Modeling HexNet in ACL2

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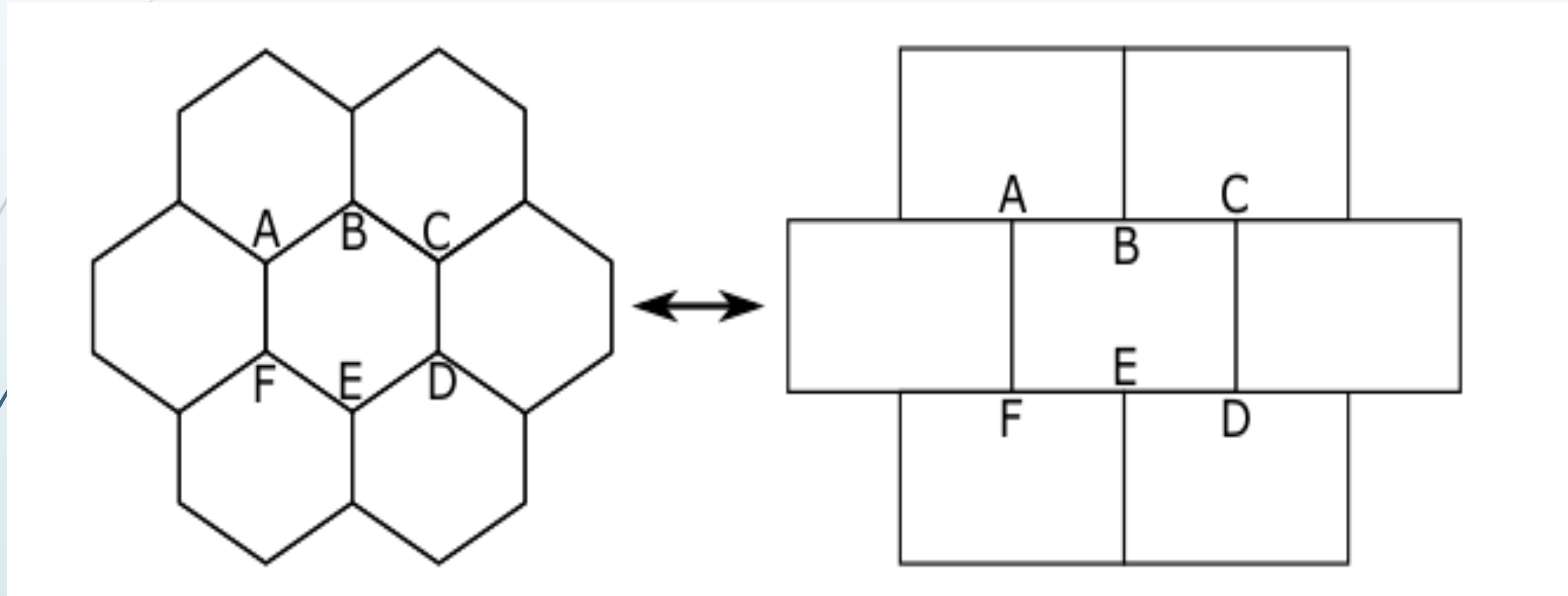
OUTLINE

- Introduction into HexNet and its features
- Implementation in ACL2
- Packet movement in a sample network
- Proof properties
- Some ACL2 events

HexNet

- The network plan is based on a hexagonal topology, hence is called **HexNet**.



This hexagonal topology can also be seen in the connections in a brick wall

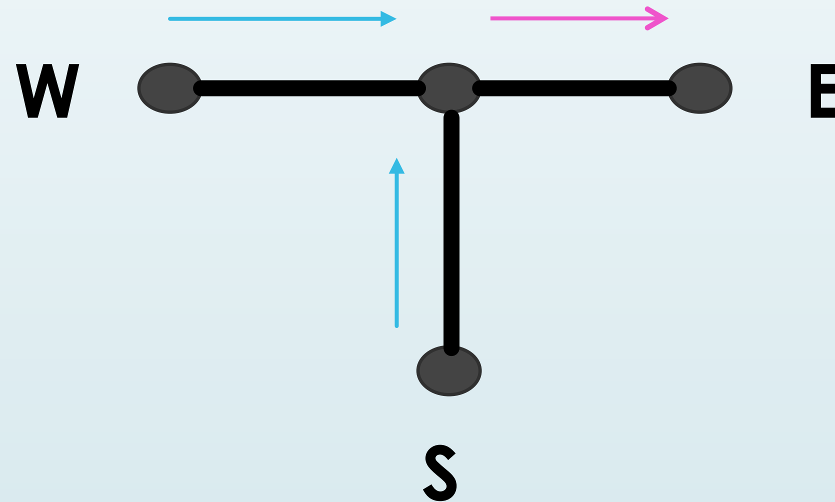
HexNet

- Each node in the network is called a JUNCTION.
- A Junction can either be
  - REPEATER (degree of 3) : This accepts data and forwards it to its appropriate output.
  - DESTINATION (degree of 1) : This is an entry or exit point in the network.
- Usually, branching and merging in the network is two-way.
- Therefore, data on only two input links compete for each output link and data on each input link can leave through only two possible output links.

Our goal : Modeling the high-level description of this network and packet movement in the network

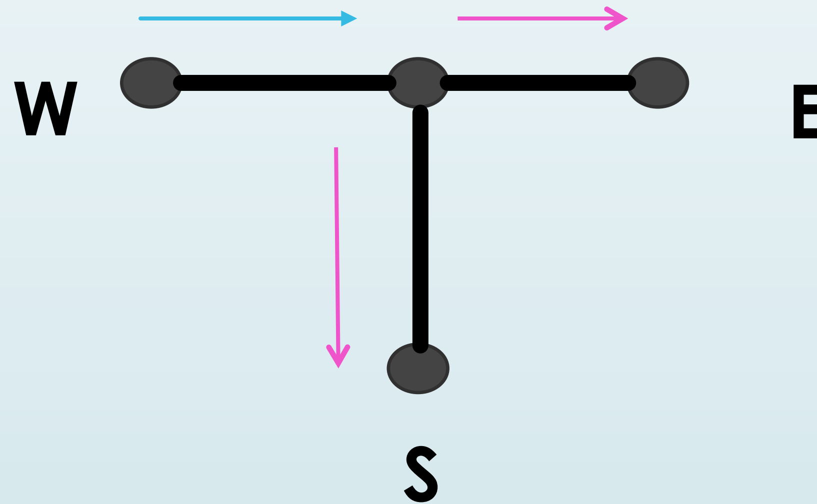
Features of the network

- **Arbitration** : Correct decision behavior when data arrives on two input links at nearly the same time. Also, a mechanism for fairness is needed.



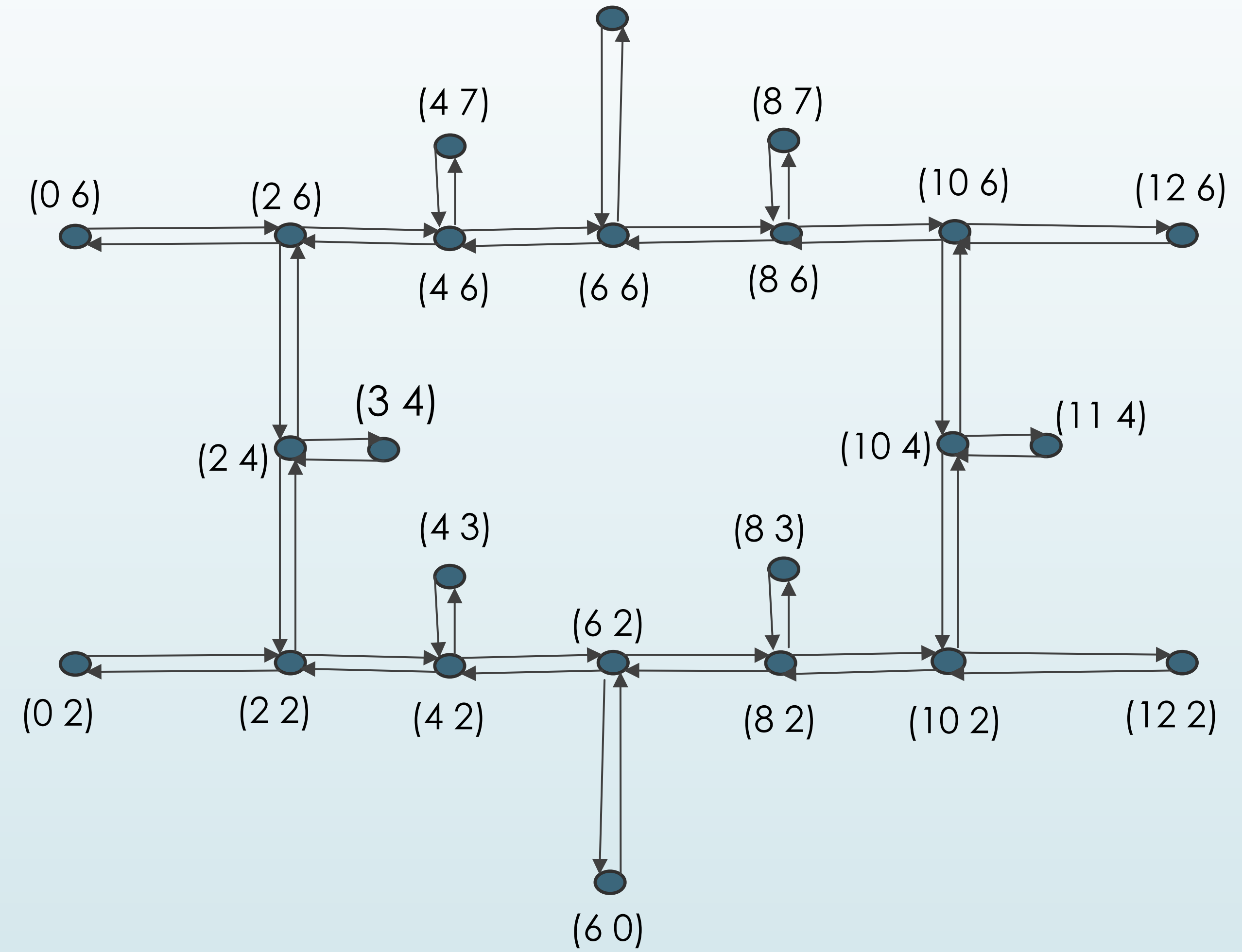
Features of the network

- **Packet Routing**: Packet coming through one input link has two possible output links to pass through. This decision is based on the comparison of the final destination and the current junction's location.

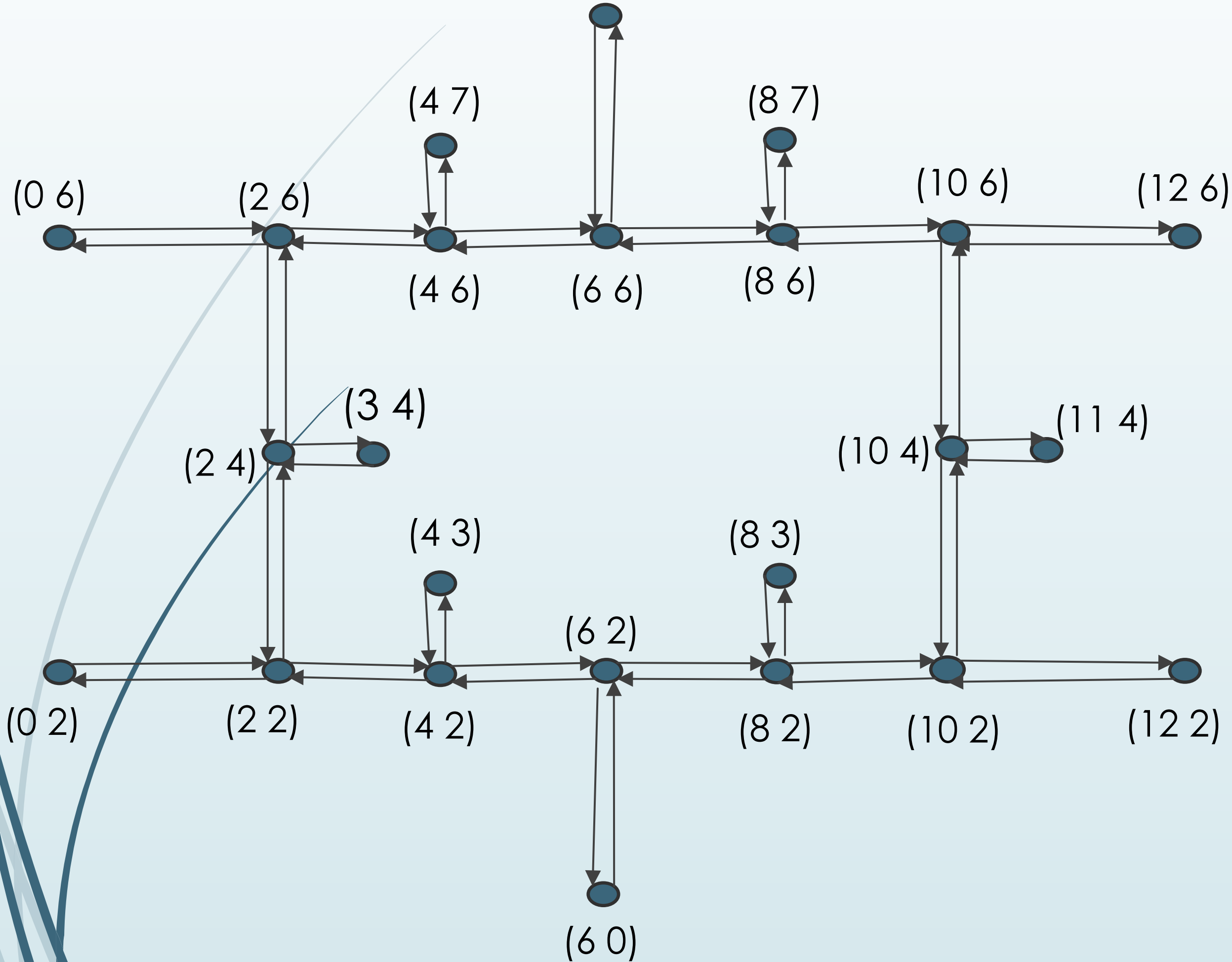


Implementation of HexNet in ACL2

- The network is modeled as a graph
- Addressing is based on a cartesian grid, as such, each junction is list of its x coordinate and its y coordinate
- There are two links between any two connected junctions to represent data movement in each direction.



Implementation of HexNet in ACL2




```
(defconst   *network*
;; junct    dest      in      out
'(((0 2)    ((2 2)    S20     S02))
  ((2 2)    ((0 2)    S02     S20)
            ((4 2)    S42     S24)
            ((2 4)    T24     T42))
  ((4 2)    ((2 2)    S24     S42)
            ((6 2)    S64     S46)
            ((4 3)    T23     T32))
  ((6 2)    ((4 2)    S46     S64)
            ((8 2)    S86     S68)
            ((6 0)    T02     T20))
  ((8 2)    ((6 2)    S68     S86)
            ((10 2)   S108    S810)
            ((8 3)    T83     T38))
  …
```

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Packets

- A packet is modelled as a list that contains
  - A turn signal, which is the next direction the packet should take
  - An address of final destination of the packet
  - An address of the origin of the packet
  - The information to be passed along
- The packets are stored on the links.
- A link can either be full or empty.
- A linkmap shows the current state of all the links in the network at a given time.

Pkt1 - '(E (8 7) (0 2) data)

E – turn_signal

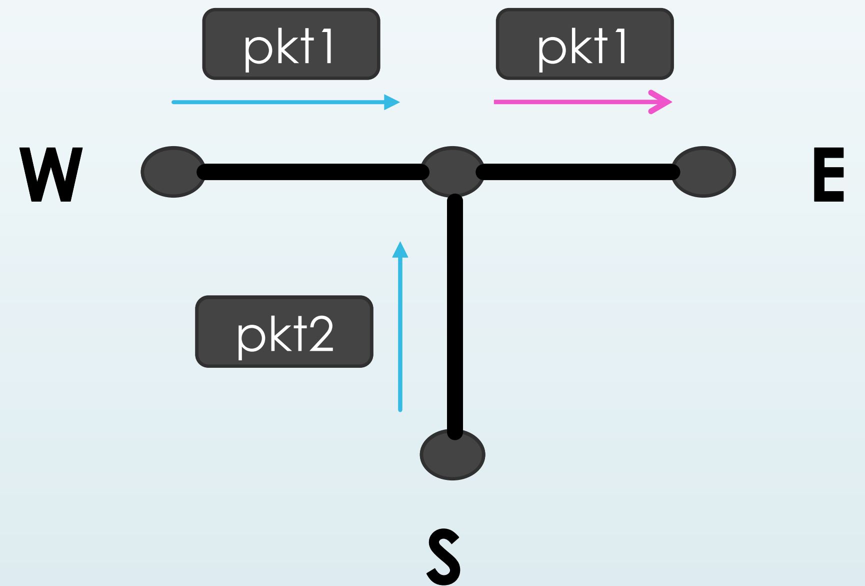
(8 7) – coordinates of the final destination

(0 2) – coordinates of the origin of the packet

```
(defconst *linkmap*
'((S02 (E (12 2) (0 2) data))
  (S20)  (S24)  (S42)  (S46)  (S64)
  (S68)  (S86)  (S810)  (S108)
  (S1012)  (S1220)  (T20)
  (T02)  (T32)  (T23)  (T38)
  (T83 (W (3 4) (8 3) data)) ...
```

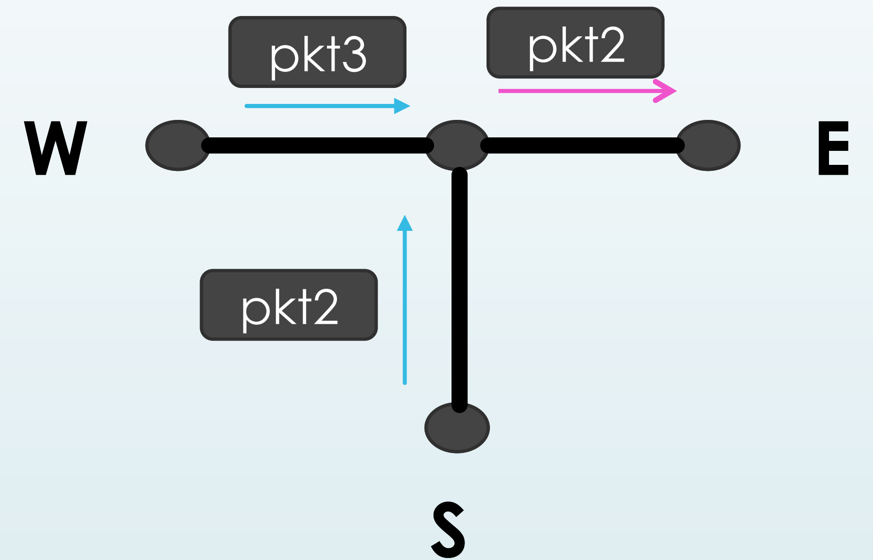
Arbitration in the Model

- Arbitration is based on the output direction
- One of the packets is chosen to proceed while the second waits



Arbitration in the Model

- Arbitration is based on the output direction
- One of the packets is chosen to proceed while the second waits
- However, to facilitate fairness, the model has to remember the decision at the previous step if there is another tie at that junction



Arbitration in the Model

- Arbitration is based on the output direction
- One of the packets is chosen to proceed while the second waits
- However, to facilitate fairness, the model has to remember the decision at the previous step if there is another tie at that junction

Outlink – link in the output direction

Inputs – links with packets

St – statemap that stores previous step decisions

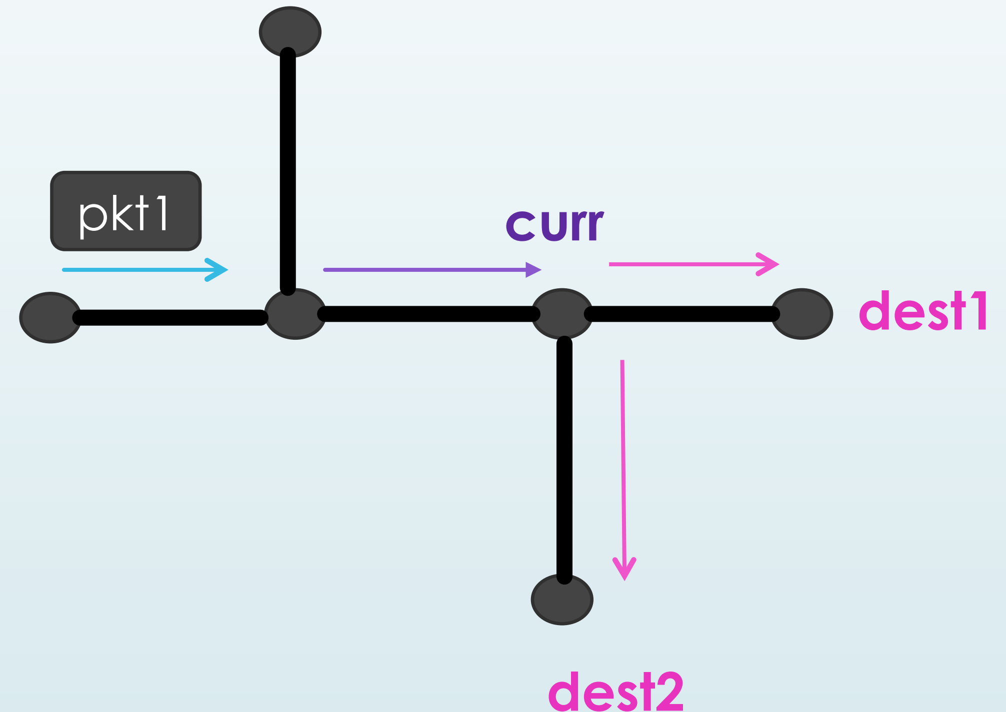
```
(defun arbiter (outlink  inputs   st)
  (cond
     ((atom inputs)          (mv nil st))
     ((atom (cdr inputs))        (mv (car inputs) st))
     (t     (let*    ((entry    (assoc-eq outlink st))
                      (pref      (cdr entry)))
          (if    (and  pref
                         (member-eq   pref   inputs))
                (let* ((new-pref    (car  (remove-eq  pref  inputs)))
                         (new-st  (update-alist   outlink  new-pref  st)))
                  (mv pref new-st))
            (let* ((new-pref    (cadr inputs))
                     (new-st   (update-alist   outlink   new-pref    st)))
               (mv (car inputs) new-st)))))))
```

Packet Routing

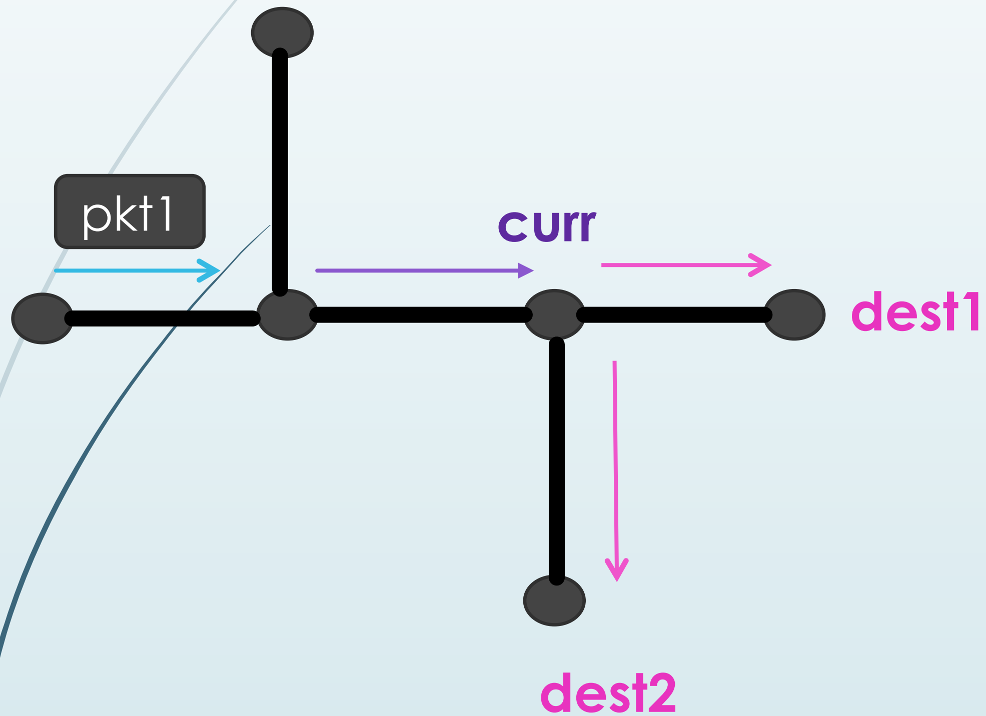
- The network uses **Advanced Address Decoding**
- This means that the routing function calculates the next direction, i.e. turn-signal, a step before it makes the turn.
- Comparison is made between the final destination of the packet and the address of next junction.

Turn_signal (pkt1) = East => curr

Routing_function (dest1 dest2 curr final g) = (compare curr final) => East or South

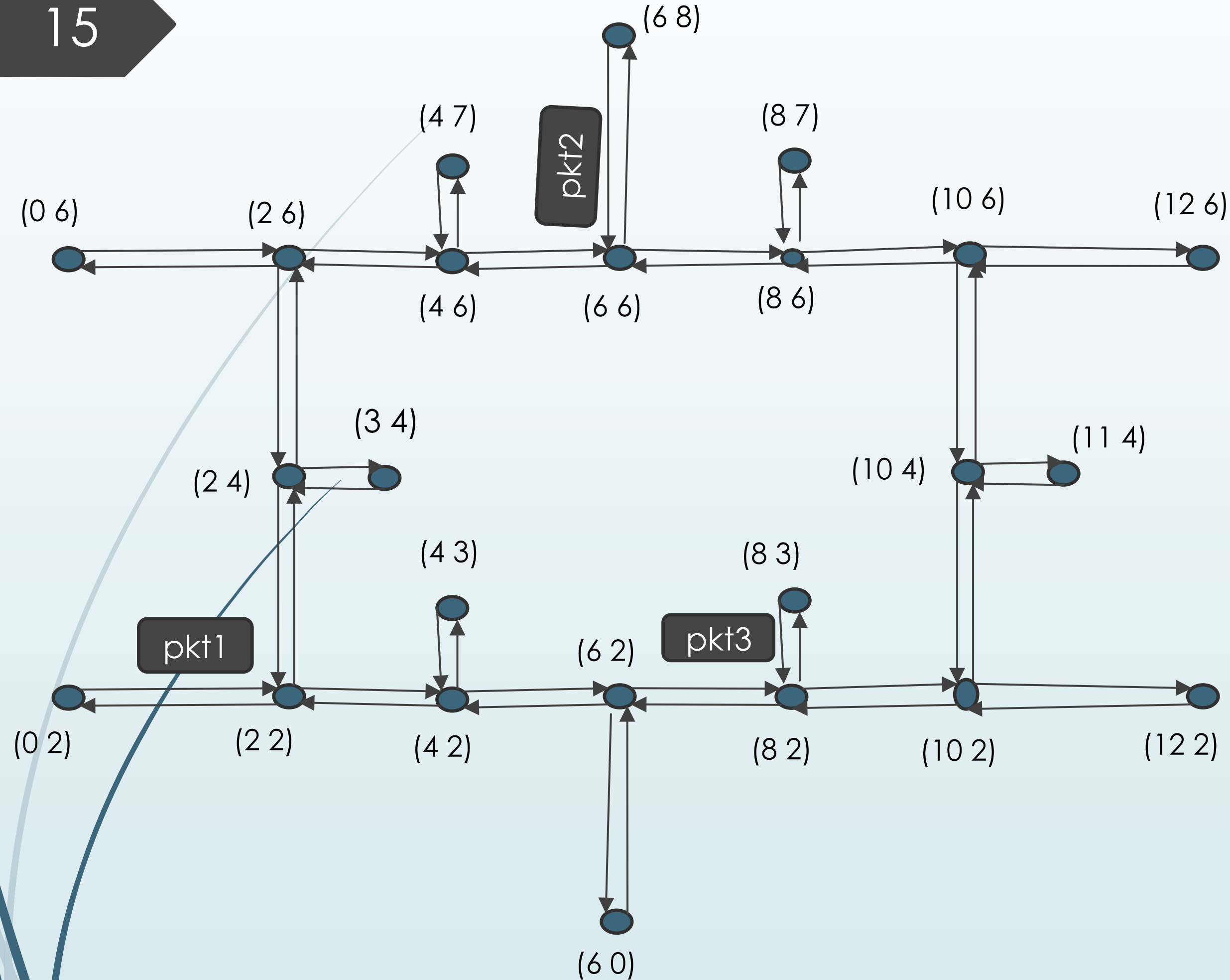


Routing Packet Traffic




```
(defun routing-normal (dest1 dest2 curr final g)
 (let* ((dest1-x (car dest1))  (dest1-y (cadr dest1))    (dest2-x (car dest2))
       (dir1  (get-direction curr dest1 g))  (dir2 (get-direction curr dest2 g))
       (curr-x (car curr))       (curr-y (cadr curr))
       (final-x (car final))       (final-y (cadr final)))
    (if (isTerminal dest1 curr g)
          (if (equal dest1 final)       dir1
               (if (isTerminal dest2 curr g)
                    (if (equal dest2 final)      dir2      (cw "Bad route "))
               dir2))
        (if (isTerminal dest2 curr g)
             (if (equal dest2 final)        dir2        dir1)
             (cond      ((< curr-y final-y)
                              (if (< curr-y dest1-y)      dir1        dir2))
                        ((> curr-y final-y)
                              (if (> curr-y dest1-y)      dir1        dir2))
                        ((< curr-x final-x)
                              (if (< dest1-x dest2-x)    dir2        dir1))
                        ((> curr-x final-x)
                              (if (< dest1-x dest2-x)    dir1        dir2)))))))
```

Example



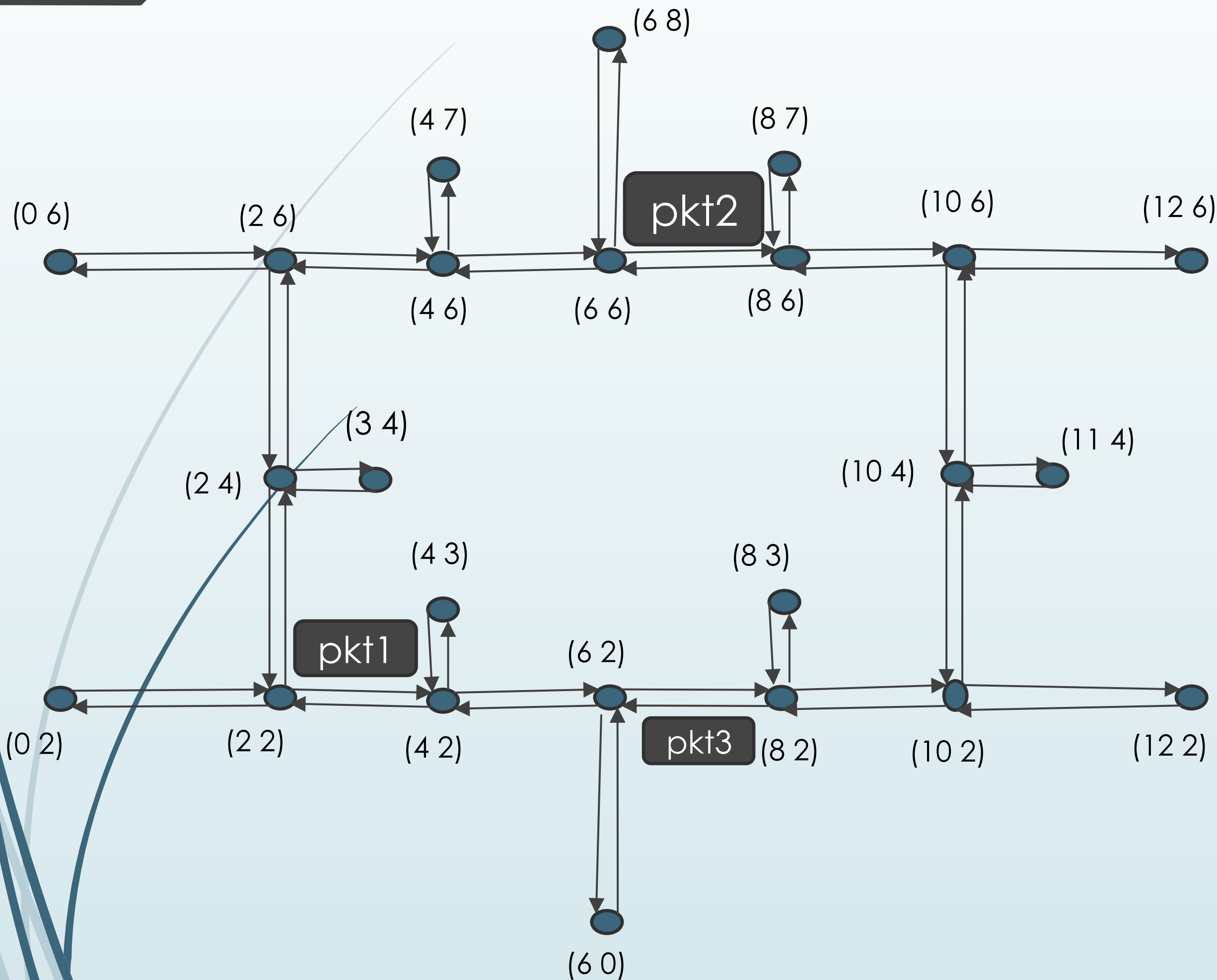
- Linkmap before execution

(S02 (E (12 2) (0 2) data))

(T83 (W (3 4) (8 3) data))

(T68 (E (12 2) (6 8) data))

Example



- Linkmap before execution

(S02 (E (12 2) (0 2) data))

(T83 (W (3 4) (8 3) data))

(T68 (E (12 2) (6 8) data))

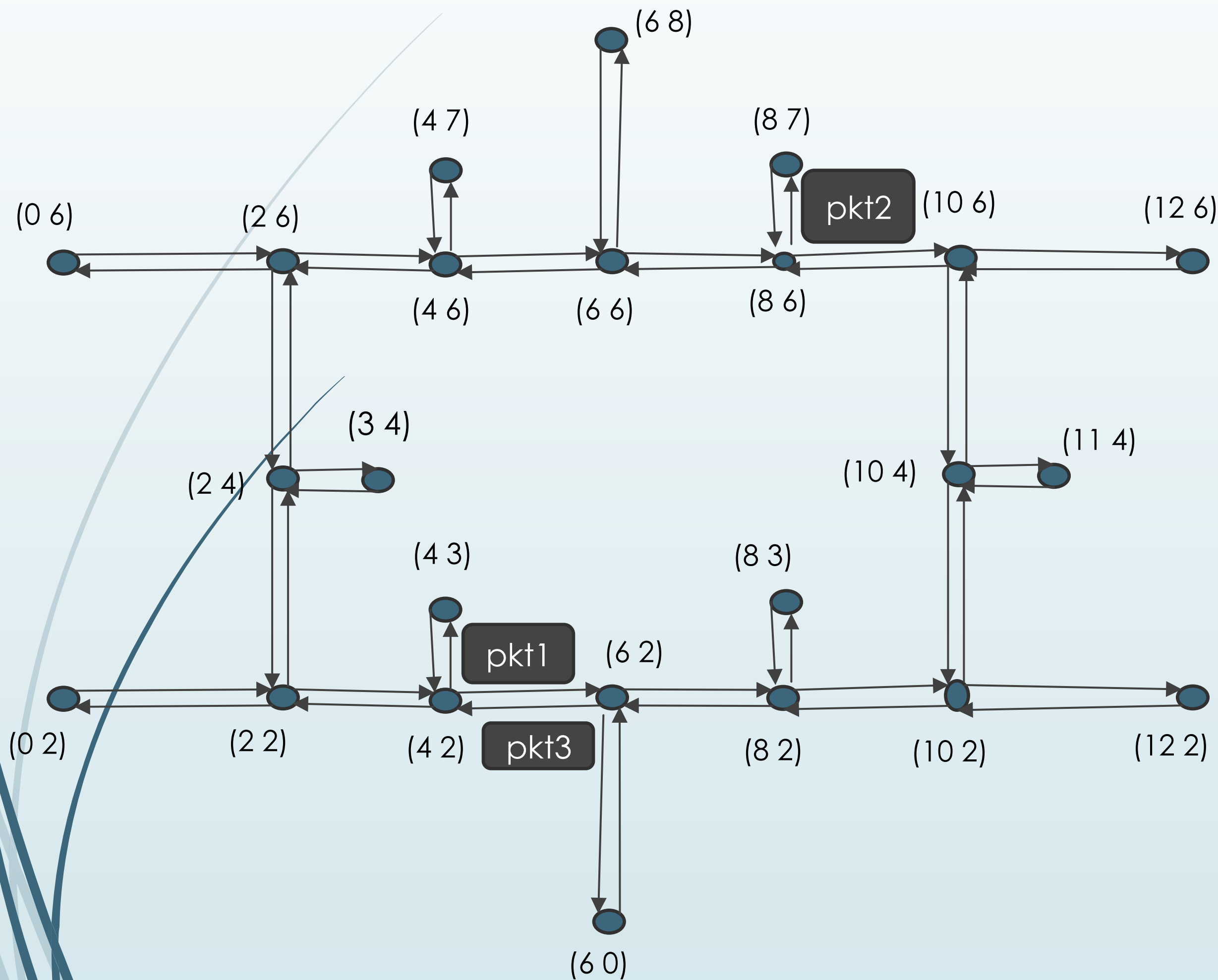
- Linkmap after 1 step

(S24 (E (12 2) (0 2) DATA))

(S86 (W (3 4) (8 3) DATA))

(S686 (E (12 2) (6 8) DATA))

Example



- Linkmap before execution

(S02 (E (12 2) (0 2) data))

(T83 (W (3 4) (8 3) data))

(T68 (E (12 2) (6 8) data))

- Linkmap after 1 step

(S24 (E (12 2) (0 2) DATA))

(S86 (W (3 4) (8 3) DATA))

(S686 (E (12 2) (6 8) DATA))

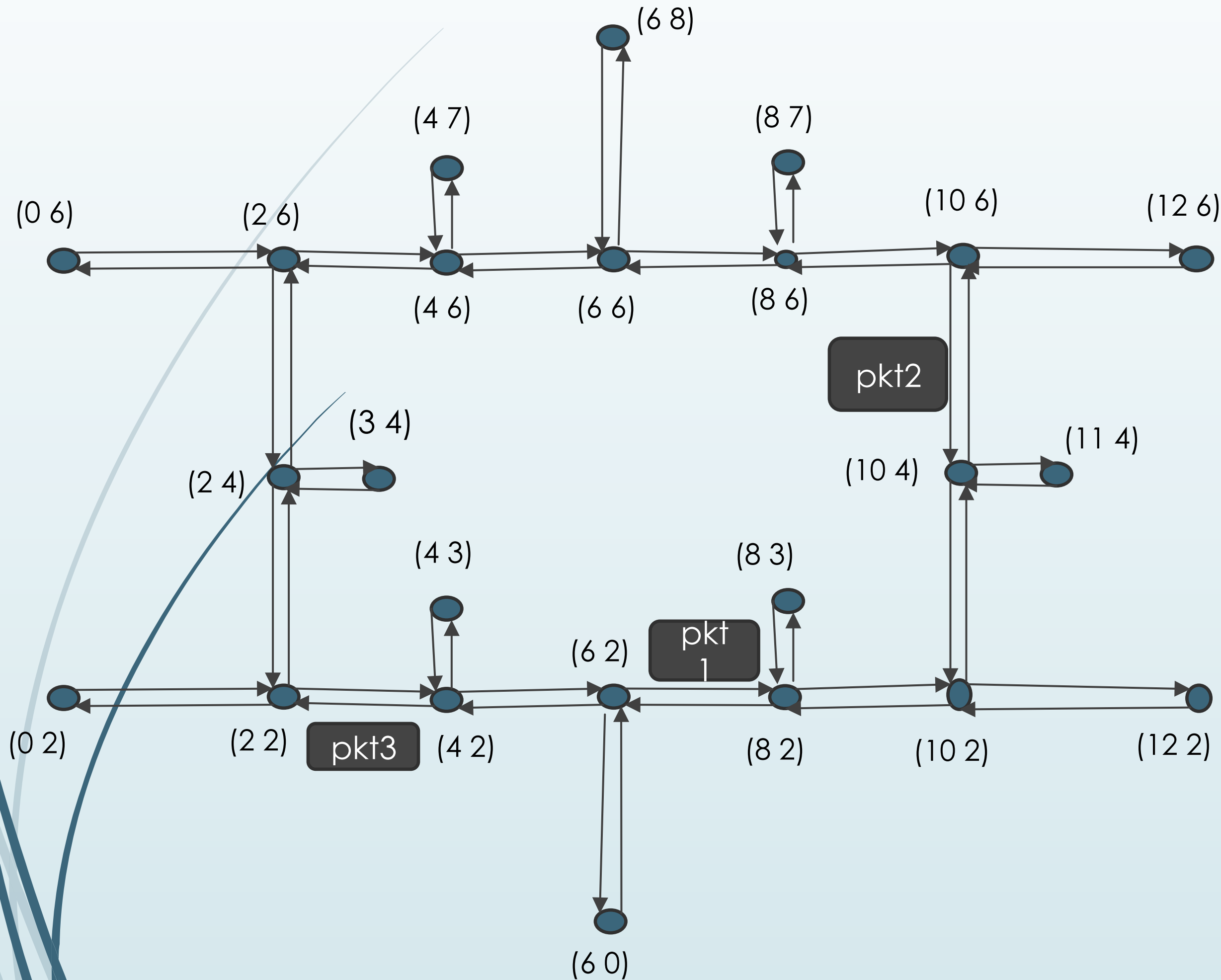
- Linkmap after 2 steps

(S46 (E (12 2) (0 2) DATA))

(S64 (W (3 4) (8 3) DATA))

(S610 (S (12 2) (6 8) DATA))

Example



- Linkmap before execution

(S02 (E (12 2) (0 2) data))

(T83 (W (3 4) (8 3) data))

(T68 (E (12 2) (6 8) data))

- Linkmap after 1 step

(S24 (E (12 2) (0 2) DATA))

(S86 (W (3 4) (8 3) DATA))

(S686 (E (12 2) (6 8) DATA))

- Linkmap after 2 steps

(S46 (E (12 2) (0 2) DATA))

(S64 (W (3 4) (8 3) DATA))

(S610 (S (12 2) (6 8) DATA))

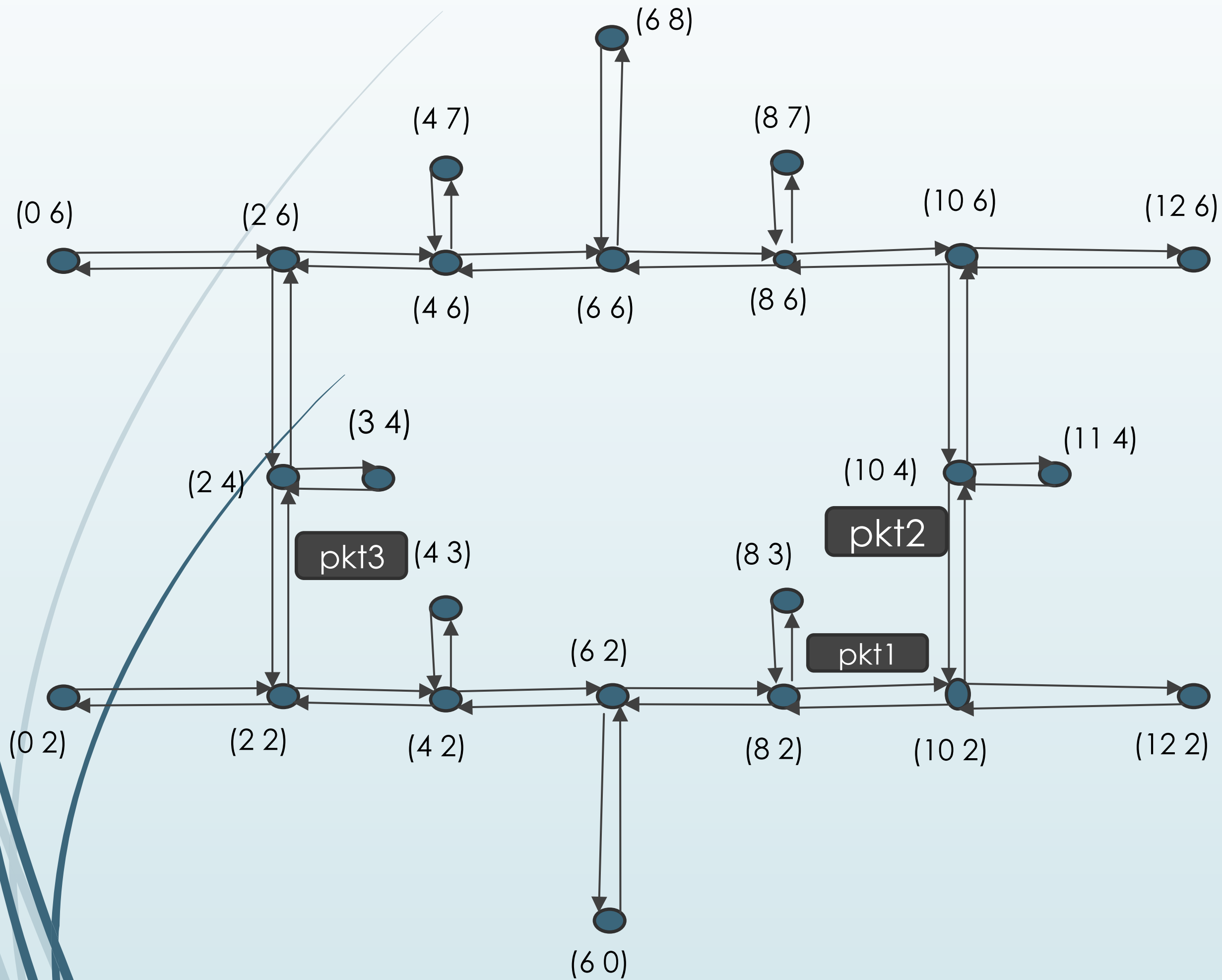
- Linkmap after 3 steps

(S68 (E (12 2) (0 2) DATA))

(S42 (N (3 4) (8 3) DATA))

(T106 (S (12 2) (6 8) DATA))

Example



- Linkmap before execution

(S02 (E (12 2) (0 2) data))

(T83 (W (3 4) (8 3) data))

(T68 (E (12 2) (6 8) data))

- Linkmap after 1 step

(S24 (E (12 2) (0 2) DATA))

(S86 (W (3 4) (8 3) DATA))

(S686 (E (12 2) (6 8) DATA))

- Linkmap after 2 steps

(S46 (E (12 2) (0 2) DATA))

(S64 (W (3 4) (8 3) DATA))

(S610 (S (12 2) (6 8) DATA))

- Linkmap after 3 steps

(S68 (E (12 2) (0 2) DATA))

(S42 (N (3 4) (8 3) DATA))

(T106 (S (12 2) (6 8) DATA))

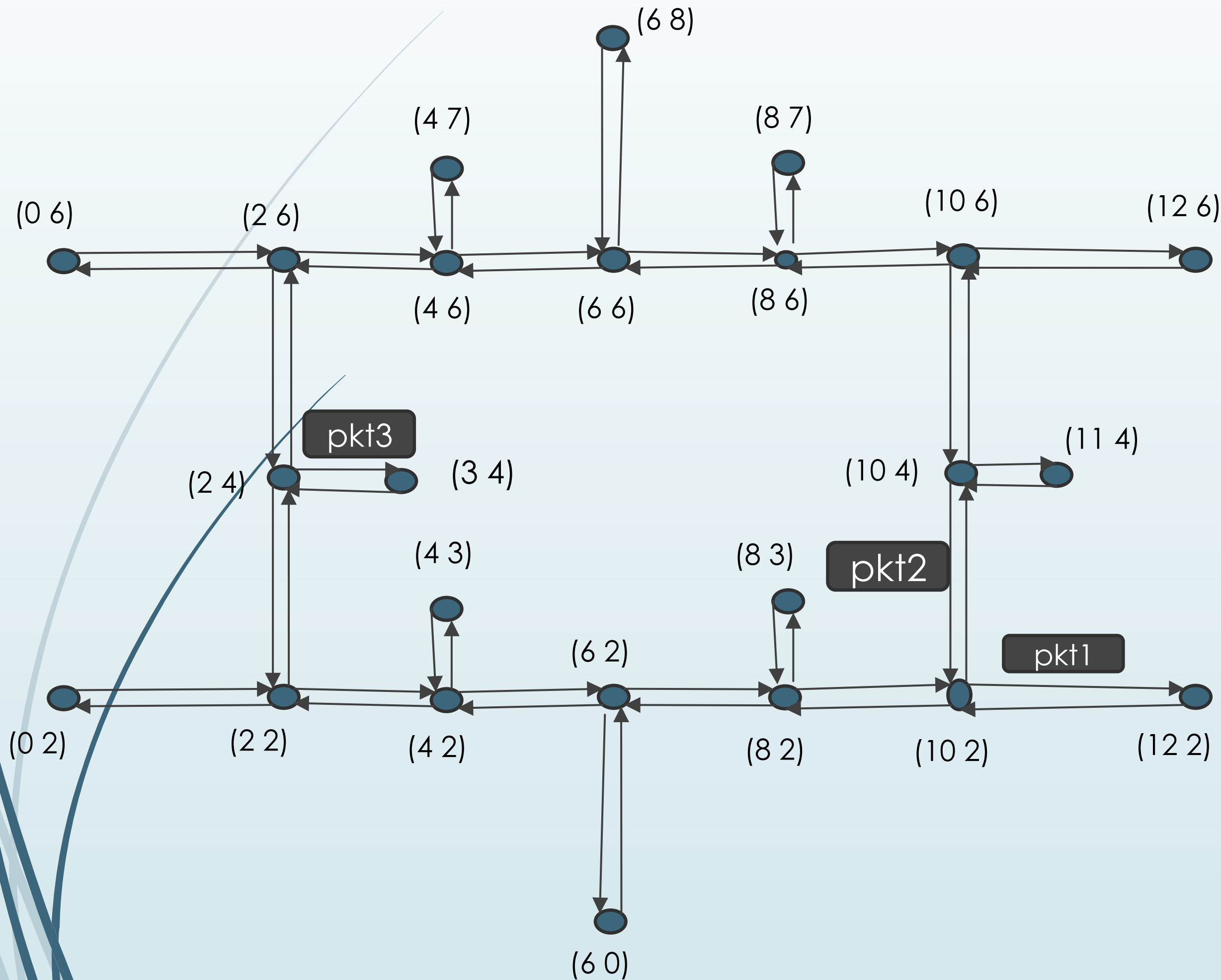
- Linkmap after 4 steps

(S810 (E (12 2) (0 2) DATA))

(T42 (E (3 4) (8 3) DATA))

(T104 (E (12 2) (6 8) DATA))

Example



- Linkmap after 4 steps

(S810 (E (12 2) (0 2) DATA))

(T42 (E (3 4) (8 3) DATA))

(T104 (E (12 2) (6 8) DATA))

- Linkmap after 5 steps

(S1012 (DONE (12 2) (0 2) DATA))

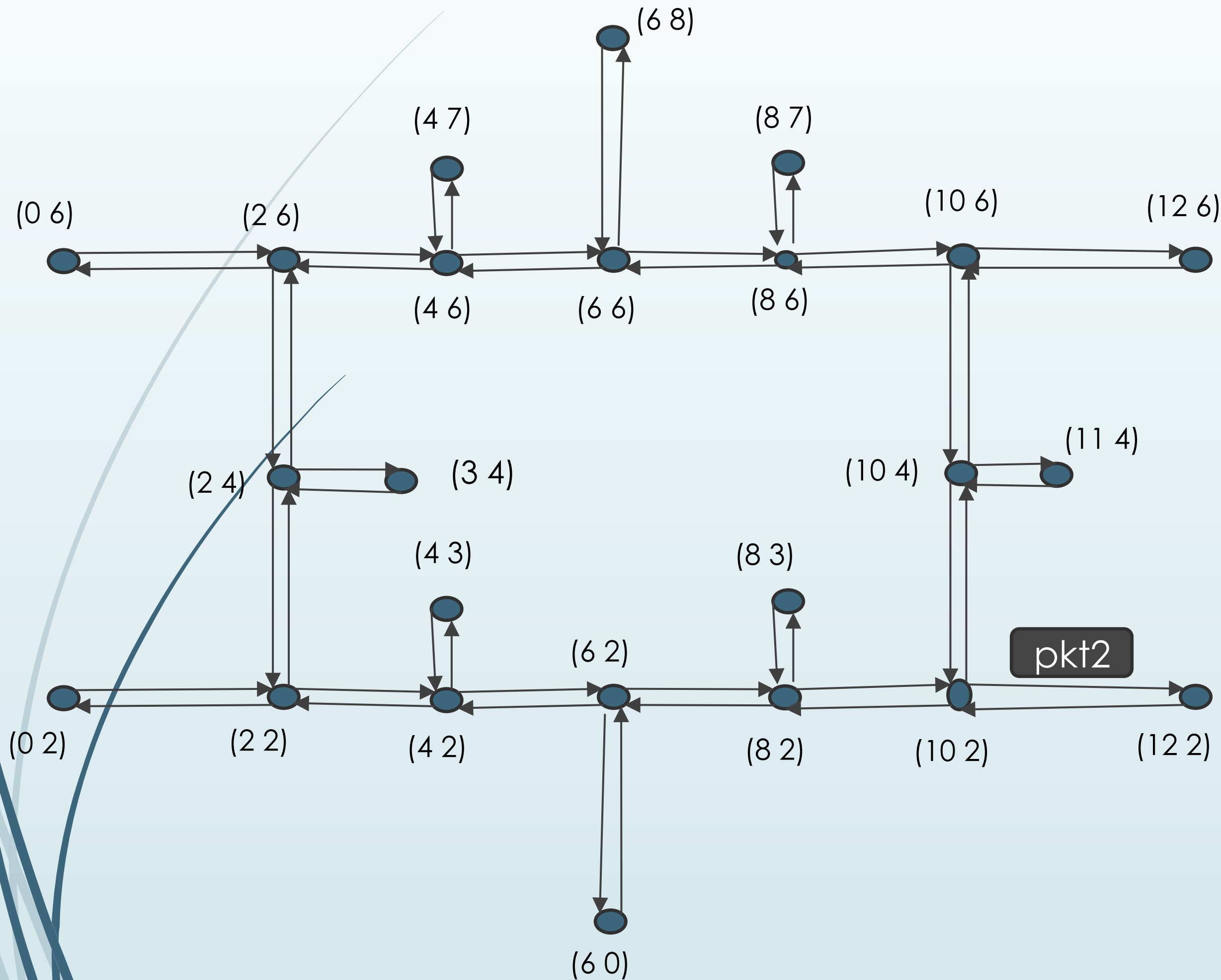
(S23 (DONE (3 4) (8 3) DATA))

(T104 (E (12 2) (6 8) DATA))

The statemap records that preference should be given to pkt2 if there is a tie in the next step.

(S1012 . T104)

Example



- Linkmap after 4 steps

(S810 (E (12 2) (0 2) DATA))

(T42 (E (3 4) (8 3) DATA))

(T104 (E (12 2) (6 8) DATA))

- Linkmap after 5 steps

(S1012 (DONE (12 2) (0 2) DATA))

(S23 (DONE (3 4) (8 3) DATA))

(T104 (E (12 2) (6 8) DATA))

The statemap records that preference should be given to pkt2 if there is a tie in the next step.

(S1012 . T104)

- Linkmap after 6 steps

(S1012 (DONE (12 2) (6 8) DATA))

Proof Properties

- Reachability: Every information source can send data to every destination.

- Diameter: The number of steps that the communication from source to destination will take

```
(defun update-link (junct dest lt st g)        "Calculates update for the next link"
  (let* ((outlink (outlink-lookup junct dest g)))
     (if (cdr (assoc-eq outlink lt))
          (if (equal (car (cadr (assoc-eq outlink lt))) 'Done)
              (let ((new-lt (update-alist outlink nil lt)))
               (mv new-lt st))
          (mv lt st))
   (let* ((stack (remove-equal dest (sources junct g)))
          (inputs (current-inputs junct dest stack lt g)))
      (if (endp inputs)
        (mv lt st)
       (let* ((result (mv-list 2 (oracle outlink inputs st)))
              (input (car result))
              (new-st (cadr result)))
        (if (atom (cdr (assoc-eq input lt)))
             (mv nil nil)
         (let* ((pkt (cadr (assoc-eq input lt)))
                (final (cadr pkt))
                (turn_signal (routing junct dest final g)))
             (if turn_signal
               (let* ((new-pkt (cons turn_signal (cdr pkt)))
                      (new-link-state (update-alist outlink (list new-pkt) lt))
                      (new-lt (update-alist input nil new-link-state)))
                (mv new-lt new-st))
              (mv nil nil)))))))))
```

```
(defun step-junct (junct neighbors lt st g)     "Updates all output links in a junction"
  (if (endp neighbors)
    (mv lt st)
   (let ((dest (car neighbors)))
    (if (junctp dest g)
        (let* ((result (mv-list 2 (update-link junct dest lt st g)))
               (new-lt (car result))
               (new-st (cadr result)))
          (step-junct junct (cdr neighbors) new-lt new-st g))
      (mv nil nil)))))

(defun run (juncts lt st g)     "Updates the Junctions by a step"
  (if (endp juncts)
    (mv lt st)
   (let* ((junct (car juncts))
          (neighbors (sources junct g))
          (result (mv-list 2 (step-junct junct neighbors lt st g)))
          (new-lt (car result))
          (new-st (cadr result)))
    (run (cdr juncts) new-lt new-st g))))
```