CHAPTER 6

RESULTS AND DISCUSSIONS

6.1 INTRODUCTION

In this chapter an analysis of three proposed protocols which were presented have been compared. The performance insight of the proposed protocols VELSCP, CIDT and VELCT have been described. The performance of the protocols have been analysed and compared among themselves.

6.1.1 Scenario Setup

The performance of the three proposed protocols have been evaluated in a highly mobile environment using NS-2. The parameters are given in table 6.1. The simulation uses random waypoint mobility model. The sensor nodes are deployed in a geographical area of 1000 x 1000 m² with a speed limit of 5 m/s to 30 m/s. The base station is located in the square region (x=500, y=1050). The sensing range is 20 m. The antenna is set to be omni-directional. The radio range within the cluster is set to 40 m to 60 m. The radio range between the clusters is set to 120 m. Further communication energy parameters are set as $E_{th} = 0.01$ J, $E_{elec} = 50$ nJ/bit/m², $E_{DA} = 5$ nJ/bits/signal and $E_{amp} = 0.0013$ pJ/bit/m⁴ (Heinzelman et al 2002). The size
of data packet is 256 bytes. The random waypoint model has been selected for assigning sensor node mobility. The simulation time is 100 s. The performance of the proposed routing protocol has been determined by the total number of nodes and the speed of the mobile sensor nodes within the set network.

### Table 6.1 Basic simulation parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>$1000 \times 1000 \text{ m}^2$</td>
</tr>
<tr>
<td>Base station location</td>
<td>$(x=500, y=1050)$</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>500</td>
</tr>
<tr>
<td>$E_{elec}$</td>
<td>50 nJ/bit/m$^2$</td>
</tr>
<tr>
<td>$E_{amp}$</td>
<td>0.0013 pJ/bit/m$^4$</td>
</tr>
<tr>
<td>$E_{DA}$</td>
<td>50 nJ/bit/signal</td>
</tr>
<tr>
<td>Data packet size</td>
<td>256 bytes</td>
</tr>
<tr>
<td>Transmission range within cluster</td>
<td>40 m to 60 m</td>
</tr>
<tr>
<td>Transmission range between clusters</td>
<td>120 m</td>
</tr>
<tr>
<td>Sensing range</td>
<td>20 m</td>
</tr>
<tr>
<td>Mobility</td>
<td>5 m/s to 30 m/s</td>
</tr>
<tr>
<td>Mobility Model</td>
<td>Random Waypoint Model</td>
</tr>
<tr>
<td>Simulation Time</td>
<td>100 s</td>
</tr>
</tbody>
</table>
6.1.2 Performance Metrics

The network parameters that are used for evaluating the performance are packet delivery ratio, throughput, total energy and delay. To show the effect of the proposed topology management schemes in VELSCP, CIDT and VELCT, these protocols have been evaluated with respect to the number of sensor nodes and speed of mobile sensor nodes in the network.

6.2 IMPLEMENTATION AND RESULTS

6.2.1 Influence on number of nodes

The variations in the number of sensor nodes indicate a great impact on the performance of large scale mobile wireless sensor networks. The sensor node density is increased from the initial setup of 100 sensor nodes to 500 sensor nodes. As this gets varied, the performance of each topology management schemes in terms of packet delivery ratio, throughput, total energy and delay have been evaluated. The results are illustrated pictorially in figures 6.1 to 6.4.

6.2.1.1 Packet Delivery Ratio with respect to Number of nodes

By evaluating the proposed schemes with respect to number of nodes, the packet delivery rate of VELCT is found to be higher when compared to VELSCP and CIDT. Figure 6.1 shows the variations of the proposed protocols and it evidently depicts that VELCT incurs 98.962% (approx) delivery of data packets towards the sink. In contrast, VELSCP and CIDT deliver only 97.01% (approx) and 95.12% (approx) of data packets
respectively. Ultimately, VELCT delivers data in better rate when compared to VELSCP and CIDT as illustrated in figure 6.1 and table 6.2.

![Packet Delivery Ratio versus Number of nodes](image)

Figure 6.1 Packet Delivery Rate with respect to Number of nodes

<table>
<thead>
<tr>
<th>Number of nodes</th>
<th>Packet Delivery Rate (in Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VELSCP</td>
</tr>
<tr>
<td>100</td>
<td>97.71</td>
</tr>
<tr>
<td>200</td>
<td>96.52</td>
</tr>
<tr>
<td>300</td>
<td>95.12</td>
</tr>
<tr>
<td>400</td>
<td>93.91</td>
</tr>
<tr>
<td>500</td>
<td>92.34</td>
</tr>
</tbody>
</table>
6.2.1.2 Throughput with respect to Number of nodes

The throughput of these protocols have been evaluated by varying the number of nodes. From the simulation results it is clear that, VELCT offers better throughput than VELSCP and CIDT as illustrated in figure 6.2 and table 6.4. VELSCP and CIDT have a throughput of 74.16% (approx) and 85.28% (approx) respectively. VELCT on the other hand has a throughput at an average rate of 89.16% (approx). Hence, VELCT shows maximum throughput when compared with VELSCP and CIDT. The comparative ranges of the proposed protocols have been depicted in table 6.3.

![Throughput versus Number of nodes](image)

Figure 6.2 Throughput with respect to Number of nodes
Table 6.3  Throughput with respect to Number of nodes

<table>
<thead>
<tr>
<th>Number of nodes</th>
<th>Throughput (in Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VELSCP</td>
</tr>
<tr>
<td>100</td>
<td>0.863</td>
</tr>
<tr>
<td>200</td>
<td>0.761</td>
</tr>
<tr>
<td>300</td>
<td>0.713</td>
</tr>
<tr>
<td>400</td>
<td>0.690</td>
</tr>
<tr>
<td>500</td>
<td>0.681</td>
</tr>
</tbody>
</table>

6.2.1.3   Total Energy with respect to Number of nodes

The total energy consumption of VELSCP, CIDT and VELCT have been evaluated by varying the number of sensor nodes. It is clear that, VELSCP and CIDT exhibits slightly higher residual energy consumption than VELCT as illustrated in figure 6.3. Even though all the three proposed protocols provide an optimum range of energy consumption, VELCT consumes comparatively minimum energy. The main reason is that, VELCT estimates the threshold with coverage distance, RSS, robustness in connection and traffic to discover the optimum path. Further, VELCT uses the DCT to connect all cluster heads with the base station. Figure 6.3 shows that, VELCT consumes 490 mJ (approx) of the total energy but VELSCP and CIDT consumes slightly higher energy of 772 mJ and 1078 mJ approximately. The simulated values have been given in table 6.4.
Figure 6.3  Total Energy with respect to Number of nodes

Table 6.4  Total Energy with respect to Number of nodes

<table>
<thead>
<tr>
<th>Number of nodes</th>
<th>Total Energy (in mJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VELSCP</td>
</tr>
<tr>
<td>100</td>
<td>121</td>
</tr>
<tr>
<td>200</td>
<td>176</td>
</tr>
<tr>
<td>300</td>
<td>238</td>
</tr>
<tr>
<td>400</td>
<td>263</td>
</tr>
<tr>
<td>500</td>
<td>280</td>
</tr>
</tbody>
</table>
6.2.1.4 Delay with respect to Number of nodes

In general, wireless sensor network is associated with higher end-to-end delay during data packet transmission and the proposed routing protocol tolerates the delays. VELCT exhibits minimum packet delivery delay when compared to VELSCP and CIDT. This is because, VELCT ensures timely estimation of traffic capacity of DCT to deliver data packets to the sink in timely manner. VELCT show better performance when compared to VELSCP and CIDT. Figure 6.4 clearly illustrates the delay in VELSCP, CIDT and VELCT. VELSCP has an average delay of 5.9 ms (approx), CIDT has an average delay of 4.66 ms (approx) and VELCT has an average delay of 2.26 ms (approx). It is concluded that, VELCT exhibits minimum delay during delivery of data packets. The simulation values of the proposed protocols have been shown in table 6.5.

![Figure 6.4 Delay with respect to Number of nodes](image-url)
Table 6.5 Delay with respect to Number of nodes

<table>
<thead>
<tr>
<th>Number of nodes</th>
<th>Delay (in milli seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VELSCP</td>
</tr>
<tr>
<td>100</td>
<td>3.495</td>
</tr>
<tr>
<td>200</td>
<td>4.597</td>
</tr>
<tr>
<td>300</td>
<td>5.464</td>
</tr>
<tr>
<td>400</td>
<td>6.932</td>
</tr>
<tr>
<td>500</td>
<td>8.991</td>
</tr>
</tbody>
</table>

6.2.2 Influence on sensor nodes mobility

Sensor node mobility has greater impact in the behaviour of routing protocols. The proposed protocols VELSCP, CIDT and VELCT have been evaluated by varying the speed of mobile sensor node from 5 m/s to 30 m/s.

6.2.2.1 Packet Delivery Ratio with respect to Speed

The packet delivery ratio in VELCT is higher when compared to VELSCP and CIDT. Figure 6.5 shows the packet delivery ratio variations of the three proposed protocols in a highly mobile environment, and it evidently depicts that VELCT offers 98.707% (approx) delivery of data packets.
towards the sink. In contrast, VELSCP and CIDT deliver only 95.293% (approx) and 93.858% (approx) of data packets respectively. Ultimately, VELCT delivers data packets at a better rate when compared to VELSCP and CIDT. The simulated values of the proposed protocols have been shown in table 6.6.

![Packet Delivery Ratio versus Speed](image)

**Table 6.6** Packet Delivery Ratio with respect to Speed

<table>
<thead>
<tr>
<th>Speed (in m/s)</th>
<th>Packet Delivery Ratio (in Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VELSCP</td>
</tr>
<tr>
<td>5</td>
<td>98.012</td>
</tr>
<tr>
<td>10</td>
<td>95.901</td>
</tr>
<tr>
<td>15</td>
<td>94.921</td>
</tr>
<tr>
<td>20</td>
<td>93.393</td>
</tr>
<tr>
<td>25</td>
<td>91.461</td>
</tr>
<tr>
<td>30</td>
<td>89.459</td>
</tr>
</tbody>
</table>
6.2.2.2 Delay with respect to Speed

Figure 6.6 clearly portrays the delay in VELSCP, CIDT and VELCT with respect to the speed of sensor nodes. It is noted from figure 6.6, that VELSCP, CIDT and VELCT provide an average delay of 2.73 ms, 6.16 ms and 9.43 ms respectively in highly mobile environment. Hence, VELCT offers minimum delay when compared with VELSCP and CIDT. The simulated values of the proposed protocols have been depicted in table 6.7.
### Table 6.7 Delay with respect to Speed

<table>
<thead>
<tr>
<th>Speed (in m/s)</th>
<th>Delay (in milli seconds)</th>
<th>VELSCP</th>
<th>CIDT</th>
<th>VELCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>4.91</td>
<td>3.03</td>
<td>1.53</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>6.96</td>
<td>4.13</td>
<td>2.11</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>9.42</td>
<td>5.15</td>
<td>2.63</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>10.93</td>
<td>7.03</td>
<td>3.01</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>11.91</td>
<td>8.45</td>
<td>3.44</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>12.42</td>
<td>9.15</td>
<td>3.67</td>
<td></td>
</tr>
</tbody>
</table>

### 6.3 SUMMARY

In this chapter, the proposed topology management schemes were evaluated among themselves by increasing the number of sensor nodes and by increasing mobility of the network. In terms of increase of number of sensor nodes, VELCT outperforms CIDT and VELSCP in terms of PDR by 2% and 4% respectively. Similarly, the throughput of VELCT is higher than CIDT and VELSCP by 5% and 17% respectively. In terms of total energy consumption, VELCT consumes 1.5 times and 2.2 times less power than CIDT and VELSCP. Evaluation also indicates that the delay in estimating the route is significantly lesser for VELCT. Also, it is noted that VELCT achieves better performance in terms of PDR by 3.5% and 5% than CIDT and VELSCP, and delay time has been reduced by 2.25 times and 3.5 times with respect to the sensor node mobility. From the simulation results, it is clear that VELCT provides more stable links, better throughput, less energy utilization and better PDR with reduced network traffic when compared to
VELSCP and CIDT. Finally, it is concluded that VELCT achieves better performance when compared to VELSCP and CIDT, thereby mended to adapt highly mobile large scale wireless sensor networks.