Basic study on a train control system integrating operation control and safety control

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Contents

1. Introduction

- We propose a train operation control system that controls trains and facilities according to a plan consisting of detailed position and time.

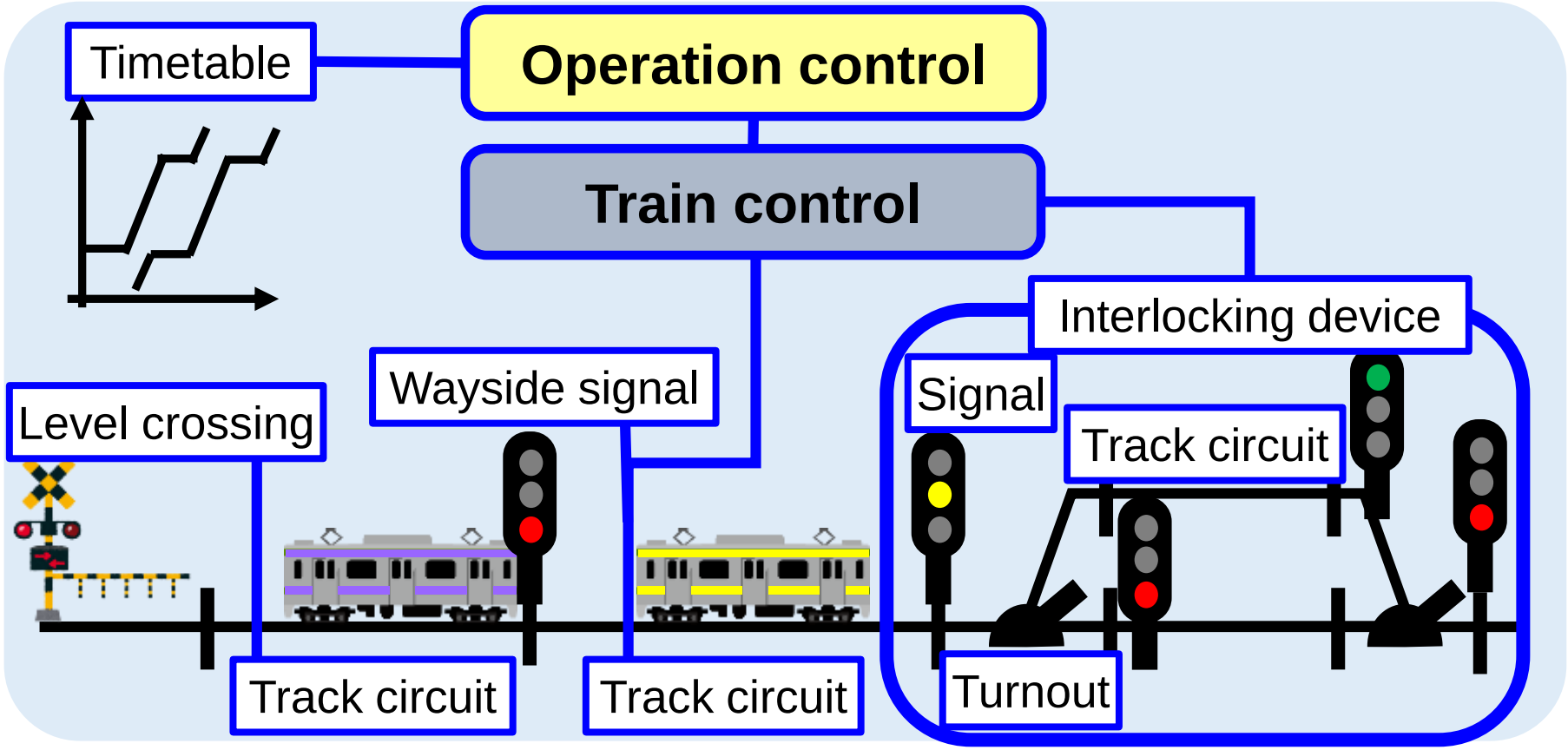
- In this system, more flexible control is realized by the train performance curve from the central equipment that integrates operation control and safety control.

- This report describes the control method based on the "band" that adds a safety margin to the performance curve, as well as safety and system availability. Furthermore, the feasibility was confirmed by a network simulator.

2. FUNCTIONAL INTEGRATION OF "SAFETY CONTROL" AND "OPERATION CONTROL"

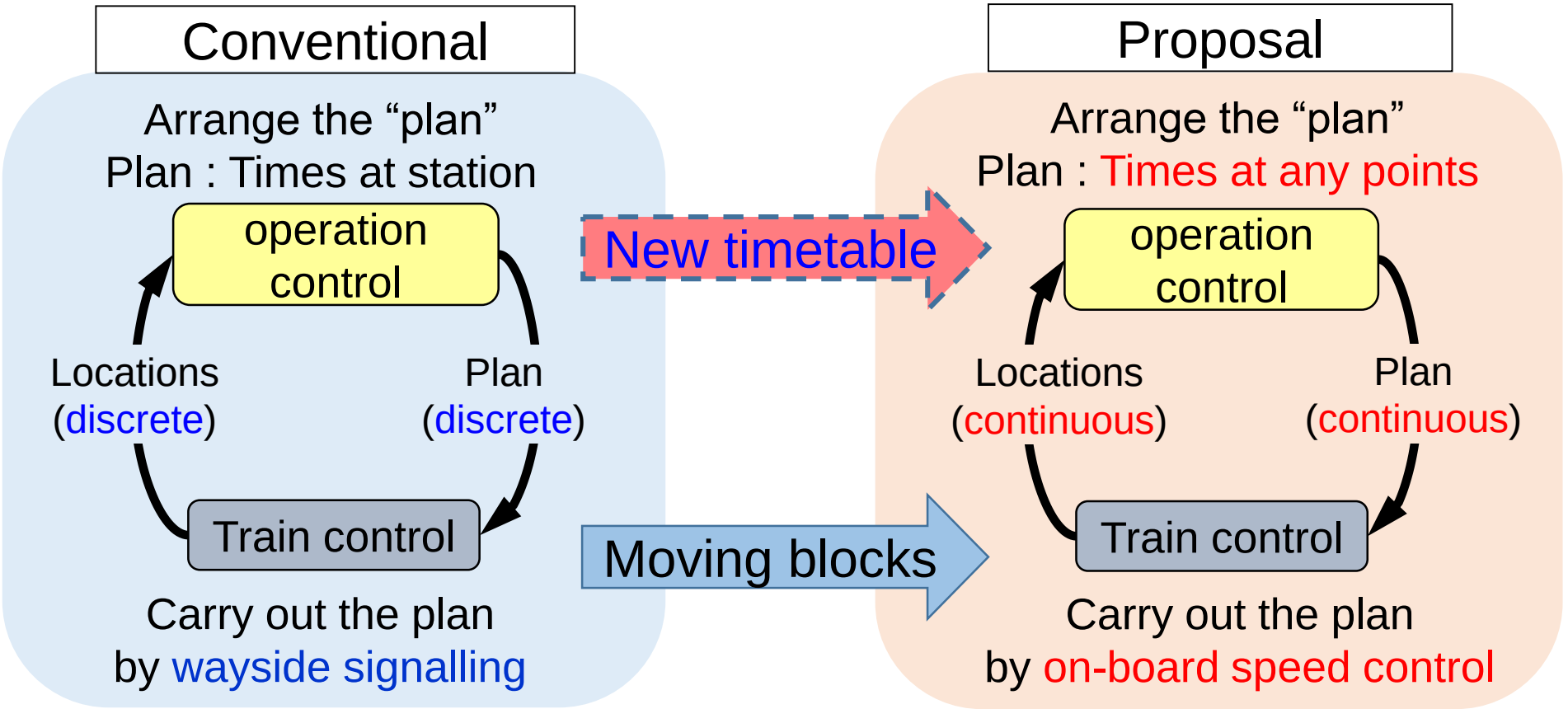
2.1 Outline

- Train control collects locations which have discrete values.
- Operation control has timetable which has also discrete values.
- Each element is connected by wire cables.



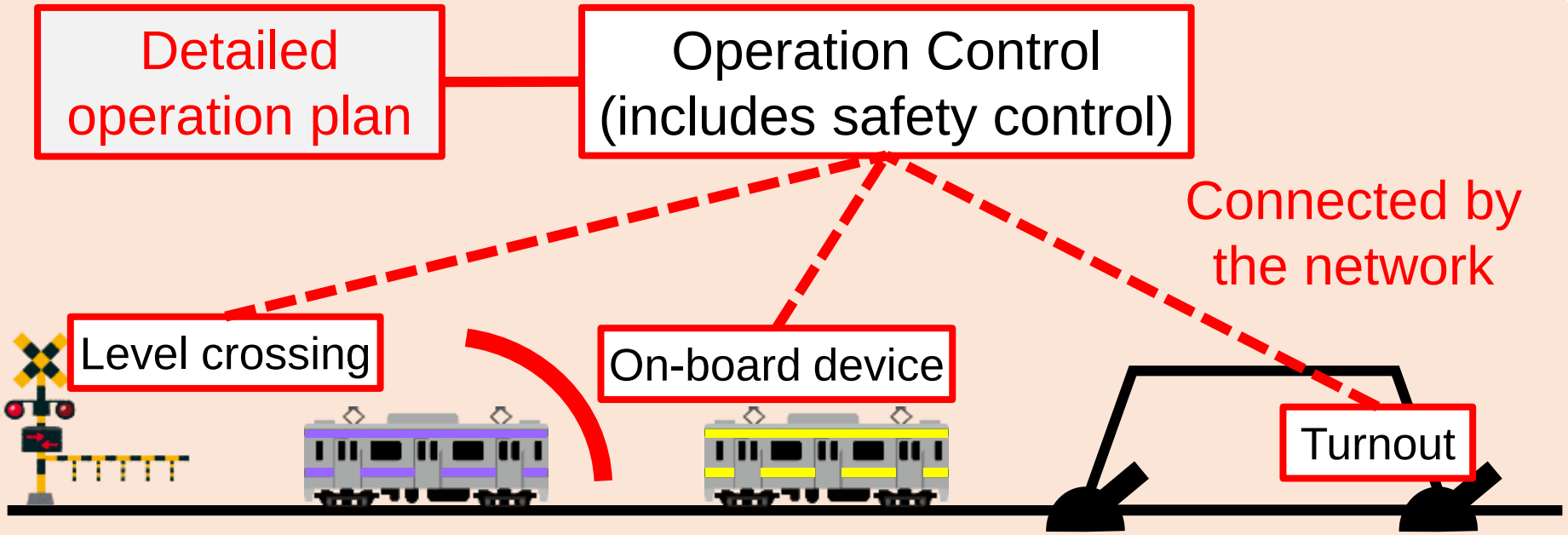
Improvement of current situations

- How to integrate operation control and Train control closely.
- Two system exchange train location and operation plan.
- By moving blocks, train locations became continuous values.
- By new timetable, operation plan should be continuous values.



Composition of System Proposed

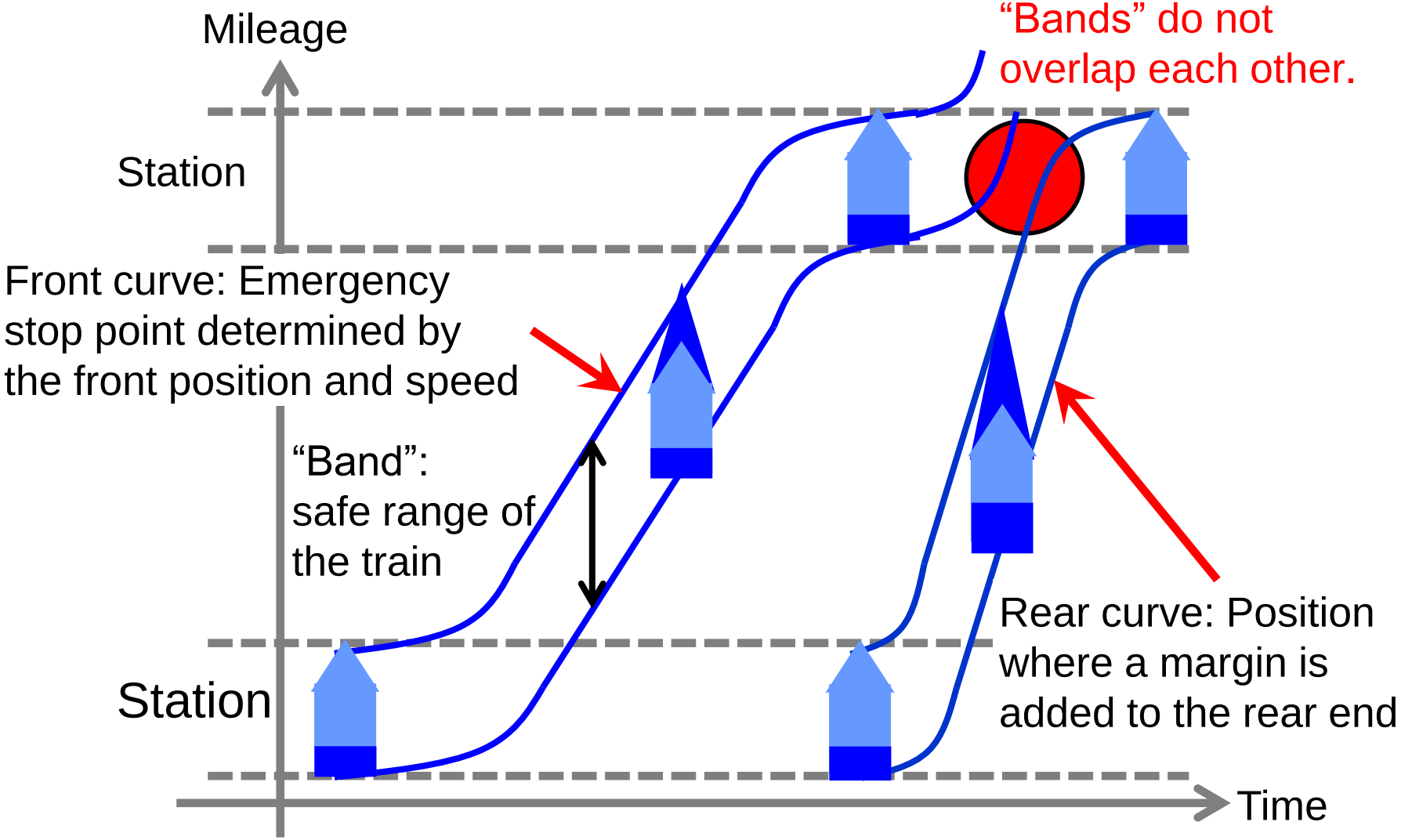
- Train manages its own location and velocity with continuous value, according to the instruction from Operations Control.
- Operations Control: integrating operation control and Train control.
- Each element is connected by the network (including wireless).



Composition of proposal system

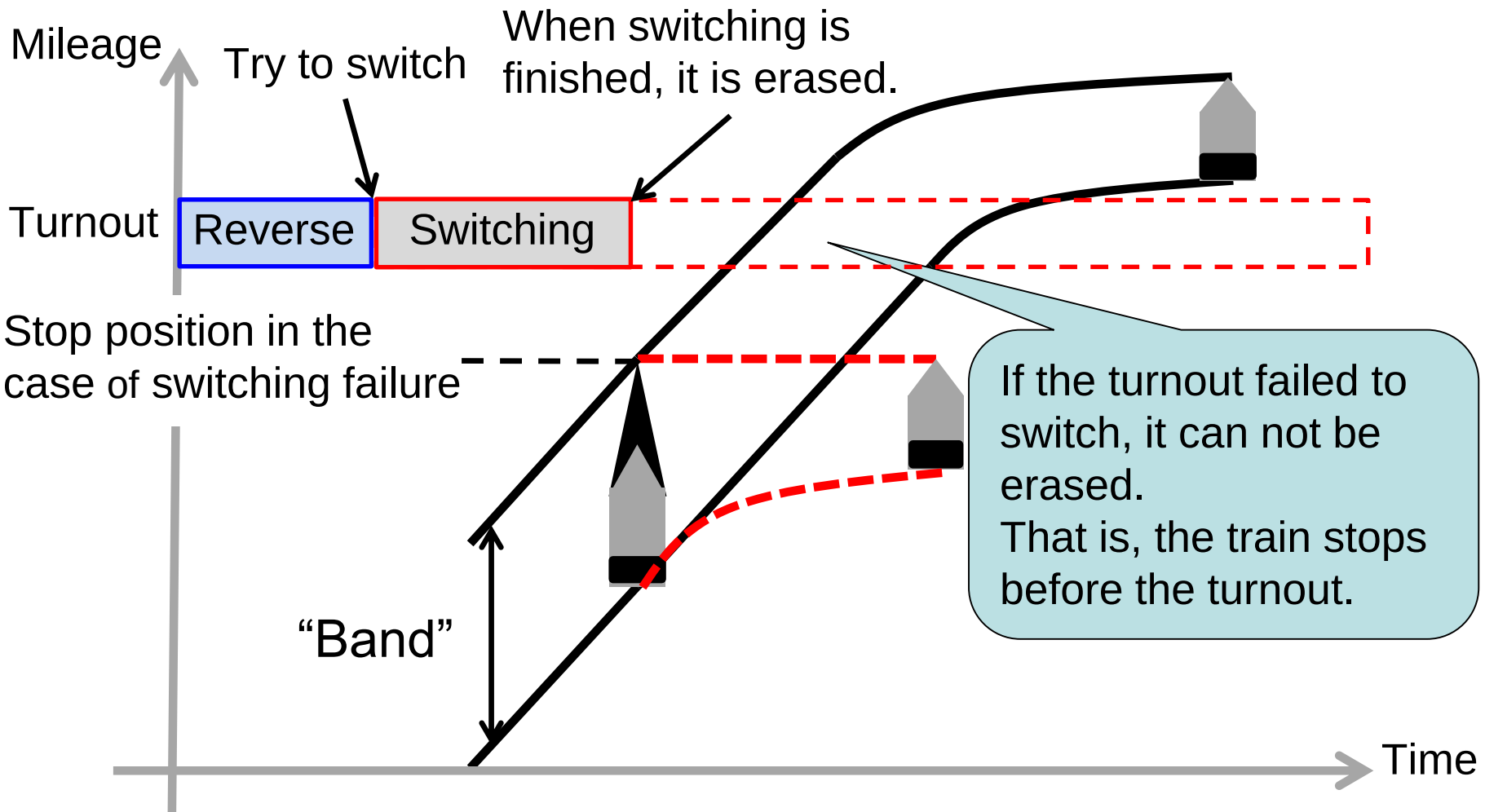
2.2 Control Method

- “Control map” is the operation plan in the Operations Control device.
- “Band” means safe zone of each train.



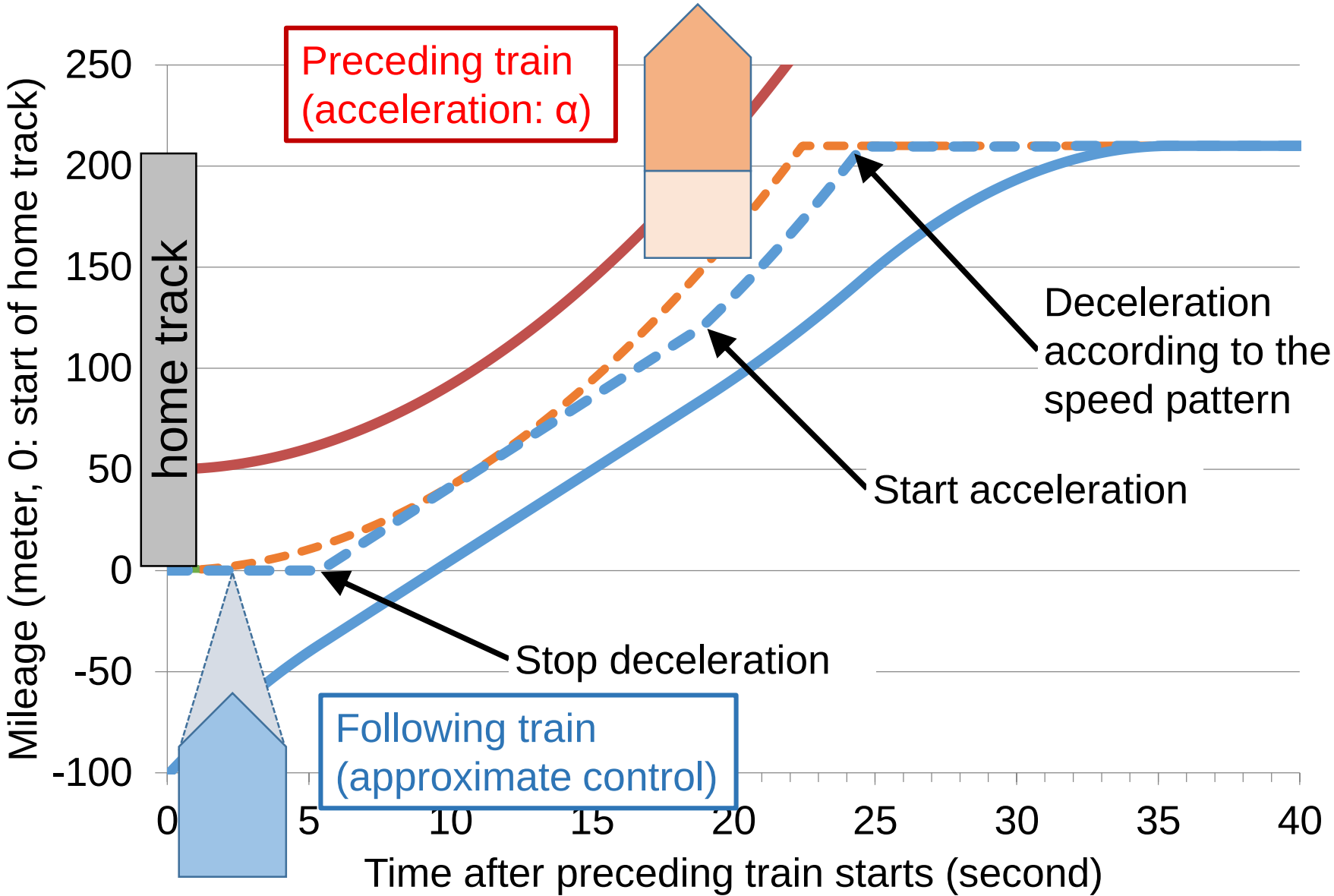
Route control

- “Control map” can also contain barriers of route.
- Barriers are corresponding to turnouts and level crossings etc.



Headway control

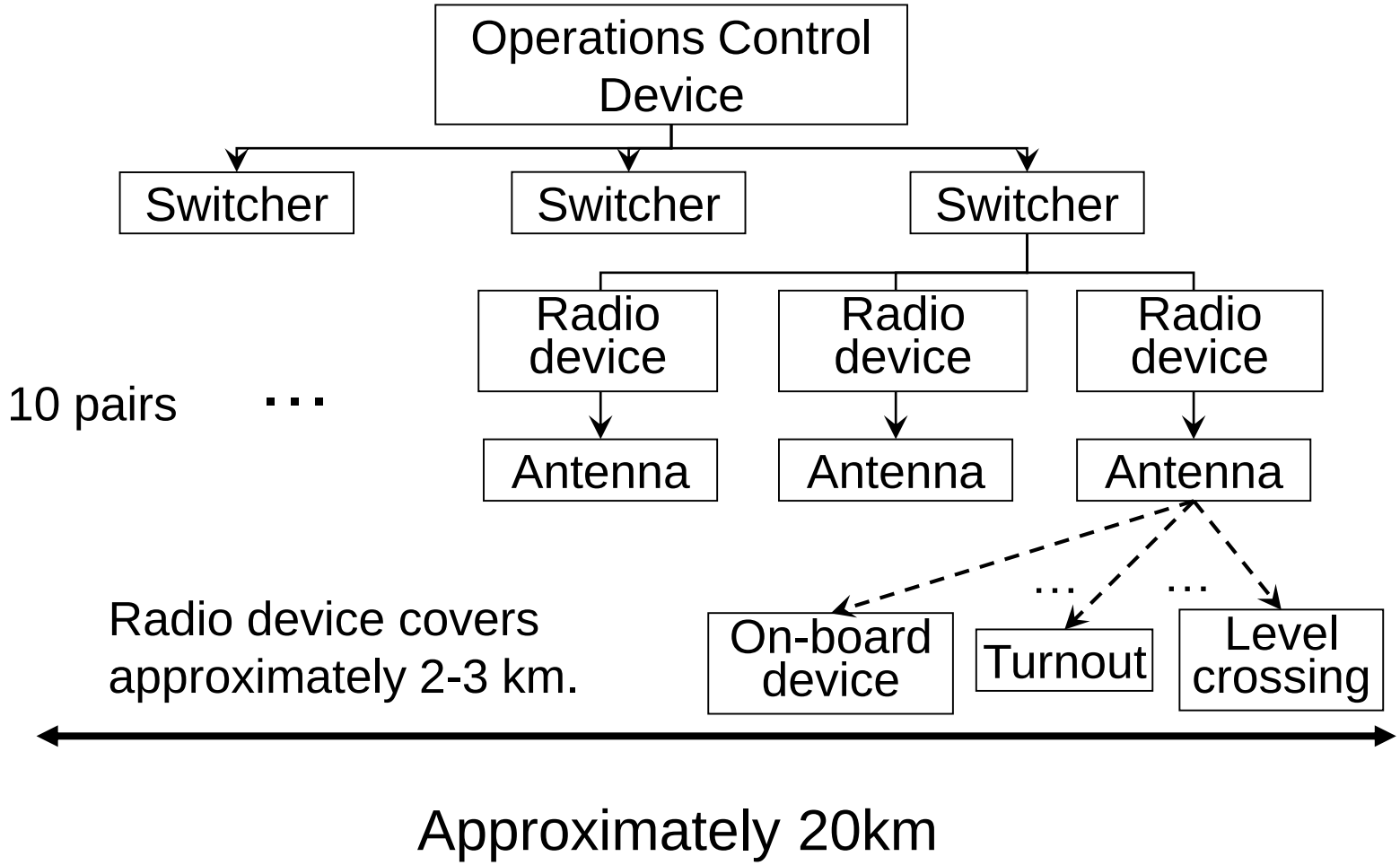
- Moving blocks can shorten the headway around the station.



3 STUDY OF SYSTEM ARCHITECTURE

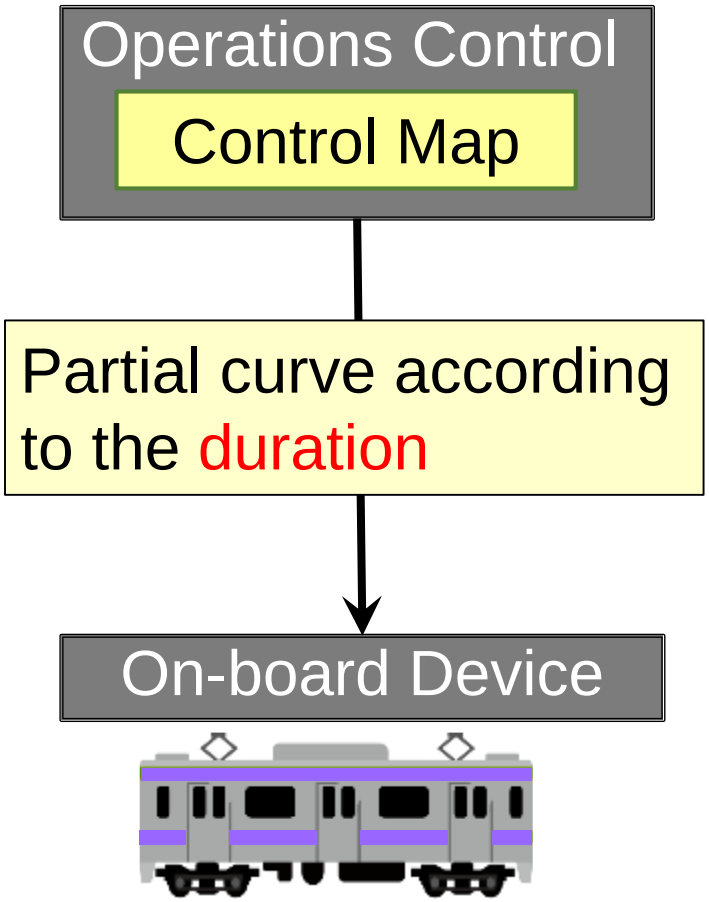
3.1 Network load

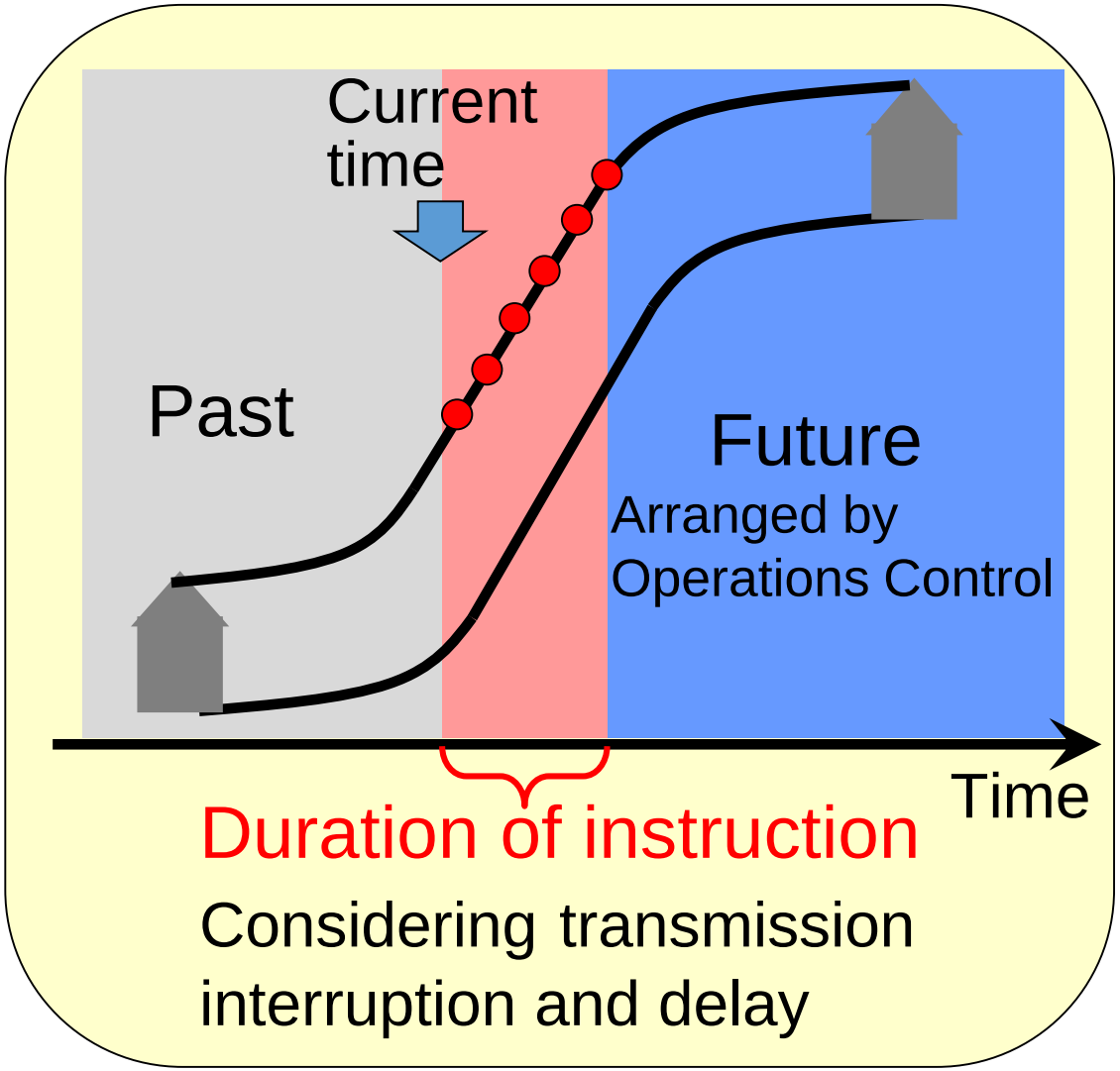
- Composition of the network for case study
- 10 pairs antennas covers a railway line of approximately 20km.



Volume of instruction

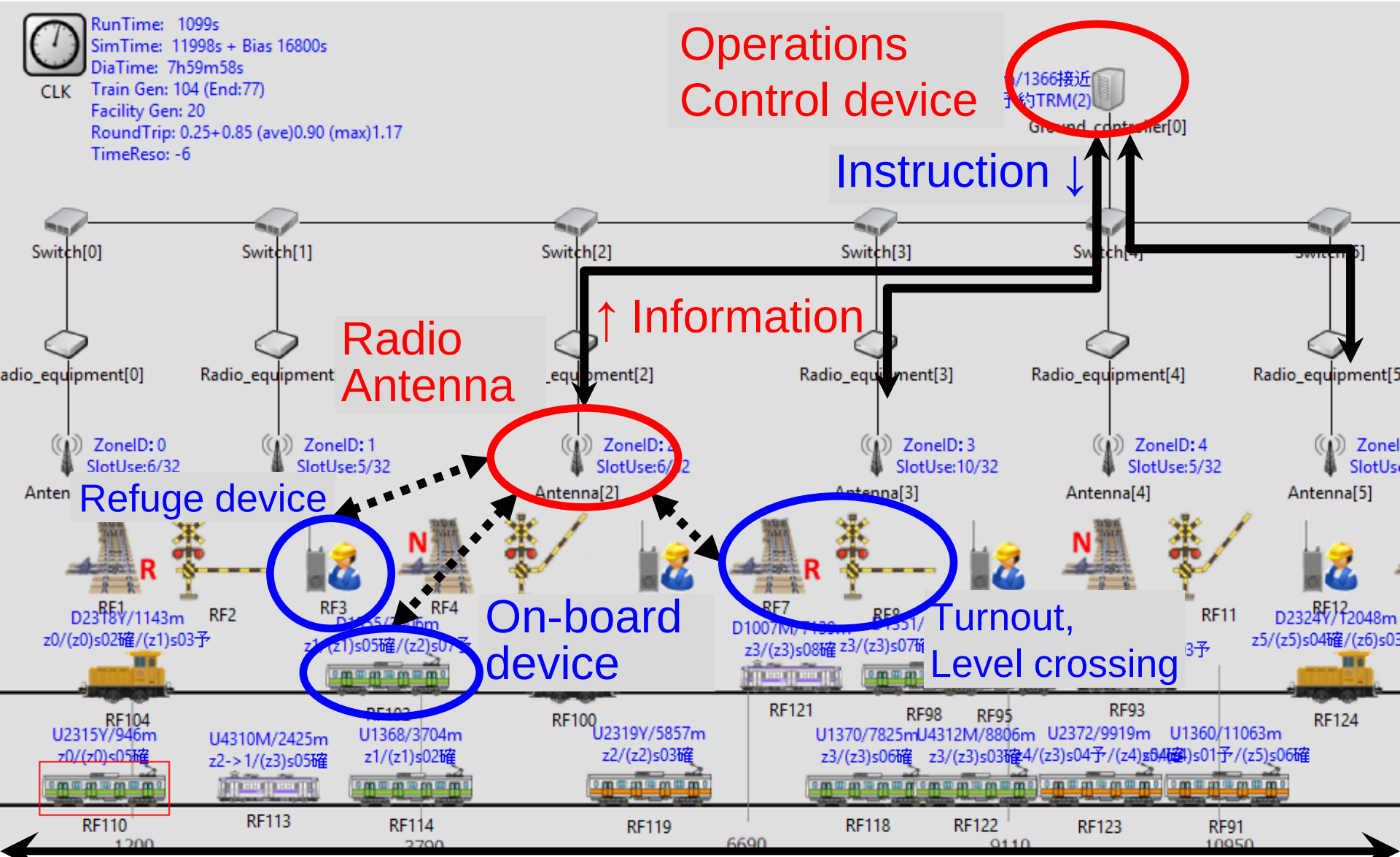
- Partial plan is send to on-board device from Operations Control.





Volume of information is estimated to be 150~180byte

Simulation using TCNET by R.T.R.I.



Result of simulation

- There is no bottlenecks on the network.
- Even if information is concentrated on the central unit, the line usage rate is low.

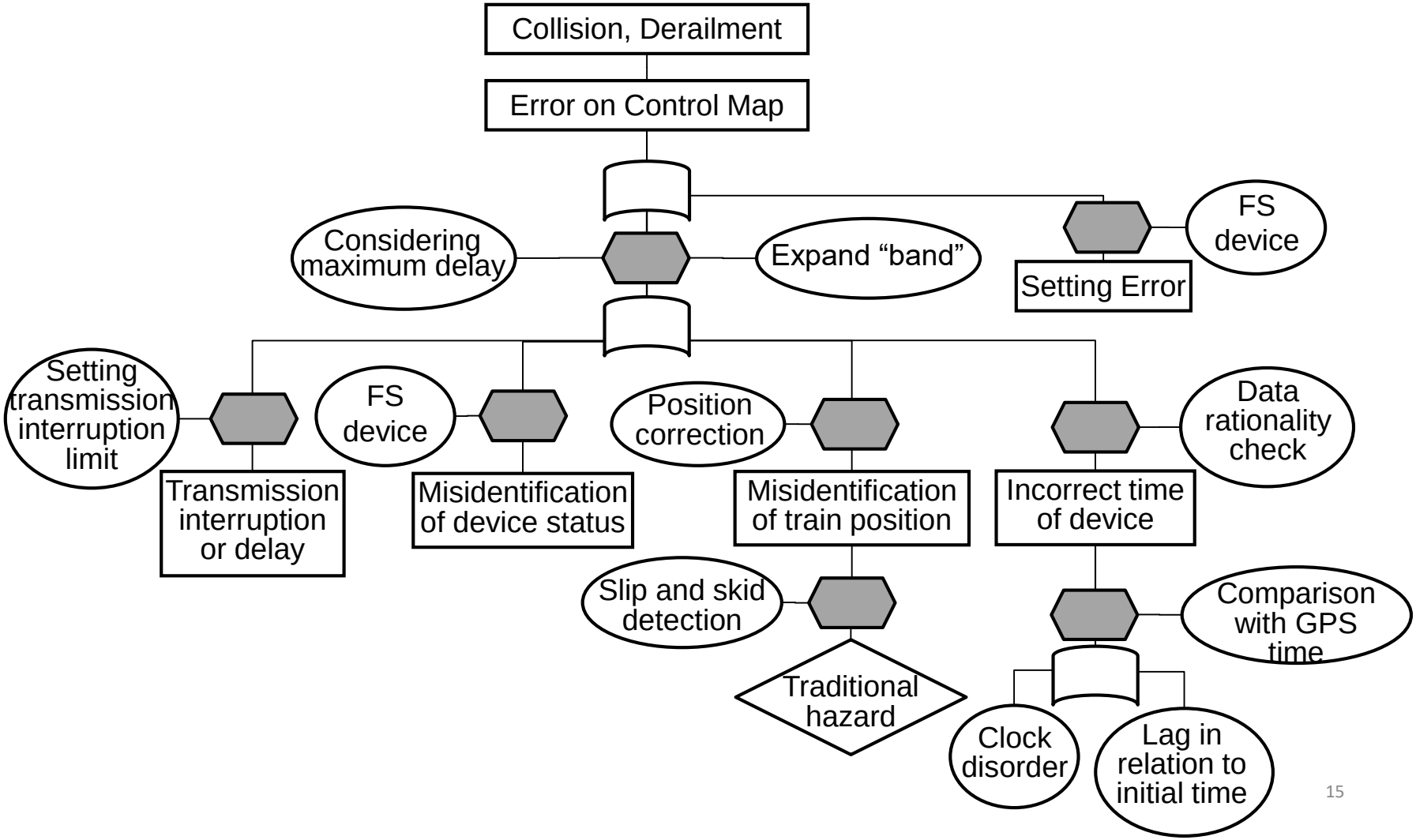
			8 trains	30 trains
Configuration	Number of antenna		10	
	Communicable device		36 per antenna	
	Transmission cycle (second)		1 sec	
	Transmission speed (bps)		wired:10M,wireless:64k	
	Length of packet (byte)		wired:7740,wireless:180	
Result	Line utilization (wired)	Operations Control => switcher	12.9%	12.9%
		Switcher => Operations Control	13.3%	12.7%
		Switcher => radio device	1.3%	1.3%
		Radio device => switcher	1.3%	1.2%
	(wireless)	Antenna => on-board	21.6%	32.9%
		On-board => antenna	11.3%	23.0%
	Round-trip time (second)		Ave.: 0.90, Max.:1.17	

3.2 Requirement of safety
FMEA (Failure Mode and Effects Analysis)

Device	Failure mode	Effect	Detection	Safe control
On-board, turnout, level crossing, etc.	Incorrect position	Error of control map	Detect slip and skid, checking corrected position	Expand band
	Incorrect device status		Use fail safe device	Set barrier
	Clock malfunction	Old control map	Rationality check of time stamp	Expand band Set barrier
	No information	Cannot set new band	Set transmission interruption limit, maximum delay	
Operations Control device	Error on control map	Collision, derailment	Use fail safe device	No output
	Clock malfunction	Difference of entire system time	Compare with GPS time, rationality check of time stamp	Emergent brake, output alert
	No information	Device shutdown	Set transmission interruption limit, maximum delay	

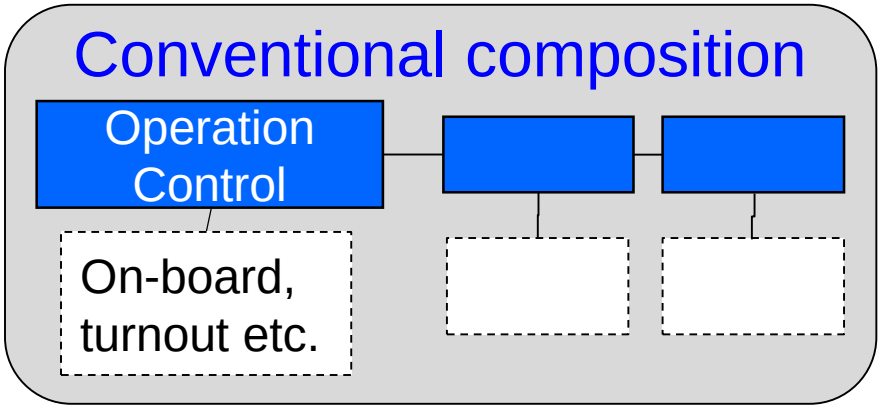
FTA (Fault Tree Analysis)

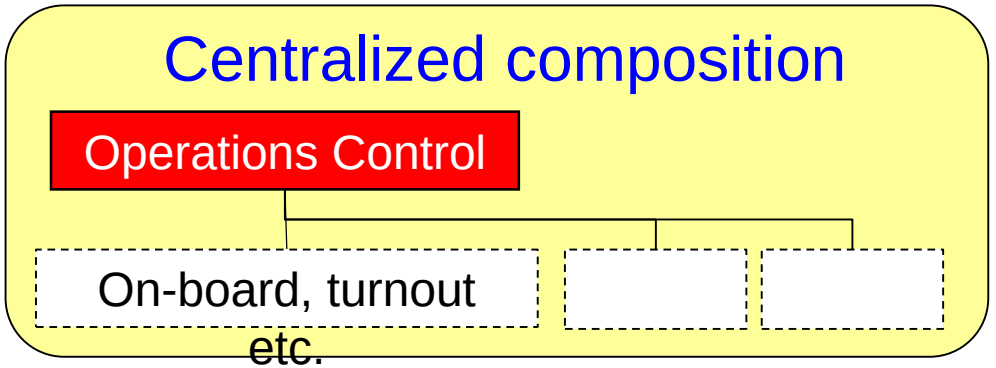
- Collision and derailment is set as the top events.
- Error of Control Map causes the top events

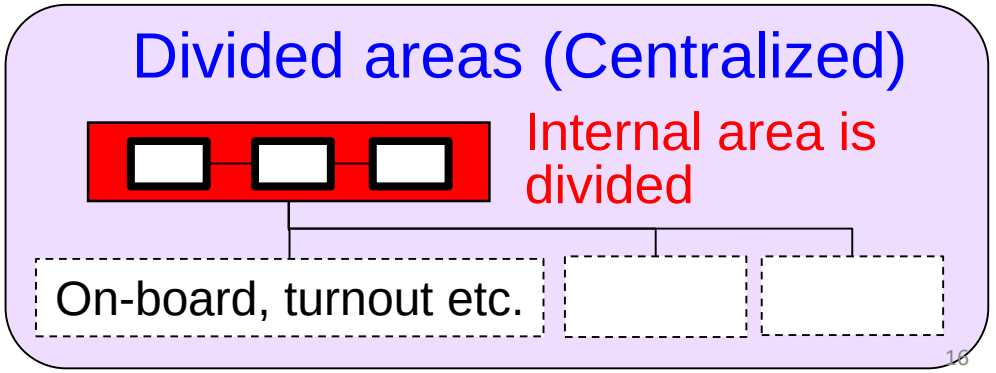


3.3 Requirement of system availability
Composition of system

- These assumptions is set.
  - Failure frequency of each device is 10^-5 per hour.
  - Repair time is 2 hours for the central device, and 1 hour for other.
- Compared three type of composition.

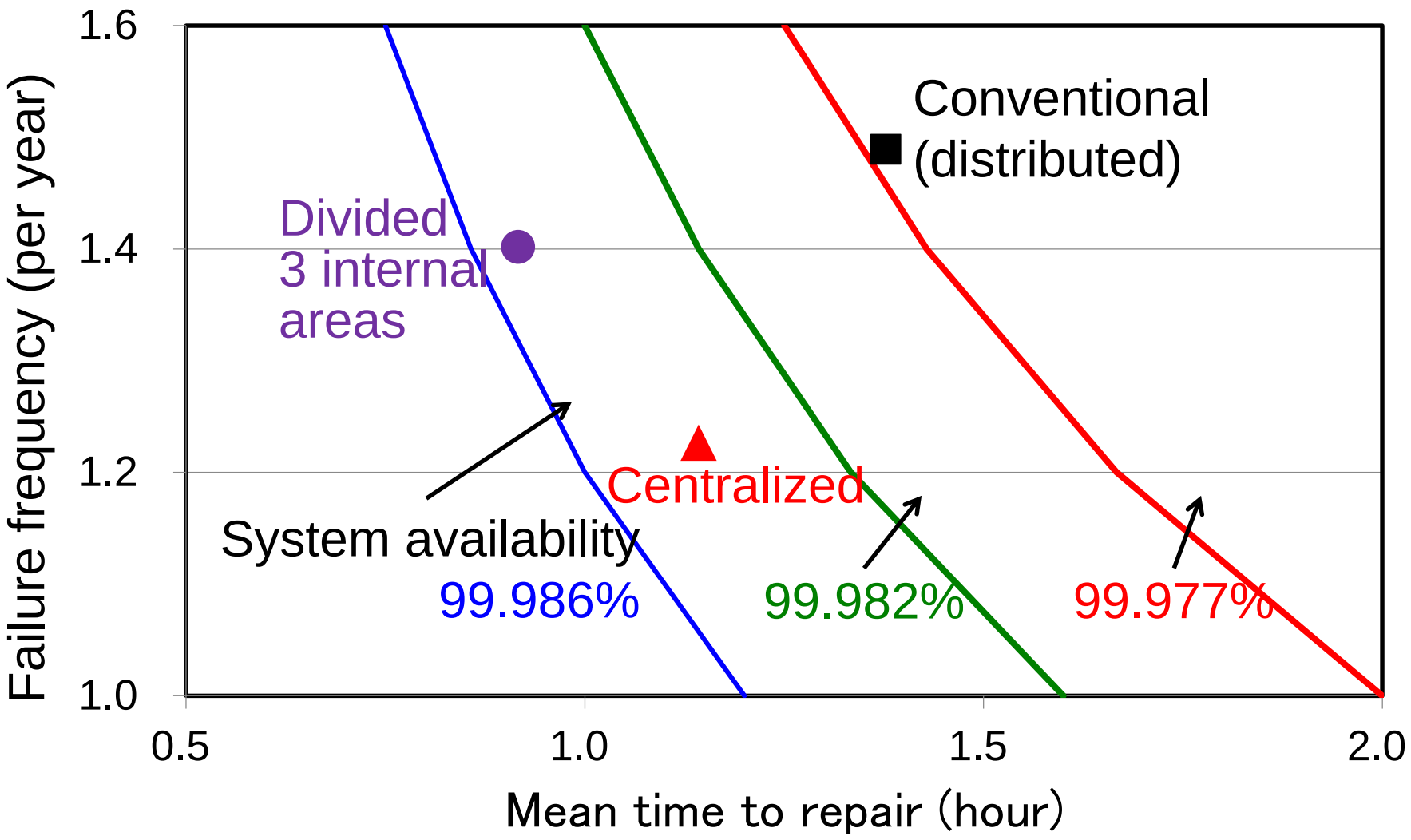






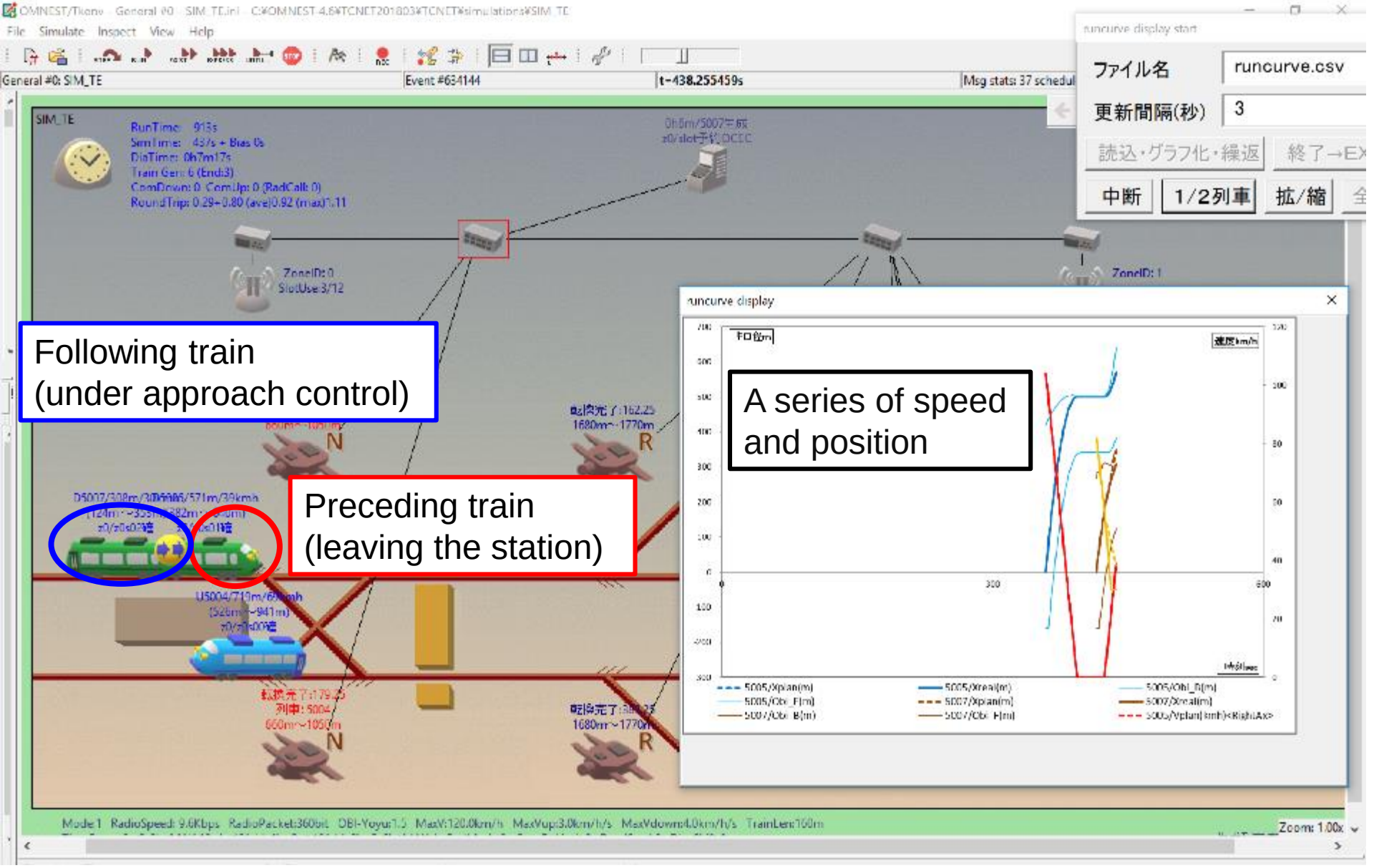
Result of availability

- 3 internal areas is the best as for availability.



4. VERIFICATION OF CONTROL

4.1 Headway control (Screenshot of simulation)



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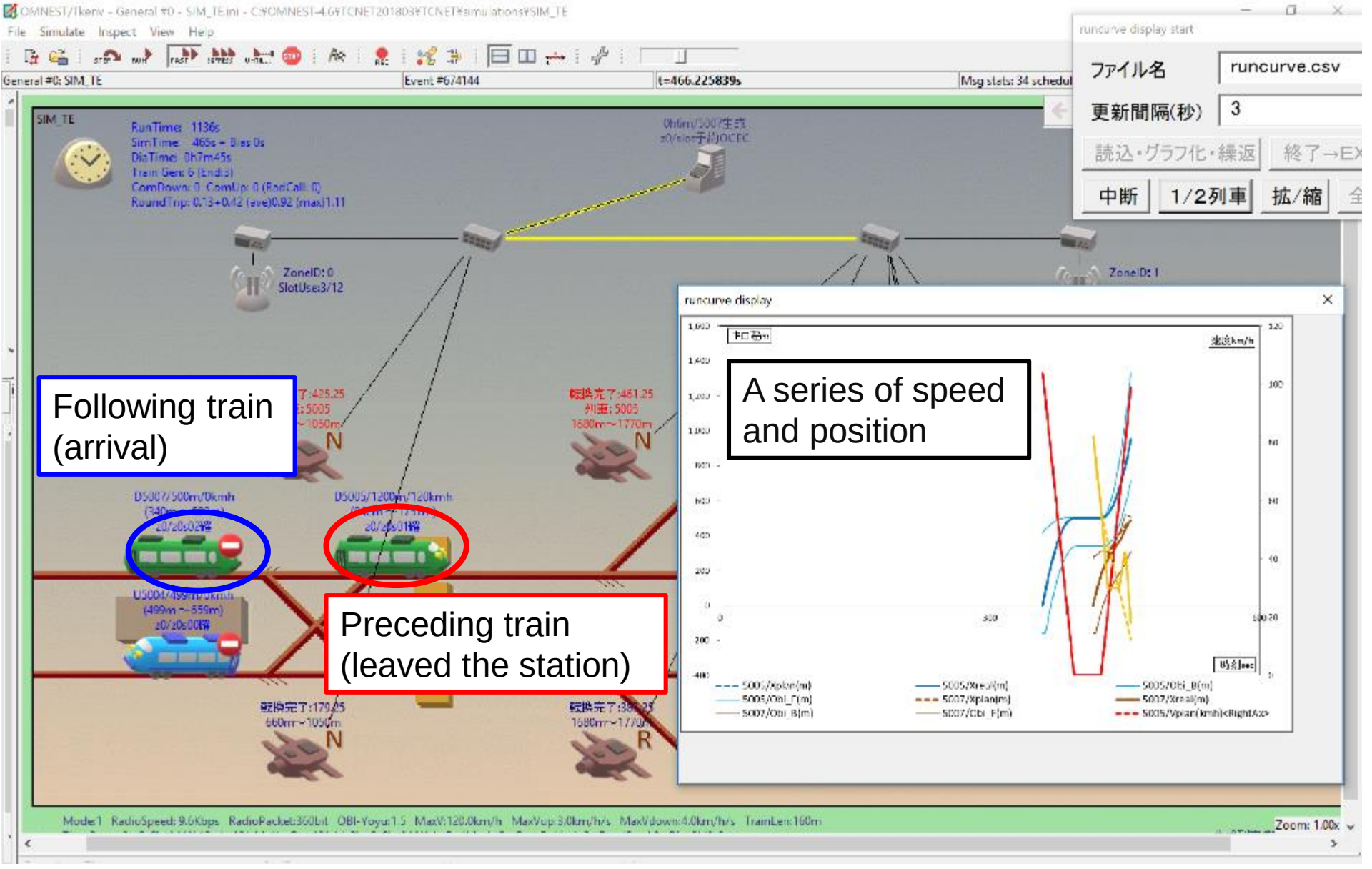
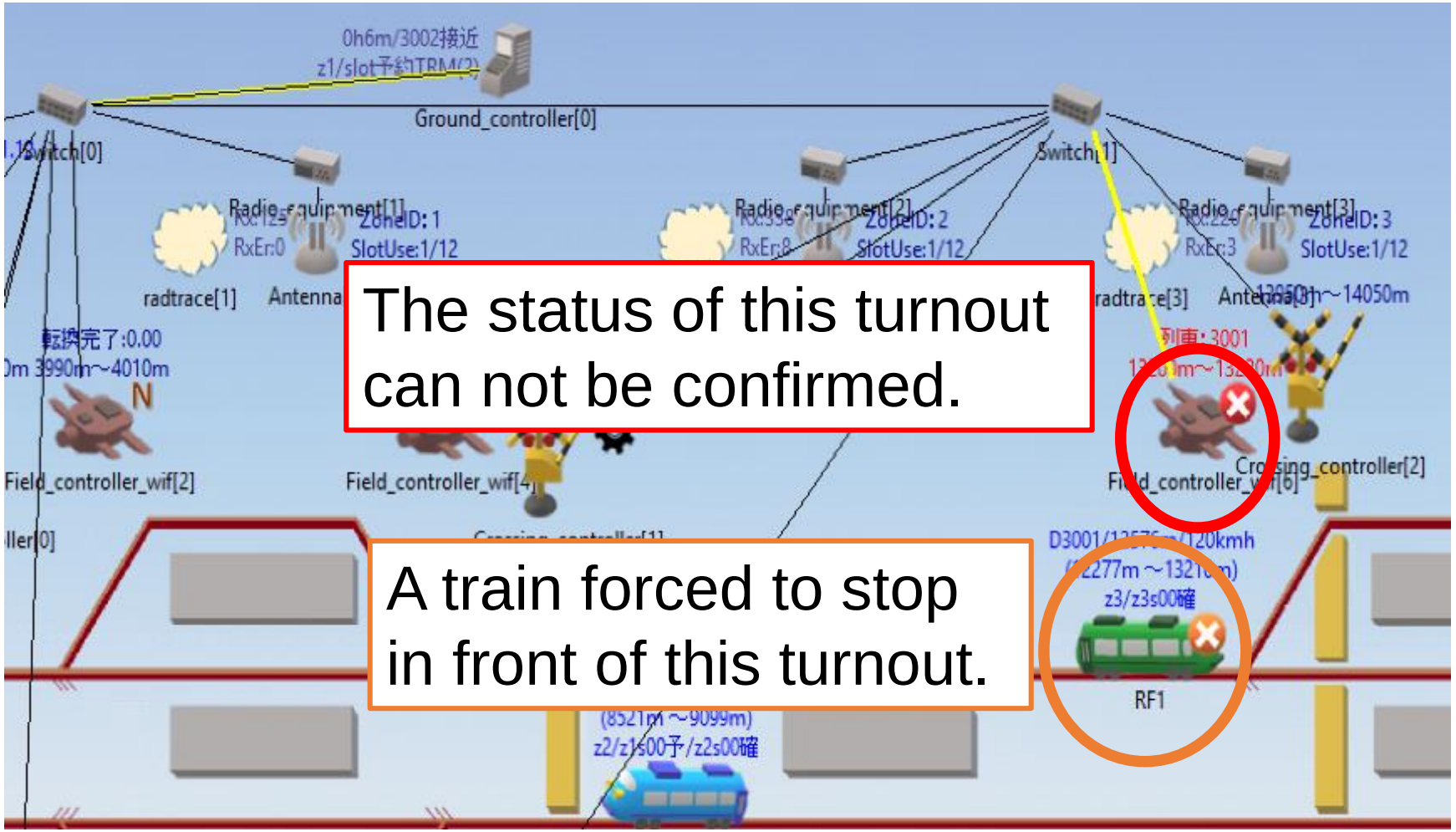


4.2 Safe control (Screenshot of simulation)



5. CONCLUSION

- We designed a highly flexible train operation system in which data are acquired with due consideration for train operating conditions and device status from an information network.
- In order to operate trains according to planned performance curves, we created the basic specification includes control method of trains and turnouts.
- Under the centralized logic there is no risk of bottlenecks forming on the transmission path, and it is possible to build a system that has just as good availability as conventional systems.
- We implemented the basic safety control and train approach control in a simulator, and demonstrated that the function can be realized in an environment including the entire network.

Thank you for your attention!