CLAIMS

1. A controller, comprising:

a non-transitory computer memory component storing a set of computer-executable instructions, a list of braking intervals for a plurality of vehicles operating on an electric transportation line, and a list of acceleration intervals for the plurality of vehicles; and

a processing component configured to execute the set of computer-executable instructions to at least operate on the list of braking intervals and the list of acceleration intervals to reduce an energy consumption of the electric transportation line over a period of time by shifting one or more acceleration intervals of the list of acceleration intervals in time with respect to one or more braking intervals of the list of braking intervals;

characterized in that the computer-executable instructions include the steps of performing an algorithm that uses an objective function which describes an optimization problem which involves minimizing, by synchronizing between movements of braking and movements of accelerations over a time period represented by a set of time slots, the resulting energy consumption of each time slot, wherein said algorithm shifts at least one acceleration interval belonging to the neighborhood of each braking interval by bringing the starting time of said acceleration interval closest to the braking interval's starting time, wherein the neighborhood of a braking interval is the set of acceleration intervals that can be synchronized during at least one predetermined time slot, wherein the acceleration interval is delayed or advanced accordingly with allowed intervals as defined by an optimization window matrix defining a pool of intervals, and in that once an acceleration interval has been shifted, it is removed from the pool of intervals and cannot be shifted anymore.

2. The controller of claim 1, wherein the set of computer-executable instructions includes instructions, for each braking interval of the list of braking intervals, for:

computing an original objective function for reducing energy consumption for the current braking interval under consideration;

initially designating an optimal shift for an acceleration interval associated with the current braking interval;

initially designating an acceleration interval as a closest acceleration interval associated with the current braking interval; and

computing a set of acceleration intervals in a neighborhood of the current braking interval.

3. The controller of claim 2, wherein the set of computer-executable instructions further includes instructions, for each acceleration interval in the set of acceleration intervals in the neighborhood, for:

shifting a current acceleration interval under consideration by a shift amount to synchronize the current acceleration interval with the current braking interval; and

computing a current objective function for reducing energy for the current braking interval based on at least the shifted current acceleration interval.

4. The controller of claim 3, wherein the set of computer-executable instructions further includes instructions, for each acceleration interval in the set of acceleration intervals in the neighborhood, for:

when the current objective function is less than the original objective function:

setting the original objective function to the current objective function;

setting the optimal shift to the shift amount;

setting the closest acceleration interval to the current acceleration interval under consideration; and

un-shifting the current acceleration interval by the shift amount.

5. The controller of claim 4, wherein the set of computer-executable instructions further includes instructions, for each braking interval of the list of braking intervals, for:

applying the optimal shift to the closest acceleration interval.

6. The controller of claim 5, further comprising a communication component configured to communicate the optimal shift to a corresponding vehicle of the plurality of vehicles.

7. The controller of claim 1, further comprising a communication component configured to control communication of signals to the vehicles for controlling movement of the vehicles according to the one or more acceleration intervals that are shifted in time with respect to the one or more braking intervals.

8. A method, comprising:

receiving a timetable in a controller, where the timetable is associated with a time schedule of braking intervals and acceleration intervals for a plurality of vehicles operating on an electric transportation line;

generating an energy model using the controller, where the energy model is associated with the timetable and relates to how regenerative energy is transferred throughout the electric transportation line;

synchronizing one or more of the braking intervals of the plurality of vehicles with one or more of the acceleration intervals of the plurality of vehicles during a period of time of operation of the plurality of vehicles on the electric transportation line by shifting the one or more acceleration intervals in time, using the controller, based at least in part on the energy model;

characterized in that it further includes the step of performing an algorithm that uses an objective function which describes an optimization problem which involves minimizing, by synchronizing between movements of braking and movements of accelerations over a time period represented by a set of time slots, the resulting energy consumption of each time slot, wherein said algorithm shifts at least one acceleration interval belonging to a neighborhood of each braking interval, by bringing a starting time of said acceleration interval closest to a braking interval's starting time, wherein the neighborhood of a braking interval is the set of acceleration intervals that can be synchronized during at least one predetermined time slot, wherein the acceleration interval is delayed or advanced accordingly with allowed intervals as defined by an optimization window matrix defining a pool of intervals,

and wherein once an acceleration interval has been shifted, it is removed from the pool of intervals and cannot be shifted anymore.

9. The method of claim 8, further comprising computing a resulting energy consumption of the electric transportation line over the period of time, using the energy model on the controller, based on how regenerative energy produced by the plurality of vehicles is spread through the electric transportation line, and based on how much of the regenerative energy is reused by the plurality of vehicles in response to the shifting of the one or more acceleration intervals.

10. The method of claim 8, wherein the energy model relates to at least one of a network topology for the electric transportation line, an ohmic resistance energy loss, an equipment energy loss, or an energy transfer between at least two of a first vehicle of the plurality of vehicles, a second vehicle of the plurality of vehicles, a track associated with the first vehicle, and a track associated with the second vehicle.

11. The method of claim 8, further comprising communicating at least one time shift of the one or more acceleration intervals from the controller to one or more corresponding vehicles of the plurality of vehicles.

12. The method of claim 11, further comprising at least a first vehicle of the one or more corresponding vehicles of the plurality of vehicles adjusting a respective acceleration phase based on the at least one time shift that is communicated.

13. The method of claim 12, further comprising transferring regenerative energy produced by a second vehicle of the plurality of vehicles to the first vehicle during a braking phase of the second vehicle and an adjusted acceleration phase of the first vehicle.

14. A system, comprising:

a controller configured to process a list of braking intervals and a list of acceleration intervals associated with a plurality of vehicles configured to operate on an electric transportation line to determine shifts in time of one or more of the acceleration intervals with respect to one or more of the braking intervals that result in

a reduced consumption of energy by the electric transportation line over a period of time; and

a communication component configured for operable coupling with the controller and to control communication of the shifts in time determined by the controller to the vehicles, for controlling movement of the vehicles;

characterized in that the controller is also configured to perform an algorithm that uses an objective function which describes an optimization problem which involves minimizing, by synchronizing between movements of braking and movements of accelerations over a time period represented by a set of time slots, the resulting energy consumption of each time slot, wherein said algorithm shifts at least one acceleration interval belonging to a neighborhood of each braking interval, by bringing a starting time of said acceleration interval closest to a braking interval's starting time, wherein the neighborhood of a braking interval is the set of acceleration intervals that can be synchronized during at least one predetermined time slot, wherein the acceleration interval is delayed or advanced accordingly with allowed intervals as defined by an optimization window matrix defining a pool of intervals, and wherein once an acceleration interval has been shifted, it is removed from the pool of intervals and cannot be shifted anymore.

15. The system of claim 14, wherein the controller is configured to:

relate a first braking interval of the list of braking intervals to a set of acceleration intervals of the list of acceleration intervals in a neighborhood of the first braking interval, wherein the neighborhood includes all acceleration intervals of the list of acceleration intervals that occur in a same time space as the first braking interval;

select an acceleration interval of the neighborhood and shift the acceleration interval that is selected with respect to the first braking interval such that a local energy consumption is reduced; and

remove the acceleration interval that is selected from the list of acceleration intervals.

16. The system of claim 14, wherein the controller is configured to employ an energy model and a heuristic greedy algorithm to determine the shifts in time of the

one or more of the acceleration intervals with respect to the one or more of the braking intervals that result in the reduced consumption of energy.

17. The system of claim 16, wherein the heuristic greedy algorithm provides the computation of an objective function that includes minimizing, over the determined period of time as represented by a set of time slots, a resulting energy consumption of each time slot.

18. The system of claim 16, wherein the energy model relates to at least one of a network topology for the electric transportation line, an ohmic resistance energy loss, and equipment energy loss, or an energy transfer between at least two of a first vehicle of the plurality of vehicles, a second vehicle of the plurality of vehicles, a track associated with the first vehicle, and a track associated with the second vehicle.

19. The system of claim 14, wherein at least a portion of the reduced consumption of energy results from a transfer of regenerative energy produced by a first vehicle of the plurality of vehicles during a braking interval to a second vehicle of the plurality of vehicles during an acceleration interval.

20. A method comprising:

processing, with a controller, a list of braking intervals and a list of acceleration intervals associated with a plurality of vehicles configured to operate on an electric transportation line to determine shifts in time of one or more of the acceleration intervals with respect to one or more of the braking intervals that result in a reduced consumption of energy by the electric transportation line over a period of time;

communicating to the vehicles, with a communication component operably coupled to the controller, information of the shifts in time determined by the controller, for controlling movement of the vehicles;

characterized in that it further includes the step of performing an algorithm that uses an objective function which describes an optimization problem which involves minimizing, by synchronizing between movements of braking and movements of accelerations over a time period represented by a set of time slots, the

resulting energy consumption of each time slot, wherein said algorithm shifts at least one acceleration interval belonging to a neighborhood of each braking interval, by bringing a starting time of said acceleration interval closest to a braking interval's starting time, wherein the neighborhood of a braking interval is the set of acceleration intervals that can be synchronized during at least one predetermined time slot, wherein the acceleration interval is delayed or advanced accordingly with allowed intervals as defined by an optimization window matrix defining a pool of intervals, and wherein once an acceleration interval has been shifted, it is removed from the pool of intervals and cannot be shifted anymore.