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Resource Optimized Spectral Route Selection Protocol for WMSN Surveillance Application

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Abstract: Most of the energy-aware routing protocols used for routing in Wireless Multimedia Sensor Networks (WMSN) employ shortest path routing for efficient transmission of data.The increasing availability of low cost wireless sensor devices enable audio, video and text data being sensed and transmitted through wireless network.However, Wireless Multimedia Sensor Networks (WMSN) requires a new routing algorithm for effective multimedia transmission. In this study we plan to develop a Resource Optimized Spectral Route Selection (RO-SRS) technique for efficient transmission of multimedia content with high and stable quality of service in WMSN surveillance applications. Spectral route selection strategy is designed by aggregating the sensed multimedia data content with similar size and same destination sink into different groups. The possible routes between the sensed multimedia content sensors to respective sink are selected from the wireless sensor communication. This point allowsmore links to be available for RO-SRS to explore more routingpaths and enables RO-SRS to be different from existing route selection technique. With possible routes, spectrum of routes is identified for efficient transmission with high throughput, minimal data loss and delay. Simulation comparison in this paper indicates that RO-SRS is highly suitable for multimedia transmission in WMSNs.

Key words: Wireless Multimedia Sensor Networks (WMSN), resource, spectral route selection, routing, employ

INTRODUCTION

Wireless multimedia sensor networks are used to enhance existing surveillance applications against crime and terrorist attacks. Largescale networks with wireless multimedia sensor networks of video sensors extend the ability of law-enforcement agencies in monitoring more sensitive areas, keeping watch on public events, private properties criminal identification and so on. Multimedia sensors record potentially relevant activities (i.e. occurrence of thefts, road traffic patrol, traffic violations) and make multimediacontent accessible for future query. Many prevalent research for sensing multimedia information using wireless technologies has received greater attention due to the increasing in surveillance applications. To achieve an improvement in (Quality of user Experience) QoE, Joint User Experience and Energy Efficiency (U-UEEE) (Singhal *et al.,* 2014) method was presented using scalable video coding. However, to improve the geographic routing, a Two Phase geographic Greedy Forwarding (TPGF) (Shu *et al*., 2010) was presented owing to improvement in multimedia transmission. Another method based on Ant model was introduced in (Cobo *et al*., 2010) with the aim of providing significant QoS for multiple types of services in wireless multimedia sensor networks. Rapid advances for multimedia streaming have set the stage for layered multicasting (Shao *et al*., 2011), optimal bandwidth assignment (Xia *et al*., 2011) in WMSN. Layered multicast for multimedia streaming realized the full potential for network coding using flow optimization. On the contrary, the optimal bandwidth assignment for multiple coded video was performed aiming at achieving maximal user satisfaction. Reliable and fast content discovery was performed in (Wang and Yeo, 2011) using peer nodes to improve the rate of throughput and minimize the time delay using hybrid content discovery mechanism. Another method based on overall compression was presented by Wang *et al*. (2011) using spatial correlation model resulting in the improved data delivery through efficient identification of route path. The additional challenges created by the scalability for video multicasting must be addressed in order to deploy a model for improved video quality. Hua *et al*. (2011), an optimal

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resource allocation problem was introduced to significantly reduce the average PSNR and therefore improve the data delivery. On the other hand, a differential coding-based scheduling framework was designed in (Wang *et al*., 2013) for WMSN with the objective of improving the network throughput and energy efficiency. Yuan *et al*. (2015), mulsemedia content delivery through flow adaptation and packet priority scheduling was designed. An empirical model for WMSN based on Common Sensed Area (CSA) was designed to improve the data aggregation model. In this study we propose a Resource Optimized Spectral Route Selection (RO-SPRS) technique aiming at improving the quality of service for efficient transmission of multimedia content in WMSN surveillance applications. First, based on the aggregated sensed multimedia content, a Gaussian Distribution-based data aggregation model is proposed to reduce the amount ofdelay while identifying the routing in the network, where Gaussian density is applied to distribute one sensor node in WMNS with similar size.Then, a Poisson distribution function is applied to prevent network congestion and therefore reduce data loss during transmission once the route has been identified. Finally, the possible optimal routes between the sensed multimedia content sensors to the corresponding sink node are identified based on the spectrum band with an objective to improve the rate of throughput. It is shownthat by integrating the Gaussian distribution spectrum route schemes, the proposedalgorithm can achieve higher rate of throughput by minimizing the delay and data loss in WMSN.

Literaiure review: A number of research works on routing multimedia sensed data in WMSN has been conducted. The research works can be classified into medium access control where end-to-end routing was established based on AODV (Scott *et al*., 2010; Colonnese *et al*., 2013) aiming at improving the peak signal noise to ratio, using spectrum sharing (Keshavarz *et al*., 2013) where a distributed power allocation scheme was used to reduce the interference between the users in the network. However in (Dai *et al*., 2012), the authors provided a method based on correlation aware QoS routing in order to achieve efficient delivery of visual information. As previously mentioned, WMSN not only enhance the quality of service with minimum delay but also reduced the error rate during transmission. In (Pudlewski and Melodia 2010), Compressive video streaming was designed using difference vector aiming at improving the sparsity through which the video streaming is transmitted at reduced error rate. At the same time to improve the sensing performance, a model based on sub carriers was introduced in (Song *et al*., 2010). A survey of QoS routing protocols for WMSN was presented in (Aswale and Vijay Ghorpade, 2015). Method for secured data fusing through route computation problem was designed in (Gao *et al*., 2015) to improve the total transmission volume. Providing efficient content delivery in WMSN consists of a very challenging problem but several methods have been proposed in the literature for QoS supportin these kinds of networks. Bradai *et al*. (2014), an efficient bandwidth allocation mechanism was introduced to improve the effectiveness in terms of video quality and bandwidth utilization under different network conditions. Another method using cross layer architecture (Meddour *et al*., 2012) was introduced to optimize the network resources. Differentfrom the well-known route selection problem in WMSN, weaddress a unique problem for WMSNs regarding how to find optimal route to send the aggregated multimedia data content in such a way that efficient transmission with minimal delay and data loss is achieved.

MATERILAS AND METHODS

Resource optimized spectral route selection: In this section, we plan to develop a Resource Optimized Spectral Route Selection (RO-SRS) technique for efficient transmission of multimedia content in WMSN surveillance applications.

Problem formulation: Let us consider a wireless multimedia sensor Network expressed as 'G = (V, E)' where 'V' represents the set of sensor nodes with multimedia data content and 'E' represents the communication links between the sensor nodes 'Sn_i = SN_1, SN_2,..,SN_n'. Let us further assume that 'SR' be a radius of sensor node where 'Dis (Sn_i, SN_j)' and 'Dis (Sn_i, Sn_j)<2SR, then the distance between the two nodes is formulated as given below.

$$Dis(SN_i, SN_j) = \sqrt{(a_i - a_j)^2 + (b_i - b_j)^2} \quad (1)$$

If 'Dis (SN_i,SN_j)<2SR', where 'SR' represents the multimedia sensing range and sensors 'SN_i' and 'SN_j' are neighboring nodes that share the sensing area. Our routing protocol is formulated as a resource optimized spectral route selection problem, where the objective is minimizing data loss and delay in order to meet efficient transmission with high throughput between the sensed multimedia content sensors to respective sink. The solution space consists of combinations of all possibleroutes that provide a connection between the source node and the sink node.

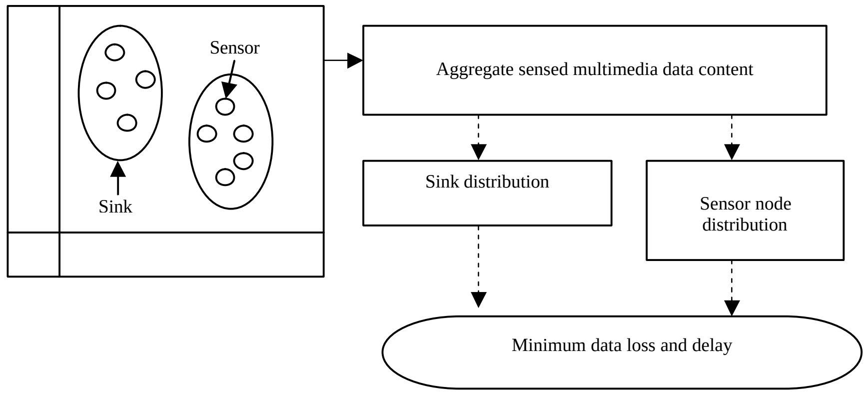

Fig. 1: Block diagram of gaussian distribution-based data aggregation

Gaussian distribution-based data aggregation: As mentioned in the previous section, the abovedescribed spectral route selection yield minimum data loss and delay with the sensed multimedia content. In this section we considerthe problem of minimum data loss and delay during route selection, i.e., finding spectral band which maximizes the rate of throughput utility. Spectrum route selection in RO-SRS technique allows the sensor nodes to switch in a dynamic manner by aggregating the sensed multimedia data content between different channels. The sensed nodes communicate with eachother with similar size and same destination sink into different groups. The Gaussian distribution-based data aggregation determine how the sensors aredistributed in the transmission area possessing similar size and specify a sink that holds a group of sensors into different groups.The Gaussian distribution-based data aggregation is used as sensors deploymentin RO-SRS techniquedue to its high capability where the number of sensor nodes is very large with differentiated channels (bands) for different groups.On the other hand, Poisson distribution model is used for sinks distribution that includes same destination sink into different groups. Figure 1 shows the block diagram of Gaussian distribution-based data aggregation.

Let us consider 'n' sensor nodes '$Sn_i = SN_1, SN_2, \ldots SN_n$where i = 1,2,...n' and 'm' sink nodes '$S_j = S_1, Sn_2, \ldots, S_m$ where I = 1,2,..., m', over a square region with sensor nodes distributed to each sink over a circularregion equal to '$\pi r^2 S_i$'.The sink nodes in WMSN are distributed using the Poisson distributionrepresented by 'γ_i' such that '$\gamma_i = SN_i/Area$' where 'SN_i' symbolizes the sensors in each sink in WMSN and 'Area' symbolizes the area of WMSN. The probability of 'm_i' sinks distributionover group of sensors with one sink for eachgroup of sensors that includes same destination into one group is given by:

$$\mathrm{Prob}(S_i) = \frac{\left(\frac{SN_i}{Area}\right)^{m_i}}{m_i} \tag{2}$$

On the other hand, the Gaussian density in RO-SRS technique distributes one sensor node in WMNS with similar size that has coordinates 'a_2, b_2' to monitor square area 'Area' using'(σ a_2, b_2)' is mathematically formulated as given below:

$$f(a_2, b_2) = \frac{1}{\sqrt{2\pi\sigma a_2^2 b_2^2}} e^{\frac{(a_2 - b_2)^2}{2\pi\sigma a_2^2 b_2^2}} \tag{3}$$

In this way, sensed multimedia data content with similar size using Gaussian density and same destination sink using Poisson distributioninto different groups are aggregated resulting in minimum data loss and delay. The algorithmic description of multimedia data aggregation using Poisson and Gaussian distribution:

Multimedia data aggregation algorithm:

Input: Sensor nodes '$Sn_i = SN_1, SN_2 \ldots SN_n$' sink nodes '$S_j = S_1, S_2, \ldots, S_m$'
Output: Minimized data loss
Step 1: Begin
Step 2: For each sensor nodes 'SN_i'
Step 3: For each sink nodes 'S_j'
Step 4: Send data from 'Sn_i' to 'S_j'
Step 5: Group sensor nodes 'Sn_i' based on similar size using (3)
Step 6: Group sink nodes 'S_j' based on same destinatioon using (2)
Step 7: End for
Step 8: End for
Step 9: End

As shown in the figure, the multimedia data aggregation initially groups the sensor nodes based on similar size using Gaussian distribution function aiming at reducing the delay. Next, the sink nodes are grouped based on the same destination using Poisson distribution function aiming at minimizing the data loss.

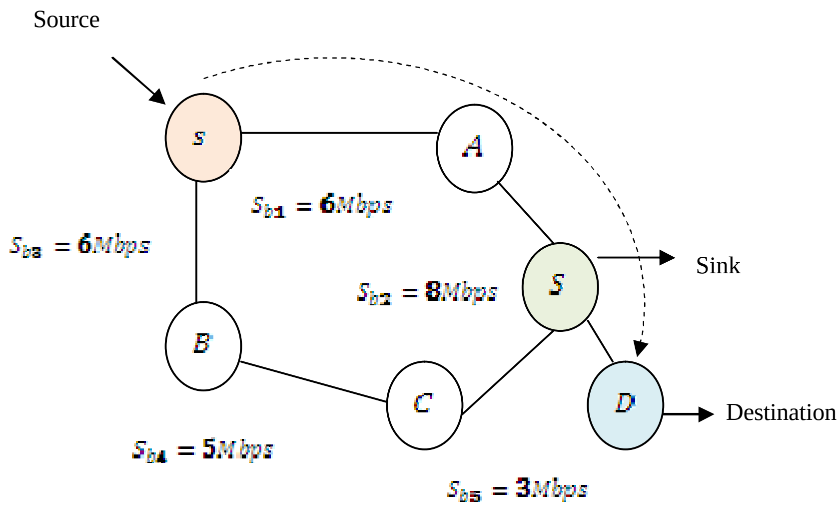

Fig. 2: Block diagram of route selection in WMSN using spectrum bands

Spectral route selection: Once, the sensed multimedia data content are aggregated with similar size and same destination, the possible routes between the sensed multimedia content sensors to respective sink are selected from the wireless sensor communication. The RO-SRS technique routes traffic across paths with higherspectrum availability via a new routing metric. The forwarding routing path then adapts to the dynamic spectrum conditions and uses the linkwith the highest spectrum availability at that time. This point allowsmore links to be available for RO-SRS to explore more routingpaths and enables RO-SRS to be different from existing route selection technique. With possible routes, spectrum of routes is identified for efficient transmission with high throughput.

The ultra wide band used for packets transmission in WMSN is decided based on the spectrum conditions. Therefore, a route path in RO-SRS technique comprises of a sequence of sensor nodes from source to the destination where two sensor nodes considered as neighboring sensor nodes when they have at least one spectrumblock in common.

Figure 2 shows the block diagram of route selection in WMSN using spectrum bands. Let's consider a WMSN as shown in figure where the source node and destination nodes are represented by 'S' and 'D' respectively.

As illustrated in the figure, the source node ''S' reaches the destination node 'D' through two route paths 'S-A-D' and 'S-B-C-D' respectively. Let us further assume that the spectrum bands available at each sensor nodes are different. As illustrated in the figure, the Sensor node 'A' has two spectrum bands available '$Spectrum_{b1}$ (S_{b1}) = 6 Mbps, $Spectrum_{b2}$ (S_{b2}) = 8Mbps' whereas the sensor nodes 'B' and 'C' has '$Spectrum_{b3}$ (S_{b3}) = 7Mbps, $Spectrum_{b4}$ (S_{b4}) = 8Mbps, $Spectrum_{b5}$ (S_{b5}) = 4Mbps' through the sink node. At the same time, the source and destination nodes '(S,D)' have all the spectrum bands between (S_{b1}-S_{b5}) '1 and 5'.

When a data packet has to be flown from the source to the destination, the possible routes between the sensed multimedia content sensors to respective sink is selected based on the higher bandwidth spectrum band. But, the selected path possessing higher bandwidth spectrum results in load distribution as all data packets passes through the higher bandwidth spectrum band, resulting in lower throughput. With the objective of improving the throughput, the RO-SRS technique, the idea behind the Spectral route selection based on spectrum band is to apply spectrum availability.

In the example of figure the aggregate band width between 'S-A-S-D' is '14 Mbps' whereas 'S-B-C-S-D' is '14 Mbps'. As shown in the figure, the possible routes between the sensed multimedia content sensors to respective sink are 'S-A-S-D'' and 'S-B-C-S-D' respectively. The spectral route selection in RO-SRS technique routes the data packets through 'S-A-S-D'during the first cycle and then through 'S-B-C-S-D', during the second cycle, reducing the congestion and resulting in higher throughput. Let us further consider that '$Time_{fb}$' symbolizes the fraction of time during which the sensor node 'SN_i' is free to send the data packets through spectrum band 'b'. Then, the throughput achieved between pair of nodes 'SN_i' and 'Sn_j' is mathematically evaluated as given below.

$$T(SN_i, SN_j, b) = MAX(b)(SN_i, SN_j) \quad (4)$$

The spectral route selection based on spectrum band routes sensed multimedia data across paths with higher spectrum availability, resulting in better utilization of the available spectrum and therefore improving the rate of throughput. The algorithmic representation of optimal throughput arrived through spectral route selection based on spectrum band.

Spectrum Route Identification algorithm:
Input: Source Node 'S' Sink Node '$S_i = S_1, S_2, ..., S_n$', Destination Node'DN'
Output: Optimal throughput
Step 1: Begin
Step 2: For each source node 'S'
Step 3: For each destination node 'DN'
Step 4: Perform route identification based on spectrum bandwidth using (4)
Step 5: End for
Step 6: End for
Step 7: End

As shown in the figure, the spectrum route identification algorithm utilizeavailable spectrum bands by routing sensed multimedia content over pathswith higher spectrum availability. In RO-SRS technique, routes possessing highest spectrum band are then selected as candidate routes through which the sensed multimedia content is transmitted. With possible routes, spectrum of routes is identified for efficient transmission resulting in higher rate of throughput.

RESULTS AND DISCUSSION

Simulation experiments were conducted to analyze the performance of RO-SRS technique by using Network Simulation package (NS2). This environment is used to test the proposed WMSN management system and compare it with existing multimedia broadcast model. In our simulation, the WMSN is divided into multiple groups with each group consisting of many sensor nodes. Each group is responsible for aggregating the sensed multimedia data content about its environment with sensor nodes distributed in square area 'Area'. The simulation parameters are listed in Table 1. In order to evaluate the performance of our simulation, certain metrics are introduced to describe the supposed WMSN configurations. The simulation performance parameters are in the following.

Table 1: Simulation settings

Simulation parameters	Values
Simulation time	400ms
Number of runs	7
Node density	70
Node speed	0–10 m sec^{-1}
Transmission radius	105 M
Coverage area	1200×1200 m
Packet size	200 Kbps
Bandwidth	20 MHz
Initial energy	20J
Number of data packets	10, 20, 30, 40, 50, 60, 70

Throughput demonstration of RO-SRS: The main goal of our experiments is to determine the rate of throughput for providing efficient transmission of data packets to the wireless multimedia sensor network with resource optimization.We randomly generated networks between 10 and 70 data packets. We created at random networks with data packets in the range 10-70, data packet size 200 Kbps, coverage area limit 900×900 m. To achieve results in a reasonable time, we set node speed to 0-0 m sec, limiting the execution time of RO-SRS. With this network setting the rate of throughput is defined as given below.

Throughput: is one of performance metrics calculated at each sink node. Throughput measures the number of successful packets received at the sink node to the total number of the packets sent to the sink node. The rate of throughput is formulated as given below.

$$T = \frac{DP_r}{DP_s} * 100 \quad (5)$$

Where 'T' measures the throughput which is the ratio of data packets received 'DP_r' to the data packets sent 'DP_s' in WMSN.

Figure 3 shows the rate of throughput versus data packets sent. In Fig. 3, we can observe that the rate of throughput grows with the rate of data packets being sent. The experiment was conducted for data packets in the range from 10-70 but for number of data packets with 40, given network was infeasible reducing the rate of throughput. However, the rate of throughput increased with the increase in the data packets being sent. The rate of throughput is themost significant one in terms of the data packets transmission. This is implied by the fact that spectral route selection requirements improve the solution space significantly and consequentlythe rate of throughput solutions grows. With spectrum of routes identified using RO-SRS, the data packets arrived are successfully routed through available spectrum band, resulting in the improved rate of throughput. By applying RO-SRS, the rate of throughput is said to be improved by 11.80% compared to O-UEEE and 25.37% compared to TPGF.

Delay demonstration of RO-SRS: In the simulation, to clearly compare the features of both RO-SRS and existing

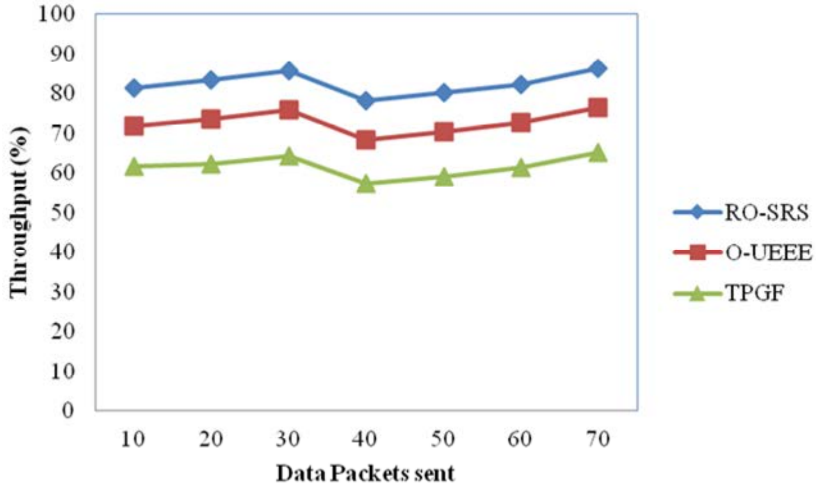

Fig. 3: Measure of throughput rate

Optimization of User-Experience and Energy-Efficiency (O-UEEE) (Singhal *et al.*, 2014) and Two Phase geographic Greedy Forwarding (TPGF) TPGF (Singhal *et al.*, 2014) we simplify the delay for identifying the routes as following defined, Delay: is the amount of time taken for each sensor nodes to identify the routes with the objectives of transmitting their corresponding packets to the destination. In order to measure the delay rate, actual and estimated time to identify the routes between source destination pair ‘S-D’ is obtained. The difference between them with respect to the sensor density is the resultant delay rate. The delay rate for identifying the routes is as given below.

$$D = \sum_{i=1}^{n} SN_i * \left(\text{Actual Time}(S-D) - \text{EstimatedTime}(S-D)\right) \quad (6)$$

Where ‘SN_i’, ‘S’ and ‘D’ symbolizes the sensor node density, source sensor node and destination node respectively. The delay rate is measured in terms of milliseconds (ms). Based on the simulation goals and the definition of thedelay, the major comparisonmetrics in this simulation is with respect to the node density.

In the simulation, the network size is fixed in 600×400 M. Foreach fixed number of sensor nodes (network density) andtransmission radius (‘SR’), the average numberof routes and the average number of path length are computed from 7 simulation results using 105 different sensor nodes for networkdeployment. Then, we change the node number (from15-105) and transmission radius (from 60-105 M)to obtain different values. Figure 4 is the simulation results on the routing delay found by applying RO-SRS, O-UEEE (Singhal *et al.*, 2014) and TPGF (Shu *et al.*, 2010) respectively.By comparing the average node density we can easily see that RO-SRS find more number of route paths than O-UEEE and TPGF. This is because as shown in the figure, the routing delay by applying RO-SRS is less than the two other methods. It is easy to conclude that after data aggregation average routing delay of RO-SRS is reduced. This is because of the application of Gaussian distribution function based on similar size that tends to minimize the average routing delay using RO-SRS. The average delay observed in RO-SRS is reduced by 19.17% compared to O-UEEE and 49.24% compared to TPGF.

Data loss demonstration of RO-SRS: Finally we address the third goal of the experiments with respect to data loss showing the comparison between RO-SRS, O-UEEE and TPGF and defined as follows. Data loss: In order to measure the effectiveness of the technique, the rate of data loss has to be measured. The rate of data loss is the amount of data loss occurred during transmission of multimedia content that measures the difference between the data packets sent and the data packets received. The data loss is measured as given below

$$DL = DP_s - DP_r \quad (7)$$

where ‘DL’, ‘DP_s’ and ‘DP_r’ represents the data loss, data packets sent and data packets received respectively. It is measured in terms of kilo bits (Kb). For all scenarios and network patterns, data loss is increasing with the data packet density. Seven unique experiments were conducted for each network size. Analysiswas conducted

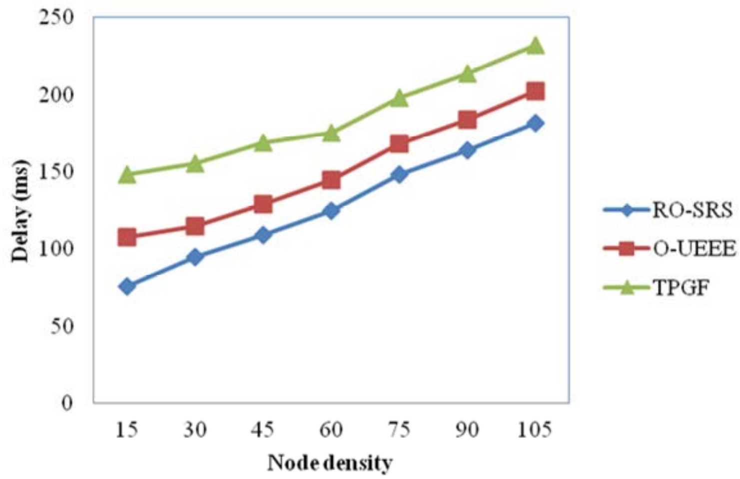

Fig. 4: Measure of routing delay

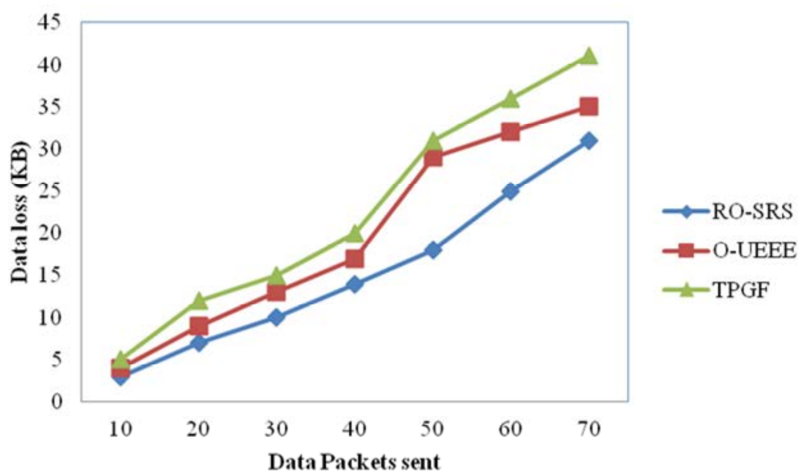

Fig. 5: Measure of data loss

for different set of node density (10–70) and node speed (0-8 m sec^{-1}). The results presented in Fig. 5 shows the data loss when sink nodes are grouped based on the same destination. We can see that the values of data loss decreased with the decrease in the data packets sent, when nodes are grouped based on the same destination using Poisson distribution. Moreover, the values of the observed parameter also increase with the increase in the number of data packets when different sink nodes exist in the network. The important observation from the figure given above is that the data loss during routing is directly proportional to the number of data packets sent. Therefore though major deviations are not being observed but comparatively the RO-SRS proved to be better. Column difference shows the percentage differenceof the particular routing scenario with respect to the data loss occurrence using three different methods. The data loss for 10-data packets and 20-data packets was reduced in RO-SRS by 33.33 and 28.57% in the case compared with O-UEEE; 66.66 and 71.42% in the case compared with TPGF.

CONCLUSION

Using multimedia sensor nodes can enhance the capabilityof WMSNs for efficient route selection by aggregating the sensed multimedia data content with similar size and same destination sink into different groups. Efficient transmission of multimedia data content in WMSNs is a basic requirement. Inthis paper, a new Resource Optimized Spectral Route Selection (RO-SRS) is proposed to facilitate the multimediastreaming data transmission in WMSNs. The RO-SRS technique aggregates the sensed multimedia data content based on similar size using Gaussian distribution and based on the same destination using Poisson distribution function which makes RO-SRS technique be different from many existing geographic routing protocols.Both theoretical analysis and simulation comparisonin this study show that RO-SRS technique is more suitable foridentifying possible routes between the sensed multimedia content sensors to respective sink than other geographic routingprotocols in geographic WMSNs.

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