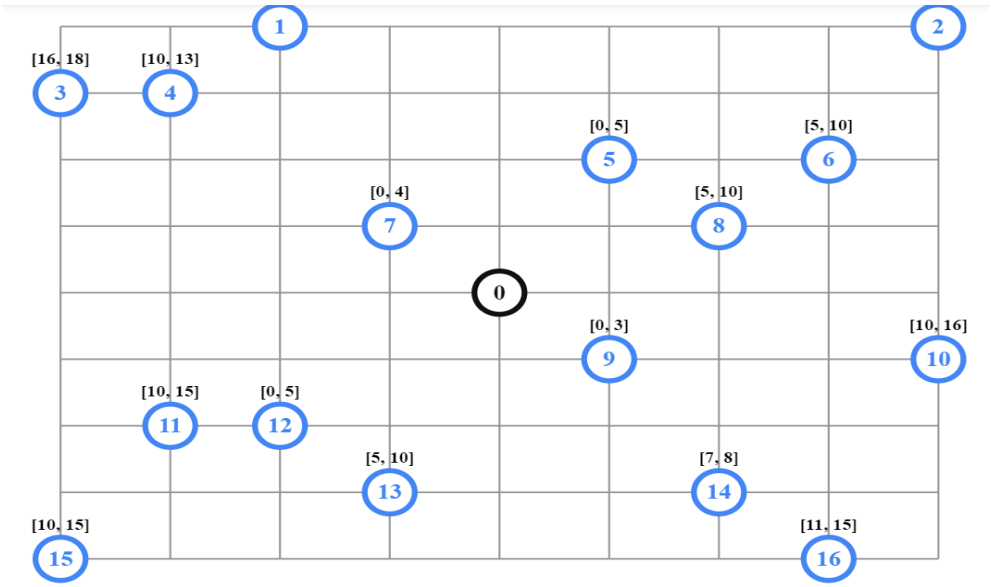
Time Window

Many vehicle routing problems involve scheduling visits to customers who are only available during specific time windows. These problems are known as *vehicle routing problems with time windows* (VRPTWs).



Importing the libraries: -

```
from __future__ import print_function
from ortools.constraint_solver import routing_enums_pb2
from ortools.constraint_solver import pywrapcp
```

We next create the data function.
1. Time_matrix: time between 2 nodes is given (instead of distance).
2.Time_window: time window (lower and upper bound for each node).
3.Number of vehicles, number of nodes and depot index is also taken in.

```
def create_data_model():

    data = {}
    data['time_matrix'] = [
        [0, 6, 9, 8, 7, 3, 6, 2, 3, 2, 6, 6, 4, 4, 5, 9, 7],
        [6, 0, 8, 3, 2, 6, 8, 4, 8, 8, 13, 7, 5, 8, 12, 10, 14],
        [9, 8, 0, 11, 10, 6, 3, 9, 5, 8, 4, 15, 14, 13, 9, 18, 9],
        [8, 3, 11, 0, 1, 7, 10, 6, 10, 10, 14, 6, 7, 9, 14, 6, 16],
        [7, 2, 10, 1, 0, 6, 9, 4, 8, 9, 13, 4, 6, 8, 12, 8, 14],
        [3, 6, 6, 7, 6, 0, 2, 3, 2, 2, 7, 9, 7, 7, 6, 12, 8],
        [6, 8, 3, 10, 9, 2, 0, 6, 2, 5, 4, 12, 10, 10, 6, 15, 5],
        [2, 4, 9, 6, 4, 3, 6, 0, 4, 4, 8, 5, 4, 3, 7, 8, 10],
        [3, 8, 5, 10, 8, 2, 2, 4, 0, 3, 4, 9, 8, 7, 3, 13, 6],
        [2, 8, 8, 10, 9, 2, 5, 4, 3, 0, 4, 6, 5, 4, 3, 9, 5],
        [6, 13, 4, 14, 13, 7, 4, 8, 4, 4, 0, 10, 9, 8, 4, 13, 4],
        [6, 7, 15, 6, 4, 9, 12, 5, 9, 6, 10, 0, 1, 3, 7, 3, 10],
        [4, 5, 14, 7, 6, 7, 10, 4, 8, 5, 9, 1, 0, 2, 6, 4, 8],
        [4, 8, 13, 9, 8, 7, 10, 3, 7, 4, 8, 3, 2, 0, 4, 5, 6],
        [5, 12, 9, 14, 12, 6, 6, 7, 3, 3, 4, 7, 6, 4, 0, 9, 2],
```

```
        [9, 10, 18, 6, 8, 12, 15, 8, 13, 9, 13, 3, 4, 5, 9, 0, 9],
        [7, 14, 9, 16, 14, 8, 5, 10, 6, 5, 4, 10, 8, 6, 2, 9, 0],
    ]
    data['time_windows'] = [
        (0, 5),  # depot
        (7, 12),  # 1
        (10, 15),  # 2
        (16, 18),  # 3
        (10, 13),  # 4
        (0, 5),  # 5
        (5, 10),  # 6
        (0, 4),  # 7
        (5, 10),  # 8
        (0, 3),  # 9
        (10, 16),  # 10
        (10, 15),  # 11
        (0, 5),  # 12
        (5, 10),  # 13
        (7, 8),  # 14
        (10, 15),  # 15
        (11, 15),  # 16
    ]
    data['num_vehicles'] = 4
    data['depot'] = 0
    return data
```

Like the distance call back functions, we have the time call back function here. Given any two nodes, it gives out the time taken between them.

```
def time_callback(from_index, to_index):
    """Returns the travel time between the two nodes."""
    # Convert from routing variable Index to time matrix NodeIndex.
    from_node = manager.IndexToNode(from_index)
    to_node = manager.IndexToNode(to_index)
    return data['time_matrix'][from_node][to_node]

transit_callback_index = routing.RegisterTransitCallback(time_callback)
routing.SetArcCostEvaluatorOfAllVehicles(transit_callback_index)
```

Time Window Constraint: -

```
time = 'Time'
routing.AddDimension(
    transit_callback_index,
    30,  # allow waiting time
    30,  # maximum time per vehicle
    False,  # Don't force start cumul to zero.
    time)
time_dimension = routing.GetDimensionOrDie(time)
# Add time window constraints for each location except depot.
for location_idx, time_window in enumerate(data['time_windows']):
    if location_idx == 0:
        continue
    index = manager.NodeToIndex(location_idx)
    time_dimension.CumulVar(index).SetRange(time_window[0], time_window[1])
# Add time window constraints for each vehicle start node.
for vehicle_id in range(data['num_vehicles']):
    index = routing.Start(vehicle_id)
    time_dimension.CumulVar(index).SetRange(data['time_windows'][0][0],
                                            data['time_windows'][0][1])
```

```
for i in range(data['num_vehicles']):
    routing.AddVariableMinimizedByFinalizer(
        time_dimension.CumulVar(routing.Start(i)))
    routing.AddVariableMinimizedByFinalizer(
        time_dimension.CumulVar(routing.End(i)))
```

```
timeDimension.CumulVar(index).SetRange(
    data.TimeWindows[0, 0],
    data.TimeWindows[0, 1]);
```

The dimension is created using the AddDimension method, which has the following arguments:

- The index for the travel time callback: transit_callback_index
- An upper bound for slack (the wait times at the locations): 30. While this was set to 0 in the CVRP example, the VRPTW has to allow positive wait time due to the time window constraints.
- An upper bound for the total time over each vehicle's route: 30
- A boolean variable that specifies whether the cumulative variable is set to zero at the start of each vehicle's route.
- The name of the dimension.

Solution printer

```
def print_solution(data, manager, routing, solution):
      time_dimension = routing.GetDimensionOrDie('Time')
    total_time = 0
    for vehicle_id in range(data['num_vehicles']):
        index = routing.Start(vehicle_id)
        plan_output = 'Route for vehicle {}:\n'.format(vehicle_id)
        while not routing.IsEnd(index):
            time_var = time_dimension.CumulVar(index)
            plan_output += '{0} Time({1},{2}) -> '.format(
                manager.IndexToNode(index), solution.Min(time_var),
                solution.Max(time_var))
            index = solution.Value(routing.NextVar(index))
        time_var = time_dimension.CumulVar(index)
        plan_output += '{0}
Time({1},{2})\n'.format(manager.IndexToNode(index),
                                                    solution.Min(time_var),
                                                    solution.Max(time_var))
        plan_output += 'Time of the route: {}min\n'.format(
            solution.Min(time_var))
        print(plan_output)
        total_time += solution.Min(time_var)
    print('Total time of all routes: {}min'.format(total_time))
```