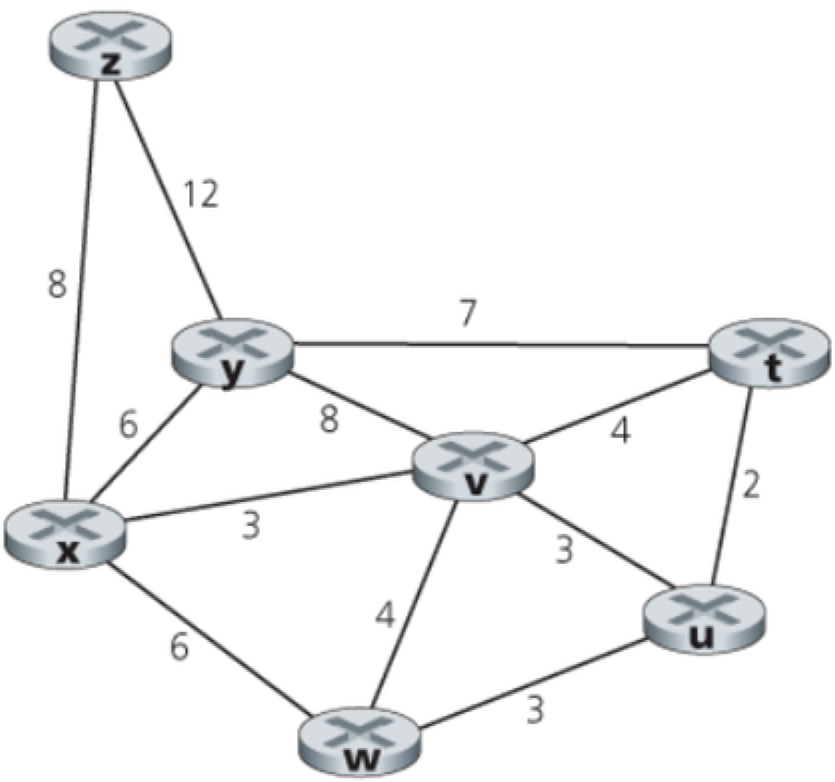
Computer Networks

Lesson 05 - Internet Layer -- Control Plane

P3. Consider the following network. With the indicated link costs, use Dijkstra’s shortest-path algorithm to compute the shortest path from x to all network nodes. Show how the algorithm works by computing a table similar to Table 5.1.



Ans

First comes the Dijkstra's algorithm for all-node shortest path in Python.

```python
#!/usr/bin/python
import heapq
from collections import namedtuple

class PQ(object):
    def __init__(self):
        self._pq = []

    def get_elements(self):
        return self._pq

    def push(self, key, value):
        heapq.heappush(self._pq, (key, value))

    def pop(self):
        (key, value) = heapq.heappop(self._pq)

        return (key, value)

Hop = namedtuple('Hop', ['current', 'previous'])

def get_link_state_routing(network, init):
    """
    use link-state algorithm to compute the forward table for selected router n
    """
    from sets import Set

    # total number of routers:
    N = len(network)

    # states:
    explored = Set()
    frontier = PQ()
    routes = {}
    table = []

    # init:
    init_hop = Hop(current = init, previous = init)
    frontier.push(0, init_hop)

    while len(explored) < N:
        # explore:
        cost, hop = frontier.pop()

        # filter:
        current = hop.current
```

```
        if current in explored:
            continue

        # update:
        explored.add(current)
        routes[current] = {
            'cost': cost,
            'parent': hop.previous
        }

        # expand frontier:
        for next_hop, link_cost in network[current].iteritems():
            if not next_hop in explored:
                frontier.push(
                    cost + link_cost,
                    Hop(current = next_hop, previous = current)
                )

        # get current state
        status = {}
        for router in network.keys():
            if router in explored:
                status[router] = (routes[router]['cost'], routes[router]['parent'])
            else:
                status[router] = next(
                    ((r[0], r[1].previous) for r in frontier.get_elements() if r[1].curren
                    (None, None)
                )
        table.append(
            ",".join(sorted(explored)) + "--" + "\t".join(str((router, status[router])) fo
        )

    # format table:
    table = "\n".join(table)
    # format routes:
    for terminal, state in routes.iteritems():
        route = [terminal]

        parent = state['parent']
        while routes[parent]['parent'] != parent:
            route.append(parent)
            parent = routes[parent]['parent']
        route.append(parent)

    return table, routes
```

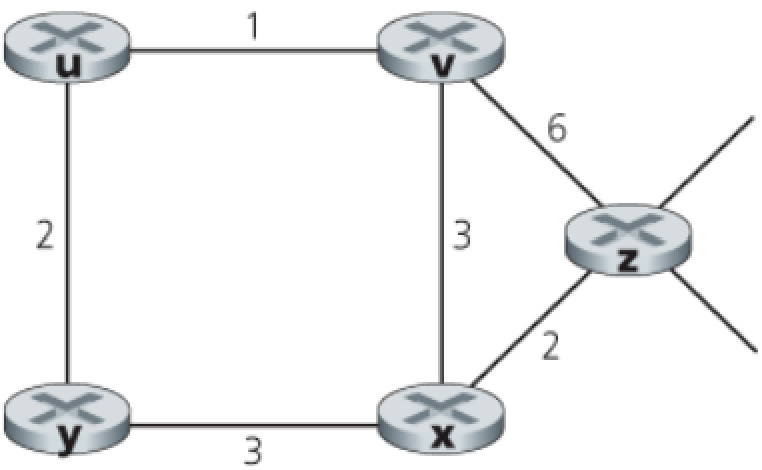
```python
if __name__ == '__main__':
    # network topology definition:
    network = {
        't': {
            'u': 2, 'v': 4, 'y': 7
        },
        'u': {
            't': 2, 'v': 3, 'w': 3
        },
        'v': {
            't': 4, 'u': 3, 'w': 4, 'x': 3, 'y': 8
        },
        'w': {
            'u': 3, 'v': 4, 'x': 6
        },
        'x': {
            'v': 3, 'w': 6, 'y': 6, 'z': 8
        },
        'y': {
            't': 7, 'v': 8, 'x': 6, 'z': 12
        },
        'z': {
            'x': 8, 'y': 12
        }
    }

    table, route = get_link_state_routing(network, 'x')

    print table
```

Execute the above script, we can get the following table for link-state algorithm state evolvement.

step	N'	D(t),p(t)	D(u),p(u)	D(v),p(v)	D(w),p(w)	D(x),p(x)	D(y),p(y)	D
0	x	Inf,None	Inf,None	3, 'x'	6, 'x'	0, 'x'	6, 'x'	
1	v,x	7, 'v'	6, 'v'		6, 'x'		6, 'x'	
2	u,v,x	7, 'v'		3, 'x'	6, 'x'			
3	u,v,w,x		6, 'v'	3, 'x'		0, 'x'		
4	u,v,w,x,y	7, 'v'		3, 'x'		0, 'x'		
5	t,u,v,w,x,y		6, 'v'	3, 'x'			6, 'x'	

step	N'	D(t),p(t)	D(u),p(u)	D(v),p(v)	D(w),p(w)	D(x),p(x)	D(y),p(y)	D
6	t,u,v,w,x,y,z					0, 'x'	6, 'x'	

P5. Consider the network shown below, and assume that each node initially knows the costs to each of its neighbors. Consider the distance-vector algorithm and show the distance table entries at node z



Ans

First is the implementation of distance vector algorithms for distributed route computing:

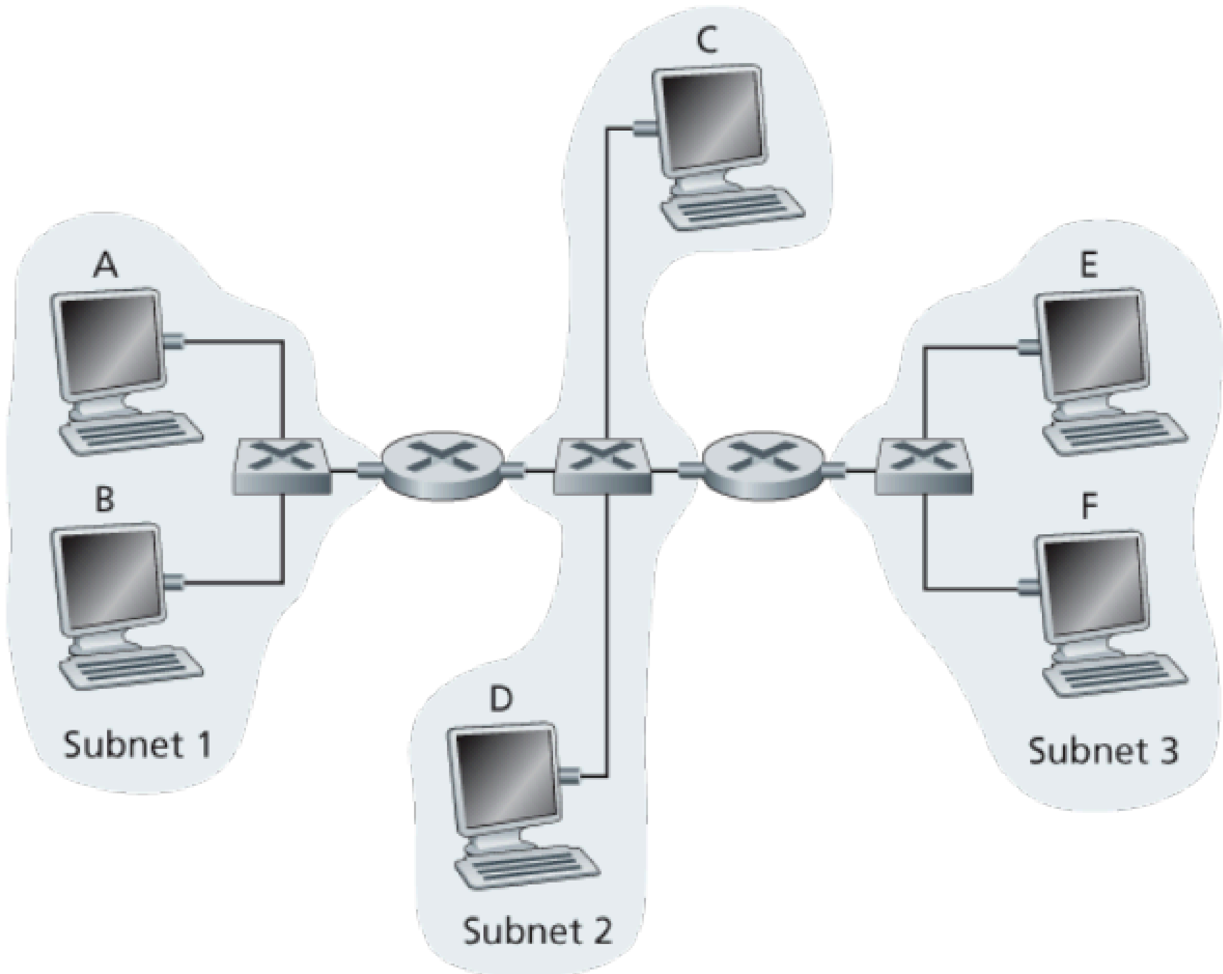
```python
#!/usr/bin/python
def get_distance_vector_routes(network):
    # set up session:
    import copy
    from pprint import pprint

    # init:
    dv_prev = copy.deepcopy(network)
    for router in dv_prev.keys():
        dv_prev[router][router] = 0
        dv_prev[router] = {
            k: (v, k) for k,v in dv_prev[router].iteritems()
        }
    dv_next = copy.deepcopy(dv_prev)
    should_broadcast = {}
    for router in dv_prev.keys():
        should_broadcast[router] = True

    while any(should_broadcast.values()):
        # compute:
        for router in network.keys():
            for neighbor in network[router].keys():
                for dest, route in dv_prev[neighbor].iteritems():
                    (cost, _) = route
                    # propose new route cost:
                    new_route = (network[router][neighbor] + cost, neighbor)
                    # keep only min:
                    if dest in dv_next[router]:
                        dv_next[router][dest] = min(dv_next[router][dest], new_route, key
                    else:
                        dv_next[router][dest] = new_route
            # should broadcast current route table:
            should_broadcast[router] = (dv_next[router] != dv_prev[router])

        # save current state:
        dv_prev = copy.deepcopy(dv_next)

        # display:
        pprint(dv_next)
        pprint(should_broadcast)

        print ""

if __name__ == '__main__':
    # network topology definition:
    network = {
```

```
        'u': {
            'v': 1, 'y': 2
        },
        'v': {
            'u': 1, 'x': 3, 'z': 6
        },
        'x': {
            'v': 3, 'y': 3, 'z': 2
        },
        'y': {
            'u': 2, 'x': 3
        },
        'z': {
            'v': 6, 'x': 2
        }
    }

    get_distance_vector_routes(network)
```

Execute the above script, we can get the following table for route table evolvement in format *destination: (cost, forward interface)*:

Step	u	v	x	y	z
1	'u': (0, 'u') 'v': (1, 'v') 'x': (4, 'v') 'y': (2, 'y') 'z': (7, 'v')	'u': (1, 'u') 'v': (0, 'v') 'x': (3, 'x') 'y': (3, 'u') 'z': (5, 'x')	'u': (4, 'v') 'v': (3, 'v') 'x': (0, 'x') 'y': (3, 'y') 'z': (2, 'z')	'u': (2, 'u') 'v': (3, 'u') 'x': (3, 'x') 'y': (0, 'y') 'z': (5, 'x')	'u': (7, 'v') 'v': (5, 'x') 'x': (2, 'x') 'y': (5, 'x') 'z': (0, 'z')
2	'u': (0, 'u') 'v': (1, 'v') 'x': (4, 'v') 'y': (2, 'y') 'z': (6, 'v')	'u': (1, 'u') 'v': (0, 'v') 'x': (3, 'x') 'y': (3, 'u') 'z': (5, 'x')	'u': (4, 'v') 'v': (3, 'v') 'x': (0, 'x') 'y': (3, 'y') 'z': (2, 'z')	'u': (2, 'u') 'v': (3, 'u') 'x': (3, 'x') 'y': (0, 'y') 'z': (5, 'x')	'u': (6, 'x') 'v': (5, 'x') 'x': (2, 'x') 'y': (5, 'x') 'z': (0, 'z')
3	'u': (0, 'u') 'v': (1, 'v') 'x': (4, 'v') 'y': (2, 'y') 'z': (6, 'v')				

P14. Consider three LANs interconnected by two routers, as shown in Figure 6.33



a. Assign IP addresses to all of the interfaces. For Subnet 1 use addresses of the form 192.168.1.xxx; for Subnet 2 uses addresses of the form 192.168.2.xxx; and for Subnet 3 use addresses of the form 192.168.3.xxx.

Ans

Below are the assigned IP addresses for subnet 1:

Device	IP Address
Host A	192.168.1.1
Host B	192.168.1.2

Device	IP Address
Router 1-2	192.168.1.3

Subnet 2:

Device	IP Address
Host C	192.168.2.1
Host D	192.168.2.2
Router 1-2	192.168.2.3
Router 2-3	192.168.2.4

Subnet 3:

Device	IP Address
Host E	192.168.3.1
Host F	192.168.3.2
Router 2-3	192.168.3.3

b. Assign MAC addresses to all of the adapters.

Ans

Below are the assigned MAC addresses for subnet 1:

Device	MAC Address
Host A	18:DB:F2:20:D1:91
Host B	18:DB:F2:20:D1:92
Router 1-2	18:DB:F2:20:D1:93

Subnet 2:

Device	MAC Address
Host C	18:DB:F2:20:D2:91
Host D	18:DB:F2:20:D2:92
Router 1-2	18:DB:F2:20:D2:93
Router 2-3	18:DB:F2:20:D2:94

Subnet 3:

Device	MAC Address
Host E	18:DB:F2:20:D3:91
Host F	18:DB:F2:20:D3:92
Router 2-3	18:DB:F2:20:D3:93

c. Consider sending an IP datagram from Host E to Host B. Suppose all of the ARP tables are up to date. Enumerate all the steps, as done for the single-router example in Section 6.4.1

Ans

Below are the steps for the above packet transmission:

1. Host E builds the following packet
    - source IP address: 192.168.3.1
    - destination IP address: 192.168.1.2
    - source MAC address: 18:DB:F2:20:D3:91
    - destination MAC address(from ARP table in Host E): 18:DB:F2:20:D3:93, interface in subnet 3 of Router 2-3
2. Router 2-3 forwards the packet to its interface in subnet 2
3. Router 2-3 builds the following packet
    - source IP address: 192.168.2.4
    - destination IP address: 192.168.1.2
    - source MAC address: 18:DB:F2:20:D2:94
    - destination MAC address(from ARP table in Router 2-3):

18:DB:F2:20:D2:93, interface in subnet 2 of Router 1-2

4. Router 1-2 forwards the packet to its interface in subnet 1
5. Router 1-2 builds the following packet
    - source IP address: 192.168.1.3
    - destination IP address: 192.168.1.2
    - source MAC address: 18:DB:F2:20:D1:93
    - destination MAC address(from ARP table in Router 1-2): 18:DB:F2:20:D1:92, Host B in subnet 1

d. Repeat (c), now assuming that the ARP table in the sending host is empty (and the other tables are up to date)

Ans

In order to set up the ARP table in sending host E, the following steps should be performed before executing steps in section c:

1. Host E builds an ARP query packet
    - source IP address: 192.168.3.1
    - destination IP address: 192.168.1.2
    - source MAC address: 18:DB:F2:20:D3:91
    - destination MAC address: FF:FF:FF:FF:FF:FF
2. Router 2-3 receives the ARP query packet, finds it is reachable through other interfaces and sends the following ARP response packet
    - IP address: 192.168.1.2
    - MAC address: 18:DB:F2:20:D3:93
3. After receiving the packet, host E sets up the correct entry in its ARP table.

After the above ARP MAC address resolution process, host E can use the procedure in section c to correctly transmit the packet.

P17. Recall that with the CSMA/CD protocol, the adapter waits K·512 bit times after a collision, where K is drawn randomly. For K=100 , how long does the adapter wait until returning to Step 2 for a 10 Mbps broadcast

channel? For a 100 Mbps broadcast channel?

Ans

The wait time for link with R = 10Mbps is

$$T_{backoff} = \frac{K * UnitTransTime}{R}$$

The time for link with R = 100Mbps is

$$T_{backoff} = \frac{K * UnitTransTime}{R}$$

P18. Suppose nodes A and B are on the same 10 Mbps broadcast channel, and the propagation delay between the two nodes is 325 bit times. Suppose CSMA/CD and Ethernet packets are used for this broadcast channel. Suppose node A begins transmitting a frame and, before it finishes, node B begins transmitting a frame. Can A finish transmitting before it detects that B has transmitted? Why or why not? If the answer is yes, then A incorrectly believes that its frame was successfully transmitted without a collision. Hint: Suppose at time t=0 bits, A begins transmitting a frame. In the worst case, A transmits a minimum-sized frame of 512+64 bit times. So A would finish transmitting the frame at t=512+64 bit times. Thus, the answer is no, if B's signal reaches A before bit time t=512+64 bits. In the worst case, when does B's signal reach A?

Ans

No. A's transmitting size must be at least R * 2 * propagation delay 2 * 325 equals 650 bits.

The worst-case situation would be: Node B starts transmission when the first bit from node A just arrives node B.

In this case, in order for node A to realize that there is a collision, it must wait long enough to receive the corrupted signal from node B. This will be another propagation delay.

So the minimum transmitting time for node A would be two times propagation delay thus the minimum frame size should be 650 bits.