CLAIMS

1. A method for distributed multi-hop packet forwarding based on geographic coordinates for vehicular communications between nodes, each node having its own geographical coordinates and the geographical coordinates of a destination node of one said vehicular communication being known, said method comprising each node obtaining its one-hop neighbor nodes' coordinates from periodically broadcast beacons from said neighbor nodes and said method comprising the steps for each node, at each hop, upon receiving a packet:

   - based on the current node's position and packet header information of the packet, verifying if the current node is closer to the destination than a previous hop; if not, dropping the packet;
   - ranking a utility of the current node as a forwarder against the utility of potential forwarder nodes which are said one-hop neighbor nodes that are closer to the destination than the previous hop;
   - if the current node is one of a predetermined number of best utility ranked forwarder nodes, then considering the current node as being in a forwarding zone; if not, dropping the packet;
   - if the current node is in the forwarding zone, waiting a period of time inversely proportional to the current node utility rank before forwarding the packet;
   - if, while waiting, the current node overhears another node forwarding the same packet, cancelling the forwarding of the packet;

   wherein the packet header comprises three node addresses: original packet source, packet destination, and packet previous hop, wherein each address includes both the respective node identifier and geographic coordinates,

and wherein said nodes are vehicle nodes or a mix of vehicle nodes and fixed nodes.

2. The method according to claim 1 further comprising each node acknowledging, to the previous hop node, the transmission of a packet by its own forwarding of the packet.

3. The method according to claim 1 further comprising each node retransmitting the packet if no acknowledgment of said packet has been received after a predetermined time limit.

4. The method according to claim 1 further comprising each node keeping a history of overheard packets and dropping packets if they are present in said history.

5. The method according to claim 1 comprising introducing transmission slotting at the network layer, by dividing the time after a packet reception into a number of forwarding slots, wherein the potential forwarder nodes distribute themselves for transmission over the slots without explicit coordination, each node being assigned one and only one slot, and each slot having zero or more nodes, wherein the slot duration is sufficiently long that nodes in different forwarding slots will not contend at the MAC level if their contention windows overlap, and the slot duration is sufficiently short that latency is mitigated, in particular the slot duration is longer but not substantially longer than the average MAC layer contention window.

6. The method according to claim 1 comprising, for ranking the utility of the current node as the potential forwarder, considering if the node is in the forwarding zone and waiting a period of time inversely proportional to the current node utility rank, the following steps for each potential forwarder node, at each hop and for each packet:

- defining the node set of potential forwarders for the current packet, said set being composed of the nodes that are both closer to the destination node than the previous hop and within the current node radio range;
- building an array from said set and sorting the array from the node closest to the destination node to the node farthest from the destination node;
- considering the index at which a node appears in said array being its utility rank as a forwarder;
- for each node in said set, assigning it a forwarding slot calculated by the value of the smallest integer not less than the division of said node utility rank divided by a predetermined number of nodes per slot;

wherein each node refrains from forwarding if the node is not one of the predetermined number of best utility ranked forwarder nodes.

7. The method according to claim 1 wherein the predetermined number of best utility ranked forwarder nodes is not more than 5, not more than 10, or not more than 15.

8. The method according to claim 1 wherein the destination node is addressable by its geographical coordinates through prior knowledge of its geographical coordinates or a through a location service.

9. The method according to claim 1 wherein ranking the utility of the node as the forwarder comprises ranking by the distance to the destination, in particular by the hop length distance.

10. The method according to claim 1 wherein ranking the utility of the current node as ~~a~~ the forwarder comprises ranking the utility of the node as the forwarder based on spatial connectivity information which is collected, aggregated, and distributed, comprising the steps of:

- each node, over a period or periods of time, recording information about its position and the CAMs, Cooperative Awareness Messages, it receives from other nodes;
- each node uploading CAM data records to a spatial connectivity server, said CAM data records comprising the geographical coordinates of each of the nodes which emitted said collected CAMs, and optionally the RSSI of said CAMs;
- the spatial connectivity server aggregating and processing said CAM data records into a spatial connectivity graph comprising nodes and edges, where the nodes are geographical locations and the edges are spatial links, wherein each spatial link is a connection between two geographic locations and comprises one or more of three quality metrics: i) expected packet delivery rate, ii) expected mean Received Signal Strength, RSSI, if available, and iii) probability of the presence of vehicles in the connected locations;
- each node, downloading said spatial connectivity graph from the spatial connectivity server;

- using said spatial connectivity graph for ranking the utility of the node as the forwarder, wherein the utility is the minimum expected packet transmission count of the graph paths between current node and the destination node, or the utility is the maximum expected mean Received Signal Strength, RSSI, of the graph paths between the current node and the destination node, or the utility is the maximum expected probability of the presence of vehicles in the graph paths between the current node and the destination node.

11. The method according to claim 1 comprising each node replacing:

the quality metric of an edge of said previously aggregated and processed spatial connectivity graph, where the edge is a spatial link which is a connection between two geographical locations, with

real-time collected data of said quality metric of said edge, when such real-time collected data is available for said connection between the two geographical locations.

12. The method according to claim 11 where the geographical location is a spatial cell of predetermined fixed or variable size.

13. The method according to claim 12 wherein the spatial cell is a rectangular area, in particular a square area, in particular a 50m by 50m square area.

14. The method according to claims 11 wherein the utility of the current node as the forwarder is calculated based on the spatial connectivity graph, comprising:

- mapping both the current node's and destination node's locations into source and destination spatial cells in the spatial connectivity graph;
- computing the path from source cell to destination cell with the minimum total expected number of transmissions from source node to destination node for each potential forwarder, using the packet delivery rate associated with each spatial link in the graph as the quality metric;
- sorting the array of potential forwarders according to the minimum total expected number of transmissions from source node to destination node of the previously computed path for each potential forwarder.

15. The method according to claim 14 comprising each node replacing the expected number of transmissions necessary to deliver the packet between each pair of adjacent geographical locations in said edges of said graph with real-time collected data for each pair of adjacent geographical locations, when such real-time collected data is available.

16. The method according to claim 10 wherein each of said CAM data records comprises, for each recurring period of time: a timestamp; the current node's own geographical location; the number of sent CAMs by the current node; the node IDs of the nodes that emitted the CAMs received by the current node; and the number and mean RSSI of said CAMs received by the current node.

17. A device for distributed multi-hop packet forwarding based on geographic coordinates for vehicular communications between nodes, each node comprising a geographical coordinate module, said device comprising a computer data processor of a current node and a computer readable non-transitory data carrier comprising the computer program instructions for causing the data processer to perform a procedure comprising:

obtaining the current node's one-hop neighbor nodes' coordinates from periodically broadcast beacons from said neighbor nodes;

upon receiving a packet,

- based on the current node's position and packet header information of the packet, verifying if the current node is closer to a destination node of the packet than a previous hop; if not, dropping the packet;
- ranking a utility of the current node as a forwarder against the utility of potential forwarder nodes which are said one-hop neighbor nodes that are closer to the destination than the previous hop;
- if the current node is one of a predetermined number of best utility ranked forwarder nodes, then considering the current node as being in a forwarding zone; if not, dropping the packet;
- if the current node is in the forwarding zone, waiting a period of time inversely proportional to the current node utility rank before forwarding the packet;
- if, while waiting, the current node overhears another node forwarding the same packet, cancelling the forwarding of the packet;

wherein the packet header comprises three node addresses: original packet source, packet destination, and packet previous hop, wherein each address includes both the respective node identifier and geographic coordinates,

and wherein said nodes are vehicle nodes or a mix of vehicle nodes and fixed nodes.

18. A non-transitory computer readable medium storing computer program instructions for execution by a data processer of a current node of a vehicular communication network participate in distributed multi-hop packet forwarding based on geographic coordinates for communications between nodes, the computer program instructions when executed cause the data processer to perform a procedure comprising:

obtaining the current node's one-hop neighbor nodes' coordinates from periodically broadcast beacons from said neighbor nodes;

upon receiving a packet,

- based on the current node's position and packet header information of the packet, verifying if the current node is closer to a destination node of the packet than a previous hop; if not, dropping the packet;
- ranking a utility of the current node as a forwarder against the utility of potential forwarder nodes which are said one-hop neighbor nodes that are closer to the destination than the previous hop;
- if the current node is one of a predetermined number of best utility ranked forwarder nodes, then considering the current node as being in a forwarding zone; if not, dropping the packet;
- if the current node is in the forwarding zone, waiting a period of time inversely proportional to the current node utility rank before forwarding the packet;
- if, while waiting, the current node overhears another node forwarding the same packet, cancelling the forwarding of the packet;

wherein the packet header comprises three node addresses: original packet source, packet destination, and packet previous hop, wherein each address includes both the respective node identifier and geographic coordinates,

and wherein said nodes are vehicle nodes or a mix of vehicle nodes and fixed nodes.