

NETMET 2021-22 class: Geolocation

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Geolocation of internet hosts



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Reasons to geolocate



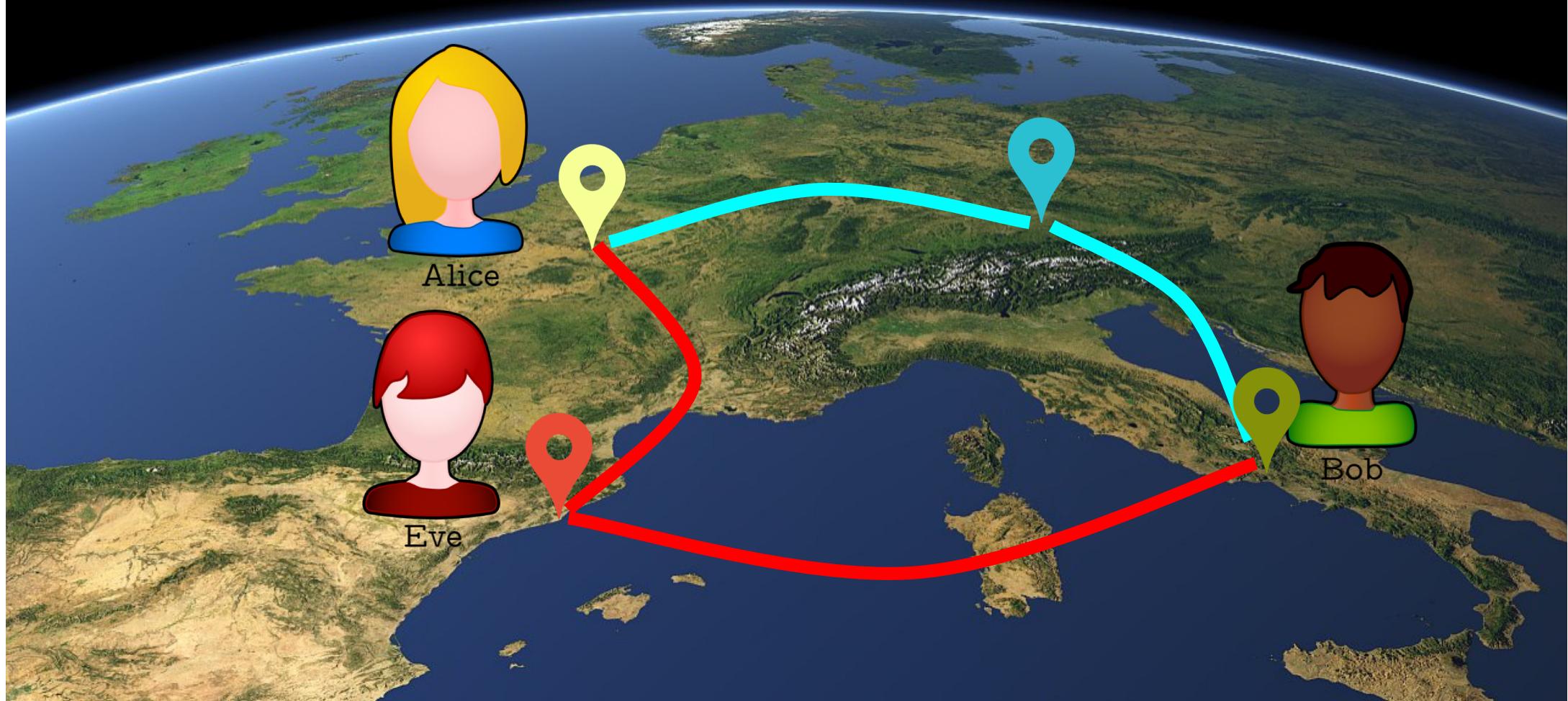
Reasons to geolocate: marketing



Reasons to geolocate: intellectual property rights



Reasons to geolocate: cybersecurity



Ways to geolocate



Ways to geolocate: metadata lookup



Ways to geolocate: RTT measurements



RTT measurements: landmarks and targets



RTT measurements: landmarks and targets

landmarks: known locations



may or may not have measurement capabilities

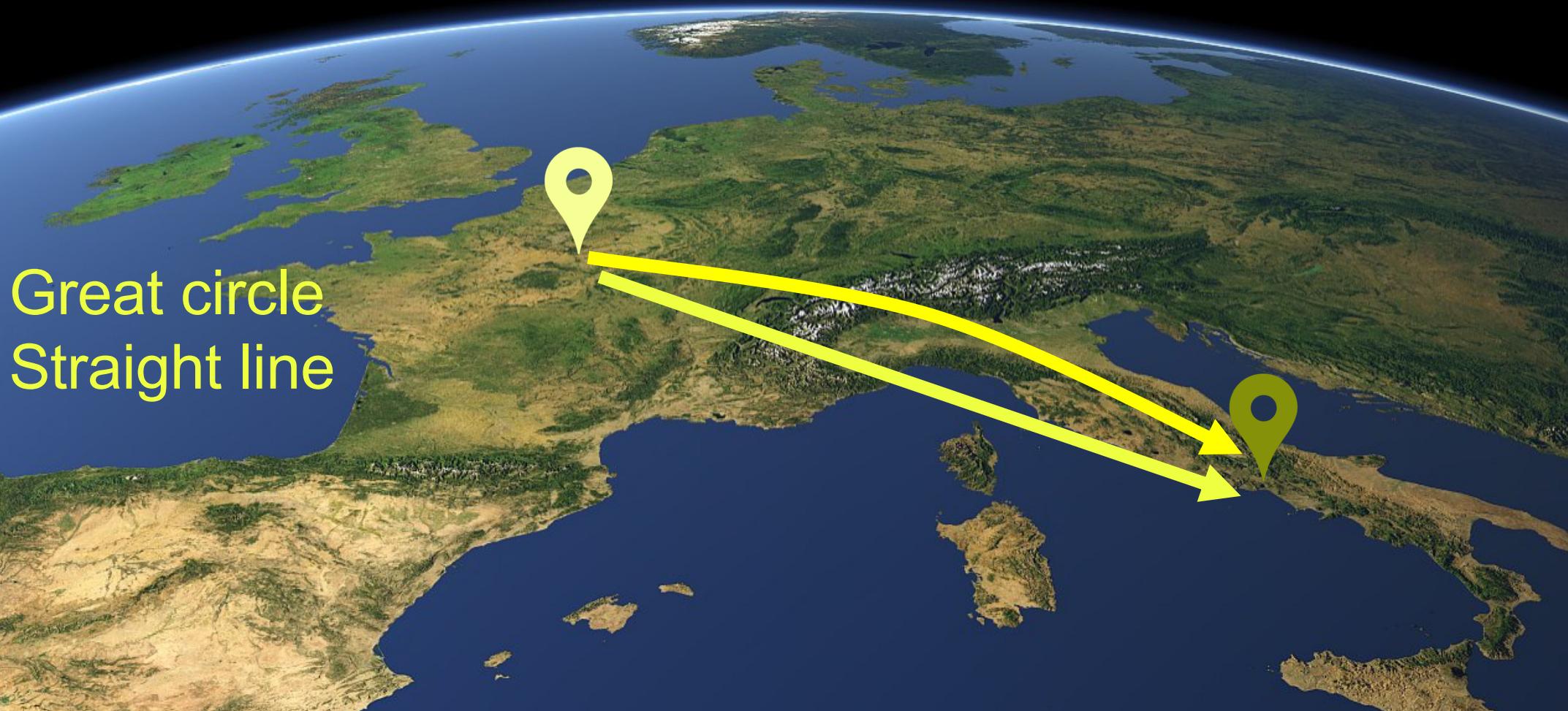


targets: unknown locations

Time-distance relationship



Time-distance relationship



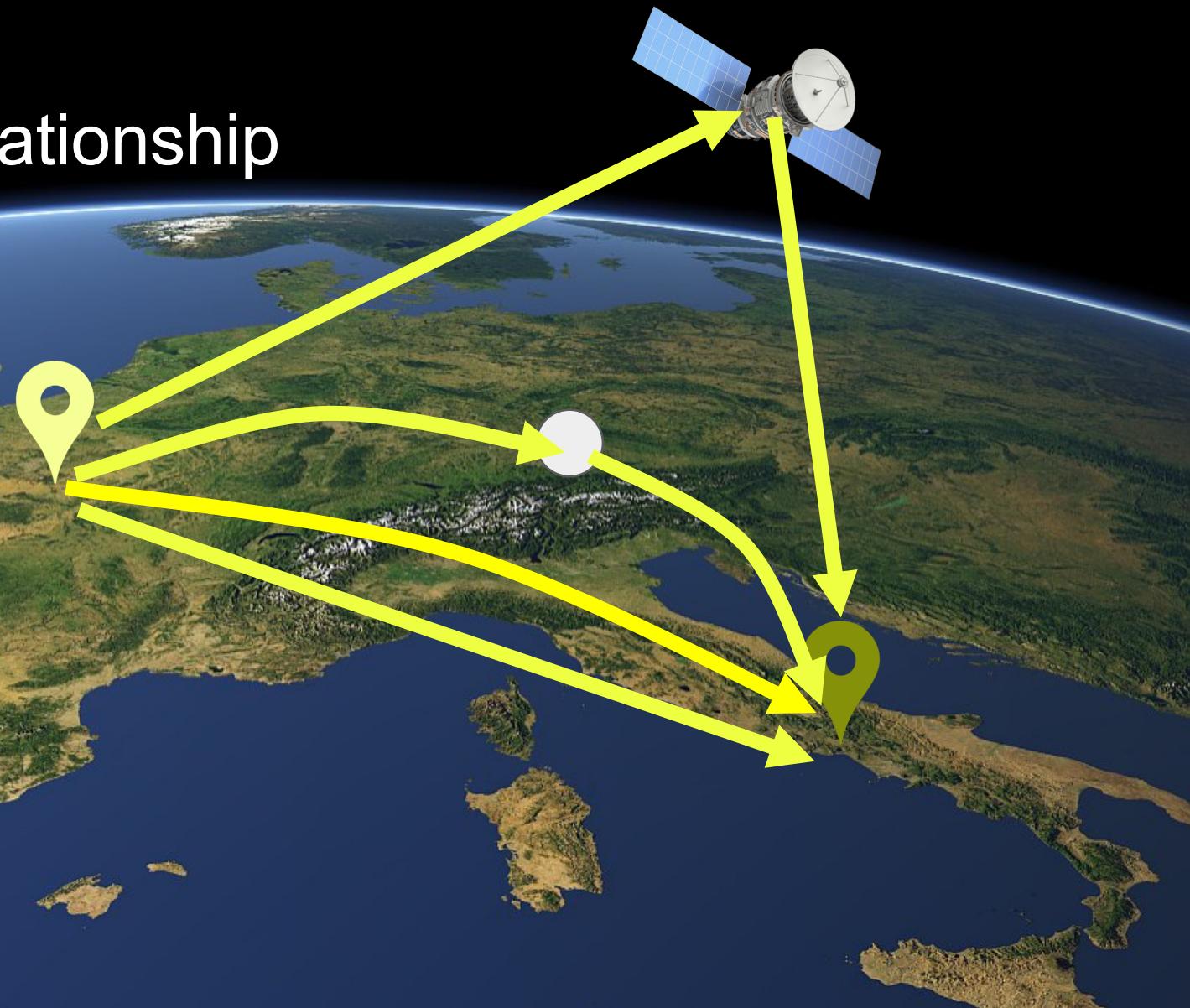
Time-distance relationship

Irregular path
Great circle
Straight line



Time-distance relationship

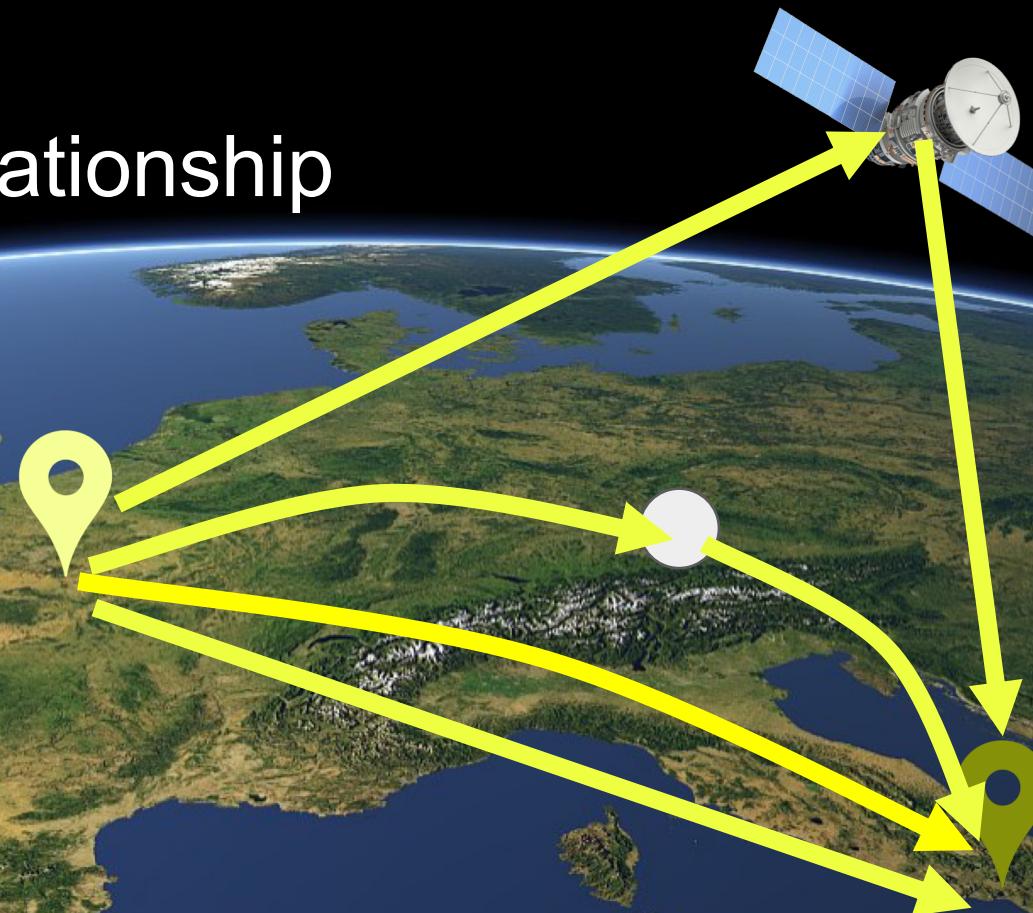
Via satellite
Irregular path
Great circle
Straight line



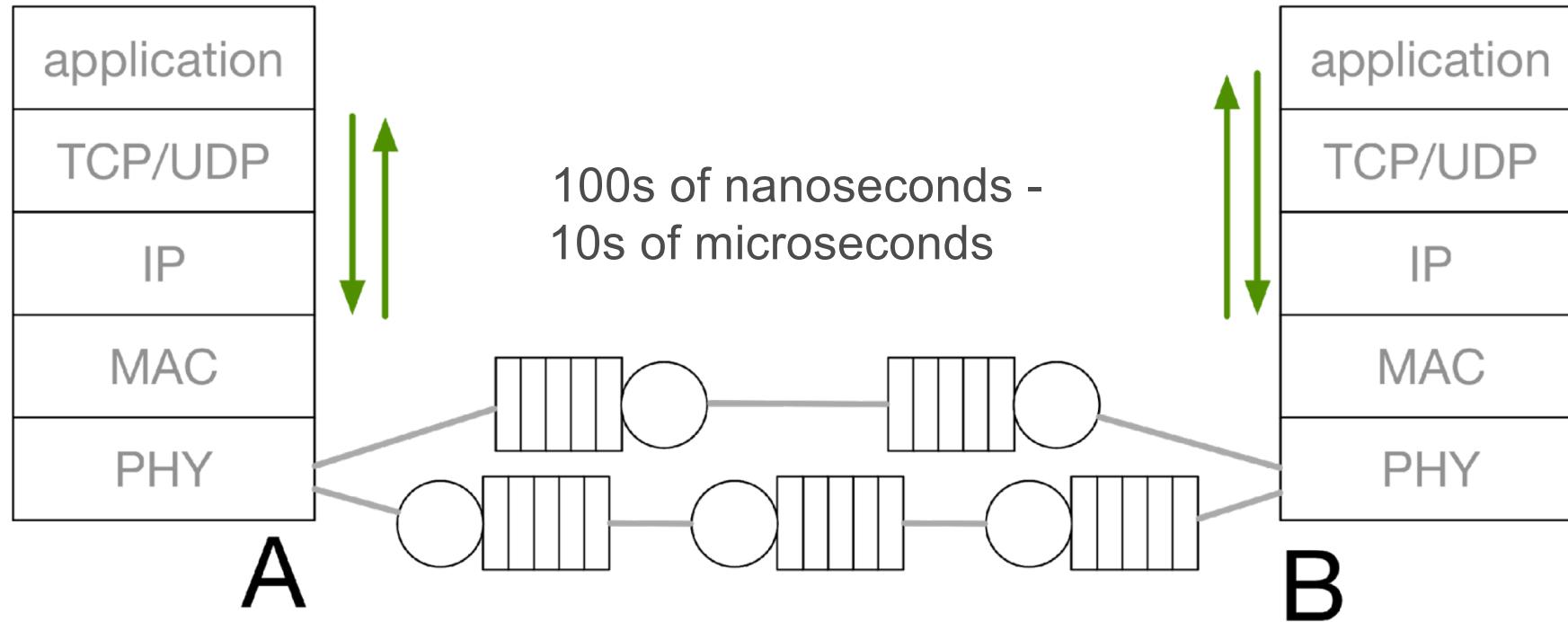
Time-distance relationship

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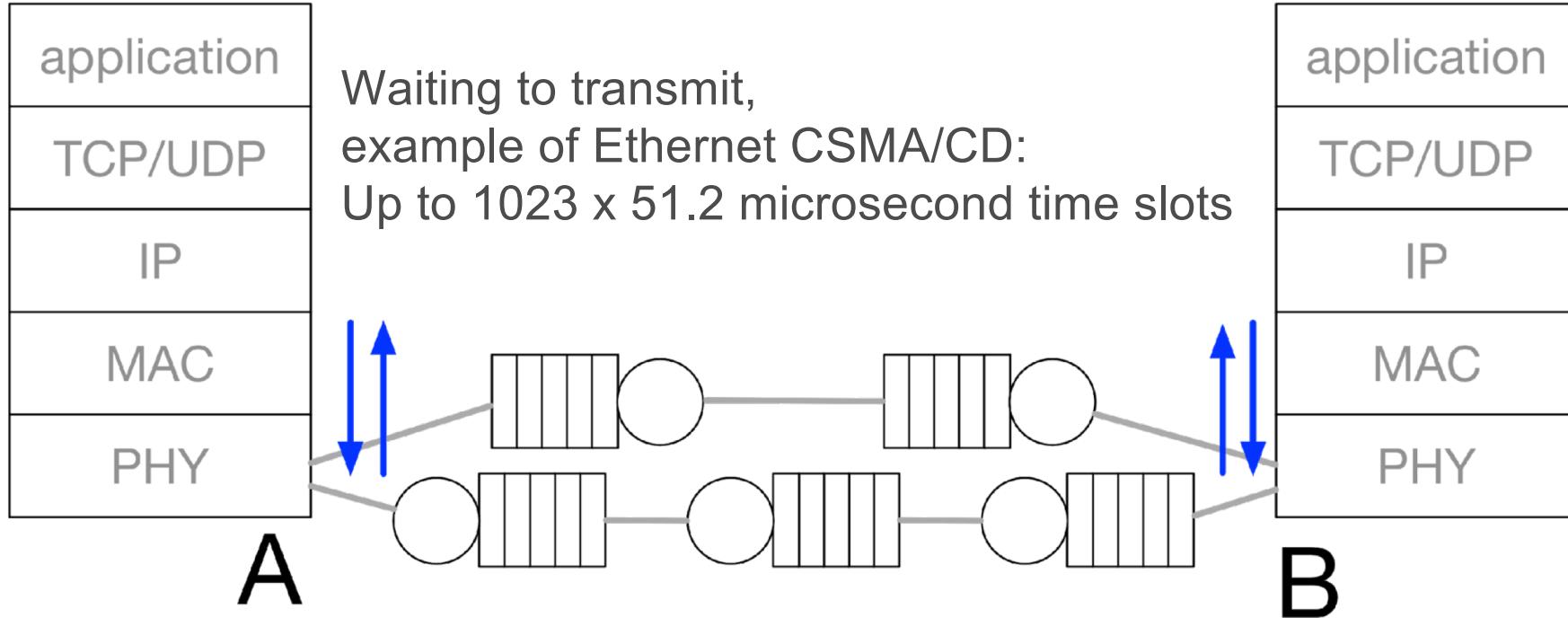
Note: routes might not be symmetric



Non-distance factors: processing delay



Non-distance factors: transmission delay



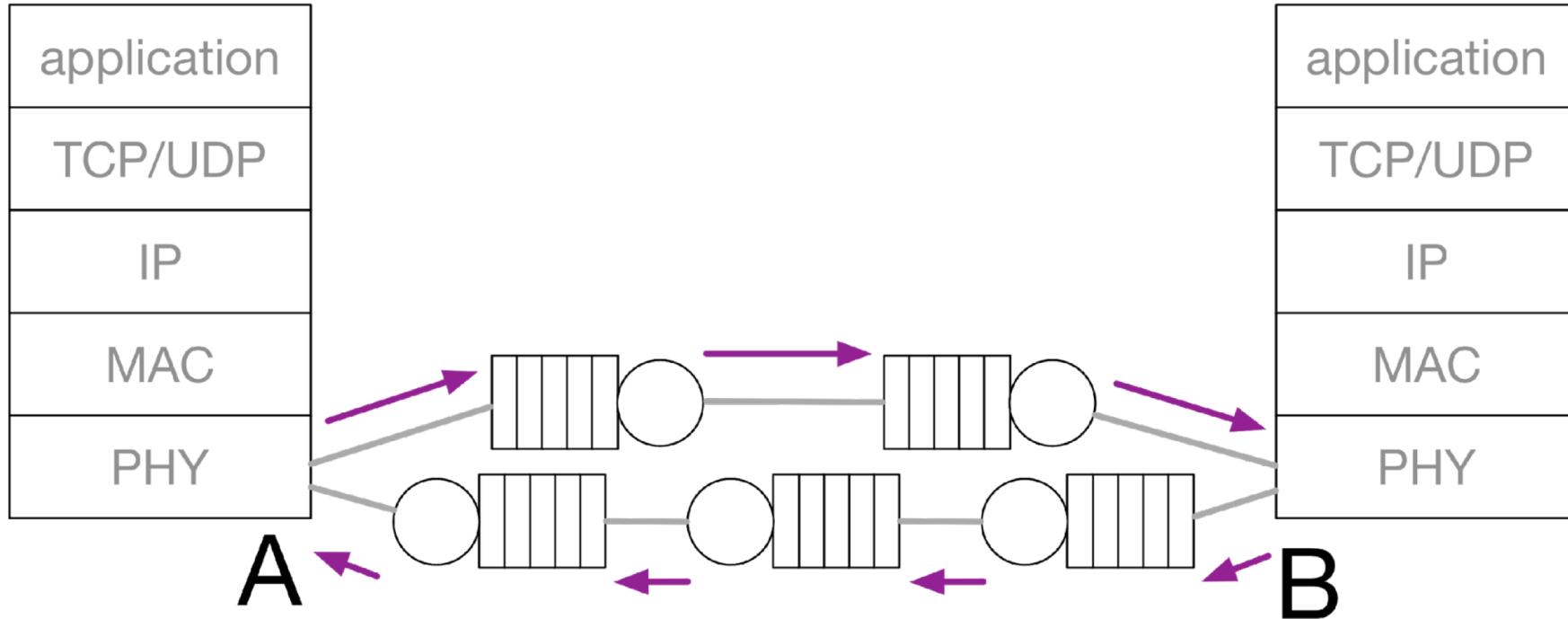
Transmitting:

9216 bytes jumbo Ethernet frame: 74 microseconds at 1 Gbps

1526 byte Ethernet frame: 1.2 milliseconds at 10 Mbps

Likely to be more pronounced at the edge

Non-distance factors: signal speed in medium



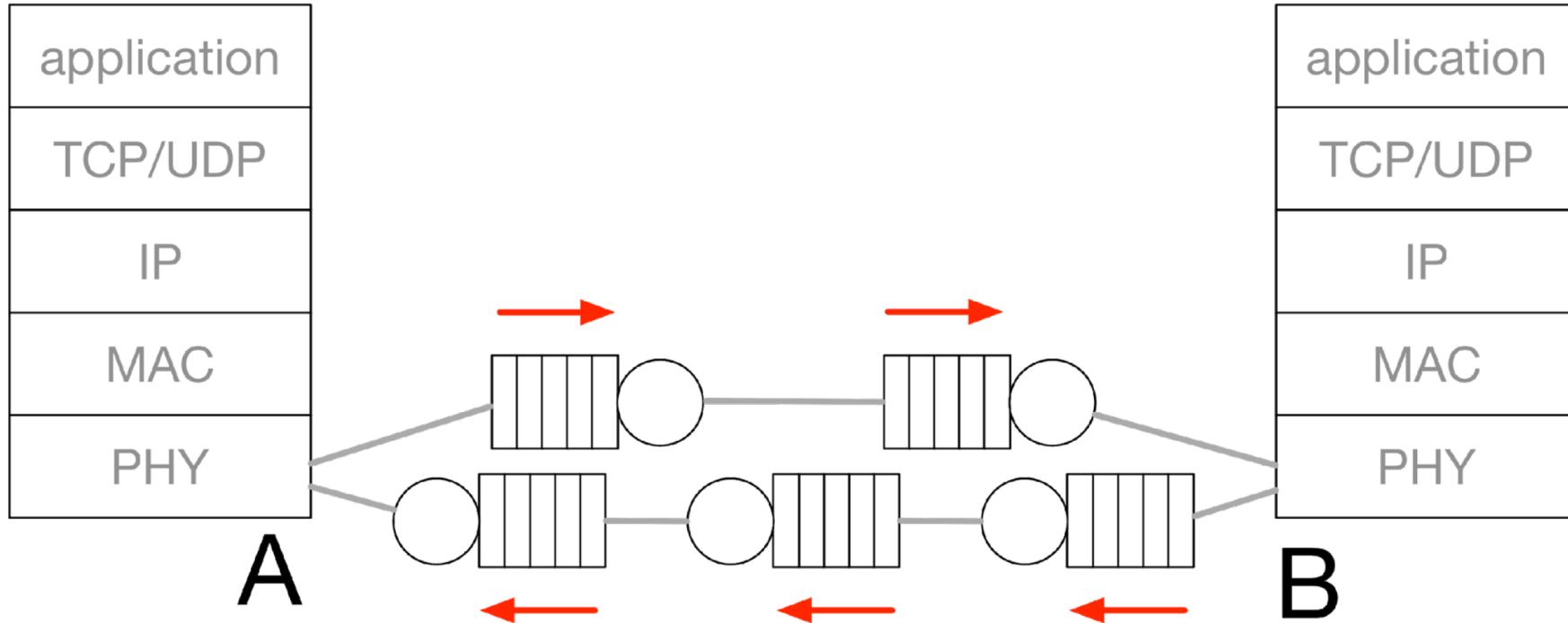
Speed of light: 300,000 km/sec

- To geostationary satellite and back: 240 milliseconds

Optical fiber at 2/3 speed of light

- Milliseconds within country
- 100 milliseconds halfway around the world

Non-distance factors: queueing delay



- Unloaded network: queueing delay almost zero
- Large buffers: 250 milliseconds not unusual,
up to six seconds observed ("bufferbloat")

Likely to be more pronounced at the edge

Closeness: Shortest Ping (Katz-Bassett+, 2006)



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Geolocate X at location of A or location of B



A



B



X

Closeness: Shortest Ping (Katz-Bassett+, 2006)

Geolocate X at location of A or location of B



A



B



X

Compare AX and BX

Choose whichever is shorter

Closeness: Shortest Ping (Katz-Bassett+, 2006)

Geolocate X at location of A or location of B



A

Works well for short RTTs!



B

Compare AX and BX



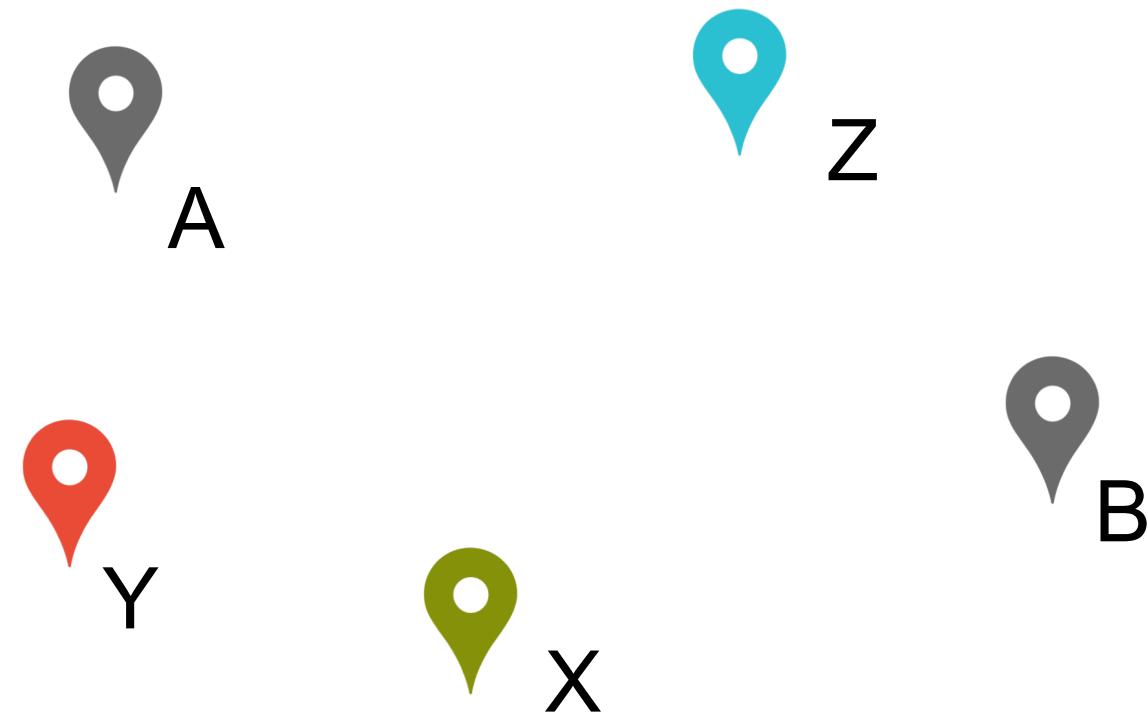
X

Choose whichever is shorter

Vector similarity: GeoPing (Padmanabhan+, 2001)



Vector similarity: GeoPing (Padmanabhan+, 2001)
Geolocate X at location of Y or location of Z



Vector similarity: GeoPing (Padmanabhan+, 2001)
Geolocate X at location of Y or location of Z

Compare

$$\begin{bmatrix} AX \\ BX \end{bmatrix}$$



A



Z

to and

$$\begin{bmatrix} AY \\ BY \end{bmatrix}$$



Y

$$\begin{bmatrix} AZ \\ BZ \end{bmatrix}$$



X



B

Vector similarity: GeoPing (Padmanabhan+, 2001)
Geolocate X at location of Y or location of Z

Compare

$$\begin{bmatrix} AX \\ BX \end{bmatrix}$$



to and

$$\begin{bmatrix} AY \\ BY \end{bmatrix}$$

$$\begin{bmatrix} AZ \\ BZ \end{bmatrix}$$



Distance in
vector space

Disk-based techniques



Maximum target distance



Within the speed of light disk



Disk-based techniques

Maximum target distance

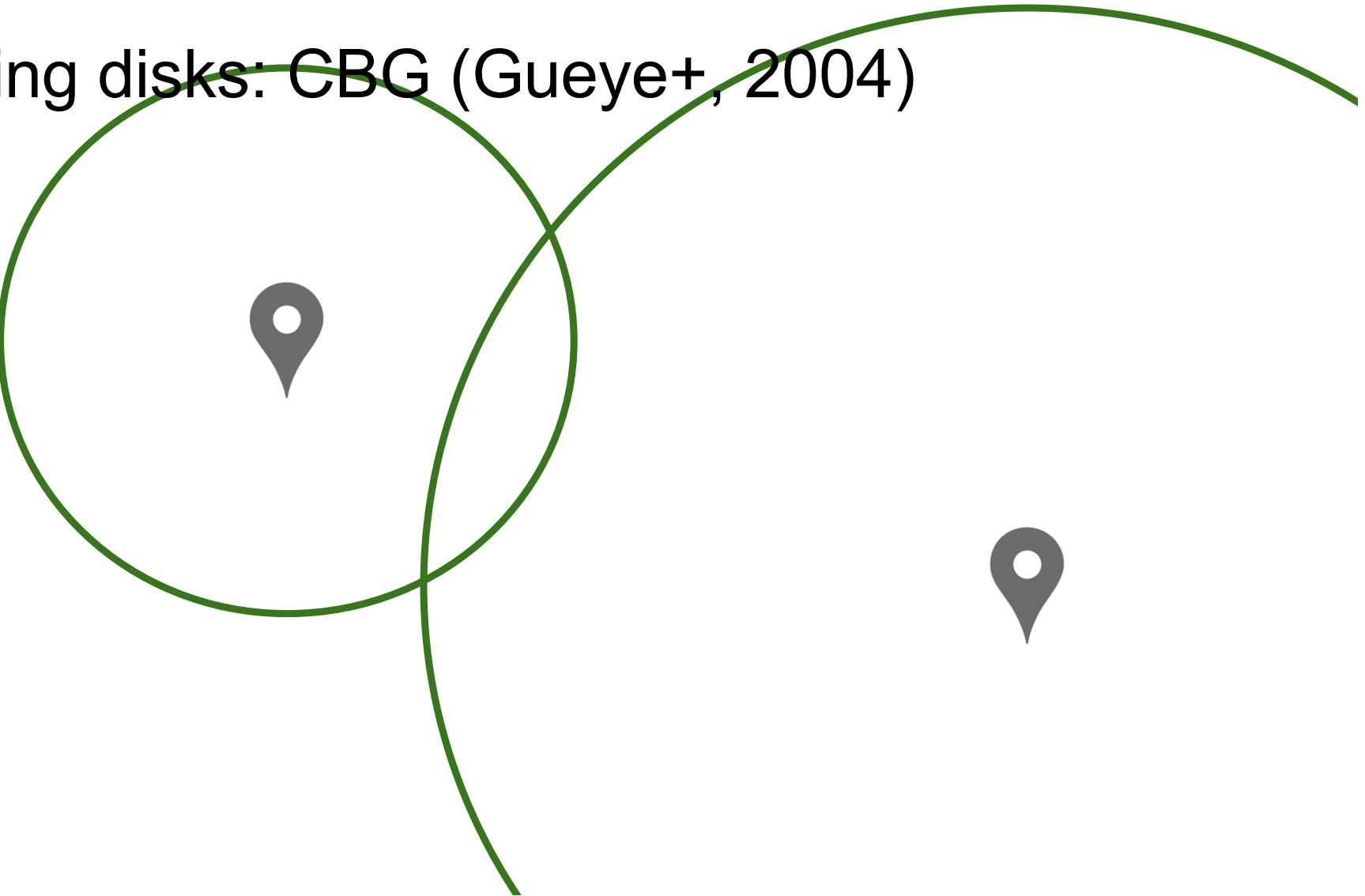
Within a smaller disk

Within the speed of light disk

Overlapping disks: CBG (Gueye+, 2004)



Overlapping disks: CBG (Gueye+, 2004)



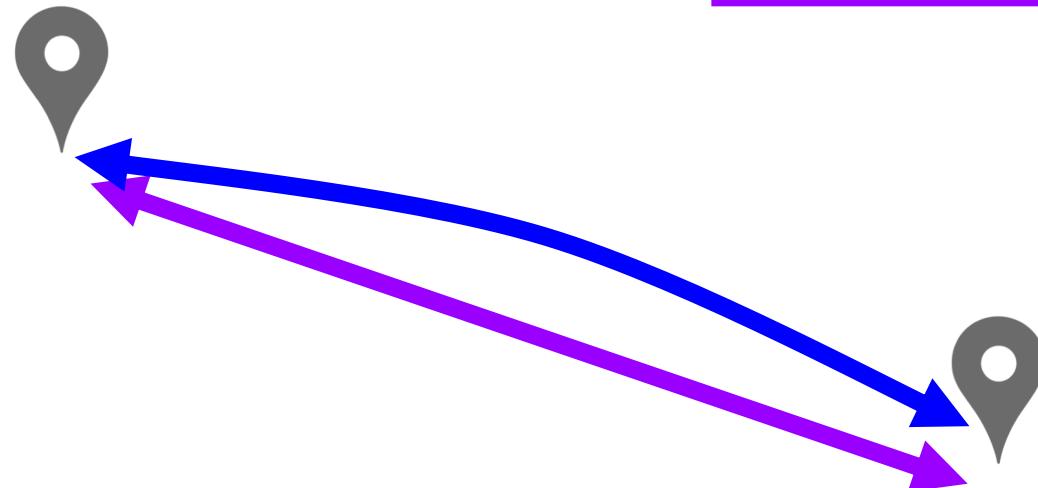
Overlapping disks: CBG (Gueye+, 2004)



Intersection of 2+ disks: “multilateration”

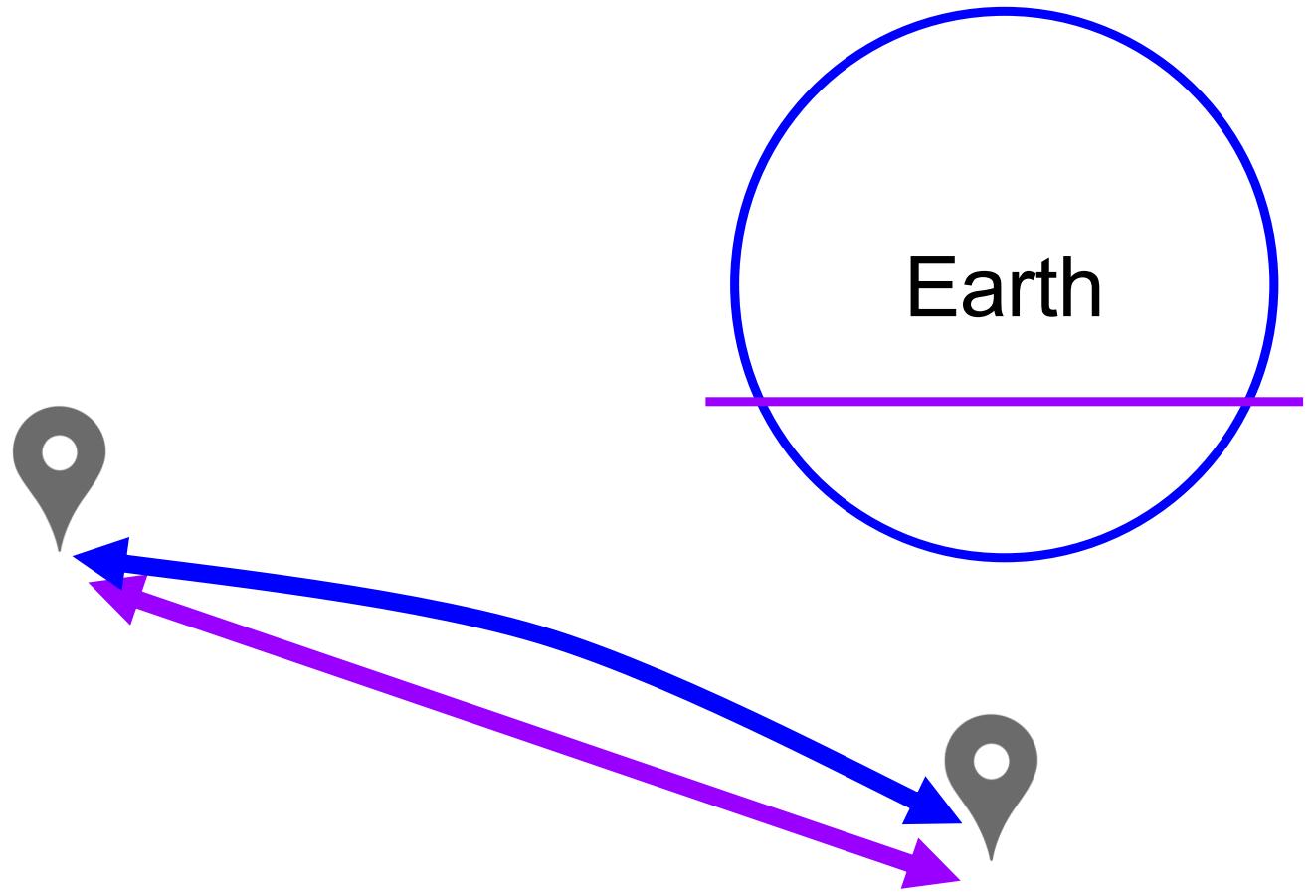
Disk calculations

Earth



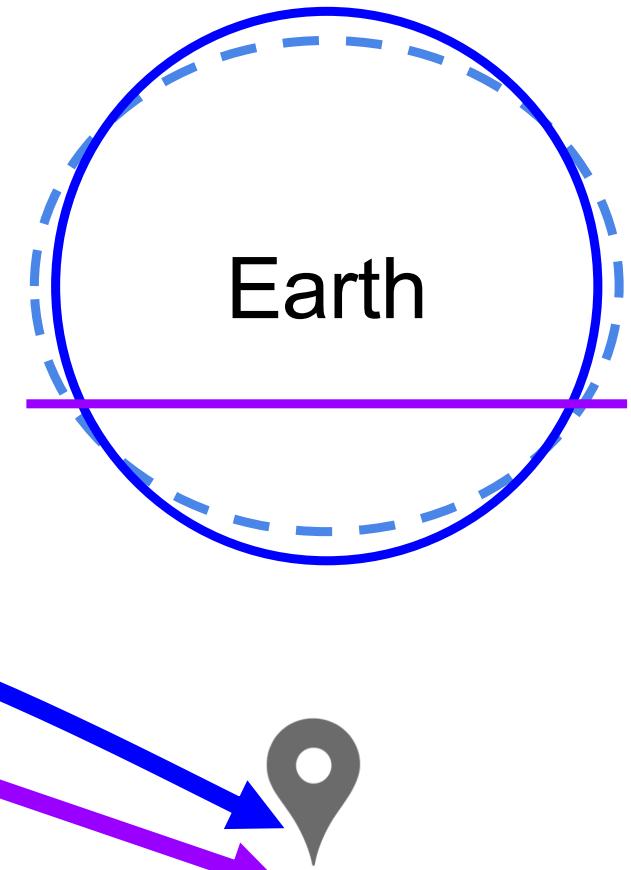
Euclidean distance: $\sqrt{((x_2-x_1)^2+(y_2-y_1)^2)}$

Disk calculations



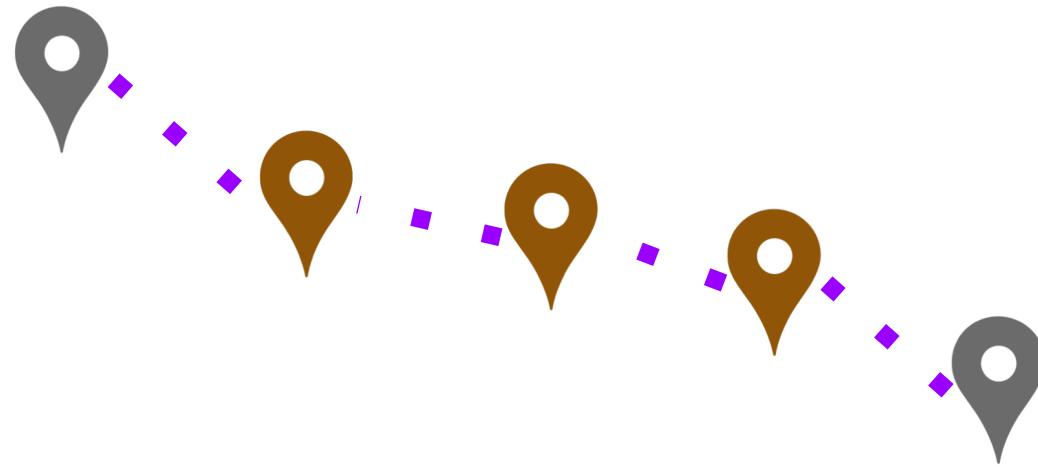
Distance on a sphere: Haversine Formula
Euclidean distance: $\sqrt{((x_2-x_1)^2+(y_2-y_1)^2)}$

Disk calculations

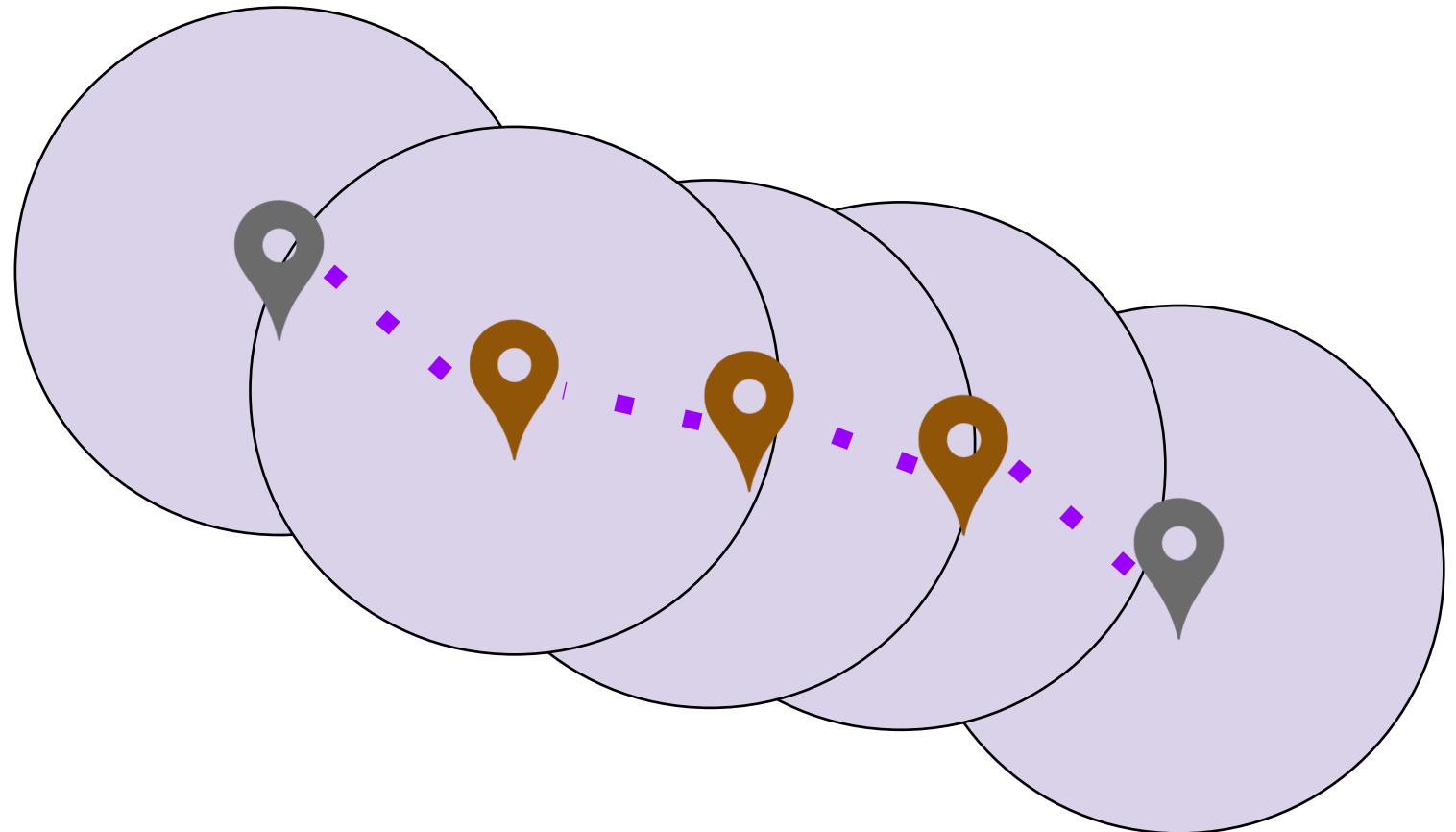


Distance on an ellipsoid:
(oblate spheroid): Vincenty's Formulas
Distance on a sphere: Haversine Formula
Euclidean distance: $\sqrt{((x_2-x_1)^2+(y_2-y_1)^2)}$

Disks + connections: TBG (Katz-Bassett+, 2006)

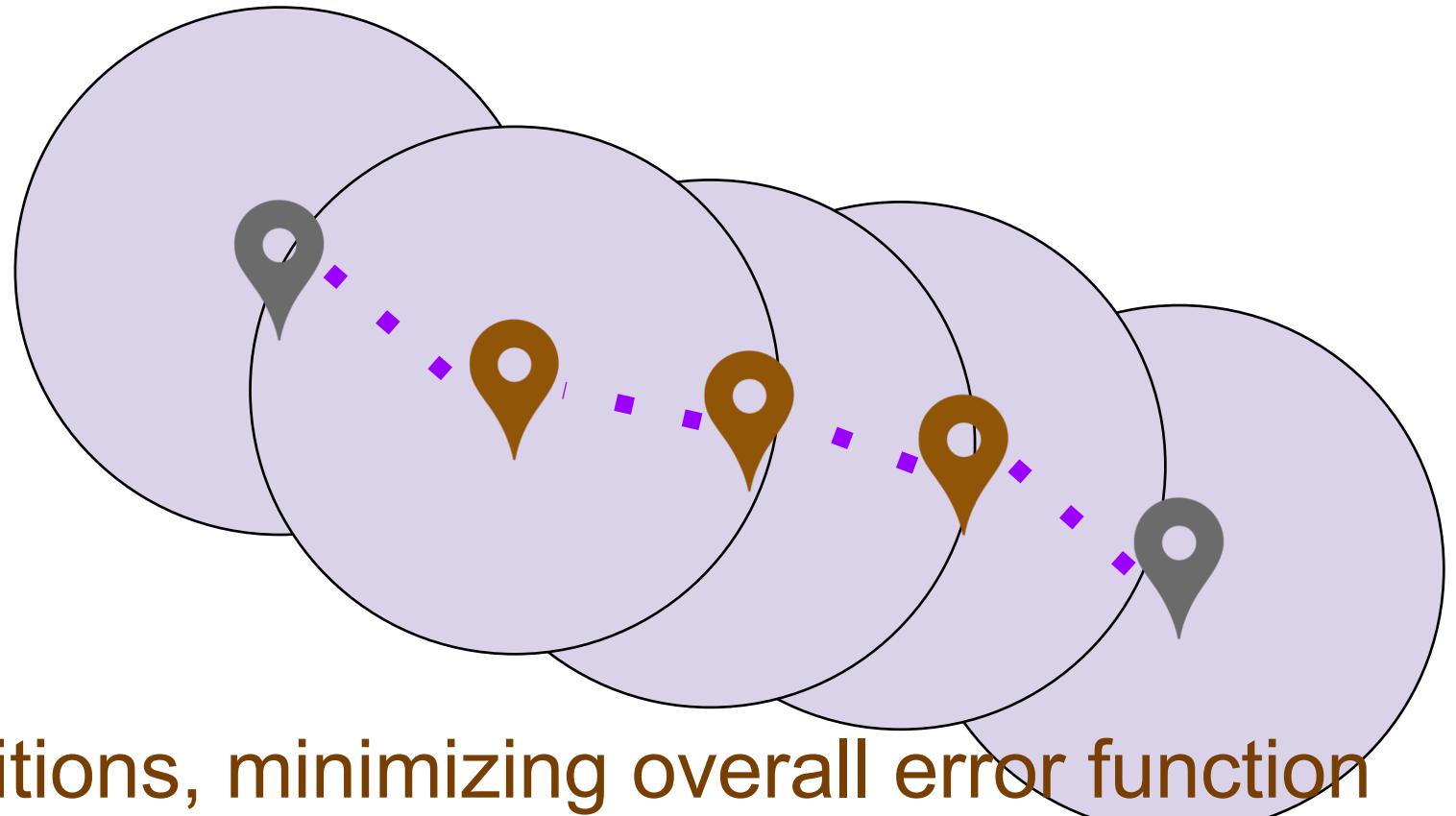


Disks + connections: TBG (Katz-Bassett+, 2006)



Traceroute for multiple delay measurements

Disks + connections: TBG (Katz-Bassett+, 2006)



Solve for positions, minimizing overall error function
Traceroute for multiple delay measurements

Connections + closeness: Street-Level (Wang+, 2011)



Connections + closeness: Street-Level (Wang+, 2011)



Traceroute for multiple delay measurements

Connections + closeness: Street-Level (Wang+, 2011)



Locate X at guessed location of web server B
Traceroute for multiple delay measurements