The Institution of Railway Signal Engineers Inc

Australasian Section Incorporated

VITAL TRAIN QUEUES

Peter Burns
MBA, BAppSci (Elect), FIEAust, FIRSE, CPEng
PYB Consulting

SUMMARY

The train queue in its most familiar form – the timetable – has been around since the dawn of railways. From time to time rail authorities have sought to use it as the basis for their safeworking systems. This occurred even in NSW up till the late nineteenth century.

Following some accidents such system went out of favour, replaced by the block working systems we are so familiar with. With the advent of new technology and the introduction of vital computers on board trains, it is perhaps time to re-assess what train queues can offer for vital signalling, considering their capabilities in the resource allocation task.

There are those that contend that allocation of resources is the fundamental thing underpinning the practice of modern signalling, as evidenced by the importance of setting a route as precursor to offering authority. But when deconstructed we quickly discover that the resources we have to allocate are really only points and routes themselves.

Are these resources really the building blocks of signalling in general, and junction management in particular that they are said to be?

This paper presents an alternate view by asking the question: how are junctions managed when there is no concept of resources? By abstracting beyond the world of physical points to one relevant to other modes of transport apart from trains, we discover the utility that train queues can offer.

This paper looks at how train queues, the building blocks of the timetable, can be used to manage junctions vitally without the need for traditional central interlockings (abstracted for the purposes of the paper). It will be shown that vital train queues, supported by peer to peer transactions between trains, can provide all that is needed for the safe regulation of trains in a railway. It will be shown that, since the discussion includes junctions without points, the same train queue mechanisms can be used to regulate other modes of transport in controlled corridors.

1 INTRODUCTION

The train queue in its most familiar form – the timetable – has been around since the dawn of railways. From time to time rail authorities have sought to use it as the basis for their safeworking systems. This occurred in NSW up till the late nineteenth century, and still occurs in parts of the US today.

Following some accidents in Australia such system went out of favour for vital signalling, replaced by the block working systems we are so familiar with.

Train queues are more familiar nowadays by their use in train control systems.

But new technology provides an opportunity for re-assessment of the potential to use train queues in vital signalling. Just as CBTC has been described by some as “train orders on steroids”, we can find benefits in putting train queues on steroids too [4].

In particular, the advent of vital computers on board trains can be seen as an enabling technology.

This paper uses as reference for discussion the user view deconstruction of basic signalling functionality which I have termed in earlier papers [1][2] the “Generic Systems Framework” (refer figure 21).

In this context, train queues can be seen to enable a protection system (section 9) which can work in conjunction with the system for issuing authorities (section 3) to reap benefits in infrastructure requirement, reliability and headway.

Using their resource allocation (section 1) capabilities, train queues also enable familiar CBTC technologies to be extended to cover junctions and other interlocked areas.

It is perhaps time to consider a comeback for vital train queues into the new generation of railway signalling.

2 NOTATION & ABBREVIATIONS

Abbreviations are as follows:

CBTC:	Communications Based Train Control;
ERTMS:	European Rail Traffic Management System;
ETCS:	European Train Control System – a component of ERTMS;
JZA 715:	Eriksson Train Control System
SSI:	Solid State Interlocking

3 AUTHORITY AND PROTECTION FUNCTIONS

Earlier papers in this series have presented the characteristics of authorities in railway signalling [1][2]. These functions are characterised by their requirement for agreement between parties (in this case, generally between the train and the infrastructure).

Another important set of functions in railway signalling are those categorised as “protection” functions. Examples of protection functions in conventional railways are:

- Train braking due to signal reverting to red in front of a train due to an equipment failure or detection of a landslide;
- Shinkansen train applying brakes and anti-derail devices due to detection of an earthquake event (communicated by having overhead power switched off)

Whereas authority functions are characterised by agreements between parties, protection functions are characterised by unilateral action taken by the train itself. No agreement is sought or required for the associated actions a train takes to maintain its own safety.

Protection involves positive detection of a hazard followed by appropriate response by train. Safety analysis ensures that cases of protection system failure are themselves appropriately protected against, iterative layers of protection often being apparent.

For the purposes of this current paper, the hazard considered and requiring protection against is that of a collision with a train ahead.

Being generic, the functions we explore should also be seen as applicable to road and air travel in controlled road and air space.

3.1 Protection on the road

One important road rule taught to all learner drivers is that you should not crash into the car ahead of you on the road.

This is so basic that it rarely appears in the list of road rules learner drivers learn by rote to pass their learner driver test, but there it is. If you crash into the back of the car ahead of you, it is your fault, no questions asked.

Knowing just this rule gets you a long way when travelling on the freeway. Cars follow each other in orderly traffic streams courtesy of this one rule.

When you join the traffic stream on the freeway, there is no requirement for you to obtain agreement (or authority) from the vehicle ahead to follow it or to avoid crashing into it. Collision avoidance in this case is a unilateral action. Knowing the location, speed and likely future progress of the car ahead, you follow at a safe distance.

3.2 The railway case

The fundamental requirement for trains following trains is the same as for cars following cars. The difference historically has been that in the general case if the train is to stop safely, it must apply brakes ahead of the point where any train ahead is visible.

Modern communications based signalling changes that situation by making available to each train the location of the train ahead even though that train may not be visible. In practical systems this information may be heavily processed, or only partly provided, but for the purposes of this paper we will simply accept its availability. The train ahead thus becomes visible to the train’s vital systems even when not visible to the driver’s eye.

In general, protection against collision between following trains can be provided utilising the same rule as applies in the road case. The train establishes a “distance to go” to a “target stopping point” and unilaterally strives to be able to stop before reaching it. The train ahead requires no knowledge of this striving and has no need to engage in any agreement with the train to rear. It has only the requirement to make itself visible.

Since no agreement is required, the collision avoiding function can be characterised as a protection function rather than an authority function.

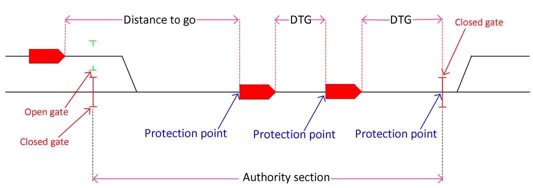
3.3 The open road concept

The distinction between an open road railway and a closed road railway has been discussed in an earlier paper [1].

In a closed road railway, a movement authority issued to a train applies to just one train between defined authority points. The authority section thus created can be in many forms depending on age and technology. It can be the section between fixed signals, that between two stations equipped with block instruments (familiar to 19th century signallers), or that covered by a single track circuit (for ETCS when pushing the limits).

In an open road railway, a movement authority issued to a train gives authority to travel between defined authority points, but does not imply that there are no other trains in that section. The sections are permissive. The authority section may typically be the several kms between junction points on the line.

Figure 1: Open road concept



An important boundary case of the open road is where entry to the railway is sought when entering the railway, and that single authority is sufficient for all subsequent train movements up to the point where the train leaves the railway (either by returning to the start point, or by leaving at some other location).

Having accepted the initial authority, train to train collisions between the multiple trains on the line are avoided using no more than the protection functions referred to above.

As is discussed below, this may be achieved using a simple application of a vital train queue.

4 TRAIN QUEUES

The concept of a train queue is familiar to most engineers working in modern train control and any other person who can read a timetable.

A train queue is simply a list of trains which will pass a strategically selected point on the rail network in the order that they will pass.

Vital train queues differ from train control train queues in that they include a safety component which must be respected. The boundaries of this safety component will be explored in this paper along with the other basic functions of the queues.

4.1 Types of train queues

Vital train queues occur in linked combinations and may be unidirectional or bidirectional. In this paper we will focus on some unidirectional applications of train queues to demonstrate the basic principles. Two simple bi-directional train queue cases will then be provided for a more complete picture.

Vital train queues considered in this paper are of three types:

- Converging
- Diverging
- Plain line;

At a basic levels these three types can be merged into a single train queue construct, with characteristics of the quoted "types" expressed depending on the permitted train movements over the section of track. The three types will be considered separately in this paper.

4.1.1 Mechanics of operation

The mechanics of operating a train on a line with queues involves inspecting the successive queues ahead on the planned path to be taken by the train up to the end of its current authority. For each train, the information sought is:

• Is the train present in each queue? The train may not proceed beyond the protection point associated with a queue in which it is not present. It must apply to join queues ahead if it wishes to proceed further.

• What is the train ahead (identity and direction) in the relevant queue? Possibilities are:

o There is a train ahead travelling on the same path. The train must avoid colliding with this train ahead using protection functionality to continually update its position and manage movement towards the protection point associated with that train.

o There is a train ahead on a converging or opposing path. The train must avoid colliding with this train ahead using protection functionality to manage movement towards the protection point associated with train queue where the path opposition occurs.

o There is no train ahead. The train may move to the protection point associated with the end of its current authority according to the rules associated with the type of authority.

For a closed-road railway, the third dot point will always apply. For the purposes of this paper we will consider the case for an open-road railway where a movement authority can cover large distances, limited generally by the presence of junction points.

The use of these concepts will be illustrated using a number of examples in the following sections.

The mechanics of operating an infrastructure object (eg points) on a line with queues is similar but involves obtaining information from the queue associated with the infrastructure object itself. This information is:

• What is the identity and path of the train at the top of the queue? This is the train to which the infrastructure object is currently allocated.

The use of this concept will also be illustrated in a later section of this paper.

4.1.2 Converging and Diverging Queues

Figure 2 below illustrates the basic train queues associated with converging and diverging junctions.

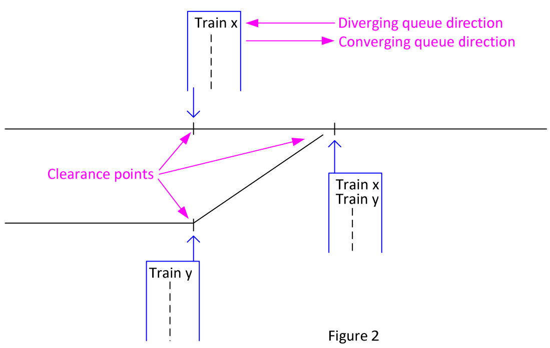


Figure 2

It can be seen that the queue arrangements are the same for both converging and diverging, differing only due to the direction of travel of the train over the junction. The queues can be viewed as existing at authority points (corresponding with the points clearance points for this case) reflecting the order of trains approaching each one. Regardless of direction of travel, each train traverses the common portion of the points and one leg.

The "train ahead" will always be taken from the queue at the toe of the points. The protection point will be at the first queue encountered in the direction of travel. The train path is given by the queue for either the normal or reverse leg (as applicable for the particular train).

4.1.3 Plain line queues

Of simpler construction is the plain line shown in figure 3 below.

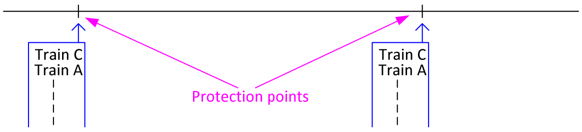


Figure 3

In this case it can be seen that the order of trains in the queues at each end of the section are the same, since passing is not possible on plain track. The train ahead is the train above the train being considered in the queue. If there is no train above the current train in the queue (eg Train C in this case), queues ahead should be successively inspected up to the end of the current authority. A train ahead can thus be identified if present.

4.1.4 Queue Properties

A train queue is a subsystem which is implemented primarily in infrastructure, though copies of the queues should also be provided to the train-borne system for each train.

All layouts can be modelled using the three types described above together with geography specific rules for placing trains in the queues as they approach and removing them as they pass or are subject to other actions. Some examples will be presented later in this paper.

Each train queue must contain:

- The identity of each train currently planned to pass;
- The order in which the trains are planned to pass; and
- The direction in which each is planned to pass.

Train queues also need three additional properties I will mention for completeness:

- Vital persistence (they must remember their contents in face of failure; they must be able to re-start after failure);
- A trustworthy master record (what this means in practice will be explored);
- Failsafe application of rules (the rules between queues must not create an unsafe condition in case of failure or at startup).

4.1.5 Populating the queue

The train queues on a standard railway are maintained as infrastructure systems and can be populated in the first instance using the information from the Working Timetable.

It is useful to consider the alternate case where there is no timetable available and operation is on a “first come first served” basis. This type of operation mimics existing route setting practice where the queues are populated as a route is set (objects allocated) immediately prior to putting an authority in place.

For this case, the train applies to join the queue when it reaches the operating point for that queue. The operating point should be at minimum at the maximum headway distance from the queue plus an adequate margin for latency in processing (needs to include allowance for time to join the queue plus allowance to obtain a subsequent authority if this is required plus a further allowance for intermittently faulty communication). It should be set generously to avoid the unnecessary checking of the train.

If the queue is populated with timetable information, the train joins the queue at its timetabled position. Otherwise, in the absence of train timetable information, the train joins at the rear of the queue. In this respect, the queue operates the same way as queues found in other contexts. No authority is required to join the queue at the rear, or at a pre-designated position.

Authority is required to change position in the queue. Again the rule is as for other types of queue. The authority must be gained from the train it wishes to move into the queue ahead of. An example of this action is provided later in this paper.

4.2 Train queue example on simple train line

The simplest case for application of a queue is that of trains following each other on a section of plain track.

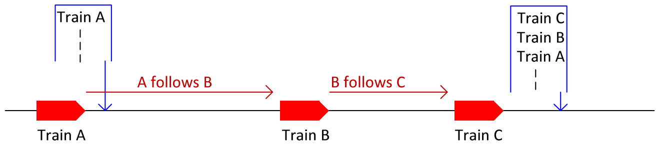


Figure 4

Figure 4 shows the basic application of a train queue to identify “train ahead” for each train in this context. In figure 4, Train B is the “train ahead” for Train A, being above it in the queue. Train A protects Train B by not running into its rear.

We can consider the case where the train is able to determine its own position, train type and speed and reports this information to the infrastructure train queue system. The train queue can then broadcast to all trains in the queue the order of trains in the queue, the protection point (generally rear of train position) associated with each one together with train type and speed (these last two optional).

Based on the information sent, each train can determine the “train ahead” relevant to itself, the target stopping point appropriate for the broadcast protection point (the train applies the appropriate margins and factors appropriate for its own situation), and the intervention braking curve (based on knowledge of the train’s characteristics and the geography).

To an external viewer, the result of this exercise can look remarkably like “moving block”. The difference is that there is no block concept here and no need for the infrastructure system (via RBC or similar) to issue movement authorities for following trains in automatic sections.

In fact, once the train queue order has been acquired once for such a section, it essentially does not change in normal circumstances. The broadcast of train position, type and speed can in principle be made by the train itself without involvement by the infrastructure system.

In such a case, safety against loss of communications is assured by the fact that the trains move only forwards. An old message will show the train ahead closer to the train to rear than is actually the case. If the train ahead were to disappear completely for some reason, the train to rear would stop safely (with margin) at its last reported position. Thus the system is failsafe against flaky communications infrastructure. The effect of poor communications is merely greater train separations than would otherwise be the case.

As a practical application, the proposed configuration for a line considered for a project not actually implemented, can be taken as an example. This project proposed to implement an extreme form of "group running" by removing all points except at the terminal station.

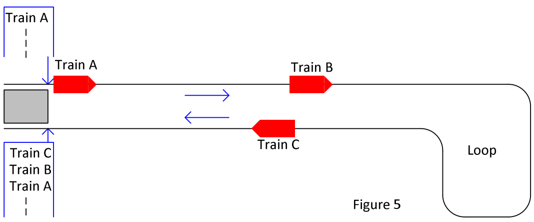


Figure 5

Figure 5 show this typical target infrastructure configuration sought for deployment of CBTC or similar systems. The line in question could be 50km or more in length with all points removed and turnaround achieved by loop.

Such a layout can be fully signalled with a single train queue (not mentioning the additional one at the start), a serviceable train based train location system (eg motion based supported by frequent passive RFID tags on track is reported as current for one supplier) and the capacity for trains to broadcast location, type and speed.

The train-board "protection" functionality can effectively perform all functions done by infrastructure based "moving block" systems with minimal need for involvement from infrastructure systems.

It can be seen from the configuration that queue order cannot change for trains actually on the line. Once a train acquires the queue order from the infrastructure, this information cannot change during the trip. Thus only "train ahead" information (position and optionally speed and train type) needs to be updated during the actual trip to allow safe management of train separation.

4.3 Converging train queues at junctions

The situation becomes more complex for the train queues when converging junctions are introduced. This is the point where many traditional CBTC systems give up altogether and leave it to a traditional interlocking.

Ignoring the requirements for point mechanisms for the moment (consider them to be ideal trail-able points) the train queues can manage the movement of trains through the junction successfully.

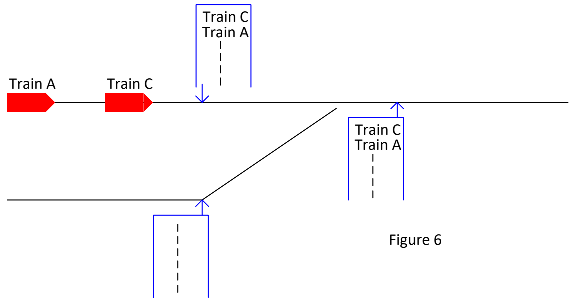


Figure 6

Figure 6 shows two following trains approaching the junction with no trains approaching on the diverge. These trains will be able to follow each other through the junction without extra risk of collision.

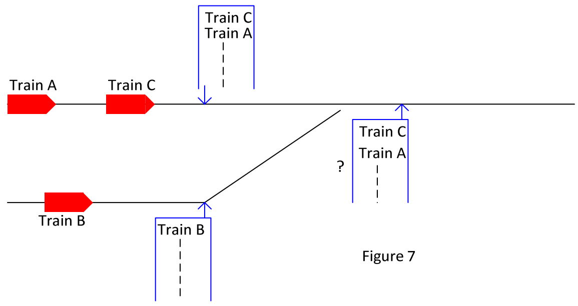


Figure 7

Figure 7 shows the case where a train then appears on the horizon on the other leg of the points and wishes to converge by joining the queue.

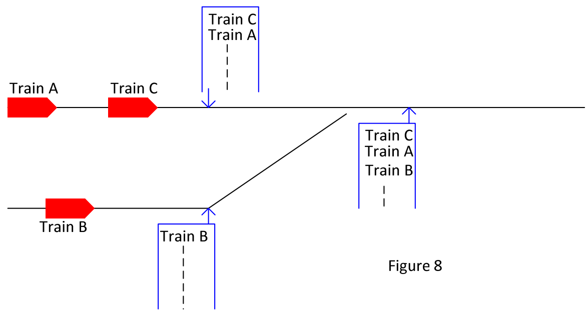


Figure 8

For this simple case the rule of the queue can be applied in the first instance. The new train can join at the back of the queue as shown in figure 8. Provided the train has authority to travel on the line, this action can be achieved with no need to obtain a further authority. In this case Train B will not enter the junction till Train A has passed through it. Train B will then follow Train A treating it as the train ahead.

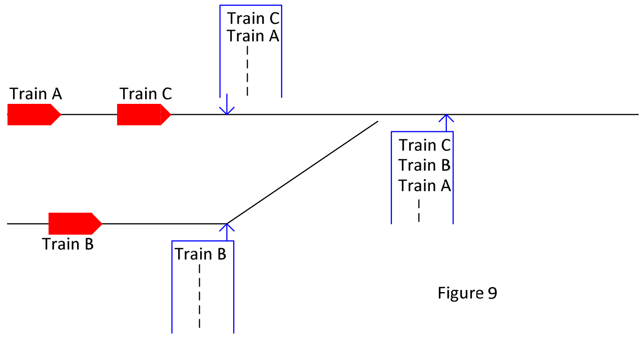


Figure 9

A more complex case occurs when train B wishes to enter the junction ahead of train A as shown in figure 9. In this case, Train B must obtain permission from Train A to go ahead. This is done by Train B obtaining a train-to-train authority to move up the queue to the position ahead of Train A. The authority must be obtained from the train which is to "let you in" to the queue. This process will be quite familiar to those who often find themselves in queues, though the process is more formalised.

Step 1: Train B "offers" (requests) authority to (from) Train A using the infrastructure system as agent. This use of the infrastructure system as agent is common for train to train authority arrangements and has been discussed in a previous paper.

Step 2: Train A "accepts" (gives permission for) the authority. The infrastructure adjusts the queue prior to communicating the acceptance to train B. Train A acquires train B as a train ahead through this process directly and Train B obtains the new queue order via the acceptance process.

Step 3: For other trains, the new queue order is obtained from the infrastructure queue system on next interrogation of this system. For the train to train situation, this step is not a safety step. A train must acquire the queue from the infrastructure queue with itself at top prior to passing the protection point for the convergence in any case.

4.4 Train queue example for at grade diamond crossing junction

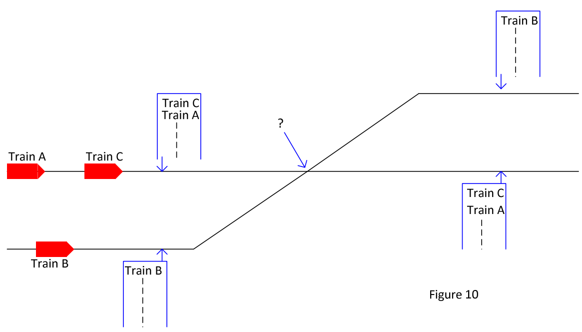


Figure 10

A similar case, but this time more realistic is that of managing an at-grade crossing with diamond crossover (no points) as shown in figure 10. The junction to be managed here is modelled as shown in figure 11 with virtual points.

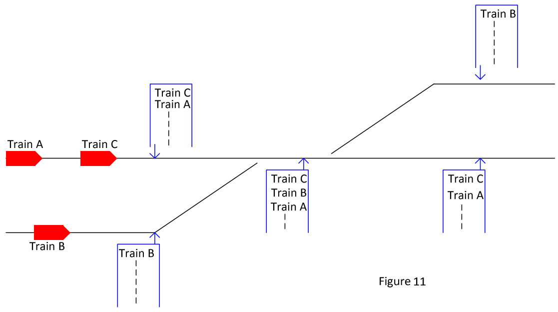


Figure 11

It can be seen that the same rules can be used for managing the junction as for the converging junction case discussed above.

A diverging junction has been added, but diverging junctions do not cause train conflicts. A train at top of the queue in the toe of points queue will always be top of queue at the clearance point queue on the road travelled. The identity of the train ahead (if any) must be acquired from a queue further forward.

The information in the clearance point queue in this case is there for the benefit of the infrastructure. This is the source of the information allocating the points in a particular position to a particular train and authorising it to move the points. At least it is for the case where physical points exist at the junction.

Before considering this actual case, we will look at one other application of train queues without actual points.

4.5 Freeway queue example for changing lanes

Concepts for train queues and authorities are readily transferable to other modes of transport. Busy freeways are well known for having queues, but the application discussed here should paradoxically reduce the amount of actual queueing whilst delivering significant safety benefits.

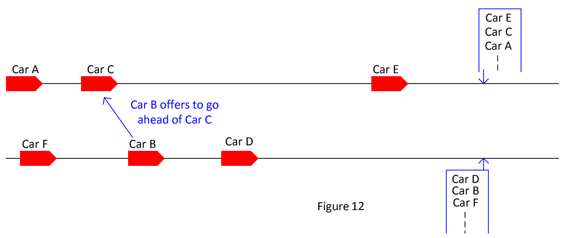


Figure 12

Figure 12 shows two lanes of traffic on a freeway, with three cars in each. We can consider these to be perhaps autonomous vehicles in controlled freeway space. They are protected from collision not by on board cameras, but by "train" queues (we'll refer to them as "lane queues" here) working as described in previous sections.

The "convoy mode" where all cars stay in their lanes is trivial. The case where a car wishes to change lanes is more interesting – an application for a virtual crossover without actual points.

We will consider the process required for such a crossover move and confirm its safety.

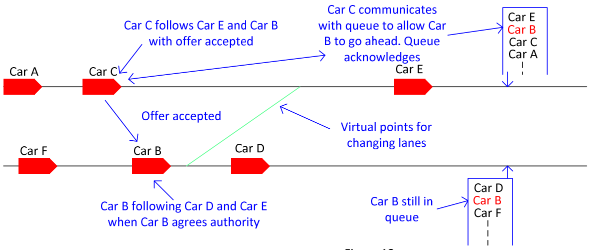


Figure 13

In figure 12, Car B is initiating the process for changing lanes by seeking permission from Car C to move ahead of it. In figure 13 Car C informs the infrastructure system of its acceptance, then Car B (when the infrastructure responds). Car B is them shown in 2 queues, fouling both lanes during the manoeuvre.

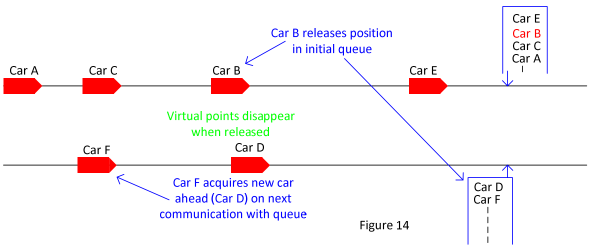


Figure 14

Figure 14 shows the situation when the change of lanes is complete. Car B releases its position in its original lane (by notifying the relevant infrastructure queue) whilst retaining its position in its new lane. The requirements for "releasing" will not be discussed further here apart from noting that a release is required even though there are no actual points. This requirement to release the train from the queue is common for all queues. This need will be discussed later.

Consider now the case of Car F who was not involved at all in any of the lane changing transactions. This is required to now acquire Car D as its new car ahead. It can do this by interrogating the infrastructure lane queue for its own lane and acquiring the new queue order directly.

In the case where Car F fails to do this, it will stop at the last reported "in lane" position for Car B which will cease reporting lane position for its former lane once it is released from that lane.

The prospect of a car suddenly stopping in the middle of a busy freeway is not pretty, but should be quite safe in this case since all cars will have rail standard safety in their calculated stopping distances. This possibility is reduced when broadcast of the queue information can be distributed between the vehicles as well as the infrastructure to improve reliability of update.

No unsafe cases are identified from broadcast of temporarily out of date information.

Of interest for this particular case is whether an infrastructure based queue is required at all for these transactions, or whether the queue can safely be constructed by each vehicle system on a peer to peer basis. The answer to that question appears to be "yes" at minimum for cases where:

- Operation of vehicles is unidirectional (ie no passing by crossing over a centre-line); and
- Non fitted vehicles can be safely managed as an issue separately from the queues.

Rather than expand further here on the applications of road based queues, we will now leave the abstract notion of junctions without points and consider the rail case where points also need to be managed at junctions.

4.6 Train queue example for allocating junction points as a resource and moving them to position

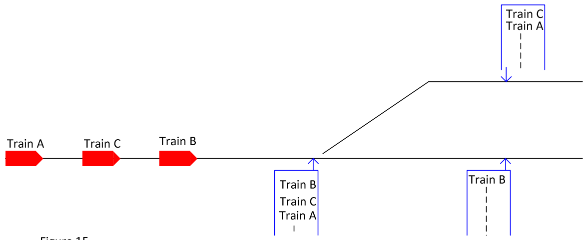


Figure 15

Figure 15 shows the situation where trains are approaching a diverging junction with points.

In order for a train to traverse the points, it requires (1) to be at the top of the queue, and (2) to be issued with an authority confirming the points are locked in position.

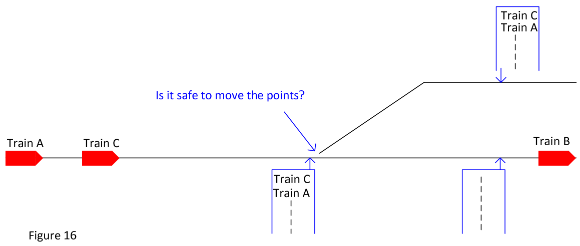


Figure 16

As discussed above, the mere presence of the train at the top of the queue bound in a certain direction is sufficient for allocation of the points to that train. It has been seen in many cases above without physical points that there is no need for any additional layers to assure safety. The points may be moved to position by virtue of the presence of the train at the top of the queue.

Since these are points, no authority will be offered until the points are actually locked in position, per conventional interlocking practice. The train queue and the authority process can achieve the whole process without the need to ever set a route.

Interestingly, this situation would have represented standard for unit lever relay based geographic interlockings in Victoria prior to the advent of SSI. It would also have represented standard practice in the UK prior to about 1920. It was the Germans (according to IRSE papers of the period) who first introduced the setting of routes by interlockings. These early German interlockings tended to obscure the need to lock and release points, but those needs were always present.

The train queue can achieve the same point controlling functionality as a route setting interlocking, but in a way which integrates more seamlessly with the ETCS and CBTC style functionality with its current popularity.

There was a development reported on at the International Convention in Lyon [3] where trains were able to call points directly. The difference between that system and the one described in this paper is subtle but important. In this paper the points are allocated and controlled by the infrastructure base train queue system. The train may influence that process by the way it applies to join the train queues along its path. In this it functions much like a signaller.

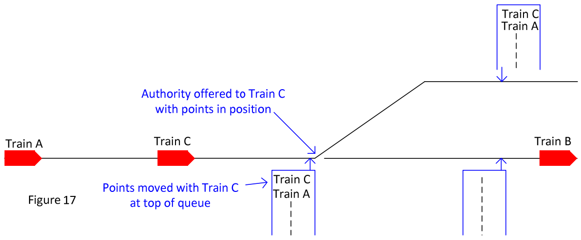


Figure 17

Release of points behind trains is also important. In the case of a points train queue, there will always be a queue corresponding to the toe and one corresponding with the clearance point. The train at top of this queue will be removed from both queues (allowing the next train to come to the top) when the train is detected clear of the points (ie no longer foul of a train traversing the points on another path) and either it or the infrastructure issues a release. The issue of the release is an important safety function but not a topic for this paper. In terms of the signalling system breakdown, the release is a section 5 (see figure 21) [1] topic and perhaps subject of a future paper.

4.7 Bidirectional operation and terminal cases

The following two examples are provided for completeness, providing the mechanisms applicable for lines where trains can operate in more than one direction.

4.7.1 Single line sections

Figure 18 below illustrates the case for control of a traditional single line section.

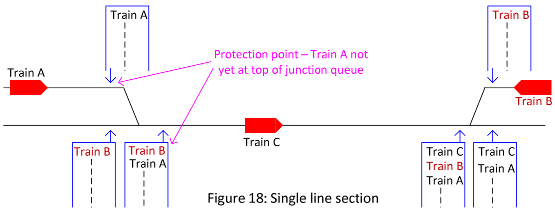


Figure 18: Single line section

In this diagram, train authorised direction is shown by colour of the train ID in the queue.

Rather than adopting the traditional Australian approach of considering the "single line section" as a significant object on its own, the single line is convenient to use the more European concept of treating it as simply the line joining two stations. The infrastructure can be shown fully with just the junction queues shown. The plain line queues carry no additional information and can sit in background.

Looking at this case, Train C is in section, clear of the left hand queues, top of the right hand queues, and able to proceed through the junction subject to an authority being provided to traverse the points.

Train A is stopped clear of the left hand points. Although it is top train in the diverge queue, it is held clear of the junction by not being top of the junction queue. It must wait for train B to pass.

Train B is in a similar situation at the far end of the section, but needs only to wait for train C to pass before it becomes top of the junction queue and is able to gain authority from the infrastructure to pass over the points and traverse the section.

For the case shown, the potential for a race condition between train A and train B is resolved to avoid the potential for a nose to nose conflict. In the general case, the train order in the junction queues at either end must be made consistent (not identical – as can be seen in the example, the contents of each queue differ). This is achieved in practice by nominating one of the queues as master. If a train wishes to join the queue from the opposite end of the single line, it must join the master end queue first before having its "train ahead" nominated.

4.7.2 Terminating trains

Figures 19 and 20 illustrate the situation where a train may terminate and change direction mid section.

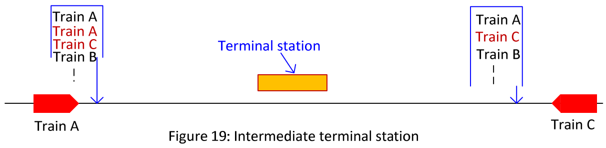


Figure 19: Intermediate terminal station

Initially, with trains approaching the terminal station from each direction, train A is shown top of the queues at either end of the section. Since train C is not top of its queue ahead and its direction is opposite to train A, it is held at its train queue ahead.

It can also be seen that Train A appears twice the left hand queue since it is scheduled to terminate and change direction.

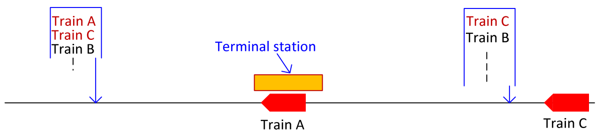


Figure 20: Intermediate terminal station

When the train stops at the station and changes direction, it can be cleared from the right hand queue, It is then clear to proceed immediately, being top of its queue ahead.

Train C is also able to proceed, being top of its queue ahead and having Train A nominated as train ahead (this time in same direction) in its queue ahead. Thus the whole sequence of train movements can occur safely.

One aspect not discussed here is the process for ad-hoc termination to occur for train A (ie Train A wishing to join the queue for the opposing direction). In this case, Train A would need to obtain authority to go ahead of Train C (top of the queue in the new direction) in order for the change in direction to occur. Authority is not required from Train B since Train C is already its train ahead in the queue and Train B will not be authorised to pass beyond the section protection point till Trains A and C have both passed.

5 CONCLUSION – VITAL AND NON VITAL QUEUES

In this paper, the use of train queues for vital control of points and signalling of trains has been discussed. Non vital train queues are commonly used by train control systems to provide train paths and avoid (safe) lock-up situations. The extension of the queue concept into the world of vital signalling can bring many benefits, including the ability to bring interlocked areas into the Communications Based signalling world.

These vital and non-vital queues can be considered to be separate with information transferred from one (considered to be the non vital planning queue) to the other (considered to be the vital current activity queue) as required and then managed according to the vital processing rules discussed.

Transferring information into the vital queue is the equivalent of a signaller operating a lever (eg setting a route) and can be treated at the same level of vitality. For more than 30 years, the Victorian JZA 715 system operated with just this split, allocating objects (setting routes with non vital locking) in the non vital Train Describer system, then locking those routes, issuing authorities and subsequently releasing them in the vital (geographic relay) interlocking system.

In the cases described in this paper, locking of points, issuing of authorities, releasing of authorities and freeing points are all tasks carried out by the vital train queue functionality, not the non vital portion.

In many ways, this effective replacement of a formal route setting function by a communications based queue management function involves a return to signalling principles considered conventional in UK prior to 1920, and conventional in Victorian (unit lever) geographic relay interlockings prior to the introduction SSI.

Thus the principles and functionality are not new or unconventional. What is new is the transfer of signalling functionality from the infrastructure based systems to the train centred communication based systems to open the way to a new generation of signalling.

6 REFERENCES

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[2] Burns, P. 2016, *Proceedings, Institution of Railway Signal Engineers Perth Meeting, July 2016*, Time Based Movement Authorities;

[3] Denis, Guillaume 2014, *Alstom presentation*, *IRSE Convention – Lyon – June 2014,* 'URBALIS Fluence, Train-centric CBTC solution';

[4] Lindsey, Ron 2012, 'Traffic Control: Science or Art?', *Railway Age*, Sept 2012, pp 42-49; The actual quotation is: "*moving-block is actually dark territory on virtual steroids*"

AUTHOR

Peter Burns

Peter Graduated in Applied Science (Electronics) from Melbourne University in 1981.

He commenced as Professional Engineer with Victorian Railways that year in Signal Design., then progressed through various roles in Signal Design, Test and Development, Maintenance Management. He completed his MBA at Monash University in 1991.

Peter left PTC in 1994 to work for companies such as Alstom and Bombardier in places such as Sydney, Melbourne and Copenhagen.

In 2003, he joined with 2 colleagues to form *Rail Networks*, providing assistance over a number of years to Government as well as to Connex, the then franchisee for the Melbourne rail network.

Peter is currently director of the small consultancy firm "*PYB Consulting*" and as Chartered Engineer fills wide and various roles in rail organisations when they seek assistance. Recent projects have included RRLCMR and Signal Advisor to teams bidding and delivering various Melbourne Grade Separation projects including the Burke/North/McKinnon/Centre Rd project.

Figure 1 (Section 3.3)

Figure 1: Open road concept

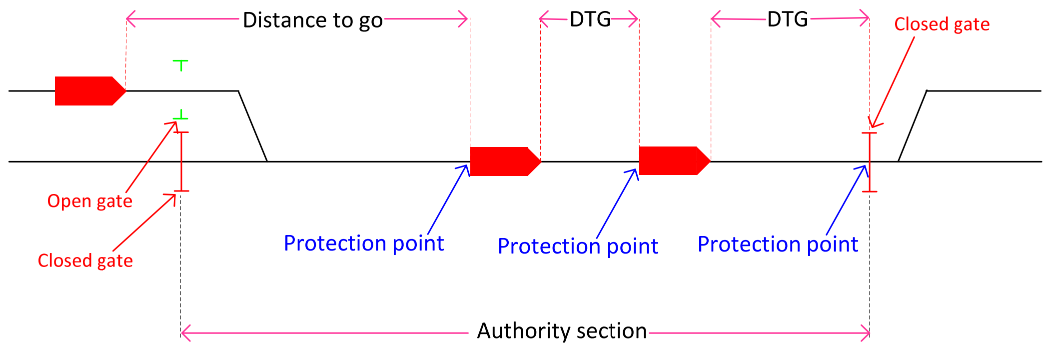


Figure 2 (Section 4.1.2)

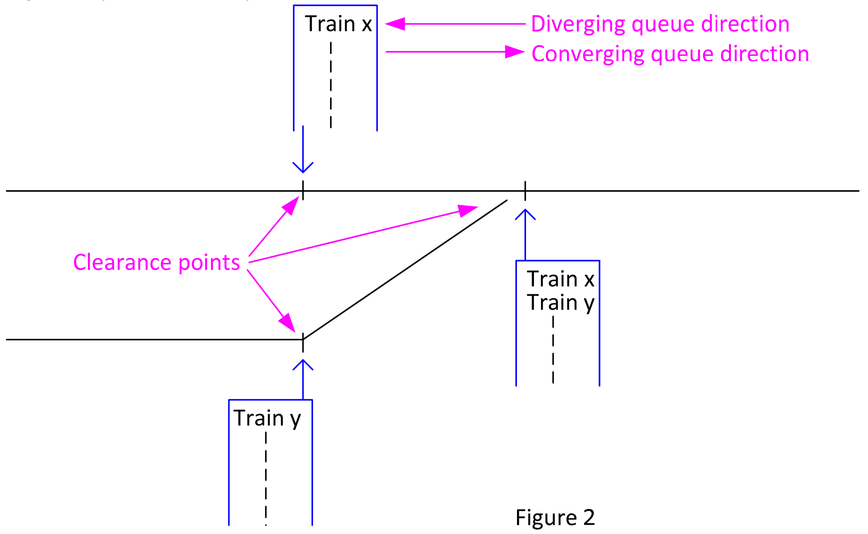


Figure 2

Figure 3 (Section 4.1.3)

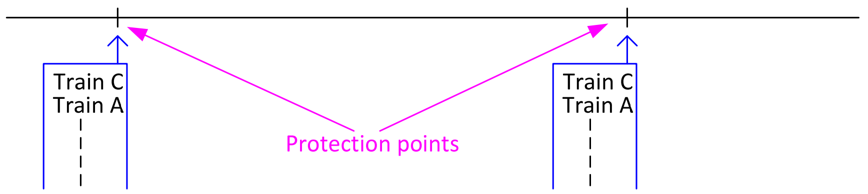


Figure 3

Figure 4 (Section 4.2)

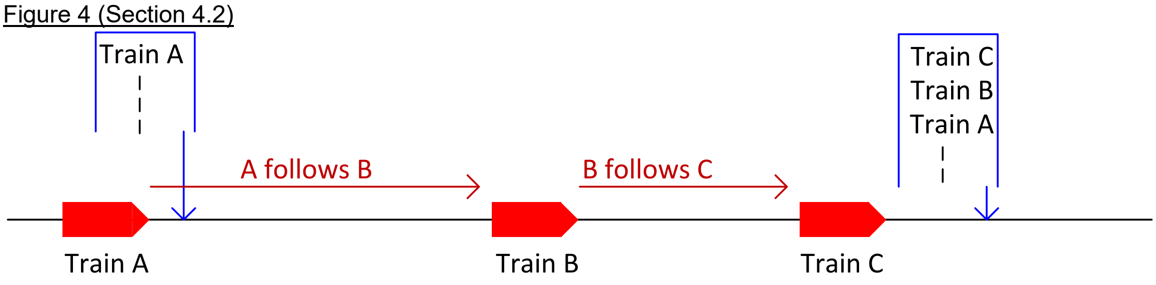
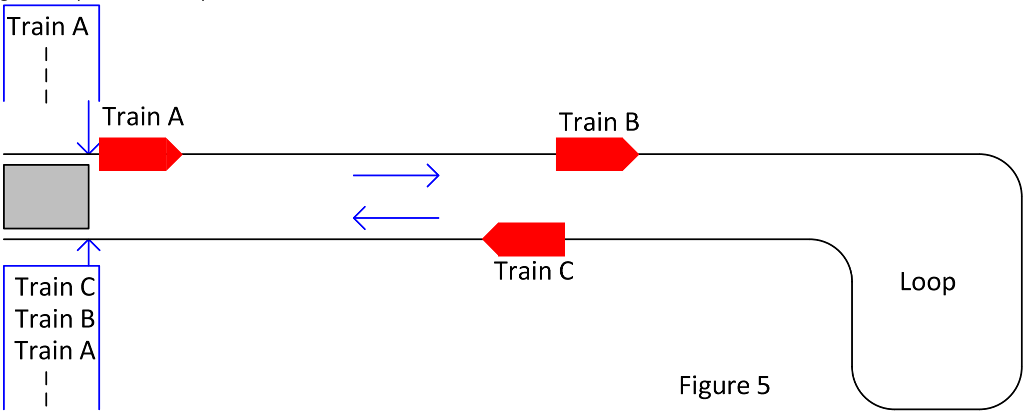


Figure 4

Figure 5 (Section 4.2)



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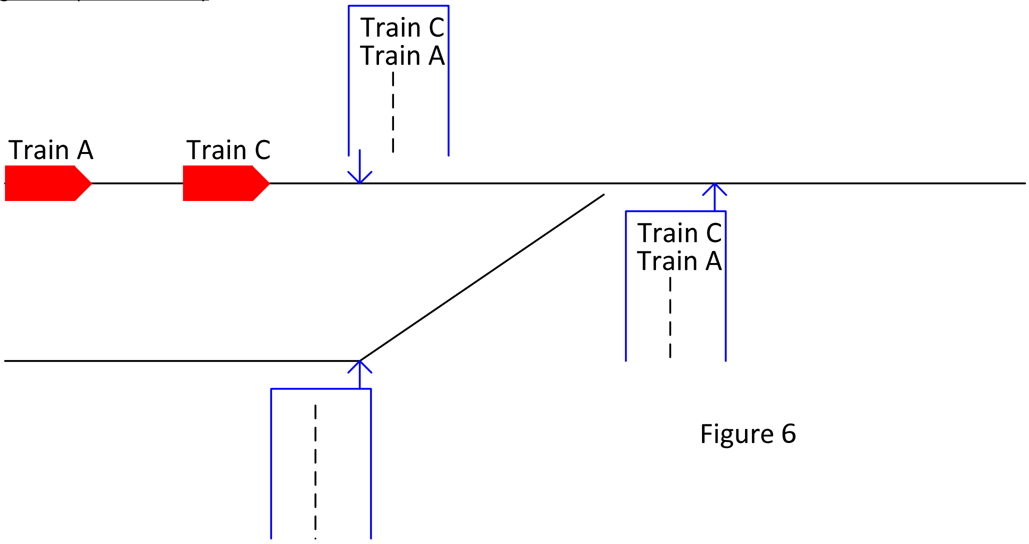

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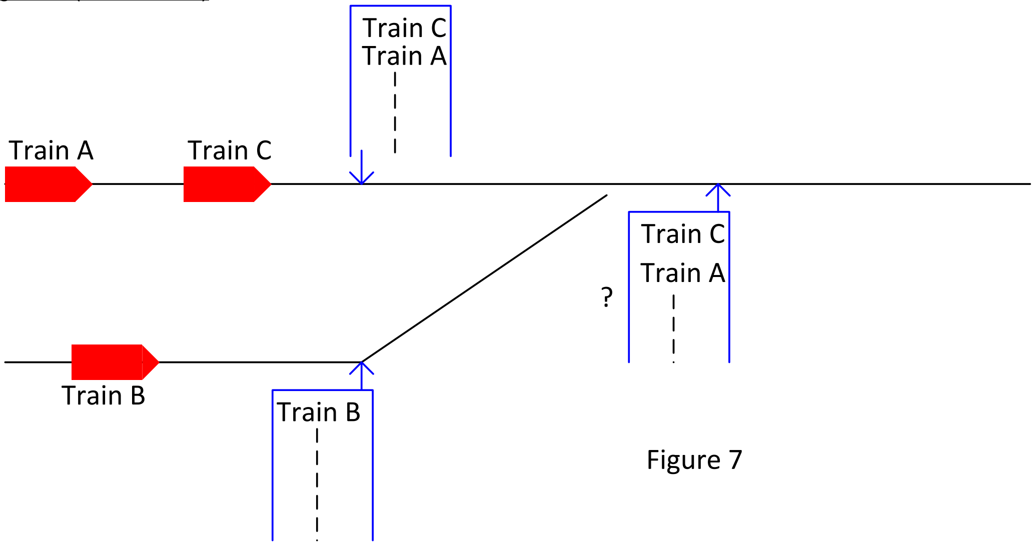


Figure 8 (Section 4.3)

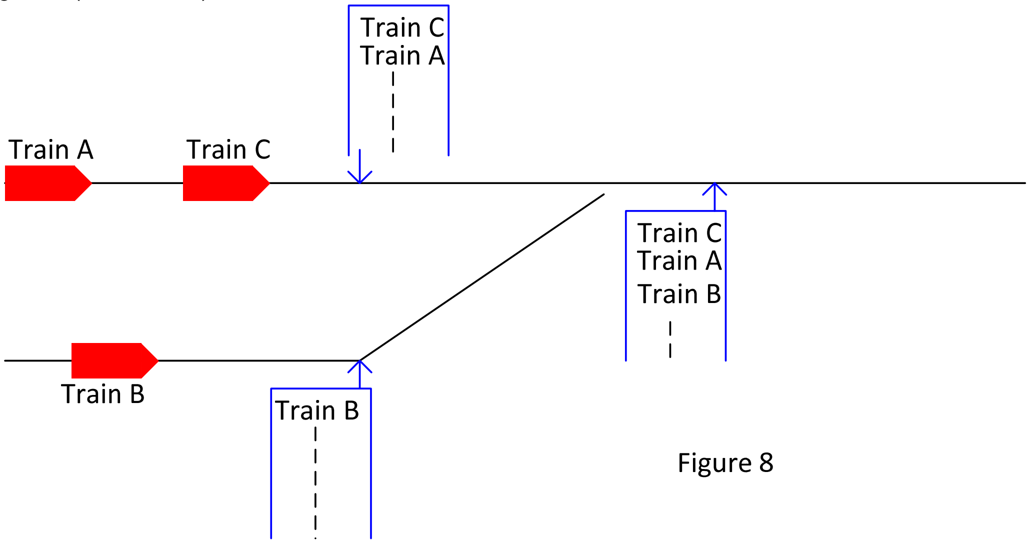


Figure 8

Figure 9 (Section 4.3)

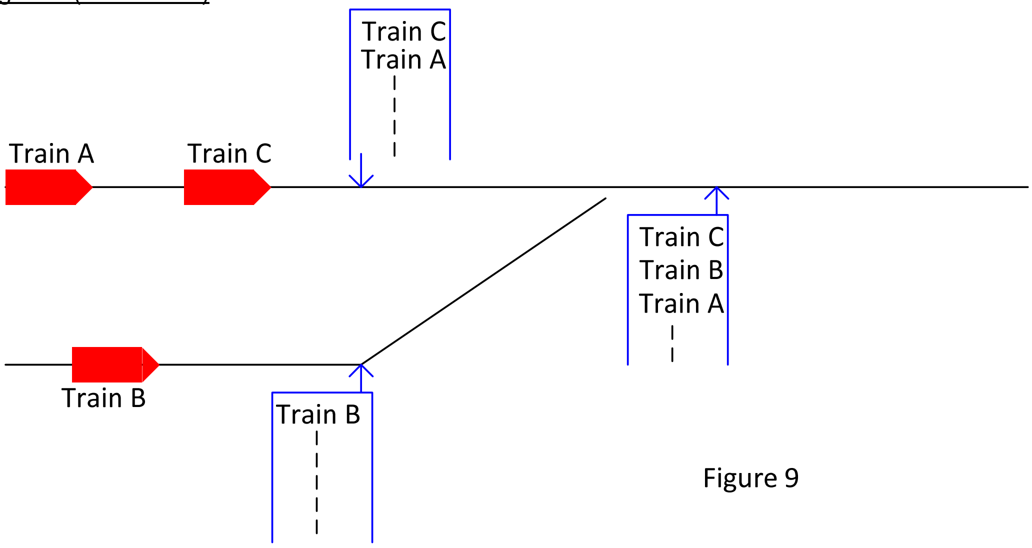


Figure 9

Figure 10 (Section 4.4)

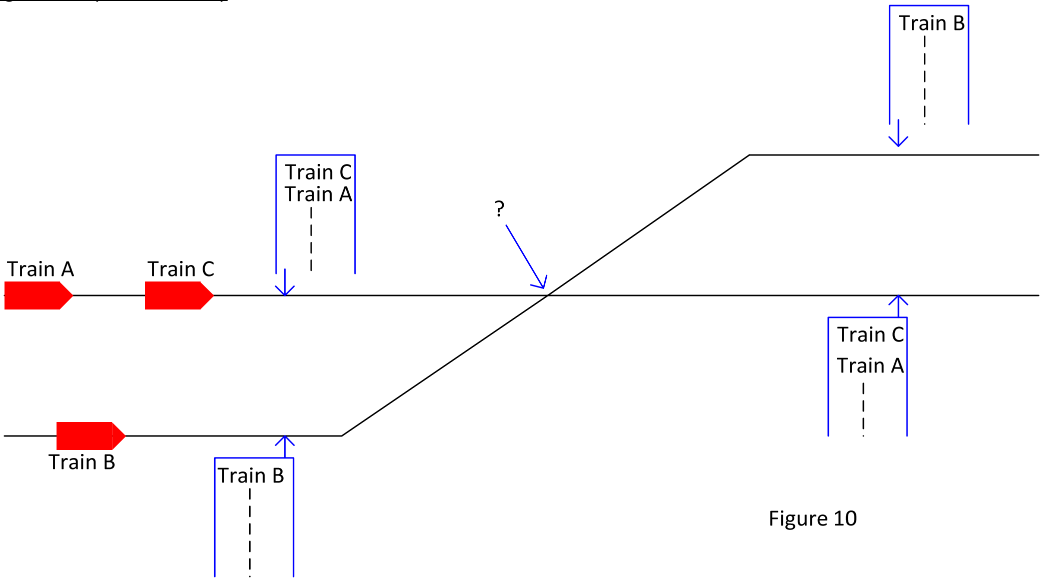


Figure 10

Figure 11 (Section 4.4)

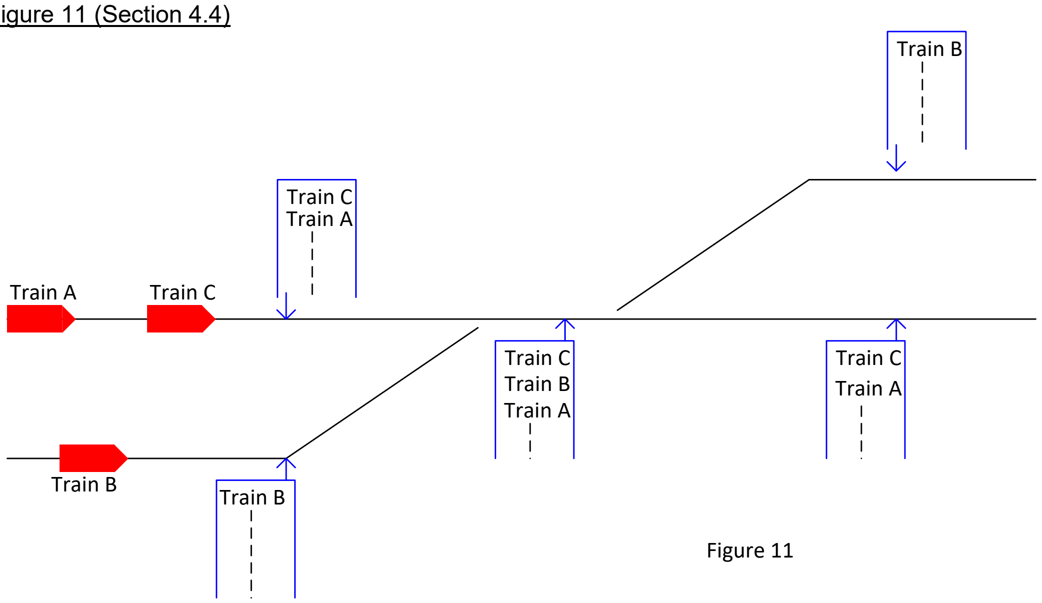


Figure 11

Figure 12 (Section 4.5)

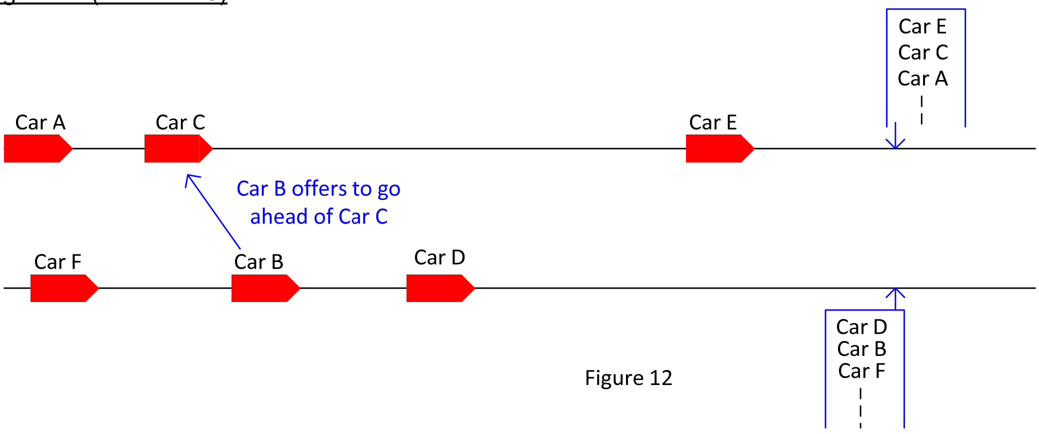


Figure 12

Figure 13 (Section 4.5)

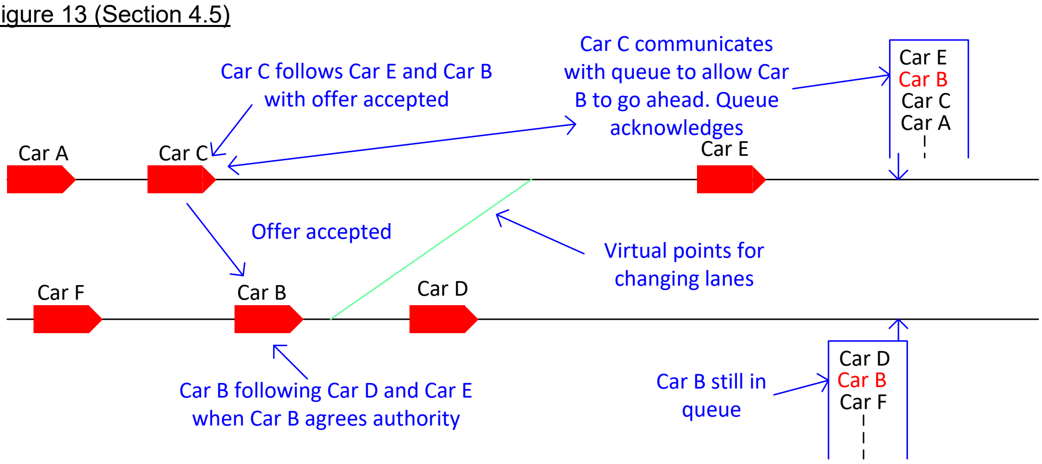


Figure 13

Figure 14 (Section 4.5)

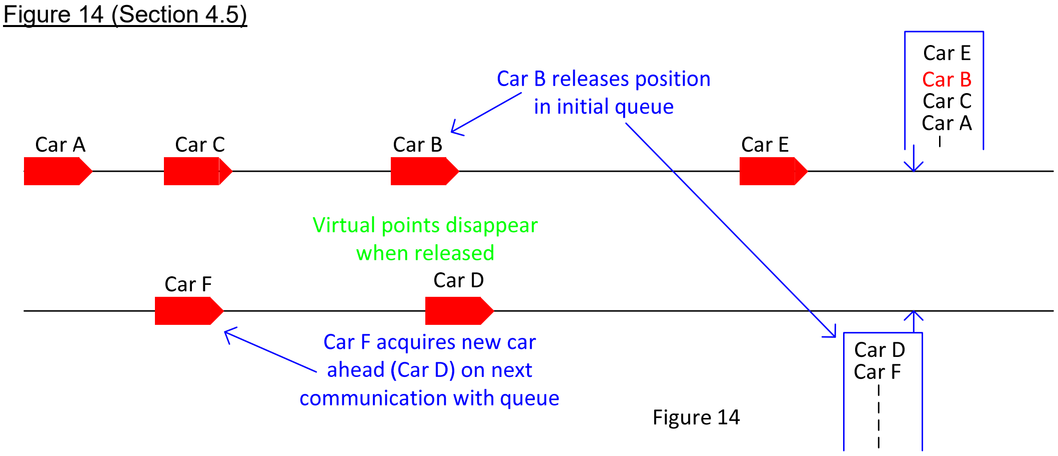
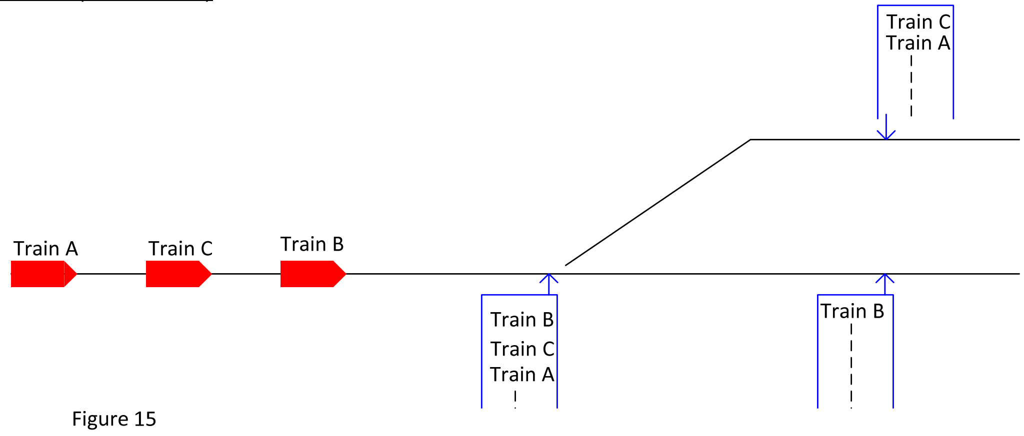


Figure 15 (Section 4.6)



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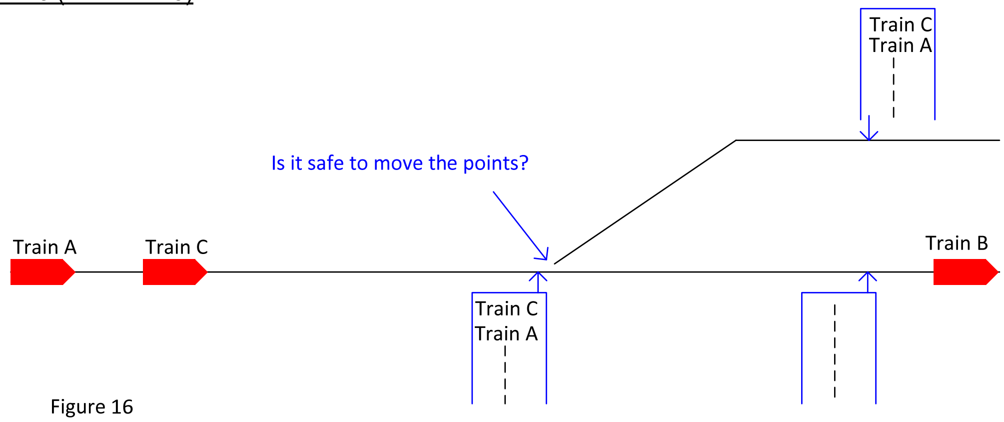

Figure 17 (Section 4.6)

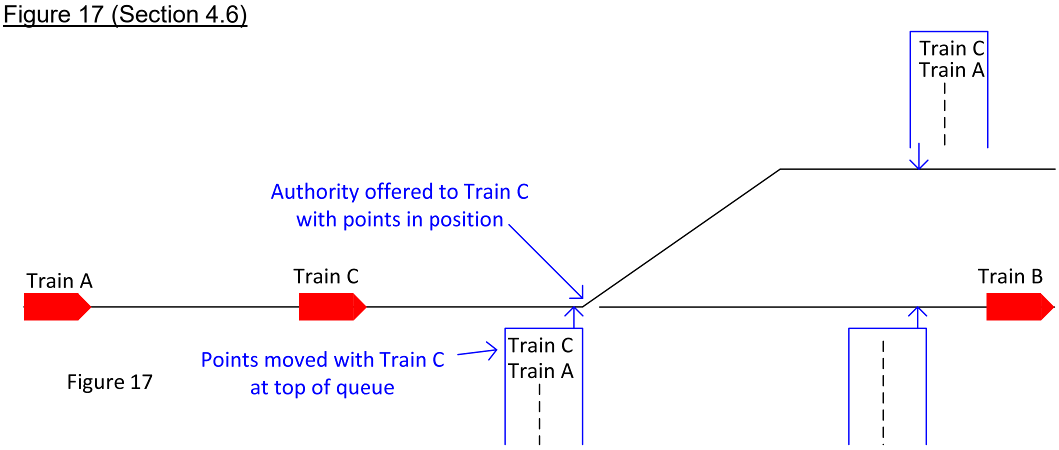

Figure 18 (Section 4.7.1)

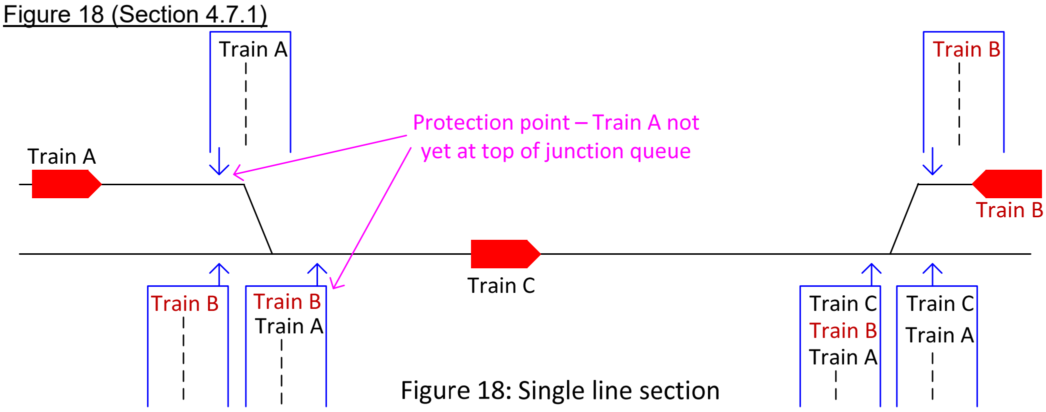

Figure 18: Single line section

Figure 19 (Section 4.7.2)

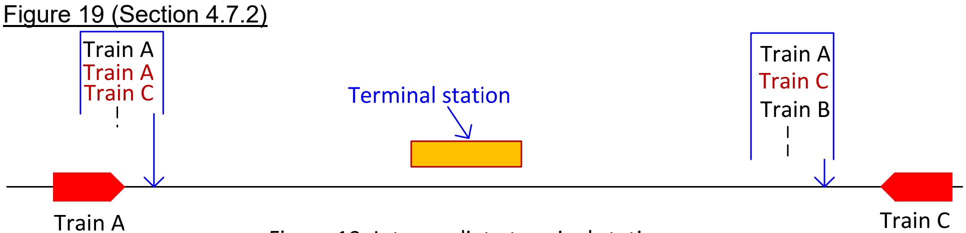

Figure 19: Intermediate terminal station

Figure 20 (Section 4.7.2)

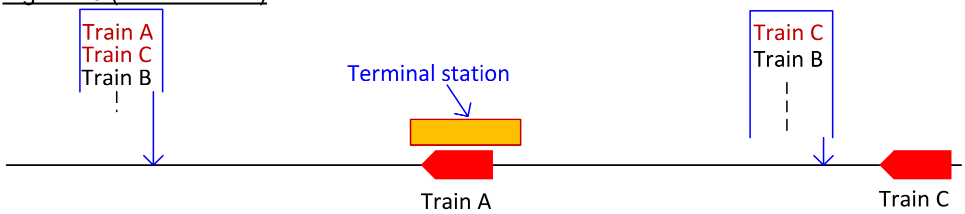

Figure 20: Intermediate terminal station

Figure 21 - Generic Signalling Framework