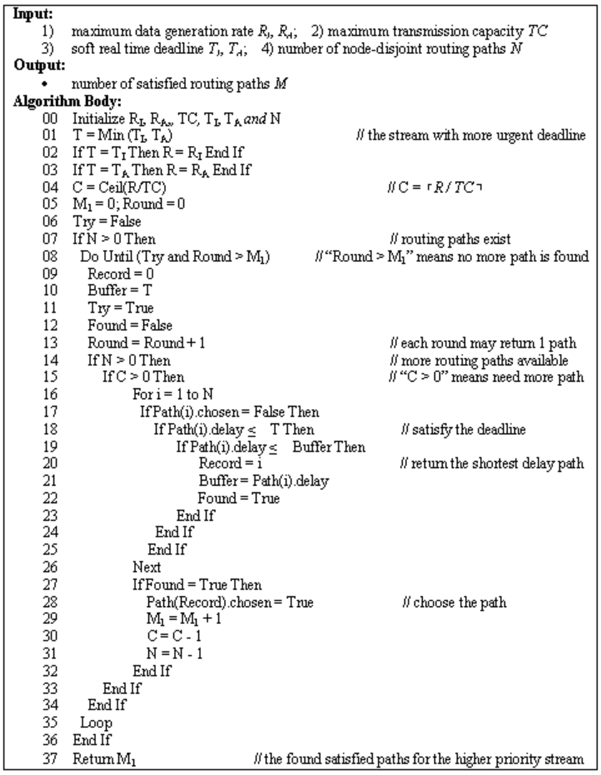
MPMPS is shown in Figure 4. MPMPS algorithm has two phases: 1) searching the maximum number of paths for the stream with the higher priority; 2) searching the maximum number of paths for the stream with the lower priority.

Due to the space limitation, we only show the pseudo code of the first phase of MPMPS in Figure 5. After finishing the searching work for the stream with the higher priority, the searching work for the stream with the lower priority will be conducted by using the similar code as presented in Figure 5 and return another number M_2. The final maximum number of paths $M = M_1 + M_2$.

The time complexity of this algorithm is $O(n^2)$ where n is the number of possible routing paths that can be found by repeatedly executing the TPGF.

7 Simulation & Evaluation

To demonstrate and evaluate MPMPS, we use a new WSNs simulator called NetTopo [23], in which the TPGF is implemented. In this simulation, we consider a WMSN for a fire monitoring application in a forest in which the image stream is more urgent and important than the audio stream in terms of reflecting the fire event.



```
Input:
    1) maximum data generation rate $R_I$, $R_A$;   2) maximum transmission capacity $TC$
    3) soft real time deadline $T_I$, $T_A$;   4) number of node-disjoint routing paths $N$
Output:
    • number of satisfied routing paths $M$
Algorithm Body:
    Initialize $R_I$, $R_A$, TC, $T_I$, $T_A$ and N
    T = Min ($T_I$, $T_A$)                                      // the stream with more urgent deadline
    If T = $T_I$ Then R = $R_I$ End If
    If T = $T_A$ Then R = $R_A$ End If
    C = Ceil(R/TC)                                              // C = ⌈R / TC⌉
    $M_1$ = 0; Round = 0
    Try = False
    If N > 0 Then                                               // routing paths exist
      Do Until (Try and Round > $M_1$)                          // "Round > $M_1$" means no more path is found
        Record = 0
        Buffer = T
        Try = True
        Found = False
        Round = Round + 1                                       // each round may return 1 path
        If N > 0 Then                                           // more routing paths available
          If C > 0 Then                                         // "C > 0" means need more path
              For i = 1 to N
                If Path(i).chosen = False Then
                  If Path(i).delay ≤  T Then                    // satisfy the deadline
                    If Path(i).delay ≤  Buffer Then
                      Record = i                                // return the shortest delay path
                      Buffer = Path(i).delay
                      Found = True
                    End If
                  End If
                End If
              Next
              If Found = True Then
                Path(Record).chosen = True                      // choose the path
                $M_1$ = $M_1$ + 1
                C = C - 1
                N = N - 1
              End If
          End If
        End If
      Loop
    End If
    Return $M_1$                                 // the found satisfied paths for the higher priority stream
```

Fig. 5. Search the maximum number of paths for the stream with the higher priority.

The end to end transmission delay in WSNs is actually determined by the number of hops. Thus, to find out the path with the shortest transmission delay D_{e2e} is to find out the path with the smallest number of hops:

$$D_{e2e} = H * D_{hop}, \tag{11}$$

where H is the number of hops and D_{hop} is the average delay of each hop.

Table 1. Simulation parameters

Parameter	Value
Network Size	500 m * 500 m
Number of Base Station	1
Number of Sensor Node	399
Number of Source Node	1
Video Sensor Generation Rate R	72 kbps
Sensor Node Maximum TC	12 kbps
Sensor Node Transmission Radius	48 m
Delay of Each Hop D_{hop}	20 ms
Video Stream Time Constraint	280 ms
Splitted Image Stream Time Constraint	280 ms (Inherit from video)

Splitted Audio Stream Time Constraint	320 ms (Tolerable constraint)

The parameters used in our simulation are shown in Table 1. The time constraint of video stream is 280 ms. Because the image stream actually plays the key role for reflecting the fire event, it should inherit the time constraint of video stream which is also 280 ms. The time constraint of audio stream is extended to tolerable constraint 320 ms, which allows it to use the routing path with relative longer transmission delay.

7.1 Comparison

As shown in Figure 6, when a fire event is detected, after repeatedly executing the TPGF routing algorithm, six node-disjoint routing paths are found in total from the video source node (red color node) to the base station (green color node).

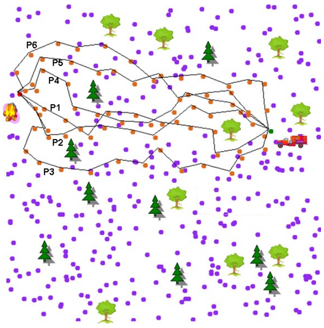


Fig. 6. Six available routing paths are found by using the TPGF routing algorithm

The end to end transmission delays of these six routing paths are shown in Table 2.

Table 2. The end to end transmission delay

Routing path	End to end transmission delay
Path No. 1	240 ms
Path No. 2	260 ms
Path No. 3	320 ms
Path No. 4	260 ms
Path No. 5	240 ms
Path No. 6	300 ms

Since there is no related research work in WMSNs, to prove the effectiveness of MPMPS, we compare MPMPS with another version of MPMPS (named as MPS algorithm) which does not split the video stream (72 kbps) into image stream (48 kbps) and audio stream (24 kbps) but still guarantees the end to end transmission delay of video stream, which means only the end to end transmission delays of all node-disjoint routing paths are used as the parameters for choosing the qualified routing paths. Within these six node-disjoint routing paths, if the MPS is used, only 4 paths (Path No. 1, 2, 4 and 5) are qualified for transmitting video stream since the deadline of video stream is 280 ms. Thus, for every one second, the received data by the base station can be 48 kb (image stream 32 kb, audio stream 16 kb) as shown in Table 3.

Table 3. Data received by the base station for every one second when using MPS algorithm

Path	E2E Delay	Used	Image Stream	Audio Stream
No. 1	240 ms	Yes	8 kb	4 kb
No. 2	260 ms	Yes	8 kb	4 kb
No. 3	320 ms	No	0 kb	0 kb
No. 4	260 ms	Yes	8 kb	4 kb
No. 5	240 ms	Yes	8 kb	4 kb
No. 6	300 ms	No	0 kb	0 kb

However, when using the MPMPS, the video stream (72 kbps) is split into image stream (48 kbps) and audio stream (24 kbps). Based on these six found routing paths, four of them are chosen (in pink color) for image stream transmission and the remaining two paths are used for audio stream transmission as shown in Figure 7. For every one second, the received data by the base station can be increased from 48 kb to 72 kb (image stream 48 kb, audio stream 24 kb) as shown in Table 4.

Table 4. Data received by base station for every one second when using MPMPS

Path	E2E Delay	Used	Image Stream	Audio Stream
No. 1	240 ms	Yes	12 kb	0 kb
No. 2	260 ms	Yes	12 kb	0 kb
No. 3	320 ms	Yes	0 kb	12 kb
No. 4	260 ms	Yes	12 kb	0 kb
No. 5	240 ms	Yes	12 kb	0 kb
No. 6	300 ms	Yes	0 kb	12 kb

The simulation result of Figure 8 shows that using MPMPS can greatly increase the total received multimedia streaming data by the base station.

7.2 Demonstration of MPMPS execution

The execution of MPMPS algorithm is demonstrated in Figures 9, 10, 11 and 12.

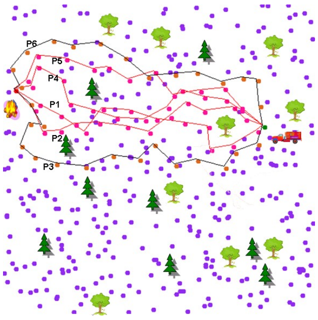


Fig. 7. Video streaming with MPMPS, four paths are chosen for image stream, and two paths are used for audio stream

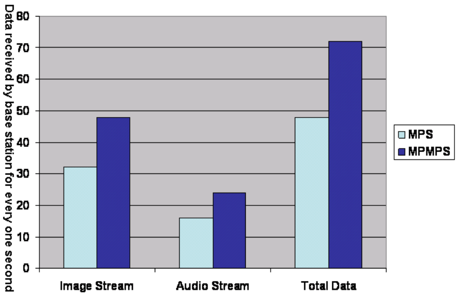


Fig. 8. Data received by the base station (kb) for every one second

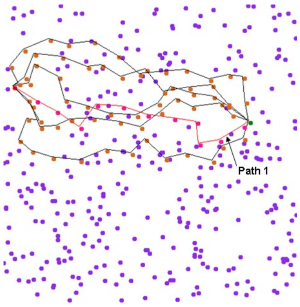


Fig. 9. Choose the path No. 1

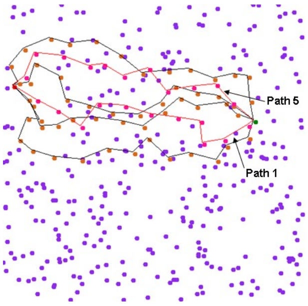


Fig. 10. Choose the path No. 5

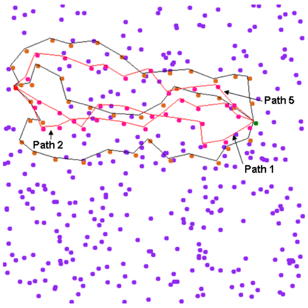


Fig. 11. Choose the path No. 2

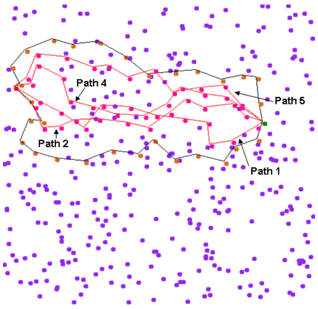


Fig. 12. Choose the path No. 4

Four routing paths are chosen for image stream transmission. In Figure 9, path No. 1 is chosen for image stream transmission first since it has the shortest end to end transmission delay. In Figure 10, path No. 5 is chosen after the path No. 1 because it has the second shortest end to end transmission delay. In Figures 11 and 12, path No. 2 and path No. 4 are chosen respectively for image stream transmission.

8 Conclusion

Video sensors can be used to enhance the capability of WSNs for event description. Efficiently gathering and transmitting video in WSNs is extremely important when the underlying infrastructure, e.g. 3G cellular networks or WLANs, does not exist. In different applications, image and audio streams have different importance levels. Higher priority should be given to the more important stream to guarantee the using of limited bandwidth and energy in WSNs. In this paper, we presented the MPMPS scheme in transport layer based on our previous research work: the TPGF multi-path routing algorithm. The major contributions of this MPMPS scheme have two aspects: 1) supporting multiple priorities; 2) choosing the maximum number of paths to maximize the throughput of the streaming data transmission. Simulation result shows that using MPMPS can effectively choose the maximum number of paths for video transmission.

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