## ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>Artificial Bee Colony algorithm</td>
</tr>
<tr>
<td>ACO</td>
<td>Ant Colony Optimization</td>
</tr>
<tr>
<td>ADC</td>
<td>Analog to Digital Converter</td>
</tr>
<tr>
<td>AES</td>
<td>Advanced Encryption Standard</td>
</tr>
<tr>
<td>AFST</td>
<td>Adaptive Fusion Steiner Tree</td>
</tr>
<tr>
<td>APTEEN</td>
<td>Adaptive Periodic TEEN</td>
</tr>
<tr>
<td>BA</td>
<td>Backward Ant</td>
</tr>
<tr>
<td>BS</td>
<td>Base Station</td>
</tr>
<tr>
<td>CBR</td>
<td>Constant Bit Rate</td>
</tr>
<tr>
<td>CH</td>
<td>Cluster Head</td>
</tr>
<tr>
<td>CSMA/CA</td>
<td>Carrier Sense Multiple Access with Collision Avoidance</td>
</tr>
<tr>
<td>CWSN</td>
<td>Cluster-based Wireless Sensor Network</td>
</tr>
<tr>
<td>DA</td>
<td>Designated Path</td>
</tr>
<tr>
<td>DAG</td>
<td>Aggregated Data</td>
</tr>
<tr>
<td>DCA</td>
<td>Double Cluster Head Algorithm</td>
</tr>
<tr>
<td>DCRDA</td>
<td>Double Cluster head based Reliable Data Aggregation</td>
</tr>
<tr>
<td>DEDA</td>
<td>Delay-bounded and Energy-efficient Data Aggregation</td>
</tr>
<tr>
<td>DEP</td>
<td>DEsired Progress</td>
</tr>
<tr>
<td>DP</td>
<td>Data Packet</td>
</tr>
<tr>
<td>D-PSO</td>
<td>Double Cluster Head PSO</td>
</tr>
<tr>
<td>EA</td>
<td>Energy Aware</td>
</tr>
<tr>
<td>EAGRDC</td>
<td>Energy-Aware data Gathering based on Double Cluster-</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
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</tr>
<tr>
<td>heads protocol</td>
<td></td>
</tr>
<tr>
<td>EECDA</td>
<td>Energy Efficient Clustering and Data Aggregation</td>
</tr>
<tr>
<td>EEDCA</td>
<td>Energy Efficient Double Cluster head selection Algorithm</td>
</tr>
<tr>
<td>EEDGP</td>
<td>Energy Efficient Data Gathering Protocol</td>
</tr>
<tr>
<td>EPAS</td>
<td>Energy-Efficient Protocol for Aggregator Selection</td>
</tr>
<tr>
<td>ESPDA</td>
<td>Energy-efficient Secure Pattern based Data Aggregation</td>
</tr>
<tr>
<td>ESRPSDC</td>
<td>Efficient and Secure Routing Protocol through SNR based Dynamic Clustering</td>
</tr>
<tr>
<td>FA</td>
<td>Forward Ant</td>
</tr>
<tr>
<td>GN</td>
<td>General Node</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>HEED</td>
<td>Hybrid Energy Efficient Distributed</td>
</tr>
<tr>
<td>hEPAS</td>
<td>Hierarchical Energy-Efficient Protocol for Aggregator Selection</td>
</tr>
<tr>
<td>HIDS</td>
<td>Hybrid Intrusion Detection System</td>
</tr>
<tr>
<td>IDS</td>
<td>Intrusion Detection System</td>
</tr>
<tr>
<td>IHIDS</td>
<td>Intelligent Hybrid Intrusion Detection System</td>
</tr>
<tr>
<td>IIDS</td>
<td>Integrated Intrusion Detection System</td>
</tr>
<tr>
<td>LEACH</td>
<td>Low Energy Adaptive Clustering Hierarchy</td>
</tr>
<tr>
<td>LMST</td>
<td>Local Minimum Spanning Tree</td>
</tr>
<tr>
<td>LPEDAP</td>
<td>Localized Power Efficient Data Aggregation Protocols</td>
</tr>
<tr>
<td>LRKT</td>
<td>Logic-Route Key Tree</td>
</tr>
<tr>
<td>MAC</td>
<td>Media Access Control</td>
</tr>
<tr>
<td>MCHRP</td>
<td>Multiple Cluster-Heads Routing Protocol</td>
</tr>
<tr>
<td>OF</td>
<td>Overflow</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
</tr>
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<td>---------</td>
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</tr>
<tr>
<td>PSO</td>
<td>Particle Swarm Optimization</td>
</tr>
<tr>
<td>QVF</td>
<td>Quantized Variational Filtering</td>
</tr>
<tr>
<td>RC6</td>
<td>Rivest Cipher 6</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio Frequency Identification</td>
</tr>
<tr>
<td>RN</td>
<td>Relay Node</td>
</tr>
<tr>
<td>RNG</td>
<td>Relative Neighborhood Graph</td>
</tr>
<tr>
<td>SCMRP</td>
<td>Secure Cluster based Multipath Routing Protocol</td>
</tr>
<tr>
<td>SHA</td>
<td>Secure Hash Algorithm</td>
</tr>
<tr>
<td>SI</td>
<td>Swarm Intelligence</td>
</tr>
<tr>
<td>SKADC</td>
<td>Secure Key-Tree Architecture for Double Cluster Based Routing</td>
</tr>
<tr>
<td>SNR</td>
<td>Signal-to-Noise Ratio</td>
</tr>
<tr>
<td>S-PSO</td>
<td>Single Cluster Head PSO</td>
</tr>
<tr>
<td>SRT</td>
<td>Semantic Routing Tree</td>
</tr>
<tr>
<td>SSBCR</td>
<td>Secured Sector based Bi-path Clustering and Routing</td>
</tr>
<tr>
<td>TDMA</td>
<td>Time Division Multiple Access</td>
</tr>
<tr>
<td>TEEN</td>
<td>Threshold sensitive Energy Efficient sensor Network</td>
</tr>
<tr>
<td>WSN</td>
<td>Wireless Sensor Network</td>
</tr>
</tbody>
</table>
## NOTATIONS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pbest</td>
<td>Personal best</td>
</tr>
<tr>
<td>gbest</td>
<td>Global best</td>
</tr>
<tr>
<td>$S^k$</td>
<td>Current searching point</td>
</tr>
<tr>
<td>$S^{k+1}$</td>
<td>Modified searching point</td>
</tr>
<tr>
<td>$V^k$</td>
<td>Current velocity</td>
</tr>
<tr>
<td>$V^{k+1}$</td>
<td>Modified velocity</td>
</tr>
<tr>
<td>$v_{pbest}$ and $v_{gbest}$</td>
<td>Velocity based on pbest and gbest</td>
</tr>
<tr>
<td>$v_{i}^{k}$</td>
<td>Velocity of agent $i$ at iteration $k$</td>
</tr>
<tr>
<td>$w$</td>
<td>Weighting function</td>
</tr>
<tr>
<td>$c_j$</td>
<td>Weighting factor</td>
</tr>
<tr>
<td>rand</td>
<td>Uniformly distributed random number</td>
</tr>
<tr>
<td>$S_{i}^{k}$</td>
<td>Current position of agent $i$ at iteration $k$</td>
</tr>
<tr>
<td>pbest$_i$</td>
<td>pbest of agent $i$</td>
</tr>
<tr>
<td>$w_{\text{max}}$</td>
<td>Initial weight</td>
</tr>
<tr>
<td>$w_{\text{min}}$</td>
<td>Final weight</td>
</tr>
<tr>
<td>maxIter</td>
<td>Maximum iteration number</td>
</tr>
<tr>
<td>iter</td>
<td>Current iteration number</td>
</tr>
<tr>
<td>$S_{i}^{k+1}$</td>
<td>Current position of agent $i$ at iteration $k$</td>
</tr>
<tr>
<td>$P_{bi}$</td>
<td>Best position</td>
</tr>
<tr>
<td>$P_{gi}$</td>
<td>Global best position</td>
</tr>
<tr>
<td>$V$</td>
<td>Velocity of the particle</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>Q</td>
<td>Position of the particle</td>
</tr>
<tr>
<td>t</td>
<td>Time</td>
</tr>
<tr>
<td>$\lambda_1$ and $\lambda_2$</td>
<td>Learning factors</td>
</tr>
<tr>
<td>$R_1$ and $R_2$</td>
<td>Random numbers among 0 and 1</td>
</tr>
<tr>
<td>$\omega$</td>
<td>Inertia weight</td>
</tr>
<tr>
<td>$E_{res}$</td>
<td>Residual energy</td>
</tr>
<tr>
<td>$N_i$</td>
<td>Node</td>
</tr>
<tr>
<td>$E_i$</td>
<td>Initial energy of the node</td>
</tr>
<tr>
<td>$E_{tx}$ and $E_{rx}$</td>
<td>Energy utilized at the time of transmission and reception of data</td>
</tr>
<tr>
<td>$T_{tx}$</td>
<td>Transmission range</td>
</tr>
<tr>
<td>h</td>
<td>Hop count</td>
</tr>
<tr>
<td>$\eta$</td>
<td>Operation wavelength</td>
</tr>
<tr>
<td>$P_{tx}$</td>
<td>Power transmitted by a sensor</td>
</tr>
<tr>
<td>$P_{rx}$</td>
<td>Sensitivity of the receiver</td>
</tr>
<tr>
<td>$\alpha$ and $\beta$</td>
<td>Transmitter gain and receiver gain</td>
</tr>
<tr>
<td>$\varepsilon$</td>
<td>Reflected power co-efficient of receiving antenna</td>
</tr>
<tr>
<td>$T_{LCH}$</td>
<td>Lasting time of electing CH</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Randomly generated real values</td>
</tr>
<tr>
<td>ND</td>
<td>Node Degree</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>Communication range</td>
</tr>
<tr>
<td>K</td>
<td>Number of links among the member nodes and cluster head</td>
</tr>
<tr>
<td>$P_F$</td>
<td>Link failure probability</td>
</tr>
<tr>
<td>O</td>
<td>Number of successful data delivery attempts</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td><strong>n</strong></td>
<td>Failure count</td>
</tr>
<tr>
<td><strong>E\textsubscript{RTx}</strong></td>
<td>Expected number of re-transmissions</td>
</tr>
<tr>
<td><strong>R\textsubscript{c}</strong></td>
<td>Cluster radius</td>
</tr>
<tr>
<td><strong>T\textsubscript{xr\textsubscript{min}}</strong></td>
<td>Minimum transmission range</td>
</tr>
<tr>
<td><strong>D\textsubscript{exp}</strong></td>
<td>Expected distance from cluster member to cluster head</td>
</tr>
<tr>
<td><strong>SP\textsubscript{i}</strong></td>
<td>Swarm particles</td>
</tr>
<tr>
<td><strong>F\textsubscript{i}</strong></td>
<td>Fitness function</td>
</tr>
<tr>
<td><strong>\alpha_1, \alpha_2, \alpha_3 and \alpha_4</strong></td>
<td>Weight values</td>
</tr>
<tr>
<td><strong>CH\textsubscript{M}</strong></td>
<td>Main cluster head</td>
</tr>
<tr>
<td><strong>CH\textsubscript{S}</strong></td>
<td>Subordinate cluster head</td>
</tr>
<tr>
<td><strong>U_REQ</strong></td>
<td>Upload request message</td>
</tr>
<tr>
<td><strong>U_INT</strong></td>
<td>Intimation of received upload request</td>
</tr>
<tr>
<td><strong>D_Agg</strong></td>
<td>Data aggregation message</td>
</tr>
<tr>
<td><strong>CM\textsubscript{i}</strong></td>
<td>Cluster member nodes</td>
</tr>
<tr>
<td><strong>E\textsubscript{S}</strong></td>
<td>Total energy spent</td>
</tr>
<tr>
<td><strong>E\textsubscript{tx-rx-s}</strong></td>
<td>Energy used by the sensor node during transmission, reception and in sleep mode</td>
</tr>
<tr>
<td><strong>A\textsubscript{data}</strong></td>
<td>Aggregated data arrival traffic</td>
</tr>
<tr>
<td><strong>Th</strong></td>
<td>Threshold</td>
</tr>
<tr>
<td><strong>D\textsubscript{tx}</strong></td>
<td>Current data transmitted by CM\textsubscript{i}</td>
</tr>
<tr>
<td><strong>P</strong></td>
<td>CM\textsubscript{i}’s previous history data</td>
</tr>
<tr>
<td><strong>DS\textsubscript{rx}</strong></td>
<td>Data set received from the CM\textsubscript{i}’s neighbor nodes</td>
</tr>
<tr>
<td><strong>R\textsubscript{i}</strong></td>
<td>Reputation value</td>
</tr>
<tr>
<td><strong>A_1 and A_2</strong></td>
<td>Weight factors</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Th_R_i</td>
<td>Threshold for reputation value</td>
</tr>
<tr>
<td>MXN_i</td>
<td>Malicious node</td>
</tr>
<tr>
<td>M'</td>
<td>Size of the witness set in the current round</td>
</tr>
<tr>
<td>P_f</td>
<td>Probability</td>
</tr>
<tr>
<td>T</td>
<td>Witness nodes</td>
</tr>
<tr>
<td>A_nodes</td>
<td>Number of witness nodes which agreed with the transmitted result</td>
</tr>
<tr>
<td>D_nodes</td>
<td>Total number of witness nodes which disagreed with the transmitted results</td>
</tr>
<tr>
<td>h_0, h_1, h_2, h_3, h_4</td>
<td>Hash function</td>
</tr>
<tr>
<td>K</td>
<td>Constant</td>
</tr>
<tr>
<td>a, b, c, d and e</td>
<td>Current round number</td>
</tr>
<tr>
<td>&lt;&lt;&lt;_n</td>
<td>Left bit rotation by n places</td>
</tr>
<tr>
<td>W_t</td>
<td>Expanded message word of round t</td>
</tr>
<tr>
<td>K_t</td>
<td>Round constant of round t</td>
</tr>
<tr>
<td>A, B, C and D</td>
<td>Four w-bit input registers</td>
</tr>
<tr>
<td>r</td>
<td>Number of rounds</td>
</tr>
<tr>
<td>K_mes</td>
<td>Message</td>
</tr>
<tr>
<td>KM_i</td>
<td>Initial message</td>
</tr>
<tr>
<td>SN_i</td>
<td>Sequence number</td>
</tr>
<tr>
<td>H_Li</td>
<td>Last hop to store the route information</td>
</tr>
<tr>
<td>R_mes</td>
<td>Reply message</td>
</tr>
<tr>
<td>Auth_mess</td>
<td>Authorization message</td>
</tr>
<tr>
<td>K_ri</td>
<td>Random key</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>-------------------------------------------------------</td>
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<tr>
<td>$K_{pri}$</td>
<td>Private key</td>
</tr>
<tr>
<td>$K_{Li}$</td>
<td>Level key</td>
</tr>
<tr>
<td>CH (AUTH_mes)</td>
<td>Cluster head authentication message</td>
</tr>
<tr>
<td>Route_req</td>
<td>Routing message</td>
</tr>
<tr>
<td>Route_rep</td>
<td>Route reply message</td>
</tr>
<tr>
<td>$K_c$</td>
<td>Cluster key</td>
</tr>
<tr>
<td>$K_b$</td>
<td>Branch key</td>
</tr>
<tr>
<td>$K_f$</td>
<td>Fellow key</td>
</tr>
<tr>
<td>$K_s$</td>
<td>Secret key</td>
</tr>
<tr>
<td>$z$</td>
<td>Generating element of cyclic multiplicative group</td>
</tr>
<tr>
<td>RK_c, RK_b and RK_f</td>
<td>Random numbers generated by CH</td>
</tr>
<tr>
<td>$K_{Fi}$</td>
<td>Parent share</td>
</tr>
</tbody>
</table>