ALOHA PROTOCOL, GRAPH ... 6Q
Distance Vector, Count to inf, good/bad news ... 5Q
Adaptive Dynamic Modulation, SNR, BER, Modulation, Graph ... 3Q

DOCSICS
Wireless Link Characteristics
Bellman-Ford Equation
CSMA/CD
CSMA/CA
traceroute, ICMP
BGP

Routing Protocols

goal: detemine good path from sender to reciever.
least cost, fastest, least congested.

Classification

- global information : all routers have complete topology, link cost info ... link State
- decentralized information : routers know physically-connected neighbors, link cost to neighbors. iterative process of computation, exchange of info with neighbors ... distance vector algorithm

- static : update info slowly routes change slowly
- dynamic : update info quickly. routes change quickly.

Bellman-Ford Equation (dynamic programming)

$$d_x(y) = \min_v \{ c(x,v) + d_v(y) \}$$

$d_x(y)$ = cost of least-cost path from x to y.
$\min_v$ ⇒ all neighbors v of x
$c(x,v)$ ⇒ cost of direct edge to neighbor v
$d_v(y)$ ⇒ cost from neighbor v to destination y.

Distance Vector algorithm.

$D_x(y)$ estimate of least cost from x to y
x maintains distance vector $D_x = [D_x(y) : y \in N]$

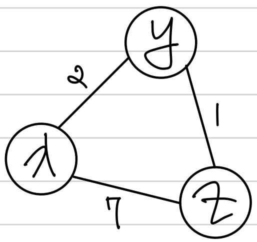
node x knows cost to each neighbor v : $c(x,v)$
maintains its neighbors' distance vectors, $D_v = [D_v(y) : y \in N]$ for each neighbor v

key idea from time-to-time, each node sends its own distance vector estimate to neighbors
when node x receives new DV estimate from neighbor, it updates its own DV using Bellman-Ford equation.

$\Rightarrow$ estimate $D_x(y)$ converge to actual least cost $d_x(y)$

iterative, asynchronous distributed local link cost change, DV update message from neighbor.
each node notifies neighbors only when its DV changes.

wait for changes in local link cost or message from neighbor
↓
recompute estimates
↓
if DV to any destination has changed, notify neighbors.



from \ to	x	y	z
x	0	2	7
y			
z			

7 or 2+1

from \ to	x	y	z
x	0	2	3
y	2	0	1
z	7	1	0

from \ to	x	y	z
x	0	2	3
y	2	0	1
z	3	1	0

from \ to	x	y	z
x			
y	2	0	1
z			

from \ to	x	y	z
x	0	2	7
y	2	0	1
z	7	1	0

from \ to	x	y	z
x	0	2	3
y	2	0	1
z	3	1	0

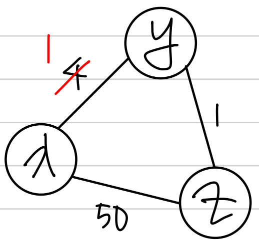
from \ to	x	y	z
x			
y			
z	7	1	0

from \ to	x	y	z
x	0	2	7
y	2	0	1
z	3	1	0

7 or 1+2

from \ to	x	y	z
x	0	2	3
y	2	0	1
z	3	1	0

Distance Vector algorithm.



link cost changes : $\boxed{\text{good news travels fast}}$

node detects local link cost change

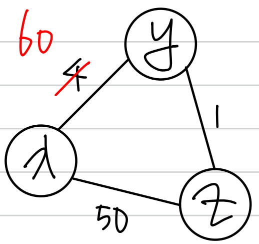
update routing info, recalculates distance vector

if DV changes, notify neighbors.

t_0 : y detects link-cost change, updates its DV, inform its neighbors.

t_1 : z receives update from y, updates its table, compute new least cost to x.
send its neighbors its DV.

t_2 : y receives z's update, updates its distance table.
y's least cost do not change, y doesn't send send a message to z.



link cost changes : $\boxed{\text{bad news travels slow}}$ ··· count to infinity.

node detects local link cost change.

Before change : $D_y(x) = 4$. $D_z(x) = 5$.

After change : $c(x,y) = 60$.

t_0 : $D_y(x) = \min\{60,\ 1+5\} = 6$

t_1 : $D_z(x) = \min\{50,\ 1+6\} = 7$

t_2 : $D_y(x) = \min\{60,\ 1+7\} = 8$

t_3 : $D_z(x) = \min\{50,\ 1+8\} = 9$

⋮

t_{44} : $D_y(x) = \min\{60,\ 1+49\} = 50$

t_{45} : $D_z(x) = \min\{50,\ 1+50\} = 50$

t_{46} : $D_y(x) = \min\{60,\ 1+50\} = 51$

⇒ 44 iterations

poisoned reverse

if z routes through y to get to x : z tells y z's distance to x is infinite
⇒ y will not route to x via z.

$D_z(x) = \min(50,\ c(z,y) + D_y(x))$, advertise $D_z(x) = \text{inf}$. to only y.

$D_y(x) = \min(60,\ 1+\text{inf}) = 60$.

$D_z(x) = \min(50,\ 60+1) = 50$

$D_y(x) = \min(60,\ 50+1) = 51$

$D_z(x) = \min(50,\ 51+1) = 50$

Internet inter-AS routing : BGP

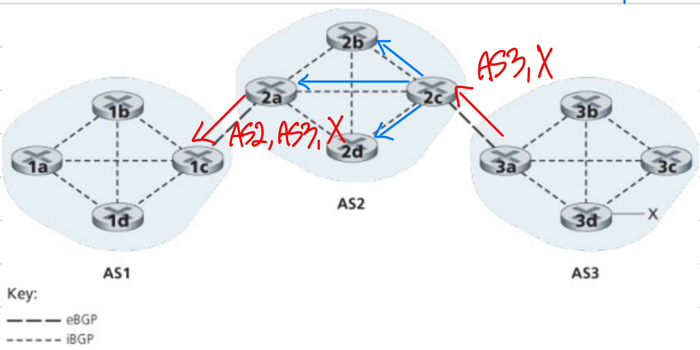
Border Gateway Protocol — the de facto inter-domain routing protocol ⇒ allow subnet to advertise its existence to rest of internet.

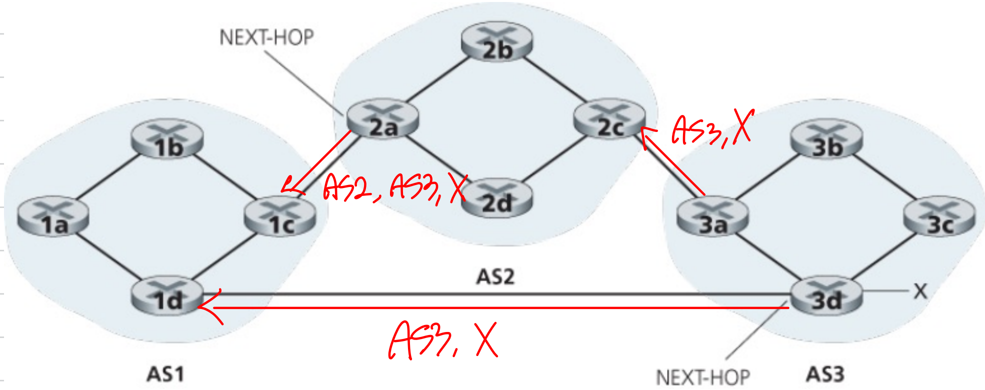
eBGP : obtain subnet reachability info from neighboring ASes.
iBGP : propagate reachability info to all AS-internal routers.
} determine good routes based on reachability info & policy

BGP session — 2 BGP routers exchange BGP messages over semi-permanant TCP connection.

policy based routing — gateway receiving route ads uses import policy to accept/decline path.
AS policy determines whether to advertise path to other neighboring ASes.

Advertisement — advertise prefix + BGP attributes.
(prefix + BGP attributes = route)
- AS-PATH | list of ASes through which prefix advertisement has passed.
- NEXT-HOP | indicates specific internal-AS router to next-hop AS





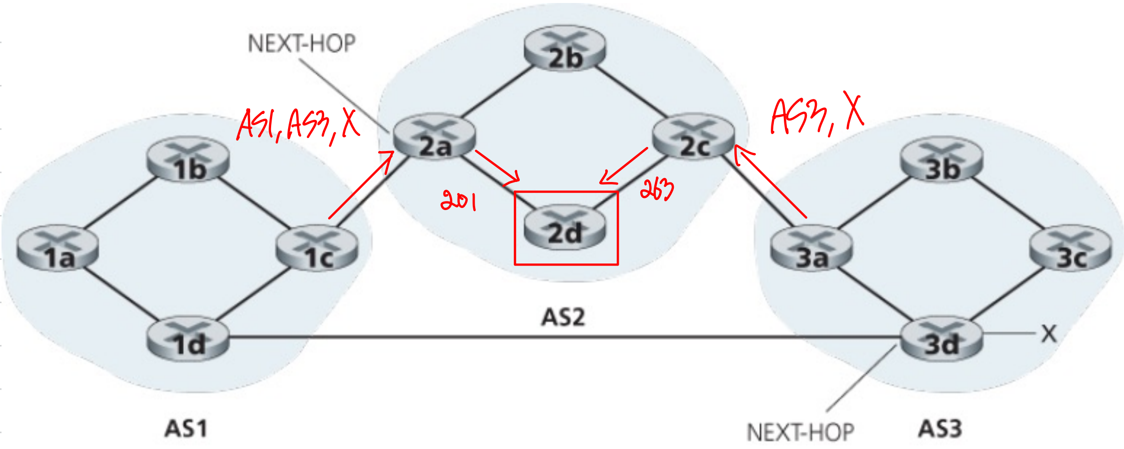
Internet inter-AS routing: BGP

BGP route selection

1. local preference value attribute : policy decision.
2. shortest AS-PATH
3. closest NEXT-HOP router : hot potato routing
4. additional criteria

Hot potato routing

choose local gateway that has least intra-domain cost.



2d-2a = 201, 2d-2c = 263 ⇒ select 2a

Internet Communication Message Protocol, ICMP

ICMP

used by hosts & routers to communicate network-level information

⇒ error reporting, echo request, reply

ICMP message carried in IP datagram payload.

↳ type + code + first 8 bytes of IP datagram causing error.

traceroute

source sends series of UDP segments to destination.

(TTL ++)

nth set datagram arrives nth router

TTL expired

⇒ discard datagram, send source ICMP msg (type 11, code 10, name of router, IP address)

⇒ ICMP msg arrives at source, records RTT.

Stopping criteria

⇒ Eventually UDP segment will arrive at destination host.

⇒ Destination returns ICMP msg (type 3, code 3)

⇒ source stops

dest port unreachable

Slotted ALOHA

assumption

all frames same size, time divided into equal size slots (time to transmit 1 frame)

↳ slot time = L/R. { L = frame size (bit), R = rate (bit per second), 1M = 10^6

node start to transmit only slot begining

nodes are synchronized.

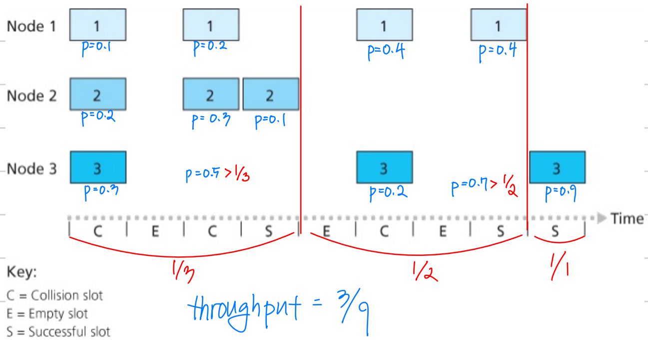
2 or more nodes transmit in slot ⇒ all nodes detect collision.

operation

when node obtains fresh frame, transmits in next slot.

if no collision : node can send new frame in next slot.

if collision : node retransmits frame in each subsequent slow with probability p until success.



pros

- single active node can continuously transmit at full rate of channel
- highly decentralized : only slots in nodes need to be synchronization
- simple

cons

- collisions, wasting slots.
- idle slots
- detect collision > transmit packet
- clock synchronization

efficiency

long-run fraction of successful slots.

$\max_p \{ {}_N C_1 \, p^1 (1-p)^{N-1} \} \Rightarrow p = 1/N$, N nodes with probaility p

max efficiency (throughput) $= \lim_{N\to\infty} N \cdot \frac{1}{N} \left(1-\frac{1}{N}\right)^{N-1} = 1/e = 0.37$

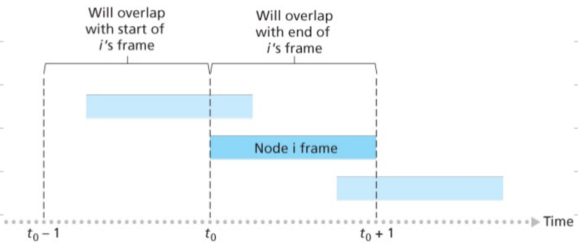
MAC Protocols :

channel partitioning	TDMA, FDMA
random access	ALOHA, CSMA, CDMA

pure ALOHA

no synchronization.

when frame first arrives, transmit immediately.



collision probability increases!

No collision when ± 1 slot transmit start & end

$$p = P(\text{node transmit}) \times P(\text{no transmit } [t_0-1, t_0]) \times P(\text{no transmit } [t_0, t_0+1])$$

$$= p \times (1-p)^{N-1} \times (1-p)^{N-1} = p(1-p)^{2(N-1)} \Rightarrow \max p = 1/2N-1$$

$f(p) = p(1-p)^{2(N-1)}$, efficiency $= \lim_{N\to\infty} f\left(\frac{1}{2N-1}\right) = 1/2e = 0.18$

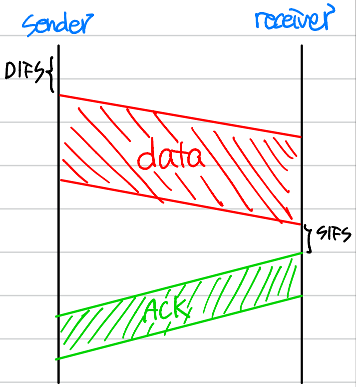
CSMA (Carrier Sense Multiple Access)	Listen before transmit ⇒ if channel sensed idle : transmit entire frame. if " busy : defer transmission
CSMA collision	propagation delay : two nodes may not hear each other's transmission collision : entire packet transmission time wasted. (∵ distance & propagation delay)
CSMA/CD (Collision Detection)	Carrier sensing, deferral as in CSMA. Collision detected within short time. ⇒ colliding transmissions aborted, reducing channel wastage collision detection in wired LAN ⇒ measure signal strength. compare transmitted, received signals collision detection in wireless ⋯ difficult ⇒ received signal strength overwhelemed by local transmission strength.
CSMA/CD Algorithm	1. NIC receives datagram from network layer, creates frame 2. If NIC senses channel idle, starts frame transmission. If " busy, waits until channel idle, then transmit 3. If NIC transmit entire frame without detecting another transmission, Done. 4. If NIC detects another transmission while transmitting, aborts and sends jam signal 5. After aborting, NIC enters binary (exponential) backoff. after mth collision, choose K from $(0 \sim 2^m - 1)$ randomly wait for K × 512 bit times. → return to 2. time to transfer K frames. (1 frame = 512 bit) more collision, longer backoff.

efficiency $= \dfrac{1}{1 + 5 \times \dfrac{t_{prop}}{t_{trans}}}$, t_{prop} = max propagation delay

t_{trans} = time to transmit max-size frame.

efficiency ⇝ 1 $\begin{cases} t_{prop} \rightsquigarrow 0 \\ t_{trans} \rightsquigarrow \infty \end{cases}$

CSMA / CA
Collision Avoidance



802.11 wireless ⇒ multi-access protocol. CSMA → sense before transmitting

⇒ no collision detection ∵ difficult to sense collision when transmitting due to weak received signals. (fading)

hidden terminal, fading ⇒ cannot sense all collisions.

sender. distributed inter-frame space

channel idle for DIFS ⇒ transmit entire frame.

channel busy ⇒ start random backoff timer. transmit after timer out

no ack, longer backoff & repeat

if no ACK, increase random backoff interval, repeat

↳ collision, un-received, crashed frame

receiver

두 노드가 서로 존재 미인식, 동시 전송인한 충돌.

received frame ok ⇒ return ACK after SIFS. (∵ hidden terminal)

short inter-frame space

avoiding collisions ⇒ avoid data frame collisions completely using small reservation packets.

allow sender to reserve channel rather than random access of data frames

⇒ avoid collisions of long data frames.

1. sender → Base Station (RTS, request-to-send)

small size packet via CSMA

RTS ⇒ collision possible, but short.

2. BS → CTS (clear-to-send) broadcast.

3. received CTS

sender : send data frame

others : defer transmission.

hidden tremial problem : B-A hear each other

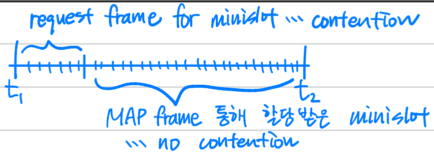
B-C hear each other

A-C cannot hear each other means A & C unaware of their interference at B.

⇒ cannot detect collision

DOCSIS | data over cable service interface spec

MAP frame for $[t_1, t_2]$



FDM : upstream, downstream ⇒ different frequency channel. parallel

TDM : upstream ⇒ time slot : some assigned, some contended

downstream MAP frame : assign upstream slots ··· MAP frame이 downstream 통해 전달. 각 upstream time slot 사용자 지정

request for upstream slots (data) transmitted random access (binary backoff) in selected slots

upstream : FDM, TDM, random access

downstream : FDM.

Wireless Link Characteristics

difference signal strength : radio signal attenuates as it propagates through matter (path loss)

interference from other sources : standardized wireless network frequencies shared by other devices. device interfere as well

multipath propagation : radio signal reflects off objects ground, arriving at destination at slightly different times.

Dynamic Adaptive Technique

SNR : signal-to-noise ratio

larger SNR : easier to extract signal from noise

BER : bit error ratio

given physical layer : increase power → increase SNR → decrease BER

given SNR : choose physical layer that meets BER requirement, giving highest throughput.

dynamically adapt physical layer. ··· change modulation technique, rate

modulation : mapping bits onto analog waveforms by modifying signal characteristics like amplitude, frequency, phase

more complex modulation ⇒ high throughput + require high SNR.

insufficient SNR → increasing error bit. data loss.

↳ decide robustness, distinguish state of signal using combination of them.

Signal attenuation : B-A hear each other

B-C hear each other

A-C cannot hear each other by interfering at B.