Naeem Ali - CBTC Solutions

Conventional vs CABS vs CBTC Signalling & their Impact to Capacity

AGENDA

Agenda

- Introduction
- Conventional Signalling
- CABS Signalling
- CBTC Signalling

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INTRODUCTION

Introduction

- Capacity definition
  - The maximum number of trains that can pass a given location during a given time period at a specified level of reliability.

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Introduction

- Several Factors that affect capacity
  - Dwell time – Time spent serving a station
  - Signal system - Minimum safety distance between trains
  - Operating margin - Allowance for longer dwells
  - Minimum headway - Minimum operational distance between trains
  - Junctions
  - Turnbacks – Points at which a train changes direction
  - Traction Power Limits – Number of trains supported in a track section

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Introduction

- Focus of this presentation is on “signalling systems” and their impact on capacity
  - Conventional Signalling
  - CABS Signalling
  - CBTC Signalling

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CONVENTIONAL SIGNALLING

Traditional Fixed Block Signalling

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Conventional Signalling

- Drivers use trackside signals to determine:
  - If the train can proceed forward (aspect)
  - The speed the train will travel at
- A simple system may have 3 aspects:
  - red – stop.
  - yellow - proceed with caution.
  - green – move at max speed.
- The location of the train is determined by track circuit occupancy.

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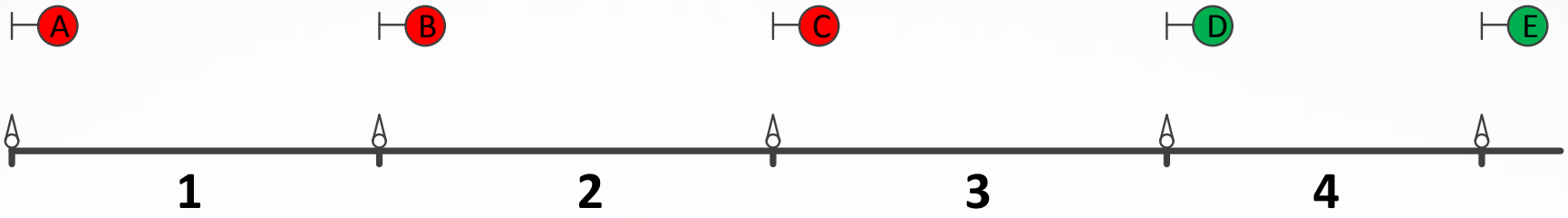
Basic Concept



- The signal engineer views the track in small chunks called blocks.
- The block length determines:
  - Safety - how far apart the trains will be kept from each other
  - Capacity – how many trains can pass through the system
- Challenge for the signal engineer
  - Increase the block length means increased margin for safety but reduced capacity
  - Reduce the block length means increased capacity but reduced margin for safety

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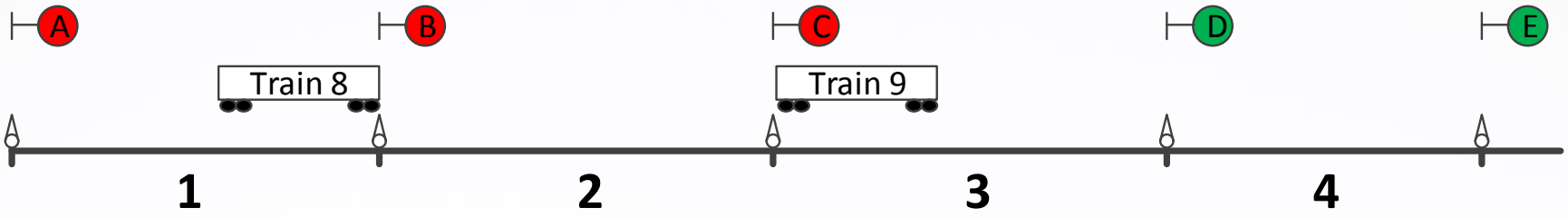
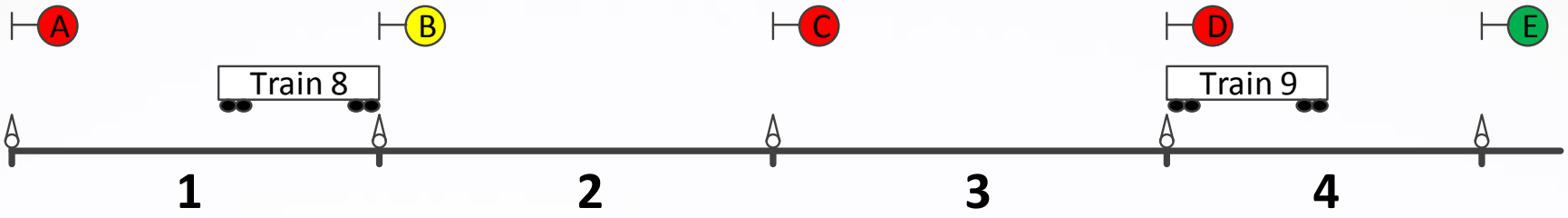
Basic Concept



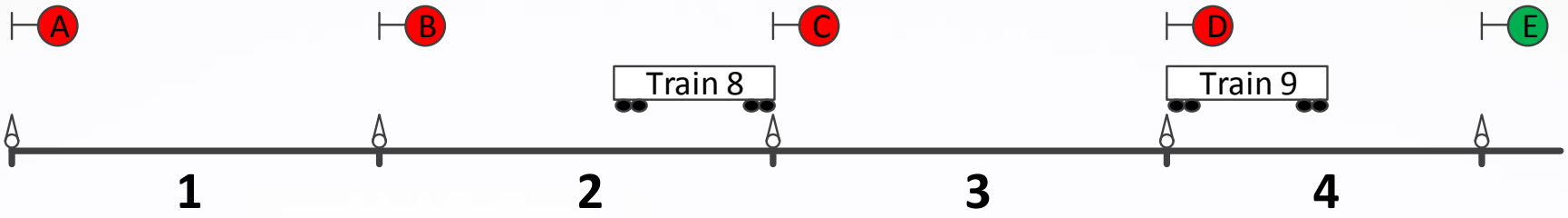
- One block separation must be maintained between trains for safety.

Basic Concept



- One block separation must be maintained between trains for safety.
- When train 9 moves into block 4, train 8 will be given a permissive aspect (yellow or green signal).

Basic Concept



- One block separation must be maintained between trains for safety.
- When train 9 moves into block 4, train 8 will be given a permissive aspect (yellow or green signal).
- Train 8 will move forward and stop at signal C, it’s an accordion effect.

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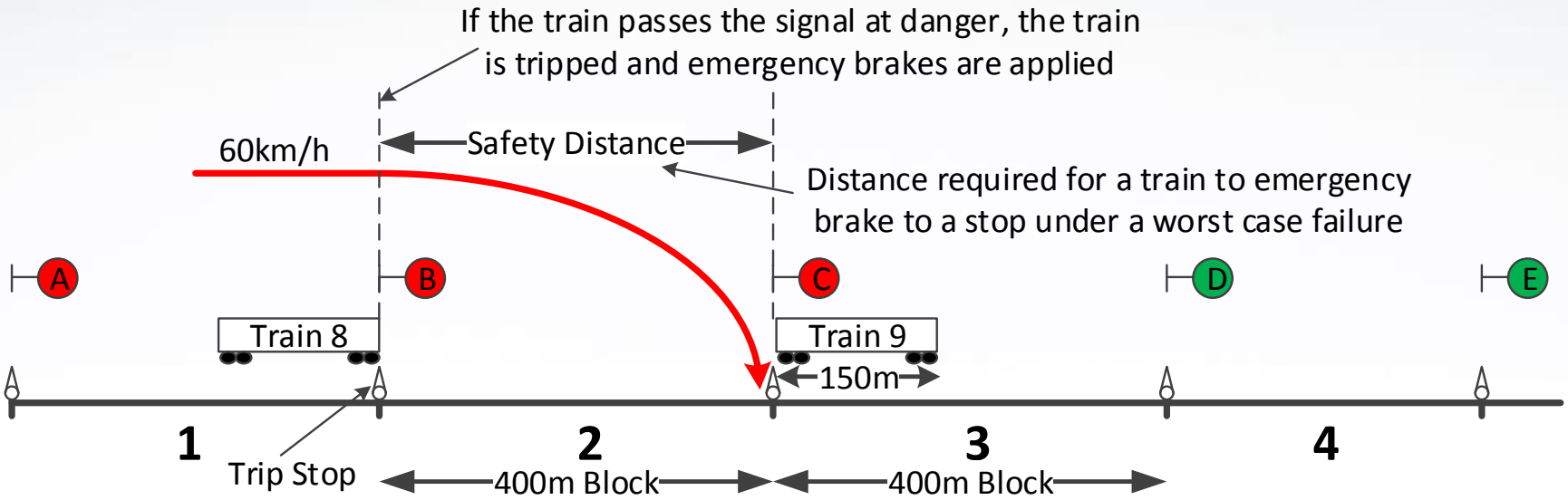
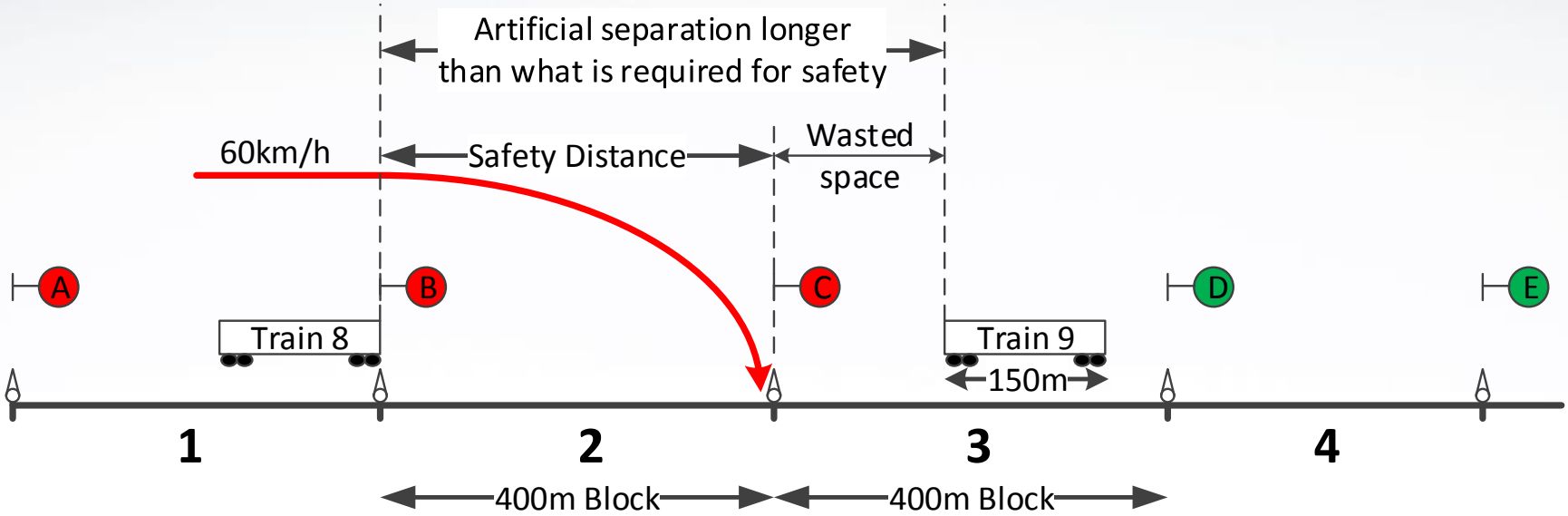
Capacity



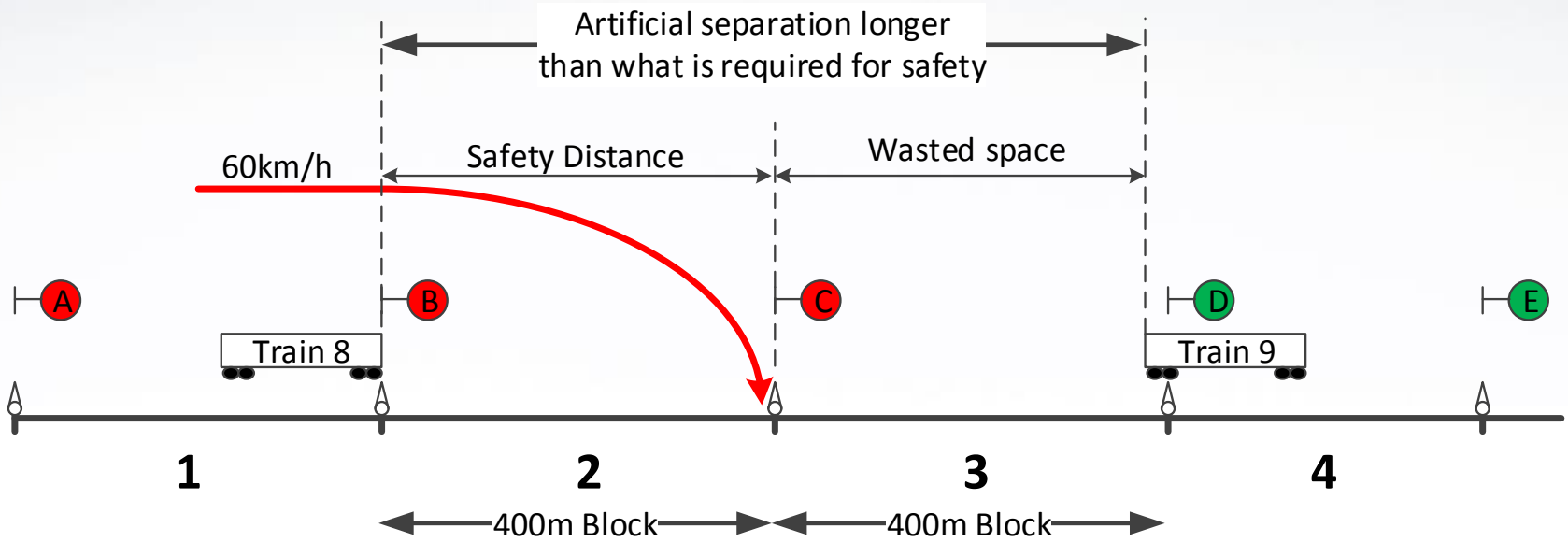
- If train 8 hits a trip stop travelling at 60kph and it requires 400m to stop, the block separating train 8 from train 9 must be at least 400m long to satisfy the safety requirement.

Capacity



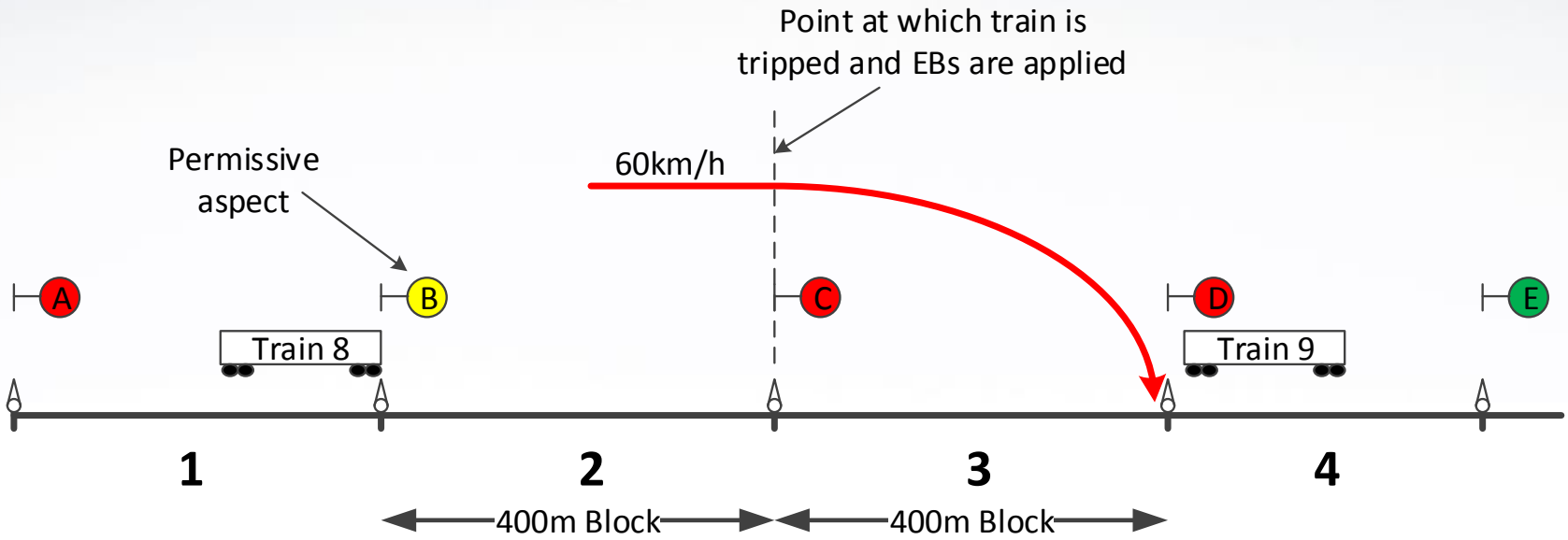
- As train 9 travels away from signal C, train 8 will not be granted a permissive aspect until train 9 has exited block 3.
- Instead, an artificial separation is created between train 8 and 9
  - even though train 8 can move closer and still maintain a safe braking distance.

Capacity



- Train 9 must completely exit block 3 before signal B provides a permissive aspect to train 8.
- As train 9 moves further within block 3, the artificial separation grows.
- The trains can be closer together, but the fixed blocks prevent train 8 from moving.

Capacity



- Once train 9 has exited block 3, train 8 will receive a permissive aspect from signal B.
- Impact to capacity –
  - 800m separation between train 8 and 9; 400m longer then what is required for safety.
  - Number of trains that can pass through the system is not optimal.

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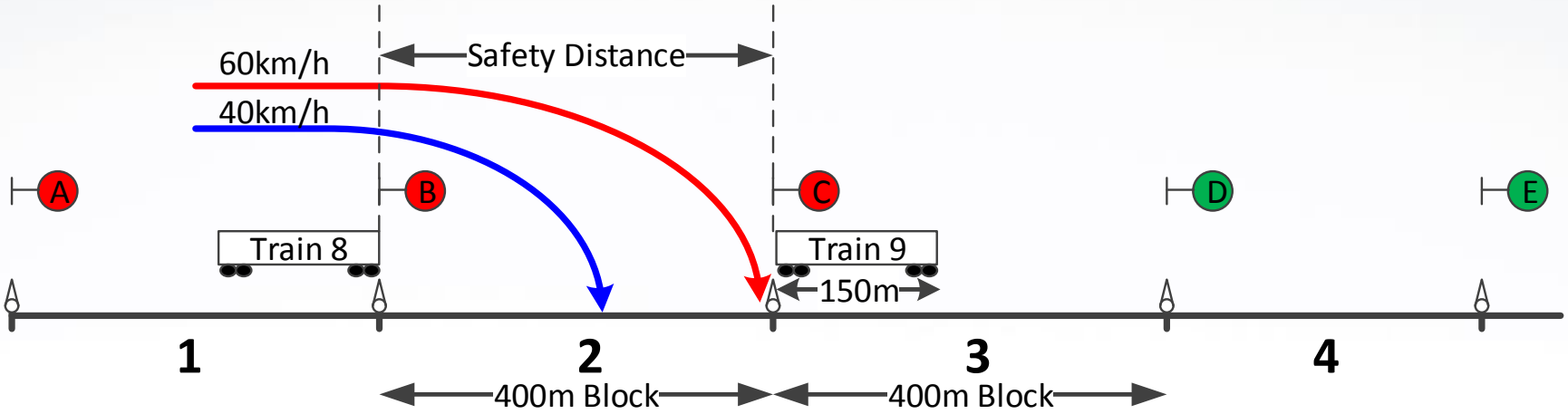
Capacity



- If a train is travelling at 40 km/h, it must adhere to the block separation designed for 60km/h.
- Static design, the signalling system cannot adjust the safety distance to the speed of the trains.

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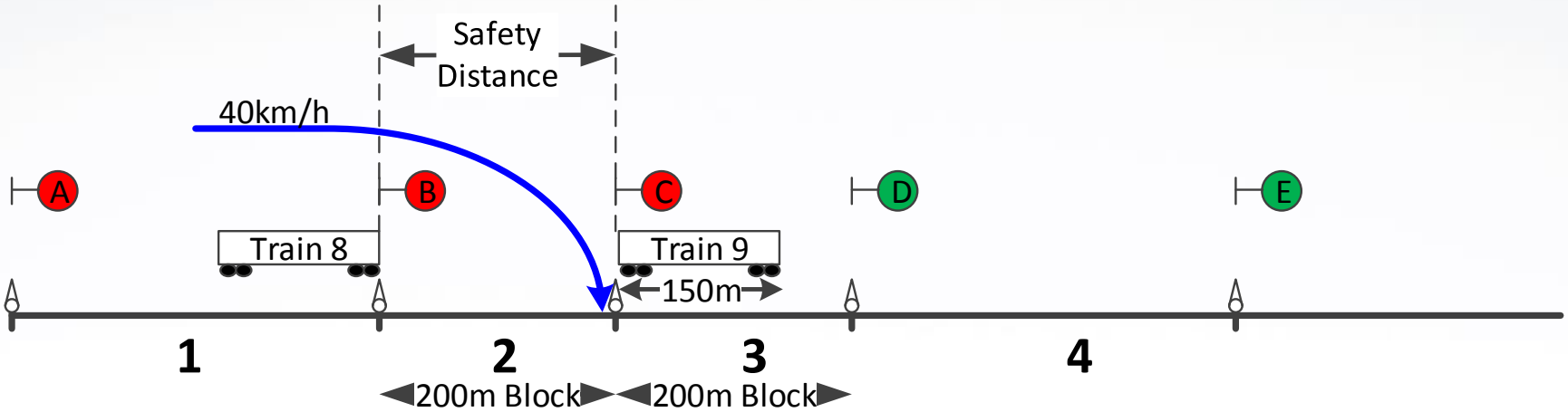
Capacity



- Smaller blocks will reduce the train separation but at the expense of line speed.
- The slower speed may cancel out the benefits of smaller blocks.
  - Fine balance between line speed and block size.

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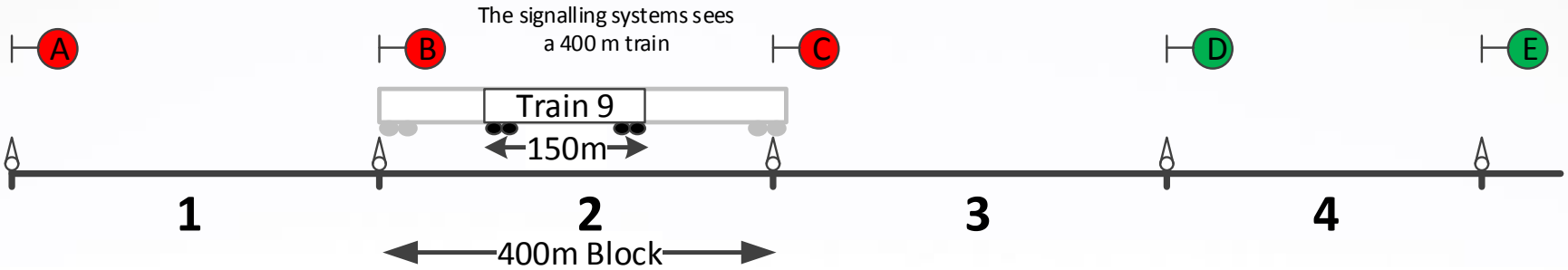
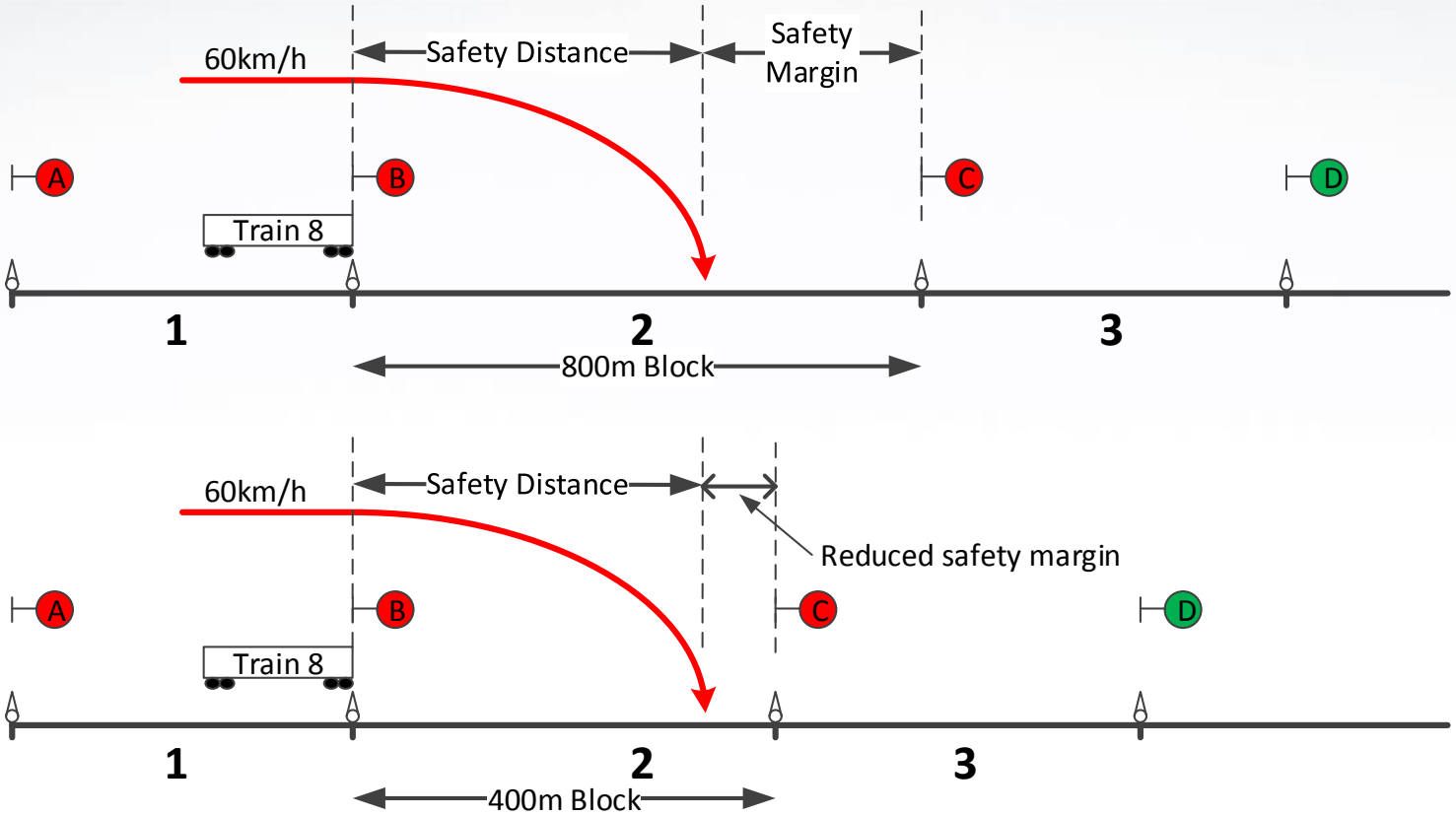
Wrap Up



- The signaling system considers the length of the train to be the same as the length of the block
  - If the block is 400m long, the train is considered to be 400m long.

Wrap Up



- Increasing the block size increases the margin for safety but reduces capacity.
- Reducing the block size decreases the margin for safety but increases capacity.

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Wrap Up

- Challenge for signal engineers is to calculate the block length for maximum capacity while ensuring safety.

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CABS SIGNALLING

Enhanced Fixed Block Signalling

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CABS Signalling

- Trackside signals are “usually” not used.
- Track circuits are used to the determine the location of the train.
- The speed and distance to go are displayed on the Train Overview Display (TOD) inside the cab and enforced by the on board ATP.
- CAB signalling has the capability to allow a train to move at multiple speeds within a block.

- Note: CABS signaling discussed here is with ATP protection.

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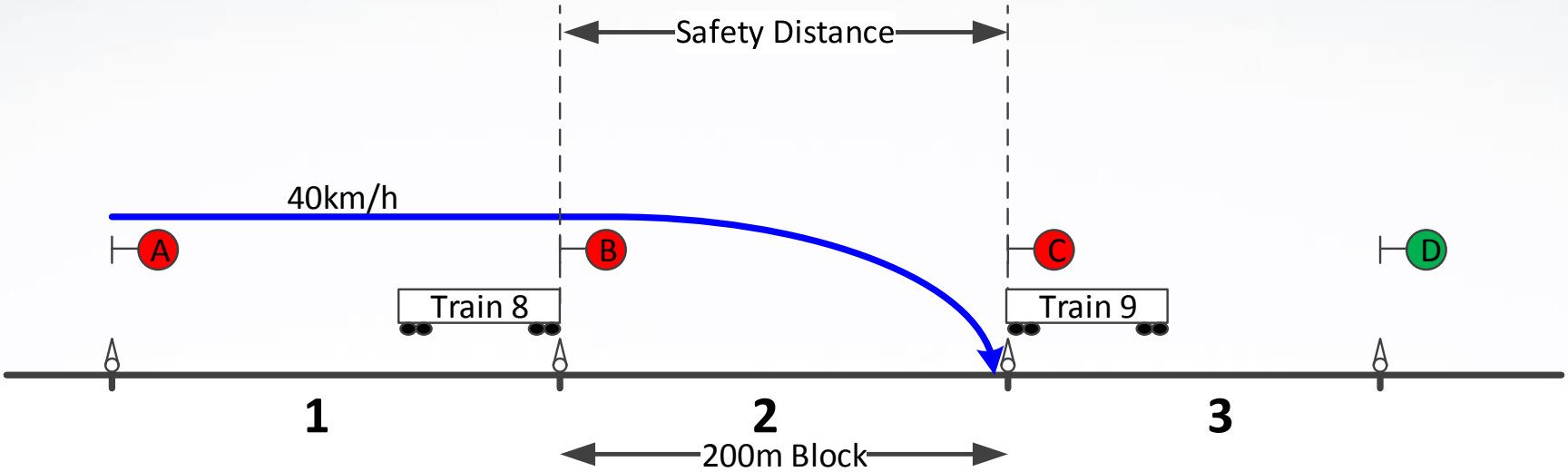
CABS Signalling

- CABS signalling does not alter the fixed block/conventional signalling concept.

CABS Signalling



- In conventional systems, the block design is based on a the line speed.
  - single speed profile.
- The block design does not allow for multiple speed profiles within the same block.

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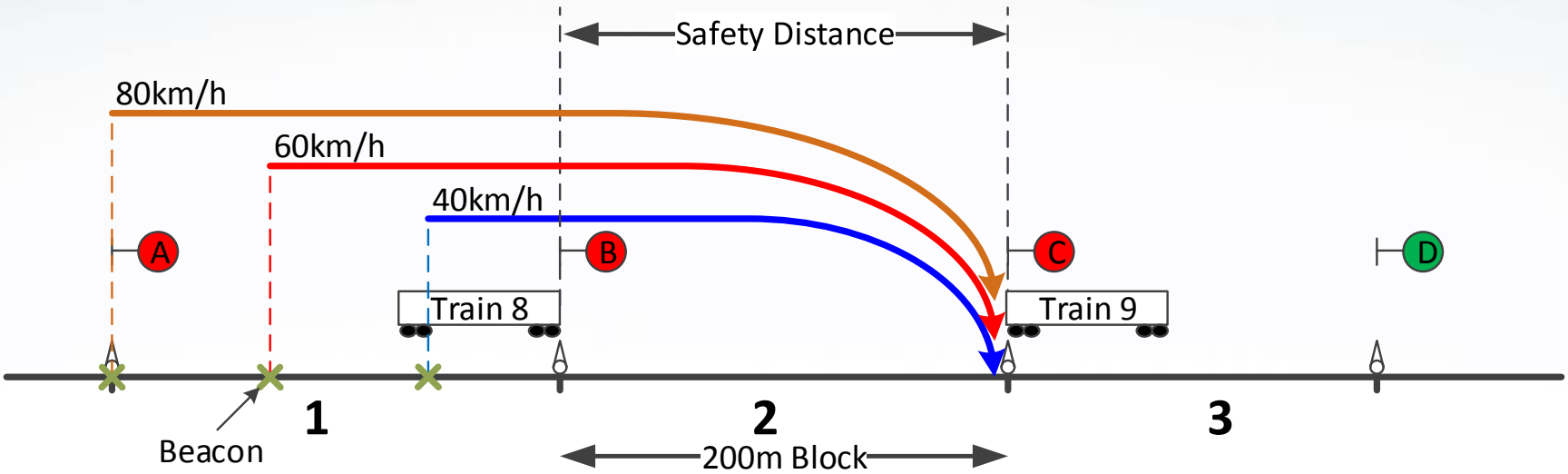
Multiple Speed Profiles



- CABS signalling allows for multiple speed profiles within the same block.
- The driver will receive an indication on the Train Overview Display (TOD) when there is a speed transition.
- Allows the train to travel at higher speeds with smaller blocks.
- Reduces the headway between trains, increasing the capacity.

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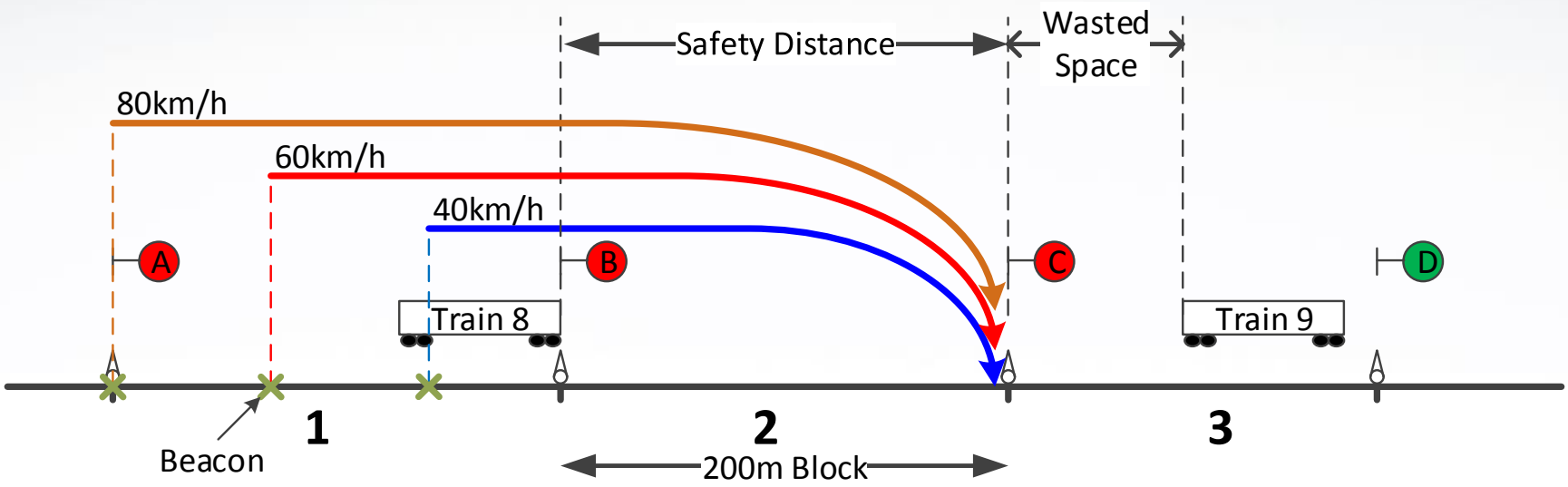
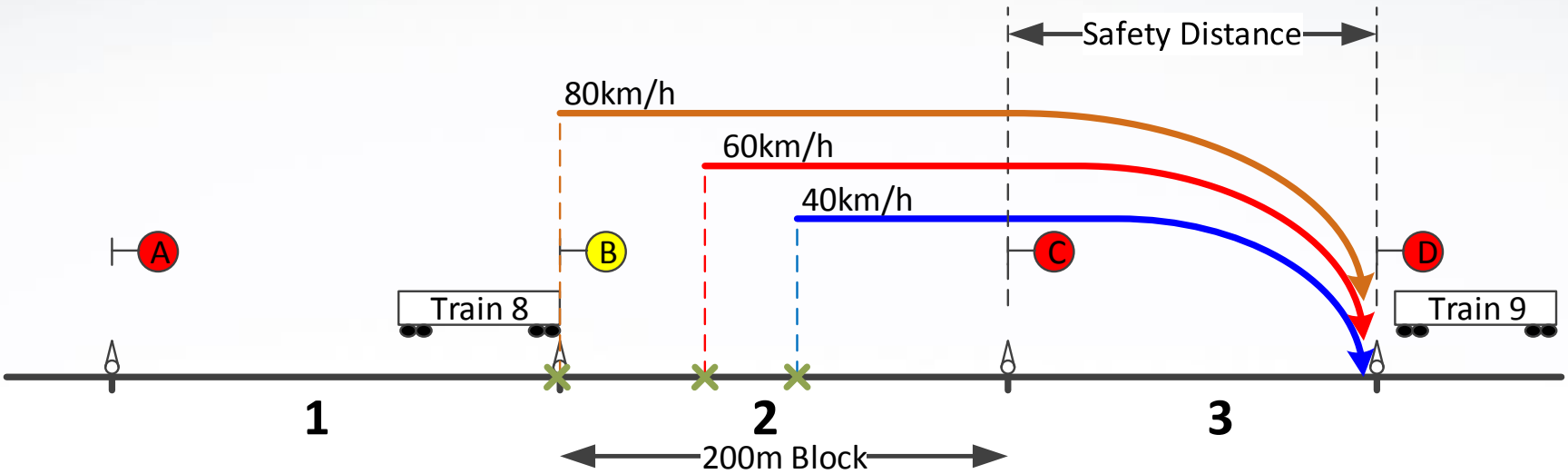
Capacity



- CABs signaling has similar limitations as conventional signaling.
- There is an artificial separation as train 9 moves away from signal C.

Capacity



- CABs signaling has similar limitations as conventional signaling.
- There is an artificial separation as train 9 moves away from signal C.
- Train 8 will not be given a permissive aspect until train 9 has exited block 3.

Wrap Up

- CABS signaling allows for smaller blocks, and therefore a marginal increase in capacity but the problems are similar to conventional signaling
  - Increasing the block size increases the margin for safety but reduces capacity.
  - Reducing the block size decreases the margin for safety but increases capacity.
  - Challenge for signal engineers is to calculate the block length for max capacity while ensuring safety.
  - The track is not utilized to it maximum capacity.

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CBTC SIGNALLING

Moving Block Signalling - A Brave New World

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- Trackside signals are not used.
- Track circuits are not used.
- Position is determined by a 2 way communication between the wayside and train.
  - Train transmits position.
  - Wayside transmits a target point.
- The train is able to determine it’s position with a resolution measured in centimeters.

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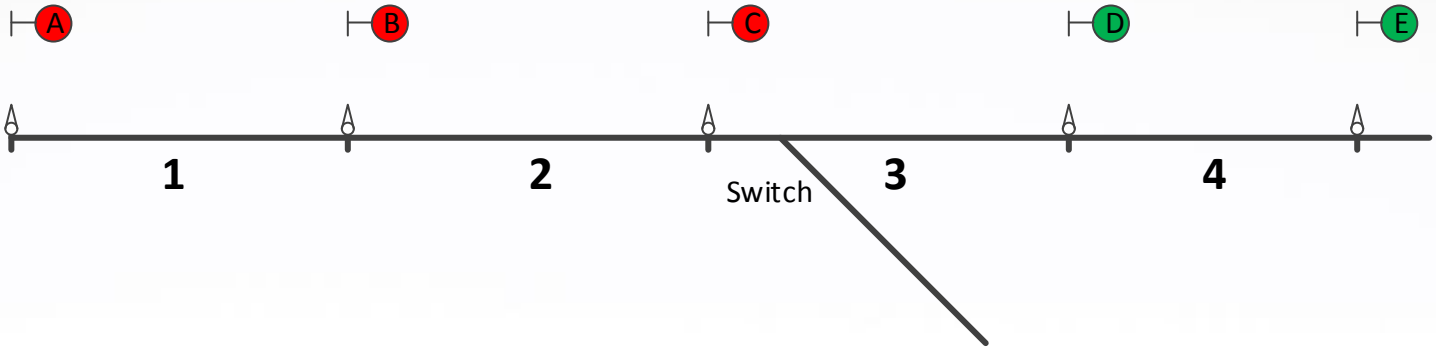
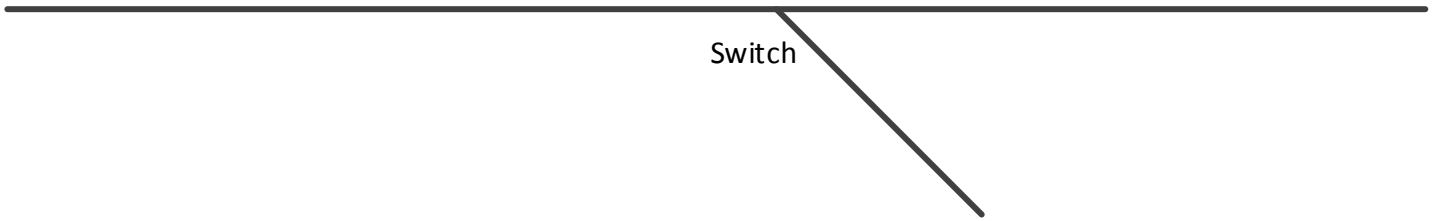
A View of the Track

Conventional/CABS Signalling (Fixed Block) – Chain of Blocks



CBTC Signalling (Moving Block) – Single Contiguous Track



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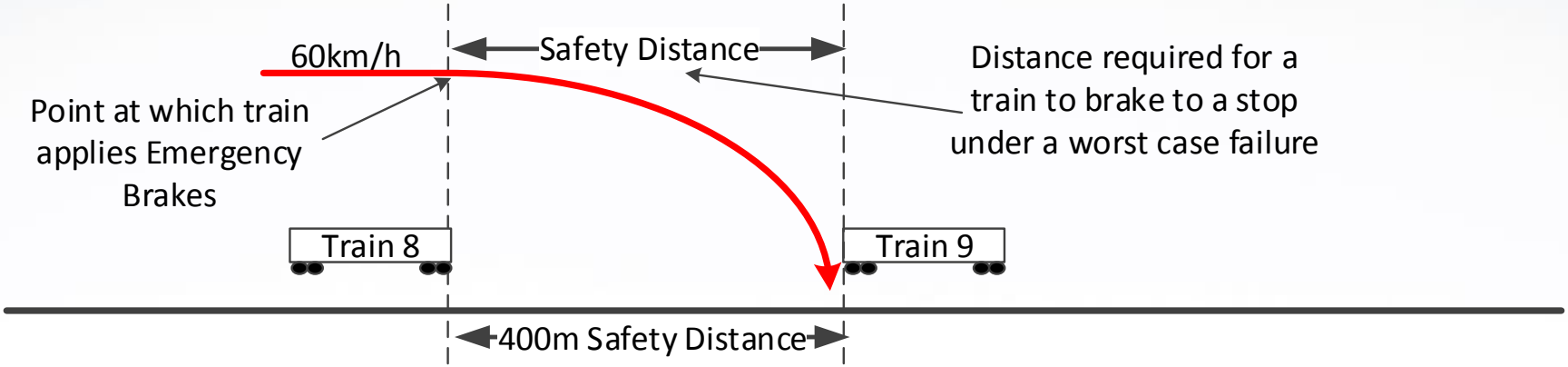
Basic Operation



- If train 8 is travelling at 60 km/h, it must maintain a 400m separation from train 9.
- This separation is not enforced by physical track circuit blocks, but a dynamic calculation by train 8.

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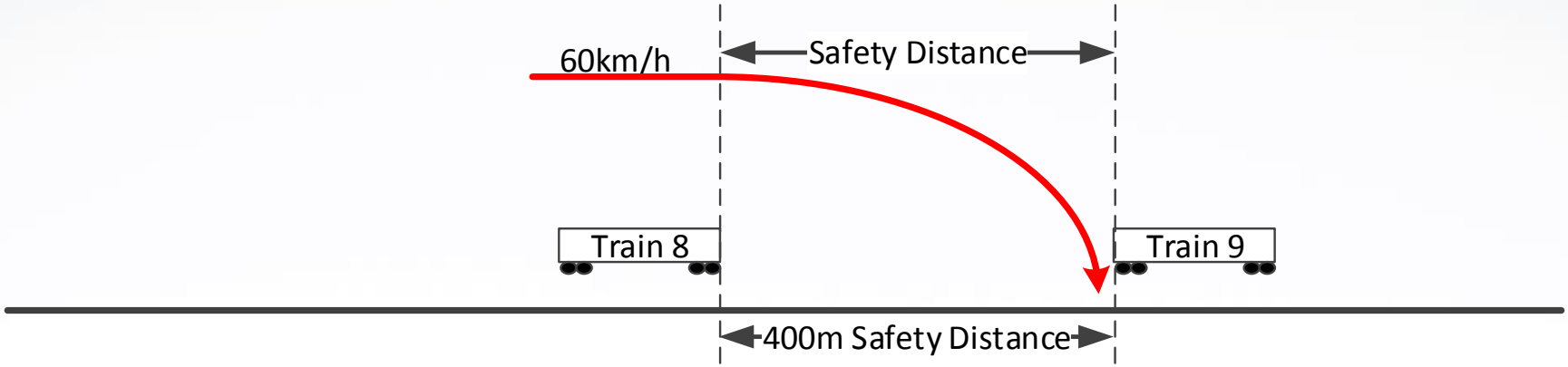
Basic Operation



- As train 9 moves forward, train 8 follows while maintaining the safety distance.
- There is no artificial separation between trains, only the bare minimum separation required to maintain the safety distance.

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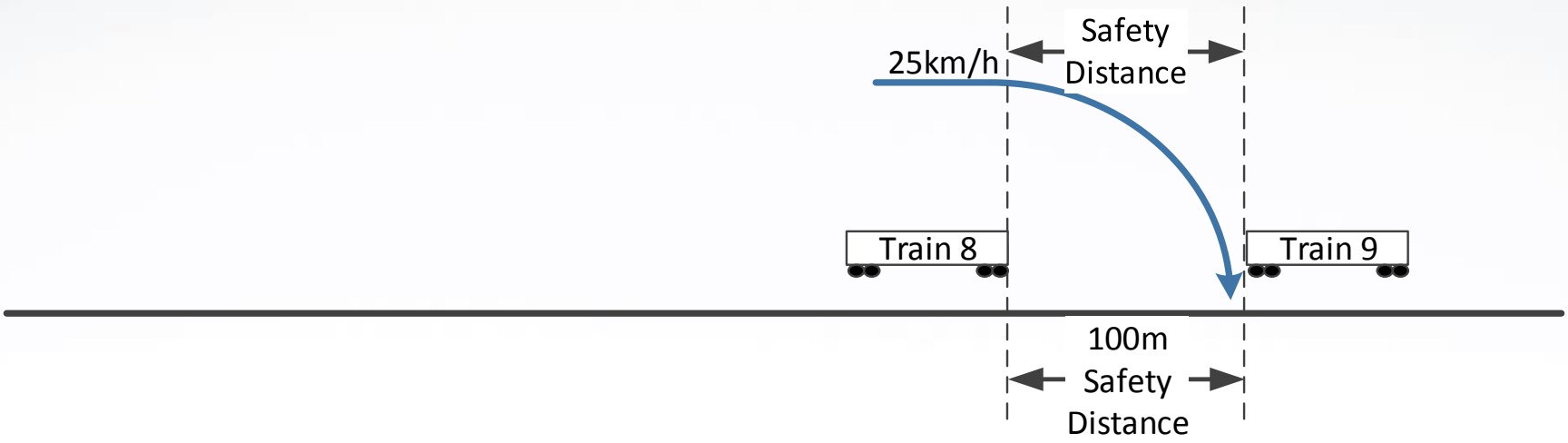
Basic Operation



- As train 9 and train 8 slow, the safety distance is reduce.

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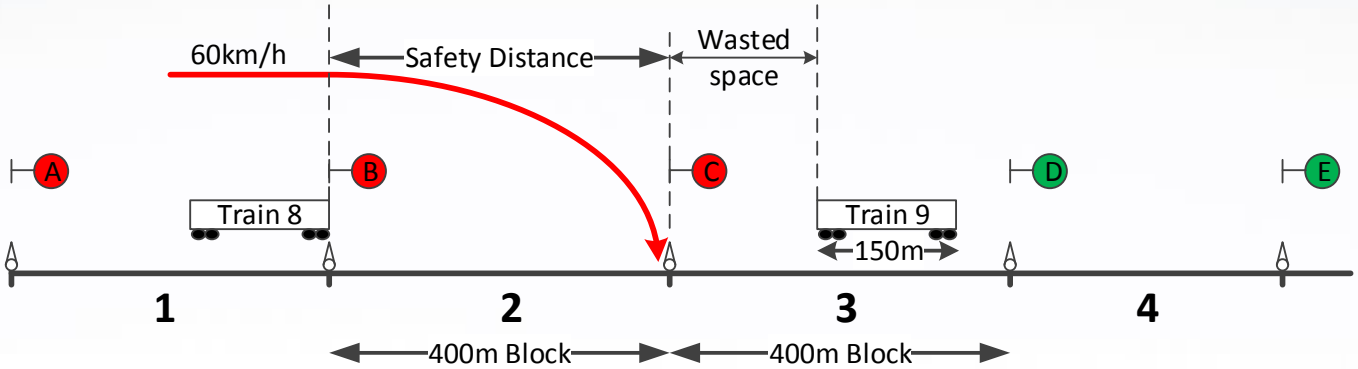
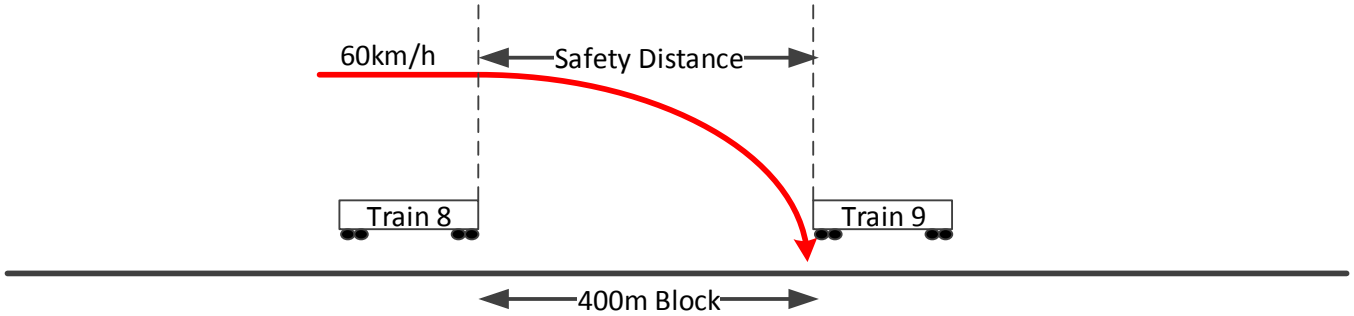
Comparison

Conventional/CABS Signalling



CBTC Signalling



Wrap Up

- The separation between trains is kept to a bare minimum required to maintain a safety distance between trains.

Wrap Up

- Safety distance is no longer a static entity enforced by fixed blocks but an adjustable distance based on a real time calculation of the train speed.
  - If the train is travelling at a high speed the safety distance is long and shrinks as the train slows .

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Wrap Up

- CBTC signaling extracts the maximum capacity per the track design.
  - The maximum number of trains will run through the system.

Conclusion

- Capacity is affected by the separation between trains.

- Each signaling system has it’s own characteristic that affects train separation.

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About the Author

- Naeem Ali is the Director and Principal Consultant of CBTC Solutions Inc.
- 18 years of experience in developing and deploying CBTC solutions
- He has worked on 7 different CBTC projects including:
  - Newark Airport People Mover (USA),
  - Jacksonville Monorail (USA),
  - Las Vegas Monorail (USA),
  - Busan Gimhae Monorail (South Korea),
  - Makkah Metro (Saudi Arabia),
  - Sao Paulo Line 17 (Brazil)
  - Toronto Transit Commission YUS Upgrade (Canada).
  - Singapore NSEW (Singapore)

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  - http://www.cbtcsolutions.ca/blog.html

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