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Transferencia confiable, TCP y control de congestión

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Knowledge Checks

Network Layer: Data plane

The network layer - where is it?

All the next statements about where (*in the network*) the network layer is implemented are true

- The network layer is implemented in hosts at the network's edge.
- The network layer is implemented in routers in the network core.

Forwarding versus routing

Consider the travel analogy discussed in the textbook - some actions we take on a trip correspond to forwarding and other actions we take on a trip correspond to routing. The following travel actions correspond to *forwarding*.

- A car stops at an intersection to "gas-up.ªnd take a "bathroom break".
- A car waits at light and then returns left at the intersection.
- A car takes the 3rd exit from a roundabout.

The following travel actions correspond to *routing*

- A car takes highway 80 between New York and Chicago, rather than highway 87 to Albany and from there take interstate 90 to Chicago.
- A traveler decides to fly to Sydney through Singapore rather than Dubai.
- a climber decides to take the South Col Route to the top of Mt Everest rather than the Northeast Ridge route.

The control plane versus the data plane

The following actions are primarily in the network-layer data plane

- Looking up address bits in an arriving datagram header in the forwarding table.
- Dropping a datagram due to a congested (*full*) output buffer.
- Moving an arriving datagram from a router's input port to output port.

The following actions correspond to contro-plane actions

- Monitoring and managing the configuration and performance if an network device.
- Computing the contents of the forwarding table.

What type of control plane?

We've seen that there are two approaches towards implementing the network control plane a per-router control-plane approach and a software-networking (*SDN*) control-plane approach. The following actions occur in a per-router control-plane approach

- Routers send information about their incoming and outgoing links to other routers in the network.
- A router exchanges messages with another router, indicating the cost for it (*the sending router*) to reach a destination host.

These actions correspond to actions in an SDN control plane

- All routers in the network send information about their incoming and outgoing links to a logically centralized controller.
- A control agent in router receives a complete forwarding table, which it installs and uses to locally control datagram forwarding.

Best Effort Service

The following quality-of-service guarantees are part of the Internet's best-effort service model

- The best-effort service really means no *guarantees* at all!

Network Layer: Control plane

What's a "good"path?

What is the definition of a "good"path for a routing protocol? Rounting algorithms typically work with abstract link weights that could represent any of, or combinations of, all of the other answers.

Dijkstra's Link-State routing algorithm

Consider Dijkstra's link-state routing algorithm that is computing a least-cost path from a node a to other nodes b, c, d, e, f. The following statements are true

- The values computed in the vector D(v), the currently known least cost of a path from a to any node v, will never increase following in iteration.
- In the initilization step, the initial cost from a to each of these destinations is initialized to either the cost of a link directly connecting a to a direct neighbor, or infinity otherwise.
- Suppose node b, c and d are in the set N'. These nodes will remain in N' for the rest of the algorithm, since the least-cost paths from a to b, c, and d are known.

What type of routing?

Here are the names of a general approach to routing with characteristics of that approach

Centralized, global routing - All routers have complete topology, and link cost information.

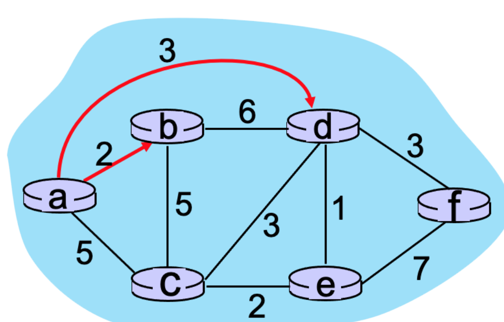
Decentralized routing - An iterative process of computation, exchange of information with neighbors. Routers may initially only know link costs to directly-attached neighbors.

Static routing - Routes change slowly over time.

Dynamic routing - Rounting changes quickly over time.

Dijkstra's link-state routing algorithm (*Part 1*)

Consider the graph shown below and the use of Dijkstra's algorithm to compute a least cost path a to all destinations. Suppose that nodes b and d have already been added to N'. What is the next node to be added to N' (*refer to the text for an explanation of notation*)? **The next node is e**

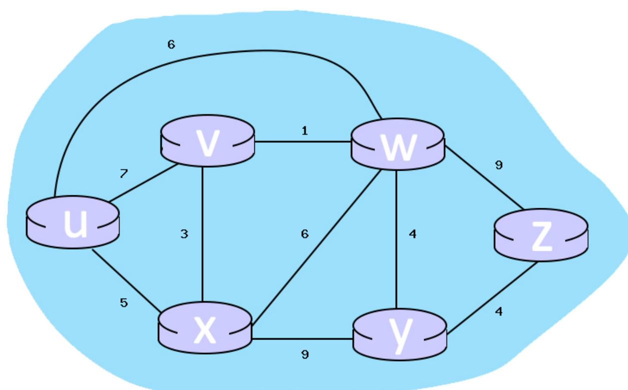


Dijkstra's link-state routing algorithm (*Part 2*)

Consider the graph previously shown and the use of Dijkstra's algorithm to compute a least cost path from a to all destinations. Suppose that b and d have already been added to N'. What is the path cost to the next node to be added to N' (*refer to the next for an explanation of notation*)? **The path cost is 4**

Dijkstra's link state algorithm (*for computing least cost paths*)

Consider the 6-node network shown below, with the given link costs. Using Dijkstra's algorithm, find the least cost path from source node U to all other destinations



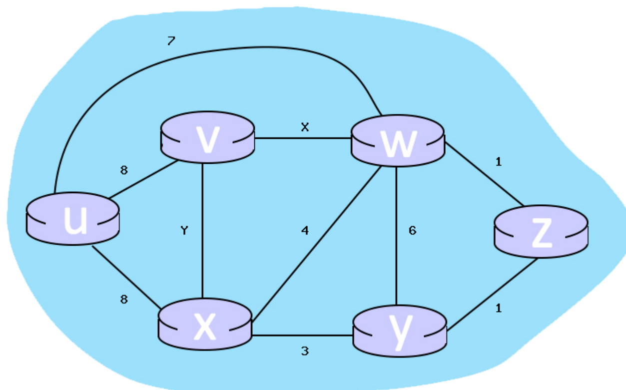
What is the shortest distance to node v and what node is its predecessor?
The answer is: 7, u.

What is the shortest distance to node y and what node is its predecessor?
The answer is: 10, w.

What is the shortest distance to node w and what node is its predecessor?
The answer is: 6, u.

Dijkstra's link state algorithm - advanced

Consider the incomplete 6-node network shown below, with the given link costs



Consider the completed table below, which calculates the shortest distance to all node from X:

Node	Shortest distance from X	Previous Node
X	0	n/a
Y	3	X
W	4	X
Z	4	Y
V	7	X
U	8	X

For link X, what is the cost associated with this link? The answer is: n/a.

For link Y, what is the cost associated with this link? The answer is: 7.

Link Layer

Link-layer services

The following services may be implemented in a link-layer protocol?

- Flow control between directly connected nodes.
- Multiplexing down from / mutiplexing up to a network-layer protocol.
- Reliable data transfer between directly connected nodes.
- Coordinated access to a shared physical medium.
- Bit-level error detection and correction.

Two dimensional parity

The following statements are true about a two-dimensional parity check (*2D-parity*) computed over a payload

- 2D-parity can detect any case of two bit flips in the payload.
- 2D-parity can detect any case of a single bit flip in the payload.
- 2D-parity can detect and correct any case of a single bit flip in the payload.

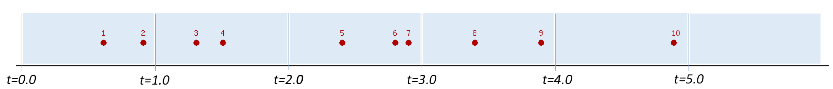
Pure Aloha and CSMA

The following statements are true about Pure ALOHA, and CSMA (*both with and without collision detection*)

- Pure Aloha and CSMA can achieve 100 % utilization, in the case that there is only one node that always has frames to send.
- There can be simultaneous transmissions resulting in collisions.

Multiple Access Protocols: Collisions

Consider the figure below, which shows the arrival of 10 messages for transmission a different multiple access wireless nodes at times $t = \langle 0{,}6, 0{,}9, 1{,}3, 1{,}5, 2{,}4, 2{,}8, 2{,}9, 3{,}4, 3{,}9, 4{,}9 \rangle$ and each transmission requires exactly one time unit



- ALOHA
  - **Suppose all nodes are implementing the Aloha protocol. For each message, indicate the time at which each transmission begins** The answer is: 0.6,0.9,1.3,1.5,2.4,2.8,2.9,3.4,3.9,4.9.
  - **Which messages transmit succesfully?** The answer is: 10.
- SLOTTED-ALOHA
  - **Suppose all nodes are implementing the Slotted Aloha protocol. For each message, indicate the time at which each transmission begins** The answer is: 1,1,2,2,3,3,3,4,4,5.
  - **Which messages transmit succesfully?** The answer is: 10.

- CSMA

  - **Suppose all nodes are implementing Carrier Sense Multiple Access (*CSMA*), but whitout collision detection. Suppose that the time from when a message transmission begins until it is beginning to be received at other nodes is 0.4 time units. (*Thus if a node begins transmitting a message at t=2.0 and transmits that message until t=3-0, then any node performing carrier sensing in the interval [2.4, 3.4] will sense the channel busy.*) For each message, indicate the time at which each message transmission begins, or indicate that messge transmission does not begin due to a channel that is sensed busy when that message arrives.** The answer is: 0.6,0.9,s,s,2.4,s,s,s,3.9,s.
  - **Which messages transmitted succesfully?** The answer is: 5, 9.

- CSMA-CD

  - **Suppose all nodes are implementing Carrier Sense Multiple Access (*CSMA*), with collision detection (*CSMA/CD*). Suppose that the time from when a message transmission begins until it is beginning to be received at other nodes is 0.4 time units, and assume that a node can stop transmission instantaneously when a message collision is detected. (*Thus if a node begins transmitting a message at t=2.0 and transmits that message until t=3.0, then any node performing carrier sensing in the interval [2.4, 3.4] will sense the channel busy.)* For each message, indicate the time at which each message transmission begins, or indicate that message transmission does not begin due to a channel that is sensed busy when that message arrives.** The answer is: 0.6,0.9,s,s,2.4,s,s,s,3.9,s.
  - **Which messages transmit succesfully?** The answer is: 5, 9.

Encaminamiento por vector-distancia, direccionamiento IP y detección de errores con CRC

1. Aplique el algoritmo de encaminamiento de vector-distancia a la siguiente topología de red.

    a) Indique el estado de las tablas de ruteo para las etapas de cold-start y luego para el envío de los primeros dos mensajes.

    Tablas de rutio para la etapa cold-start

From A to	Link	Cost
A	local	0

From B to	Link	Cost
B	local	0

From C to	Link	Cost
C	local	0

From D to	Link	Cost
D	local	0

From E to	Link	Cost
E	local	0

From F to	Link	Cost
F	local	0

Tablas de ruteo suponiendo que A inicia con el envío de mensajes

From A to	Link	Cost
A	local	0

From B to	Link	Cost
B	local	0
A	1	1

From C to	Link	Cost
C	local	0
A	3	1

From D to	Link	Cost
D	local	0
A	4	1

From E to	Link	Cost
E	local	0

From F to	Link	Cost
F	local	0

Tablas de ruteo suponiendo que B es el segundo nodo en enviar mensaje

From A to	Link	Cost
A	local	0
B	1	1

From B to	Link	Cost
B	local	0
A	1	1

From C to	Link	Cost
C	local	0
A	3	1
B	2	1

From D to	Link	Cost
D	local	0
A	4	1

From E to	Link	Cost
E	local	0

From F to	Link	Cost
F	local	0

b) Luego, indique el estado de las tablas de ruteo para el estado estacionario.

Para llegar a esta tabla se considero el orden alafabético para el envío de mensajes

From A to	Link	Cost
A	local	0
B	1	1
C	3	1
D	4	1
E	3	2
F	3	2

From B to	Link	Cost
B	local	0
A	1	1
C	2	1
D	1	2
E	2	2
F	2	2

From C to	Link	Cost
C	local	0
A	3	1
B	2	1
D	5	2
E	5	1
F	6	1

From D to	Link	Cost
D	local	0
A	4	1
B	4	2
C	7	2
E	7	1
F	7	2

From E to	Link	Cost
E	local	0
A	5	2
B	5	2
C	5	1
D	7	1
F	8	1

From F to	Link	Cost
F	local	0
A	6	2
B	6	2
C	6	1
D	8	2
E	8	1

c) Una vez alcanzado el estado estacionario , el enlace 6 se rompe. Describa la manera en cómo procede el protocolo hasta retomar un nuevo estado estacionario.

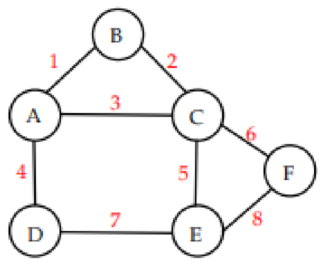
Lo primero que hace el protocolo es actualizar las tablas de ruteo de los nodos que se encuentran en los extremos del enlace 6. El costo que se actulizará con el valor *"Infinito"*. Con las tablas de ruteo actualizadas los nodos notifican a sus vecinos sobre el cambio en tabla de ruteo. Los vecinos, al recibir esta actualización, ajustan sus propias tablas de ruteo y recalculan las rutas alternativas utilizando la información que tienen de otros vecinos.

d) ¿Qué fenómeno podría causar un bucle de ruteo?

Es el problema *"Conteo a infinito"*, esto ocurre cuando un enlace falla y los nodos tardan mucho en actualizar correctamente sus tablas de ruteo, propagando información errónea de forma indefinida o por un tiempo prolongado. Esto puede llevar a bucles de ruteo.

e) Finalmente, ¿cuál protocolo en la práctica implementa el algoritmo de vector-distancia? ¿cuál es la frecuencia de los mensajes de refresco y cuál es la finalidad de los mismos?

En la práctica, el protocolo que implementa el algoritmo de vector-distancia es el **Routing Information Protocol *RIP***. Los mensajes de refresco se envían cada 30 segundos. La finalidad de estos mensajes es mantener la consistencia de las tablas de enrutamiento en toda la red.



2. Suponga que le han asignado el bloque de red 132.46.0.0/16 y que necesita configurar ocho subredes.

a) ¿Cuántos dígitos binarios se requieren para definir ocho subredes?

Recordando que el número de dígitos necesarios vienen en potencias de dos, y que se requieren configurar ocho subredes. Necesitamos $2^3 = 8$, es decir que necesitamos **tres dígitos binarios**.

b) Especifique el prefijo de red extendido que permite la creación de las 8 subredes.

Sabemos que el prefijo de red es de 16 dígitos y vamos a tomar tres dígitos prestados. Por lo que el prefijo de red extendido será **/19**.

c) Exprese las direcciones de subred en formato binario y decimal.

Red de base: 132.46.0.0/16

Subred #0 : 10000100.00101110.00000000.00000000 = 132.46.0.0/19
Subred #1 : 10000100.00101110.00100000.00000000 = 132.46.32.0/19
Subred #2 : 10000100.00101110.01000000.00000000 = 132.46.64.0/19
Subred #3 : 10000100.00101110.01100000.00000000 = 132.46.96.0/19
Subred #4 : 10000100.00101110.10000000.00000000 = 132.46.128.0/19
Subred #5 : 10000100.00101110.10100000.00000000 = 132.46.160.0/19
Subred #6 : 10000100.00101110.11000000.00000000 = 132.46.192.0/19
Subred #7 : 10000100.00101110.11100000.00000000 = 132.46.224.0/19

d) Enliste el rango de direcciones IP que pueden asignarse a la subred número 4.

La subred número 4 es 132.46.128.0/19. El rango de direciones será:

- Primer dirección : 132.46.128.1
- Última dirección : 132.46.159.254

e) ¿Cuál es la dirección de difusión (*broadcast*) de la subred número 4?

La dirección de difusión de la subred número 4 es **132.46.159.255**.

3. Suponga que se le ha asignado el bloque de direcciones de red 200.30.1.0/24.

a) Defina un prefijo de red extendido que permita crear 20 estaciones en cada subred.

Para tener 20 estaciones en cada subred, necesitamos usar 5 bits para la subred, ya que $2^5 = 32$. Esto significa que usaremos un prefijo de **/29**

b) ¿Cuál es el número máximo de estaciones que pueden asignarse a cada subred?

Con 5 bits para cada subred, tenemos **30** direcciones útiles por subred. Ya que $2^50 = 32$ y excluimos la dirección de red y la de difusión.

c) ¿Cuál es el número máximo de subredes que pueden definirse?

Usando 5 bits podemos tener $2^5 = 32$ subredes en total.

d) Especifique las subredes de 200.30.1.0/24 en formatos binario y decimal.

Red de base: 200.30.1.0/24

$$
\begin{aligned}
\text{Subred } \#0 &: 11001000.00011110.00000001.00000000 = 200.30.1.0/29 \\
\text{Subred } \#1 &: 11001000.00011110.00000001.00001000 = 200.30.1.8/29 \\
\text{Subred } \#2 &: 11001000.00011110.00000001.00010000 = 200.30.1.16/29 \\
\text{Subred } \#3 &: 11001000.00011110.00000001.00011000 = 200.30.1.24/29 \\
\text{Subred } \#4 &: 11001000.00011110.00000001.00100000 = 200.30.1.32/29 \\
\text{Subred } \#5 &: 11001000.00011110.00000001.00101000 = 200.30.1.40/29 \\
\text{Subred } \#6 &: 11001000.00011110.00000001.00110000 = 200.30.1.48/29 \\
\text{Subred } \#7 &: 11001000.00011110.00000001.00111000 = 200.30.1.56/29 \\
\text{Subred } \#8 &: 11001000.00011110.00000001.01000000 = 200.30.1.64/29 \\
\text{Subred } \#9 &: 11001000.00011110.00000001.01001000 = 200.30.1.72/29 \\
\text{Subred } \#10 &: 11001000.00011110.00000001.01010000 = 200.30.1.80/29 \\
\text{Subred } \#11 &: 11001000.00011110.00000001.01011000 = 200.30.1.88/29 \\
\text{Subred } \#12 &: 11001000.00011110.00000001.01100000 = 200.30.1.96/29 \\
\text{Subred } \#13 &: 11001000.00011110.00000001.01101000 = 200.30.1.104/29 \\
\text{Subred } \#14 &: 11001000.00011110.00000001.01110000 = 200.30.1.112/29 \\
\text{Subred } \#15 &: 11001000.00011110.00000001.01111000 = 200.30.1.120/29 \\
\text{Subred } \#16 &: 11001000.00011110.00000001.10000000 = 200.30.1.128/29 \\
\text{Subred } \#17 &: 11001000.00011110.00000001.10001000 = 200.30.1.136/29
\end{aligned}
$$

Subred #18 : 11001000.00011110.00000001.10010000 = 200.30.1.144/29
Subred #19 : 11001000.00011110.00000001.10011000 = 200.30.1.152/29
Subred #20 : 11001000.00011110.00000001.10100000 = 200.30.1.160/29
Subred #21 : 11001000.00011110.00000001.10101000 = 200.30.1.168/29
Subred #22 : 11001000.00011110.00000001.10110000 = 200.30.1.176/29
Subred #23 : 11001000.00011110.00000001.10111000 = 200.30.1.184/29
Subred #24 : 11001000.00011110.00000001.11000000 = 200.30.1.192/29
Subred #25 : 11001000.00011110.00000001.11001000 = 200.30.1.200/29
Subred #26 : 11001000.00011110.00000001.11010000 = 200.30.1.208/29
Subred #27 : 11001000.00011110.00000001.11011000 = 200.30.1.216/29
Subred #28 : 11001000.00011110.00000001.11100000 = 200.30.1.224/29
Subred #29 : 11001000.00011110.00000001.11101000 = 200.30.1.232/29
Subred #30 : 11001000.00011110.00000001.11110000 = 200.30.1.240/29
Subred #31 : 11001000.00011110.00000001.11111000 = 200.30.1.248/29

e) Enliste las direcciones de estación que pueden asignarse a la subred 6.

La subred número 6 es 200.30.1.48/29. El rango de direciones será:

- Primer dirección : 200.30.1.49
- Última dirección : 200.30.1.54

f) ¿Cuál es la dirección de difusión para la subred 2?

La dirección de la subred 2 es 200.30.1.16/29 por lo tanto la dirección de difusión es **200.30.1.23**.

4. Se le ha asignado a una organización el número de red 140.20.0.0/16 y ésta planea desarrollar VLSM. En el primer nivel de jerarquía, se necesitan configurar ocho subredes. La subred 1 necesita configurar 32 sub-redes y la subred 6 necesita configurar 16 sub-redes. Finalmente, la sub-red 6-14 necesita configurar 8 $sub^2 - subredes$.

a) Dibuje el árbol que ilustre la jerarquía necesaria para implementar VLSM.

b) Especifique las ocho subredes 140.20.0.0/16.

c) Enliste las direcciones de estación que pueden asignarse a la subred 3.

d) Indique la dirección de difusión de la subred 3.

e) Indique las 16 sub-redes de la subred 6.

f) Enliste las direcciones de estación que pueden asignarse a la sub-subred 6-3.

g) Indentifique la dirección de broadcast para la sub-subred 6-3.

h) Especifique las ocho $sub^2 - subredes$ de la sub-subred 6-14.

i) Enliste las direcciones de estación que pueden asignarse en la $sub^2 - subred$ 6-14-2.

j) Indentifique la dirección de broadcast de la $sub^2 - subred$ 6-14-2.

5. En el nivel de enlace de datos se utiliza frecuentemente el mecanismo de verificación de redundancia cíclica (*CRC: Cyclic Redundance Check*) para que una interfaz receptora concluya sobre si la trama recibida, T' contiene o no errores. Suponga que el mensaje a transmitir es $M = 1101011011$ y que el generador es $G = 10011$.

   a) Encuentre la trama, T que envía el transmisor.

   b) Realice la operación que ejecuta la interfaz receptora si el patrón de error inducido en el canal $e = 00000000000000$, ¿cuál es la conclusión del receptor?

   c) Realice lo mismo que en (b), pero ahora con un error inducido en el canal físico $e = 00100000010011$, ¿cuál es la conclusión del receptor?

   d) ¿Existe la posibilidad de que habiendo errores en T', la trama recibida, el receptor sea incapaz de detectarlos? Explique.

   e) Finalmente, realice (a)-(c) operando polinimialmente.