Study on signal priority implement technology of tram system

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Abstract

The signal intersection delay is the key factor that affects the speed of Tram. Consequently, it affects the development of Tram System. Signal priority implement technology of Tram system has been researched based on characteristics such as the right of way, vehicle speed, vehicle length, and acceleration and deceleration behavior. In this article, the method based on the signal priority implement technology about different intersection types and sectional forms is presented.

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Keywords: Tram; Signal Priority; Traffic Signal Control

1. Background

In recent years, the modern tram has become the focus of many large cities. But in the area of the city center, trams are affected by social traffic, especially the intersection signal. As a result, the preponderance of tram speed is greatly constrained. The operating speed is generally about 20km/h, with no significant advantage compared with conventional buses. Nowadays, the intersection signal delay has become the main constraints of tram speed and further confines the development of tram system. Therefore, the research of signal priority technology has great significance in the development of tram system.

2. Key Components of Tram Signal Priority System

The tram signal priority system consists of three parts, which is shown in Figure 1.

(1) Vehicle intelligent terminal (VIT)
VIT was installed in every tram. It records the information of each tram.

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(2) Road side unit (RSU)
RSU was installed in road side which is 100 meter away from the stop line. RSU read the OBU information when the tram passed.

(3) Signal priority request unit (SPRU)
SPRU was installed inside the traffic signal controller. SPRU receives request signal from RSU and transforms request signal to information which can be recognized by traffic signal controller. Then traffic signal timing was adjusted by traffic signal controller.

3. Signal Priority Operation Principle

At time $t$, the tram arrives at the RSU which is 80 to 100 meters away from the stop line. Then RSU reads the information from VIT which is installed in the tram and sends the information to SPRU. The run time $\Delta t$ during which tram moves from RSU to stop line can be estimated according to the result of traction calculation. Thus the tram is expected to arrive at the stop line at time $t + \Delta t$. SPRU adjusts the control signal according to the signal operation condition at time $t$ and $t + \Delta t$. The tram can get priority by the adjusted signal timing.

4. Intersection classification

It is required to undertake corresponding research for different types of intersections, such as Cross-intersection, T-intersection, etc. Different trams section type should also be take into consideration, including central-layout pattern, both-sides-layout pattern, and one-side-layout pattern. Furthermore, the traffic signal design is influenced by different traffic flows and features including motorized vehicle, non-motorized vehicle and pedestrian. All the factors listed above should be considered in tram signal priority research.

Intersection is divided into 5 types based on intersection type and trams section type. These 5 types are: central straight pattern, side straight pattern, side to central pattern, central turning pattern, side right-in and right-out pattern.

The specific intersection features and signal priority schemes are researched in the sections below.
5. Tram signal priority strategies

5.1. Central Straight Pattern

In central straight pattern, tram lane was set in the middle lane. Trams traveled through the intersection in a straight line. The sectional form is shown in Figure 2.

The traffic signal control adopted four-phase control mode, which is shown in Figure 3. In phase A, straight passage of east-west approaches was allowed and the other traffic directions were forbidden. In phase B, left-turn passage of east-west approaches was allowed and the other traffic directions were forbidden. In phase C, straight passage of north-south approaches was allowed and the other traffic directions were forbidden. In phase D, left-turn passage of north-south approaches was allowed and the other traffic directions were forbidden.

Tram special phase X was designed in which only tram can cross the intersection and all the other vehicles and pedestrian moving were forbidden. Different control schemes were applied based on tram arriving time.

1) If tram was expected to arrive at the stop line at the end of phase A, phase A would be extended so that tram can cross. When tram passed through the intersection, phase B would be implemented. The phase sequence did not be changed, and was still in normal process as A-B-C-D.

2) If tram was expected to arrive at the stop line at the end of phase D, phase D would be truncated so that phase A returned earlier and tram can cross. When tram passed through the intersection, phase B would be implemented. The phase sequence did not be changed, and was still in normal process as A-B-C-D.

3) If tram was expected to arrive at the stop line at other time, tram special phase X would be insert. The phase sequence was changed to A-B-X-C-D or A-B-C-X-D.
5.2. Side Straight Pattern

In side straight pattern, tram lane was set in the side of the road. Trams traveled through the intersection in a straight line. The sectional form is shown in Figure 4.

The traffic signal control adopted three-phase or four-phase control mode, which is shown in Figure 5. In phase A, straight passage of east-west approaches was allowed and the other traffic directions were forbidden. In phase B, left-turn passage of east-west approaches was allowed and the other traffic directions were forbidden. In phase C, straight and left-turn passage of north-south approaches was allowed and the other traffic directions were forbidden.

Tram special phase X was designed in which only tram can cross the intersection and all the other vehicles and pedestrian moving were forbidden. Different control schemes were applied based on tram arriving time.

(1)If tram was expected to arrive at the stop line at the end of phase A, phase A would be extended so that tram can cross. When tram passed through the intersection, phase B would be implemented. The phase sequence did not be changed, and was still in normal process as A-B-C.
(2) If tram was expected to arrive at the stop line at the end of phase C, phase C would be truncated so that phase A returned earlier and tram can cross. When tram passed through the intersection, phase B would be implemented. The phase sequence did not be changed, and was still in normal process as A-B-C.

(3) If tram was expected to arrive at the stop line at other time, tram special phase X would be insert. The phase sequence was changed to A-B-X-C.

![Phase A, Phase B, Phase C, Phase X](image)

Fig. 5. Traffic Signal Phase of Side Straight Pattern

5.3. Side to Central Pattern

In Side to Central Pattern, the position tram lane changed from road side to middle lane. Trams traveled through the intersection in a turning line. The sectional form is shown in Figure 6.

![Sectional Form of Side to Central Pattern](image)

Fig. 6. Sectional Form of Side to Central Pattern

The traffic signal control adopted two-phase mode, which is shown in Figure 7. In phase A, straight passage of north-south approaches and left-turn passage of north approach was allowed and the other traffic directions were
forbidden. In phase B, left-turn passage of east approach was allowed and the other traffic directions were forbidden.

Tram special phase X was designed in which only tram can cross the intersection and all the other vehicles and pedestrian moving were forbidden. Different control schemes were applied based on tram arriving time.

(1) If tram was expected to arrive at the stop line at the beginning of phase A, tram special phase X would be insert after minimum green time of phase A. Afterwards, remaining time of phase A would be resumed. The phase sequence was changed to A-B-A(remaining)-B.

(2) If tram was expected to arrive at the stop line at the end of phase A, tram special phase X would be insert after minimum green time of phase A. When tram passed through the intersection, phase B would be implemented. The phase sequence was changed to A-X-B.

(3) If tram was expected to arrive at the stop line at the beginning of phase B, tram special phase X would be insert after minimum green time of phase B. Afterwards, remaining time of phase B would be resumed. The phase sequence was changed to B-X-B(remaining)-A.

(4) If tram was expected to arrive at the stop line at the end of phase B, tram special phase X would be insert after minimum green time of phase B. When tram passed through the intersection, phase A would be implemented. The phase sequence changed to B-X-A.

![Traffic Signal Phase of Side to Central Pattern](image1)

**Fig. 7. Traffic Signal Phase of Side to Central Pattern**

### 5.4. Central Turning Pattern

In central straight pattern, tram lane was set in the middle lane. Trams traveled through the intersection in a turning line. The sectional form is shown in Figure 8.

![Sectional Form of Central Turning Pattern](image2)

**Fig. 8. Sectional Form of Central Turning Pattern**
The traffic signal control adopted three-phase or four-phase control mode, which is shown in Figure 9. In phase A, straight passage of east-west approaches was allowed and the other traffic directions were forbidden. In phase B, left-turn passage of east-west approaches was allowed and the other traffic directions were forbidden. In phase C, straight and left-turn passage of north-south approaches was allowed and the other traffic directions were forbidden.

Tram special phase X was designed in which only tram can cross the intersection and all the other vehicles and pedestrian moving were forbidden. Different control schemes were applied based on tram arriving time.

1. If tram was expected to arrive at the stop line at phase A, tram special phase X would be insert between phase C and phase A. When tram passed through the intersection, phase A would be implemented. The phase sequence was changed to C-X-A-B-C.

2. If tram was expected to arrive at the stop line at phase B, tram special phase X would be insert between phase A and phase B. When tram passed through the intersection, phase B would be implemented. The phase sequence was changed to A-X-B-C.

3. If tram was expected to arrive at the stop line at the beginning of phase C, tram special phase X would be insert between phase B and phase C. When tram passed through the intersection, phase C would be implemented. The phase sequence was changed to B-X-C-A.

4. If tram was expected to arrive at the stop line at the middle of phase C, tram special phase X would be insert after minimum green time of phase C. Afterwards, remaining time of phase C would be resumed. The phase sequence was changed to C-X-C(remaining)-A.

5. If tram was expected to arrive at the stop line at the end of phase C, phase C would be truncated and tram special phase X would be inserted. When tram passed through the intersection, phase A would be implemented. The phase sequence was changed to C-X-A.

![Traffic Signal Phase of Central Turning Pattern](image-url)
5.5. Side Right-in and Right-out Pattern

In Side Right-in and Right-out Pattern, tram lane was set in the side of the road. Trams traveled through the intersection in a straight line. The intersection is T- intersection, and vehicles can only turn right from and to south approach. The sectional form is shown in Figure 10.

![Fig.10. Side Right-in and Right-out Pattern](image)

Tram special phase X was designed in which only tram can cross the intersection and all the other vehicles and pedestrian moving were forbidden. Different control schemes were applied based on tram arriving time.

1. If tram was not detected to arrive, right-turn passage from and to south approach is always allowed.
2. If tram was detected to arrive, tram special phase X would be inserted. When tram passed through the intersection, phase A would be resumed. The phase sequence was changed to A-X-A.

![Phase A and Phase X](image)

6. Conclusions

Key components of tram signal priority system have been researched, and Signal Priority Operation Principle is presented according to the expected arriving time of tram. Intersection is divided into 5 types based on intersection type and trams section type. According to these, we try to propose effective strategies and approaches of tram signal priority. Adjustment scheme of traffic signal timing has also been designed based on the estimated arriving time of tram. The research result can be used in trams operation scheme. Travel time for trams can be reduced through these measures, which will lead to increased transit quality of service.

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