CHAPTER 6

MaNeRS: MAXIMIZING NETWORK LIFETIME ALONG WITH RELIABILITY AND SPEED OF ROUTING IN WIRELESS VISUAL SENSOR NETWORKS

6.1 INTRODUCTION

Wireless VSN use camera nodes to capture either image or video. These camera nodes use smart cameras that support various kinds of applications. Unlike ordinary cameras used only for monitoring, smart cameras contain internal processing power for image identification, detection, compression and alerting the personnel. WVSN (Wireless Visual Sensor Network) can collaborate with video analytics and image processing to provide some of the best features in the world. For example visual sensors can sense the armed person in an Automated Teller Machine (ATM) with the help of video analytics processing and can also indeed alarm the security personnel. Wireless VSN find application in surveillance, military, habitat monitoring and environmental monitoring, etc. Since VSN deal with acquisition of image and video, energy efficiency, longer network lifetime, higher bandwidth, higher reliability and good speed are required.

Wireless VSN are different from wireless sensor network and they require separate attention. Unlike WSN, wireless VSN obtain only 2-dimensional and 3-dimensional data. They are independent and do not need cluster head. WSN consider hierarchy routing since nodes are dependent and need data aggregation. Energy efficiency cannot be provided in hierarchical routing because dissipation is uniform and cannot be controlled. WVSN
involves flat routing since nodes are independent (any node can send the information to base station). The flat routing is energy efficient because energy dissipation depends and adapts to the traffic pattern.

VSNs gain immense importance than WSN because people from all over the globe understand either video or images than a specific language. Video or images elaborate more than the text consisting of words and numbers. Obviously, processing video or image is quite complex than processing scalar data such as words or numbers. The strength of VSNs has encouraged using energy efficient routing protocol with good throughput and less packet loss. The ideal performance of VSNs is proportional to energy conservation, high bandwidth, high reliability, low delay and low cost.

Selection of the ideal nodes for the transmission of data packet is essential for a perfect routing in VSNs. VSNs data are either two-dimensional or three-dimensional and protocols used in wireless sensor networks cannot be directly applied to VSNs. The main quality limitations that are involved in the network layer include node availability, timeliness, energy efficiency, reliability, robustness and security. VSNs are required to satisfy the basic fundamental QoS parameters in terms of bandwidth, reliability, delay, jitter, throughput and packet loss.

Delivering a few quality services competently and not taking into account other various qualities is not a good choice. Relatively, bearing in mind manifold parameters into account, and delivering a particular level of service is better. Providing reliability needs different multipath transmission and retransmissions which results in delay and waste of energy (J.Niu et al. 2014). Therefore it is understood that reliability, delay and energy are differing quality constraints and achieving them is a challenge (F.Kuipers et al. 2005).
Section 6.2 deals with the related work and background, Section 6.3 deals with the description of MaNeRS, Section 6.4 deals with the simulation results, and Section 6.5 concludes with the summary.

6.2 RELATED WORK AND BACKGROUND

In wireless sensor networks, either multipath routing or multi-hop routing is used to provide quality constraints. Multipath routing is used to provide reliability and shorter end-to-end delay. But multipath routing is not energy efficient. Figure 6.1 gives an illustration of the drawbacks of multipath routing.

![Figure 6.1 Illustration of the problems in multipath routing](image)

Considering the network without redundant deployment of nodes like the illustration above, it shows that there are two critical nodes in the network which drain all the energy at the same time during multipath routing since both the nodes are used at the same time. This reduces the network lifetime due to node death. Multipath routing uses the most nodes present in the network and the destination node may receive the same data packet multiple times and hence, it is not energy efficient. But multi-hop routing makes multiple hops to the destination but in a single path. Hence multi-hop routing is better than multipath selection routing. In the proposed algorithm, the constraints are considered at each hop. L.Cheng et al. (2010) also convey the same.
Geographic opportunistic routing is used to deliver the different quality of services without the disadvantages of multipath routing. This routing protocol has low overhead, scalability and high throughput, and it is well thought-out as a perfect choice for many wireless sensor applications, where the data progress is on the basis of the location information of the sensor nodes. Hence the data packet can be directed to a specific region and to step forward towards the sink at each hop (Sanam Shirazi Beheshtia et al. 2013).

Candidate selection and relay priority are the two important issues that are considered to transmit the data packets with the required constraints (K.Zeng et al. 2007). The former refers to the choosing of nodes, and the latter is the flow of data packet through the sensor nodes in the network. Candidate selection and relay priority form the core of the proposed system.

Long Cheng et al. (2014) have proposed a competent QoS-aware GOR (EQGOR) for WSN and deals with the above-mentioned issues. GOR provides reliability from end to end and addresses the issues of delay. They demonstrate that less the delay more the energy efficiency. Here, energy is not considered as a separate entity. Rather, on the selection of the sensor nodes energy of a camera sensor node in the network is considered. A scenario can be considered where a node has high reliability and low energy in the network. A question arises how the camera sensor node can transmit the visual data to the other camera nodes or the sink node. The disadvantage of the EQGOR is the broadcasting to all the camera nodes which will drain more energy.
He et al. (2009) have considered the data processing and visual data transmission schemes in an energy efficient manner. They proposed a distributed algorithm to make the most of network lifetime. The authors considered a cross-layer design and dealt with the residual energy. (Sayidge et al. 2006), (Alessandro Redondi et al. 2014), (Chien-Chun Hung et al. 2010), (Karim Seada et al. 2004) and (Petros Spachos et al. 2012) have considered only one or two parameters of quality of service. This paved the way to develop the protocol MaNeRS, which considers the three parameters such as reliability, delay and energy for choosing the proficient sensor nodes, which simultaneously improves the performance and lifetime of the network. The energy efficient forwarding camera nodes strive to save the energy for their turn. To guarantee high reliability the data transmitted from the camera sensor nodes can be less but energy efficient.

The basic idea of Pareto principle leads one to move towards the proposed protocol. Best node selection uses the Pareto principle also called as 80 – 20 rule states that 80 percent of the effects are due to 20 percent of the causes. If the first best nodes (20%) are selected, then it will lead to maximum (80%) efficiency in routing. Best node selection triggers 20 percent causes for 80 percent more network lifetime, reliability and less delay. In order to find...
the link estimation services, the data is flooded to all the nodes in the network. This will help one to calculate the distance between the nodes, their position towards destination, Successful Packet Transmission Ratio (SPTR) and Per hop Max Distance Progress (PMDP). There is no need for the consideration of overall reliability and end-to-end delay. The expected reliability, delay and number of hops with real values obtained through these broadcasts can be computed.

The GOR is considered as an effective routing mechanism for the multi-hop wireless networks. Each camera sensor node in the network is aware of the location and their one-hop neighbors in the network. In VSNs, the camera sensor nodes are deployed sparsely. Here, MAC layer protocol is used to provide the link quality services. The two important link estimation services considered are the Successful Packet Transmission Ratio (SPTR) and the Per hop Max Distance Progress (PMDP). SPTR is obtained by the ratio of successful messages transmitted to the number of messages transmitted by the node. The successful messages are those that reached the target with the acknowledgement. PMDP is the maximum distance between the camera sender node and the receiver camera sensor node or the intermediate camera sensor node.

Here, the receiver camera node must be within the coverage area of the sender and also towards the destination. The receiver camera sensor node competent of receiving the visual data may not be necessarily the destination or the sink node. The Euclidean distance is computed between the source, destination and the intermediate nodes. The camera sensor nodes within the coverage area (Scov) are chosen and the distances between the intermediate camera sensor nodes are calculated. There will be more number of hops if the node density is high between the source and the destination. It is best illustrated in Figure 6.3.
In the first path, there are four transmissions same as the number of hops from the source S to the destination D. But the second path makes only three transmissions to reach the destination D. Thus, PMDP will assure that it will make minimum number of hops. The hop counts increases as the density of the camera sensor node increases. The next-hop neighbors are calculated for each node. The NNL (Next hop Neighbor List) lists the one hop neighbors within the coverage area. They are defined based on the PMDP and SPTR values. The distance between the camera nodes is compared and the camera nodes within the range are put in the NNL of the sensor node. GOR gives the location information of their one-hop neighbor. SPTR and PMDP are accessed by the neighbor node. The NNL list is sorted based on the values of SPTR and PMDP.

6.3 MaNeRS DESCRIPTION

Proficient node selection is done by choosing the nodes by making four filtrations. The parameters chosen are the node’s reliability, delay, energy, bandwidth consumption with the remaining number of hops to destination. These parameters make it easy to choose the best nodes from the nodes with similar condition in a dense network. Proficient node selection leads to the best efficient routing. Four filtrations are made in choosing the
best nodes. The first filtration is based on the network coverage. The second filtration is done based on the link quality estimation services. The third filtration is done based on the node’s energy, bandwidth consumption with remaining number of hops to destination. The final filtration is done by finding the node’s reliability and delay which is compared with the expected reliability, delay.

The filtrated camera sensor nodes are sorted based on the SPTR and PMDP values in the descending order. The sorted camera nodes must be tailored so that it must be less than or equal to 25 percent of the total number of the existing camera sensor nodes. But, there must be at least one camera sensor node to forward the data packet. The efficient first three camera sensor nodes from the filtered nodes are selected for forwarding. Thus the lifetime of the network increases. The three parameters such as delay, reliability and energy of the sensor node are considered to select the best node from NNL. The camera sensor node which has high reliability, high energy and low delay is given the high priority. The camera sensor forwards the data to the destination through vibrant relaying on the basis of the priority of the camera nodes.

Reliability is considered as an important parameter and it is a foolproof method that the data transmission is reliable when the packet is transmitted to more number of camera sensor nodes. Transmitting to more number of camera sensor nodes is an option to increase the reliability when all the camera sensor nodes are considered uniformly. In VSNs, the camera sensor nodes cannot be expected to be uniform and after a single transmission, the camera sensor nodes will have several differing capabilities to transmit the data packet. The energy consumption depends on the number of nodes utilized for data packet transmission.
This work highlights that reliability can be provided by choosing efficient camera sensor nodes. Reliability does not only depend upon the number of different hops towards the destination. It is the guarantee that the data packet must be delivered without packet loss which depends on the camera sensor node’s SPTR, energy and its location within the considered coverage. Few number of hops to the destination increase the lifetime of the network and energy conservation of the other nodes. Reliability is expressed as follows:

\[ Re = SPTR, \text{within } Scov \]  

(6.1)

Delay is determined by the transmission time taken to transmit the data packet which includes the overall delay for transmission between two camera sensor nodes.

\[ De = Ri - Ss \]  

(6.2)

Ri is the receiving time of the data packet by the intermediate camera sensor node, and Ss is the sending time of the data packet by the sending camera sensor node. Energy of the camera sensor node is calculated as the variation between original energy and drained energy. Reception and transmission of data packet leads to the draining of energy from the camera sensor node.

\[ EN = ENi - ENd \]  

(6.3)

EN is the energy available. It is determined by subtracting the drained energy ENd from the initial energy ENi. The camera sensor node involves in data transmission, reception and soon drains out of energy which decreases the lifetime of the network. The camera sensor node having sufficient energy is a reliable one. The proficient camera sensor node features high reliability, low delay and sufficient energy. The basic assumption of the
end-to-end delay, reliability and then comparing with the values for each hop is an added calculation but it does not advance the idea further. The nodes in the NNL are analyzed for reliability, energy efficiency, and low delay within the selected coverage area. These selected camera sensor nodes are limited to three in number such that the first node is assigned with highest priority, the second node with less priority than the first one. The third node is assigned with the least priority. During simulation, random energy is given to all the nodes to provide variation in energy between the nodes. Energy is reduced during the transmission and reception of packets. Next, the bandwidth consumption is considered. In simulation, random bandwidth is assigned to all the nodes and then each node will calculate its bandwidth consumption based on the packet size. Bandwidth consumption, \( \text{bandc} \) is given by

\[
\text{bandc} = \frac{\text{packet size in bits}}{\text{bandwidth}}
\]

(6.4)

Consider sensor node \( i \) to be the current node and \( j \) represent all the neighbors of the current node. The estimated number of hops, expected reliability, expected delay are calculated and checked with the actual delay and the actual reliability. Here, \( \text{EstNH} \) is the estimated number of hops, \( \text{ExpRe}(i) \) is the expected reliability of node \( i \) and \( \text{ExpDe}(i) \) is the expected delay of node \( i \).

The estimated number of hops for node \( i \) is found by calculating the ratio of the distance between the source and the destination to the average of the minimum and maximum distances of the neighbours of node \( i \).

\[
\text{EstNH}(i) = \frac{\text{Distance}(i, \text{destination})}{\text{Avg}\{\text{minDistance}(i,j), \text{maxDistance}(i,j)\}}
\]

(6.5)

The expected reliability is the average of all the successful packet transmission ratio values from the neighbors to node \( i \).
\[ \text{ExpRe}\{i\} = \text{Avg}\{\text{SPTR}(i,j)\} \quad (6.6) \]

The expected delay is the ratio of the average of the minimum and maximum delay from the neighbors to node i to the maximum distance between the neighbour and node i multiplied by the estimated number of hops.

\[ \text{ExpDe}\{i\} = \frac{\text{Avg}(\text{minDe}(j,i), \text{maxDe}(j,i))}{\text{maxDist}(j,i)} \times \text{EstNH}\{i\} \quad (6.7) \]

All the constraints are checked with expected values to provide consistency. For best node selection, the nodes are prioritized such that the actual reliability of the node must be greater than the expected reliability and the actual delay of the node must be less than the expected delay.

When the VSN becomes dense, there can be more camera sensor nodes with the same ability to forward. To enhance the parameters such as bandwidth, the remaining number of hops to the destination from the current node is considered. As the number of parameters increases in choosing the proficient node, the level of efficiency of the network increases drastically. This in turn increases the efficiency of the routing path and also extends the lifetime of the network. Utmost, there will be three forwarders because three priorities are enough with the respective parameters considered. When packet headers are broadcasted with their respective priorities, additional overhead is caused to the routing. As an alternative for broadcasting, dynamic relaying is selected to forward the packets. This dynamic method considerably reduces the consumption of the energy since the camera sensor nodes that do not involve in forwarding can be in sleep mode. Overhearing takes place in broadcasting, but in dynamic relaying this is limited. The camera sensor nodes transmit the data to the finest forwarders and they in turn again transmit the data to their finest forwarders and so on.
Lastly, after selecting the proficient node, the most excellent three forwarders among the camera sensor nodes are stored in its routing table. If the identical forwarder is at hand in two or more nodes, then it is omitted on the basis of priority from the other camera sensor nodes. Redundant transmission is avoided by the omission of the identical forwarder in multiple nodes.

![Image of network nodes](image)

**Figure 6.4 Reducing repeated transmission**

In Figure 6.4, the node q can be neighbors of both nodes 1 and 2. Similarly, nodes 2 and 3 can have node r as their neighbor. According to the priority, either node 1 or node 2 can contain q, but not both. Likewise, either 2 or 3 can have r, but not both. Avoiding repeated transmission makes less use of energy.

MaNeRS make three filtrations in choosing the proficient nodes. The first filtration is based on the coverage and link quality estimation services. The second filtration is done based on present delay, reliability, energy, remaining number of hops to destination and channel capacity. The third filtration is to check redundant neighbors to avoid repeated transmission. Even though there can be many forwarders, the best among three forwarders can give a good start. The NNL is sorted in descending order based on the SPTR and PMDP. The sorted NNL must be tailored in such a way that it must be less than or equal to 25% of the total nodes present and assigned to BNL.
(Best Neighbour List) in the same order. At the same time it must be greater than 1. The BNL contains only the minimum nodes with high link quality services. These nodes are then compared respectively with each other based on their energy, delay and reliability values. The efficient first three nodes are placed in BFL (Best Forwarders List) and are assigned with the priorities based on their values.

Dynamic relaying is that any node will act as a relay node to transfer the packet to the other nodes. Dynamic relaying is the process of sending the packets to the destination using only the proficient nodes. Dynamic relaying considerably reduces the overhead, the number of transmissions and improves the network lifetime.

The proficient node selection leads to best node which relays the packet to the destination. Relaying takes place through only proficient nodes, which limits the usage of many nodes. The camera node forwards the visual data to the first node in the best forwarders list. This is done constantly until the visual data reaches the destination from the first node in the BFL.
Start

Visual Sensor Network Deployment and parameter initialization

Sender Initialization and search nearest neighbor

Sender sends RREQ to destination via intermediate neighbor nodes

If utility < threshold

Yes

No

Choose another neighbor node

Neighbor Node sends RREP to sender node

If receive Fr

Yes

No

Calculate packet size and queuing delay ($T_w$) of each neighbor

If delay < $T_w$ and also check the energy

Allocate the data rate $A_i$ to each neighbor node and send the data packet

If data packet reached destination

Yes

No

End

Figure 6.5 Flow-Chart for MaNeRS
The algorithm for MaNeRS is as follows:

if a node receive RREQ from a sender node $S_n$ then

    if utility < threshold then

        Reply to the $S_n$.

    end if

end if

if receive forwarding request ($F_{fr}$) replies from neighbor nodes then

    Determine the packet size $S_p(i)$ to each neighbor $I$.

    Estimate the queuing delay $D_e$ and energy for the packet for each neighbor based on Equation below

    $$D_e = R_i - S_s$$

    $$EN = EN_i - EN_d$$

Determine the qualified neighbors that can satisfy the deadline requirements based on $D_e$. Organize the qualified nodes in descending order of $D_e$
Allocate workload rate $A_i$ for each node.

for each intermediate node $n_i$ in the sorted list do

Send packets to $n_i$ with transmission interval $S_{p(i)} A_i$

end for

end if

6.4 SIMULATION RESULTS

MaNeRS is implemented in VSN with the same parameters implemented in VSN as with actor nodes with EMD protocol in VSN, Q-back pressure algorithm with autonomous recovery scheme, G-AODV and AODV. The performance of the implementation of MaNeRS in VSN is measured in terms of the energy drained and throughput.

Figure 6.5 shows the comparison of the energy drained between G-AODV, Q-back pressure algorithm with autonomous recovery scheme in VSN, the actor nodes with EMD protocol in VSN and MaNeRS in VSN. The graph reveals that energy drained with MaNeRS in VSN is less than the actor nodes with EMD protocol in visual sensor network, Q-back pressure algorithm with autonomous recovery scheme in VSN, G-AODV in VSN and AODV in VSN. The consumed energy is expressed in terms of milli joules versus the message interval time in terms of seconds.
Figure 6.6 Energy drained in VSN against time plotted for the four proposed protocols in VSN (AODV, G-AODV, Q-back pressure, VSAN with EMD protocol and MaNeRS).

Figure 6.7 shows the comparison of the energy consumed between G-AODV, Q-back pressure algorithm with autonomous recovery scheme in VSN, the actor nodes in VSN with EMD protocol and MaNeRS in VSN. The graph reveals that energy consumed with MaNeRS in VSN is less than actor nodes with EMD protocol in VSN, Q-back pressure algorithm with autonomous recovery scheme in VSN, G-AODV in VSN and AODV in VSN. The consumed energy is expressed in terms of milli joules versus the message interval time in terms of seconds.
Figure 6.7 Energy consumed in VSN against time plotted for the four proposed protocols in VSN (G-AODV, Q-back pressure, VSAN with EMD protocol, MaNeRS) and the existing protocol AODV.

Figure 6.8 depicts the performance of VSN in terms of throughput with the AODV, G-AODV, Q-back pressure algorithm with autonomous recovery scheme, actor nodes in VSN and MaNeRS in VSN. The graph reveals that MaNeRS in VSN outperforms actor nodes in VSN, Q-back pressure algorithm with autonomous recovery scheme, G-AODV and AODV in terms of throughput in VSN respectively. The throughput is expressed in terms of kilo bits per second versus the time in terms of seconds.
Figure 6.9 depicts the comparison of the performance of VSN in terms of packet loss. The graph reveals that MaNeRS in VSN outperforms actor nodes with EMD protocol, Q-back pressure algorithm with autonomous recovery scheme, G-AODV and AODV in terms of packet loss in VSN respectively. The packet loss is expressed in terms of 0 kilo bits per second versus the time in terms of seconds.
Figure 6.9 Packet losses in VSN through MaNeRS

6.5 SUMMARY

The comparison of the proposed MaNeRS with the existing protocols proves that the selection of the proficient selection on the basis of the parameters such as reliability, delay, energy, bandwidth with the remaining number of hops to destination results in efficient forwarder selection. The lifetime of the network is greatly increased because of the consideration in the node’s energy and relaying the packets dynamically. Avoiding redundant transmission to the same nodes maximizes the lifetime of the network. MaNeRS prove its proficiency in energy efficiency, throughput and thus the performance.