Algorithm 1: two sides relays decision

1. Only receivers in the first transmission range of the transmitter will be considered as relay in the second transmission.
2. Deciding the appropriate MCS (modulation and coding scheme).
3. Each receiver has a BLER value calculated from SINR.
4. Mapping the distance between each receiver and transmitter to the BLER of each receiver.
5. Setting the threshold value of BLER according to the QoS(quality of system), then those BLER values satisfied the threshold value are derived.
6. Depending on the mapping table of distance and BLER calculated before, the distances of receivers which BLER values satisfied the threshold value are decided.
7. Getting the maximal distance used to compare with the

distances between receivers and transmitter, the

distance of the receiver satisfied the maximal distance is

the relay.

1. Deciding the appropriate MCS (modulation and coding

scheme) and threshold BLER.

1. Mapping the distance between each receiver and transmitter to the BLER of each receiver.
2. Depending on the mapping table of distance and BLER calculated before, the distances of receivers which BLER values satisfied the threshold value are selected.
3. the distance of the receiver satisfied the maximal distance is the relay.
4. **1.5 Objectives**
5. over the past few years, single-hop vehicular transmission or multi-hop vehicular transmission in V2V communication has be widely used to deliver messages, such as hazardous situation information, road congestion information and traffic warning messages in V2V communication. These are all safety-related applications in order to reduce the possibility of vehicle trashes. So the transmission range and time delay concerned messages transmitting between transmitter and receivers count.
6. For single-hop broadcasting, because of the limitation of transmission range and the limitation of time and frequency resources. The single-hop communication is not adequate in V2V communication due to low efficiency and large latency.
7. Also, the use of multi-hop is spectrally inefficient as, in most cases, they need to transmit on orthogonal channels. And the performance of relaying processes along multiple-hop is unsuitable. [A. Bletsas, A. Khisti, D. P. Reed and A. Lippman, “A simple cooperative diversity method based on netwrok path selection”, *IEEE J. Sel. Areas Commun.*, Vol. 24, No. 3, pp.659-672, Mar. 2006.] In a multi-hop network, the same problem can be defined as hop selection and a related scheme is proposed in [L. Ruan and V. K. N. Lau, “Decentralized dynamic hop selection and power control in cognitive multi-hop relay systems”, *IEEE Trans. on Wireless. Comm.* Vol. 9, No. 10, pp. 3024-3030, Oct. 2010.] which involves power control as well to co-exist with the primary users. A common denominator in all these papers is that the secondary nodes are assumed to adapt their transmission power in order to always satisfy the interference constraint in underlay settings. However, this may not be the case in every network and the secondary nodes may have fixed transmission power. [Hussain S I, Alouini M S, Qaraqe K, et al. Reactive relay selection in underlay cognitive networks with fixed gain relays[C]//Communications (ICC), 2012 IEEE International Conference on. IEEE, 2012: 1784-1788.]
8. In this research, twice-hop transmission is utilized which is the trade-off between single- hop transmission just need to select one relay. The efficiency of twice-hop transmission is decided by adapting each transmission with an appropriate modulation and coding scheme (MCS) and selecting the proper relay vehicles. Due to different links experience varied channel states. It is important to adapt a MCS with a more robust link performance in case of experiencing worse channel states. A more robust transmission means a much lower coding and modulation rate. However, this also means that more frequency and time resources are needed for the same size of packages.
9. Also, Unreasonable selection of the relay vehicles to retransmit important information could seriously degrade the ITS applications performance in terms of latency, overhead, and reception rate. The terrible performance of the decision might have devastating consequences on the performance of the ITS applications and consequently on the safety of drivers and pedestrians. [Alotaibi M. Relay Selection for Heterogeneous Transmission Powers in Connected Vehicles[D]. Université d'Ottawa/University of Ottawa, 2017.]
10. **1.6 Relay selection**
11. Relay selection is one of the main buildings blocks of cooperative relaying and commonly channel conditions of relay links are main selection criteria. The impact of choosing a given relay node on communication of surrounding nodes and overall network has to be taken into account. The relay selection is mainly done once at network start up periodically at transmitting section. Many papers have been published based on different relay selection approaches. [Survey on Cooperative Relay Selection Approaches Nimmi Krishna M.R, Shiras S. N Department of Electronics andCommunication, MBCET, Trivandrum, India] However, many relay selection schemes demand the continuous monitoring of all available channel links, Regarding the relay selection mechanism, threshold-based relay selection has been proposed as an efficient technique for improving performance. [ S. S. Ikki and M. H. Ahmed, “Performance of multiple-relay cooperative (A-1) diversity systems with best relay selection over Rayleigh fading channels,” *EURASIP J. on Advances in Signal Processing*, p. 145, 2008.]The threshold-based relay selection relies on SINR and BLER thresholds to decide from a set of N available ones which node is satisfied for cooperation between the source and the destination. Coding and modulation scheme(MCS) is adapted to reach a target BLER value below 10%.
12. The objective for designing the transmission system is to deliver the safety-related road information in a high speed with quite low latency. On the other hand, it is efficient to utilize the limited frequency and time resources.
13. In this research, we have organized the following structure. First of all, in chapter2, system models considered are introduced.

Algorithm 2: two sides relays decision

1. Only receivers in the first transmission range of the transmitter will be considered as relay in the second transmission.
2. Deciding the appropriate MCS (modulation and coding scheme).
3. Each receiver has a BLER value calculated from SINR.
4. Mapping the distance between each receiver and transmitter to the BLER of each receiver.
5. Depending on the mapping table of distance and BLER calculated before, the BLER values of receivers is decided by the real distances between receivers and transmitter.
6. Setting the threshold value of BLER according to the QoS(quality of system), then those BLER values satisfied the threshold value are derived.
7. Getting the maximal distance of those receivers whose BLER satisfied the threshold value, the receiver satisfied the maximal distance is the relay that needed.

**Relay decision algorithm**

1.Deciding the appropriate MCS (modulation and coding

scheme) and threshold BLER.

2. Mapping the distance between each receiver and transmitter to the BLER of each receiver.

3. Depending on the mapping table of distance and BLER calculated before, the distances of receivers which BLER values satisfied the threshold value are selected.

1. the distance of the receiver satisfied the maximal distance is the relay.

**Mcs (modulation and coding scheme) efficiency calculation**

p is the packet size which is 212bytes here. The number of users is n which is 1800UE according to the vehicle mapping under one base station. T is 10HZ that is the packets transmission period. And 10MHZ is used for transmission.

MCS efficiency is decided according to the users and BW and required size of packets. Decided efficiency to make sure those parameters such as how many users can be possible in these transmission resources. to make sure resource that is enough. The same size of users, if the BW is much smaller, then we need to use much larger MCS efficiency to transmit the same packet. if smaller user, then we can allocate much larger resource for them, then can transmit more packets. Appropriate MCS means under certain bandwidth how many users that can serve. Because of the limitation of MSC, the number of user is also limited. More vehicles mean much larger MCS for the same bandwidth which need to serve more users.

Graph:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Transmission range=1000m | | | | | |
| UE: number of users | First-hop Bandwidth:  MHZ | Second-hop  right-side  Bandwidth:  MHZ | | Second-hop  left-side  Bandwidth:  MHZ | Successful transmission ratio |
| 1800 | 10 | x | | x | 56% |
| 1800 | 10 | 10 multiplex | | | 99.98% |
| 1800 | 10 | 5 | | 5 | 95.90% |
| 1800 | 5 | x | | x | 39.67% |
| 1800 | 5 | 5 multiplex | | | 77.72% |
| 1800 | 6 | x | | x | 45.74% |
| 1800 | 6 | 4 multiplex | | | 77.31% |
| 1800 | 8 | x | | x | 54.26% |
| 1800 | 8 | 2 multiplex | | | 70.90% |
| 1200 | 5 | x | | x | 54.26% |
| 1200 | 5 | 5 multiplex | | | 100% |
| 1200 | 10 | x | x | | 71.28% |
|  |  |  | | |  |
|  |  |  | | |  |
|  |  |  | | |  |

1. Different bandwidth in first hop

|  |  |  |
| --- | --- | --- |
| Transmission range=1000m | | |
| UE: number of users | First-hop Bandwidth:  MHZ | Successful transmission ratio |
| 1800 | 10 | 56% |
| 1800 | 8 | 54.26% |
| 1800 | 6 | 45.74% |
| 1800 | 5 | 39.67% |
| 1200 | 5 | 54.26% |
| 1200 | 6 | 57.54% |
| 1200 | 8 | 67.02% |
| 1200 | 10 | 71.28% |

1. 20MHZ used in both first-hop and second-hop

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Transmission range=1000m | | | | |
| UE: number of users | First-hop Bandwidth:  MHZ | Second-hop  right-side  Bandwidth:  MHZ | Second-hop  left-side  Bandwidth:  MHZ | Successful transmission ratio |
| 1800 | 10 | 5 | 5 | 95.90% |
| 1800 | 10 | 10 multiplex | | 99.98% |

3.10MHZ used in both first-hop and second-hop

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Transmission range=1000m | | | | |
| UE: number of users | First-hop Bandwidth:  MHZ | Second-hop  right-side  Bandwidth:  MHZ | Second-hop  left-side  Bandwidth:  MHZ | Successful transmission ratio |
| 1800 | 5 | 5 multiplex | | 77.72% |
| 1800 | 6 | 4 multiplex | | 77.31% |
| 1800 | 8 | 2 multiplex | | 70.90% |
| 1200 | 5 | 5 multiplex | | 100% |
| 1200 | 6 | 4 multiplex | | 99.82% |
| 1200 | 8 | 2 multiplex | | 84.93% |