A dynamic power control scheme based on node priority in V2X

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Abstract. V2X (Vehicle-to-everything) is aimed to provide efficient data sharing among communication nodes in traffics. In order to guarantee the quality of communication, V2X need to support node priority as one of QoS (Quality of Service) mechanisms, which is related to nodes’ different requirement of message dissemination. Therefore, a dynamic power control scheme based on node priority for V2X is proposed. By assigning distinct power adjustment range for each level of node priority and incorporate distribution of neighbouring nodes’ priority into power setting, it’s able to achieve flexible power control and differentiated communication performance. The performance of proposed scheme is testified through network simulation.

1. Introduction
V2X (Vehicle-to-everything) achieves frequent and reliable data sharing among all communication nodes within vehicular environment through wireless communication[1], which improves perception ability of vehicular networks and therefore, enables safer and more efficient traffics. To provide more reliable services, V2X also supports communication with QoS (Quality of Service) mechanisms, among which priority-based communication scheme is one of the most important. By distinguishing the priority of different data exchanges in V2X and serves more timely and reliable communication for high-priority messages or applications, it’s able to make full use of limited radio frequency resources and ensures quality of V2X services, which is also conducive for safety or efficiency of traffics and satisfaction of traffic participants.

2. Node priority
Concurrently, most priority-based researches of V2X focus on message priority[2], which mainly decide priority based on the content of messages. For example, safety related messages have higher priority than traffic efficiency or entertainment messages, so the queues of safety messages need to be processed before other queues. However, there are still some underlying issues. Messages with the same level of priority but belong to different nodes shares same level of communication opportunity. What’s more, the states of moving nodes and its surroundings are not considered even though the contexts are vital to both traffic safety and communication performance. With the expansion of V2X applications and users’ differentiated requirements, QoS mechanisms based on message priority only need to be upgraded.

Based on previous consumptions, we intend to incorporate node priority into V2X communication. It’s clear that nodes in vehicular networks have different importance to traffic safety or the whole networks. For example, vehicles provide special services like ambulance or police cars and dangerous
vehicles like broken cars or loaded trucks need to be assigned with higher priority for better date dissemination. Since the communication contexts and states of neighbouring vehicles are different, two vehicles might need different allocation of wireless resources and guarantees for communication, to achieve the same level of security[3]. To simplify the design of node priority-based communication, we assume there are 3 types of vehicles with priority level 1 to 3, in which higher number means higher priority. The rules for classifying vehicles into different priorities are left for future discussion.

3. A dynamic power control scheme based on node priority

By assigning different transmission powers, vehicles can have diversified communication ranges. So, we attach power level to each vehicle according to its priority. However, vehicles with fixed transmission power are not flexible for ever-changing environment of vehicular networks. So, in our proposed power control scheme, vehicles are offered with different ranges for power adjustment instead. The power range of high-priority is wider or higher than its lower priority peers. Apart from that, vehicles adjust its power based on the distribution of its neighbouring nodes, namely sending messages with high power setting when it is surrounded by lower priority vehicles and lower power when its neighbours are of higher priority. By doing so, the interference and congestions can be decreased to ensure high priority have better message dissemination. The detailed power control scheme are as follows:

1. Initiate all nodes and assign power adjustment ranges for each node.
2. Nodes broadcast periodic messages with carrying its own priority level.
3. Node maintains its neighbours list with priority, and do following steps when list is modified.
   3.1. Calculate average priority level of neighbour nodes.
   3.2. Adjust transmission power based on calculated average priority within power adjustment range.

For node $i$, its power is calculated using equation (1):

$$ p_i = \frac{(\bar{w} - w_{\min})p_{i_{\min}} + (w_{\max} - \bar{w})p_{i_{\max}}}{w_{\max} - w_{\min}} $$

where $\bar{w}$ is calculated average priority of neighbours, $w_{\min}$ and $w_{\max}$ represent minimal and maximal level of priority respectively, and $p_{i_{\min}}$ and $p_{i_{\max}}$ stand for maximal and maximal power for its power adjustment range. Therefore, the power of node $i$ is set in inverse to its neighbour’s average priority.

4. Simulation and result

4.1. Simulation parameters

The performance of proposed is evaluated in NS-3, which is a prevalent event-driven network simulator. In order to simulate real traffic environment, vehicles are moving in two-way lanes at random speed within $40 \times 1000\text{m}$ communication area. And the power adjustment ranges are set to be $[15, 25]$, $[20, 30]$ and $[25, 35]$ for priority level 1 to 3 respectively.

4.2. QoS metrics

In order to better evaluate QoS performance, we use fairness indicator (FI) [4] and QoS indicator (QI). The former integrates delay, throughput and packet loss metrics into fairness metrics. The latter consider both received messages and transmitted messages since date exchange comprises both message delivery and reception. The detailed computation of FI and QI are as follows:

$$ FI = \frac{\beta_{\text{delay}}}{\beta_{\text{delay}} + \beta_{\text{throughput}} + \beta_{\text{loss}}} \sum_i \frac{(D_i - \bar{D})^2}{\bar{D}^2} + \frac{\beta_{\text{throughput}}}{\beta_{\text{delay}} + \beta_{\text{throughput}} + \beta_{\text{loss}}} \sum_i \frac{(T_i - \bar{T})^2}{\bar{T}^2} + \frac{\beta_{\text{loss}}}{\beta_{\text{delay}} + \beta_{\text{throughput}} + \beta_{\text{loss}}} \sum_i \frac{(L_i - \bar{L})^2}{\bar{L}^2} $$

(2)
where $D_i$, $T_i$ and $L_i$ stand for delay throughput and packet drop ratio for node $i$, while $\bar{D}$, $\bar{T}$ and $\bar{L}$ are corresponding average performance of all nodes. $\beta$ is used for balancing these three metrics.

$$QI_i = \sum_{m_{ij} \in M_i^R, j \in V_i} \omega_j + \sum_{m_{ij} \in M_i^S, i \in V_k} \omega_k$$ (3)

where $M_i^R$ and $M_i^S$ refer to sets of received and sent messages. $m_{ij}$ is one element of messages sets with node $i$ as source and $j$ as sinks. $Vi$ stands for neighbour set of node $i$ and $\omega_i$ is the priority of node $i$. Therefore, messages delivered or sent by higher priority neighbours is of more importance to communication nodes.

4.3. Simulation result and analysis

Table 1. The comparison of gross throughput among communication schemes without node priority, fixed power for each priority and dynamic power control based on node priority and context.

| Vehicle Numbers | 9   | 30  | 51  | 72  | 93  | 114 |
|-----------------|-----|-----|-----|-----|-----|-----|
| throughput-no priority (Mbps) | 0.2 | 2.2 | 6.3 | 13.3| 21.8| 33.7|
| throughput-static (Mbps)        | 0.2 | 2.3 | 6.7 | 14.2| 22.7| 35.4|
| throughput-dynamic (Mbps)       | 0.2 | 2.2 | 6.6 | 14.2| 22.6| 35.6|

As table 1 shows, communication system can achieve better gross throughput when applying node priority, that’s because priority nodes reduce transmission power and facilitate message sending for high-priority nodes in the case of less interference and congestion.

Figure 1. The throughput of priority 1 to 3 in static and dynamic power control schemes.

Figure 1 shows the throughput of each priority in static power assignment and dynamic power control. The performance of throughput improves from low priority to high priority. Also, the throughput of middle priority of two schemes are close but the gap between highest and lowest priority is smaller in dynamic power control, which means it has better fairness for different priority.
As Figure 2 shows, no-priority V2X achieves the best FI since each node has same level of transmission power. However, the FI performance of dynamic power control based on node priority is better than static power assignment, since the distribution of node priority is arbitrary and therefore low priority node can achieve better performance of throughput, delay and packet loss when surrounded by its low priority fellows.

Figure 3 is the comparison of QI of priority 1 to 3 between static and dynamic power control. Since throughput mainly evaluate message transmission in which high priority nodes have more advantages, the increase of QI that include both sent and received message is gentler and the gap between different priority is smaller. Dynamic power control has closer QI for highest and lowest priority, proving its better fairness support again.
Figure 4. The average power of priority 1 to 3 and system throughput in different ratios of nodes.

Figure 4 is the average power that calculated and throughput of communication networks when the ratios of different priority node vary. We can see the throughput are roughly the same for all scenarios but the set of average power are different, showing our dynamic power control can adapt to different communication environments.

5. Conclusion
In order to improve the QoS performance of V2X, we incorporate node priority into power control for the purpose of providing differentiated communication performance based on their different requirement. Instead of assign fixed transmission power for node with different priority, we assign power adjustment range for them and each node set its transmission power based on distribution of neighbouring nodes within this range. By doing so, we are able to achieve customized services and improve flexibility for power control. Apart from throughput, we also use fairness metrics and QoS metric that considers both received sent messages to better evaluate QoS metrics of V2X. The simulation result shows our dynamic power control based on node priority can achieve differentiated communication support and has better performance in terms of throughput, FI and QI compared to static power control based on node priority and V2X without node priority. It is also adaptable to different communication scenarios.

Acknowledgments
I’d like to express my gratitude and sincere wishes to all who offered me generous help and companies in my research and life, especially my supervisor and families.

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