
AIR TRANSPORT NETWORKS

Nathalie Lenoir
September 2011

Plan of presentation

- 1- Air transport networks
 - 1-1 Basics of networks economics
 - 1-2 Characteristics of networks
- 2- Networks and competition
 - 2-1 Hubs and competition
 - 2-2 Network strategy of the low cost carriers

1-1 Basics of network economics

- Branch of economic theory dealing with network particularities
 - common analysis, even if different types of network
 - Ex.: telecom, energy, transportation
- Two main types of networks effects
 - Consumption externalities (direct network effects)
 - Production externalities (indirect network effects)
- Compatibility in networks
- Economies of scope in transportation networks

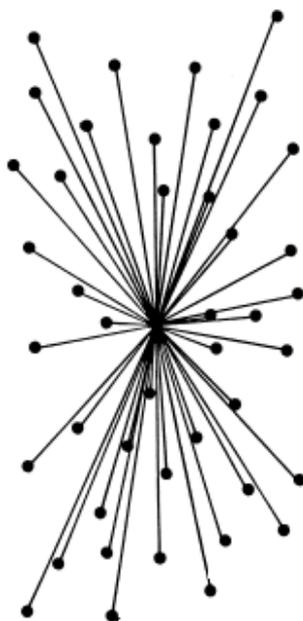
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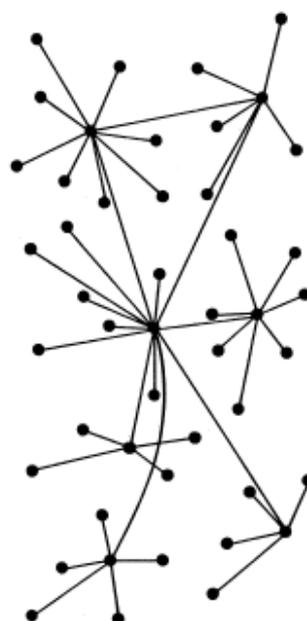
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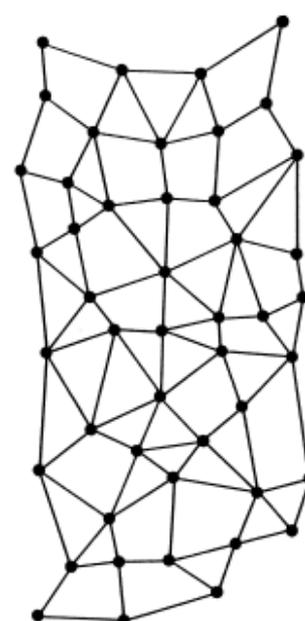
Some Networks...



Centralized



Decentralized



Distributed

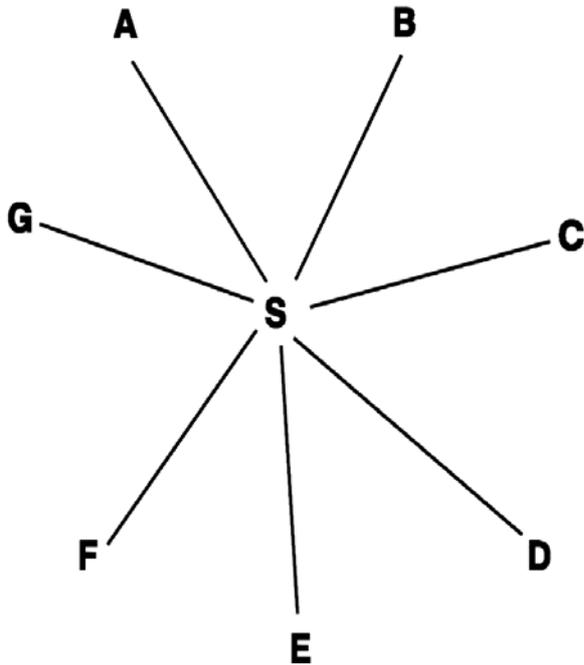
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Network components



- AS, BS are components of the networks
- They are complementary components
- AB is a composite good made by combining components
- In a centralized n components network, $n(n-1)$ goods

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Consumption externalities

- Utility from consuming a good depends on number of people consuming it
- Also called “club effect”
 - Telephone : if no one else uses it, then it is of no use to me
- One more user to the network increases utility of all users
 - By enabling new links: consumer $(n+1)$ adds $2n$ potential new goods (centralized network)

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Production externalities

- Utility of users depends on importance of supply
 - Systems of complementary products like hardware and software : utility of hardware depends on number of software developed
 - Size of network for transportation networks: each route in network is an element of the system
- Indirect externalities :
 - An extra customer brings indirect benefits to other customers, by increasing the demand for components of network (software, routes...)

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Compatibility in networks

- All components of the system are complement
 - Question of compatibility of components
- Compatibility
 - Valued by customers because increases size of network
 - But incompatibility may intensify price competition
 - Incompatibility may be preferred by dominant firm
- In air transport: Strategic games between airlines
 - Some compatible networks : geographically complementary
 - Some partially incompatible networks

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Transportation networks: Economies of scope/networks

→ Linked to shape of cost function

$$C(n_1, n_2, n_3) < C(n_1, 0, 0) + C(0, n_2, 0) + C(0, 0, n_3)$$

→ The cost of operating on three (M) routes for a given airline is less than the sum of cost of three (M) different airlines

→ True in the airline industry in general, but especially if routes originate from same point

➤ Justification for certain types of network

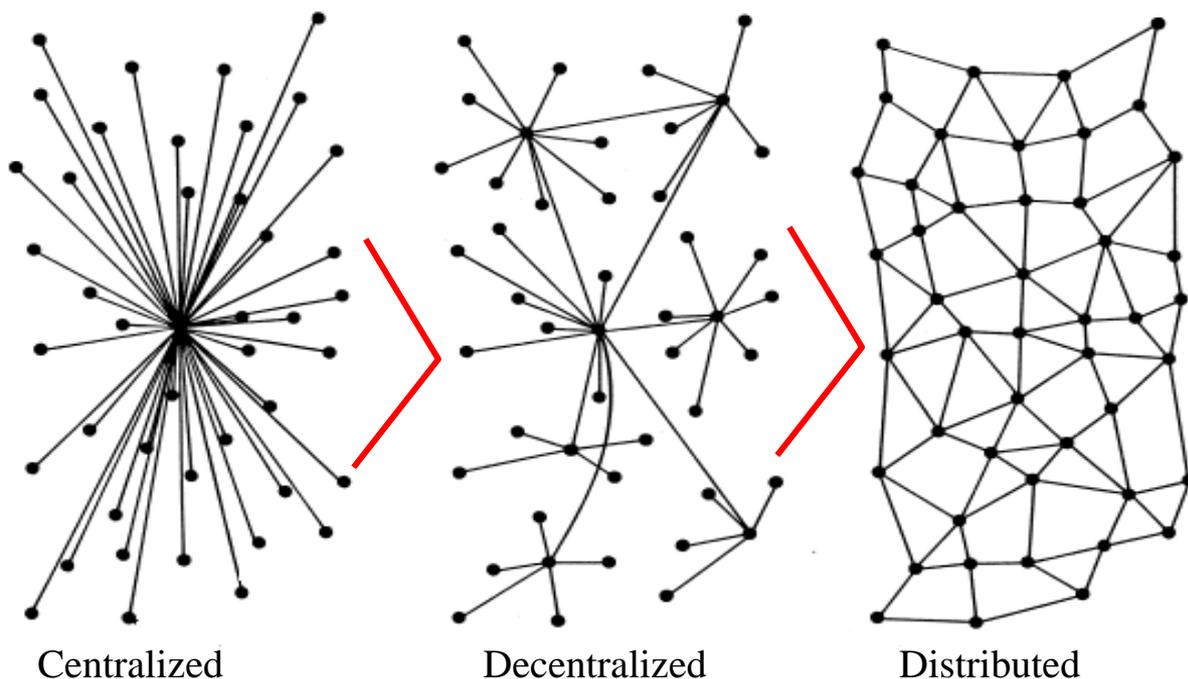
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Economies of scope ?



Centralized

Decentralized

Distributed

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1-2 Characteristics of air transport networks

→ Air transport networks are unusual :

- In most network industries, there are high fixed network costs (infrastructure) and a fixed network
- In air transport networks are “easily” changed and do not always imply high costs : they can adapt to demand or to competition

→ There are three main models:

- Point to point network: an old myth
- Hub network : the nearly universal standard today
- Low cost carriers networks



The point to point network

- Theoretically a network linking every city by a route to every other
 - also called fully connected network
 - Never really existed in air transport
- In practice, not all links can be operated
 - Result can look quite messy, (no shape !)
 - The historic network during regulated years in the USA
 - Not very efficient
 - Nowadays hard to find !

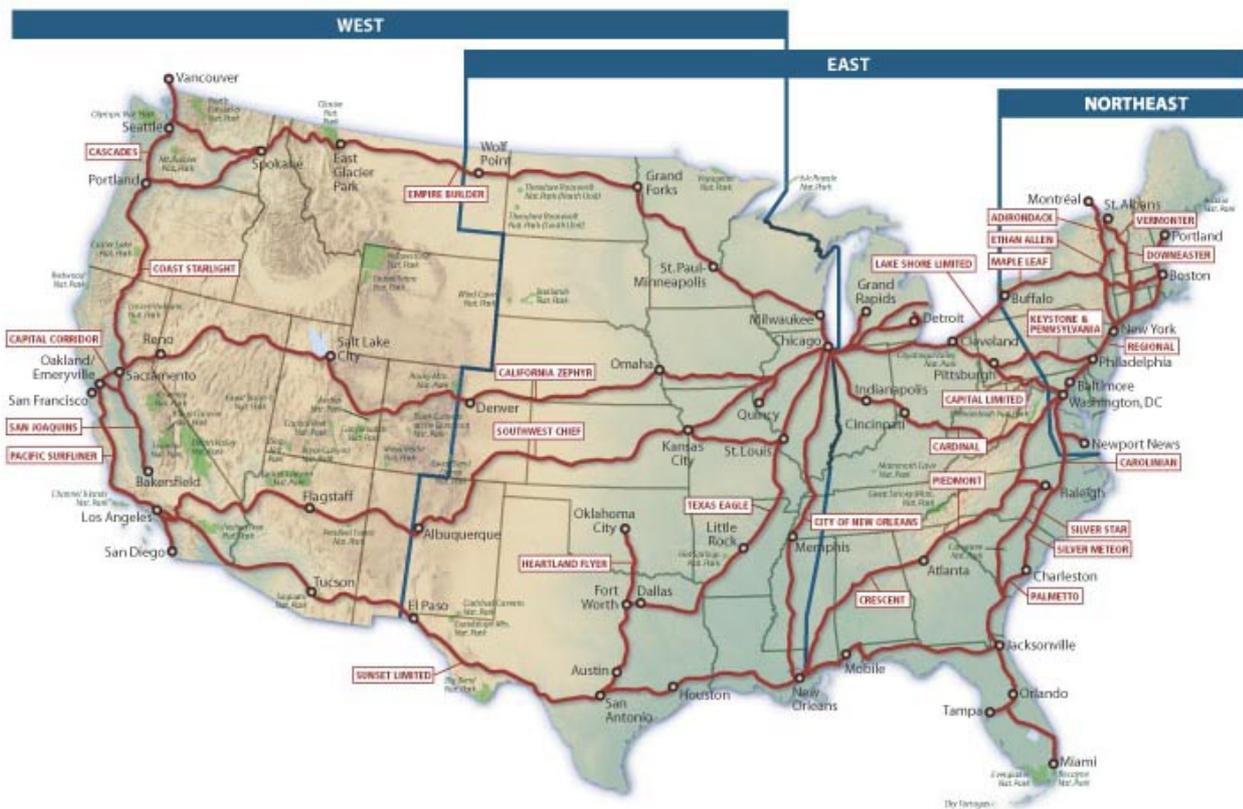
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Point to point in railroads



The Hub and spoke network



CARRIAGE WHEEL

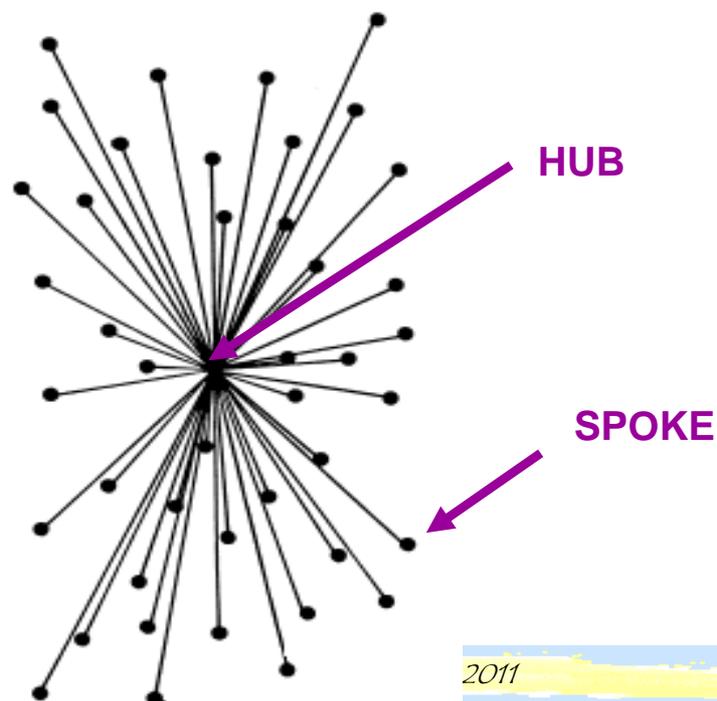
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The Hub network: a centralized network



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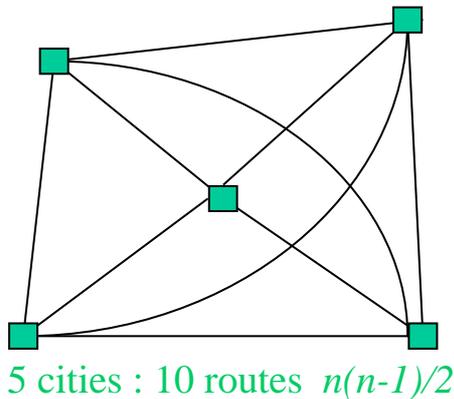


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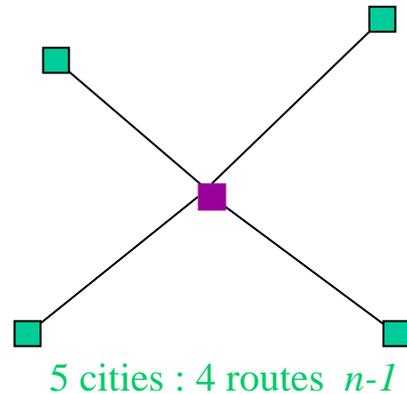


Networks : hubs versus point to point

Point to point network



Hub and spoke network



The "Hub and spokes" network

- ➔ The predominant type of network these days
 - Historic network for European airlines
 - Adopted (and perfected) by the US airlines after deregulation
- ➔ Hub networks have many advantages
 - For hub airlines and their passengers
- ➔ But also drawbacks
 - For competitors, for airports
- ➔ The main adverse effects of the hubs are linked to competition !



Where do the economies of scope come from in hubs?

- Airlines serve routes with less planes/flights, and with bigger planes
- Bigger planes means lower costs per passenger
- With lower prices more passengers come
- More passengers mean bigger planes, more frequencies and new routes
- Bigger planes mean lower costs...
- As a result : access to air transport for the middle class !



Advantages of the hub network

- For hub airlines:
 - More destinations with less flights
 - Larger planes, lower costs, more demand
 - More control at the main airport (the hub)
- For passengers
 - More destinations, more frequencies
 - Lower prices (globally)
 - Shorter connections
- For hub airports
 - More business



Drawbacks of hubs

- ✈ For hub airlines
 - Management of connections (compatibility) can be tricky and is costly
- ✈ For passengers
 - Less direct flights
- ✈ For other airlines
 - Difficulty of access to hub airports
- ✈ For hub airports
 - Congestion
 - Dependence on main hub airline



The « classical » hub

- ✈ Airlines bring passengers by “feeder routes” (short to medium haul) and redistribute them on all routes
 - Mix of short, medium and long haul routes
 - Ex: about 800 flights par day at Paris CDG
- ✈ They also take advantage of local traffic
 - Hubs usually situated in large cities
 - Mix of local and connecting passengers



Example of hub : AA hubs

American Airlines/American Eagle Dallas/Fort Worth Hub (As of March 2003)

Airport Name	Dallas/Fort Worth International Airport
AA Hub Established	1981
Eagle Hub Established	1984
Terminal Location	Terminals A, B, C
Terminal Size	3,756,311 square feet
Principal Traffic Flow	East/West/OMNI
Number of Gates	64 (plus 3 Eagle, and 8 Eagle boarding door)
Daily AA Jet Departures	471
Daily American Eagle Departures	229
AA Nonstop Cities Served	107
Eagle Nonstop Cities Served	37
International Routes	25
Connecting City-Pair Combinations	Over 3,000 in peak connecting complex.

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Example of hub : AA hubs (2003)

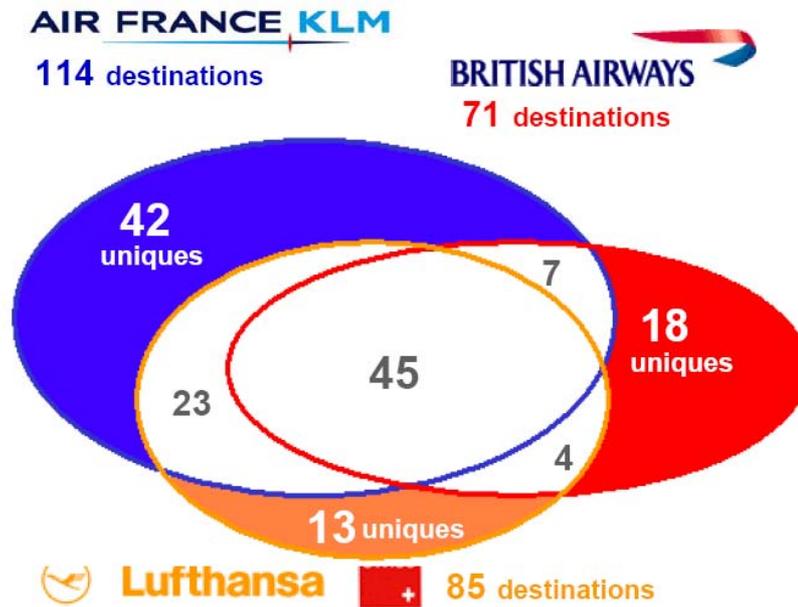
Airport Name	Chicago O'Hare International Airport
AA Hub Established	1982
Eagle Hub Established	1985
Terminal Location	Terminal 3 – Concourses G, H, K, L
Terminal Size	1.2 million square feet (688,000 leased by AA)
Principal Traffic Flow	East/West/Europe/Japan
Number of Gates	69 (26 American Eagle)
Daily AA Jet Departures	286
Daily American Eagle Departures	183
AA Nonstop Cities Served	57
Eagle Nonstop Cities Served	24
International Routes	11

A total of 469 flights

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Example of hub : Air France hub at CDG Airport (source Air France)



Source: Air France/KLM annual report 2007

Long-haul destinations from Europe (Summer 2008)

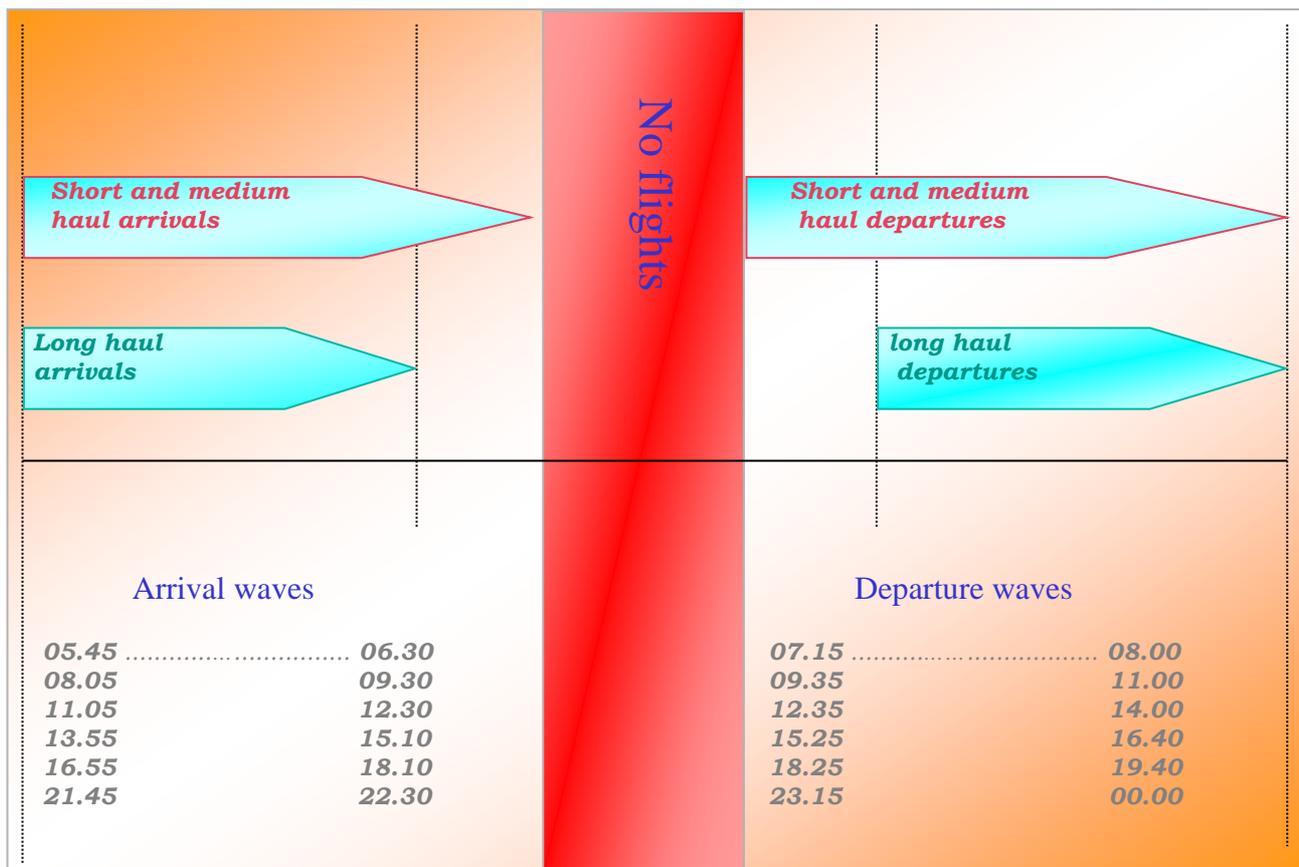
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Air France Hub : Connection banks



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Other type of hub: The 6th freedom carriers

- Some carriers take advantage of 6th freedom rights, and of their geographical position
 - Ex: Emirates in Dubai
 - But also Singapore, Thai Airways, Japan Airline...
- They collect and redistribute long haul traffic over the hub
 - Enough traffic to serve secondary routes
 - Take demand away from long haul airlines: Qantas overseas market share from Australia dropped from 41% to 28% in 10 years

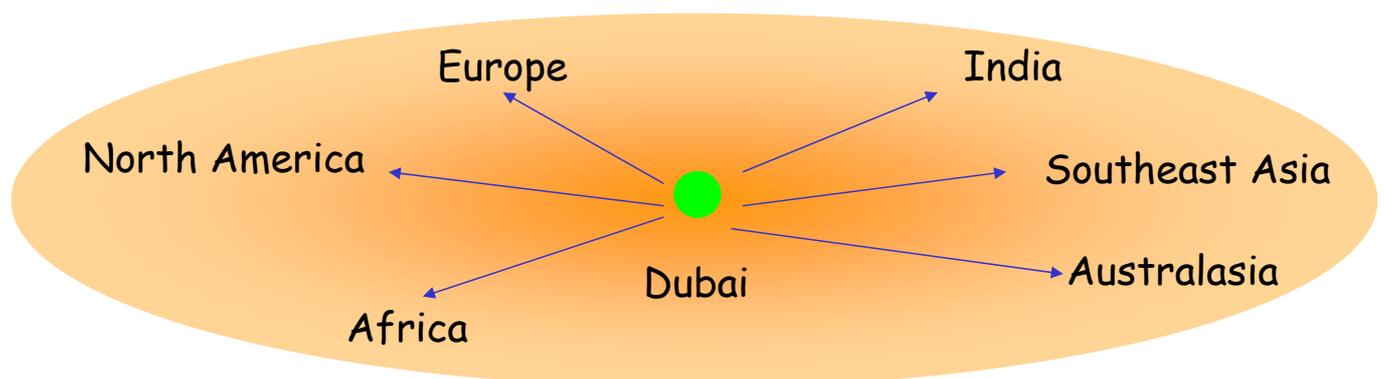
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The 6th freedom carriers : new opportunities



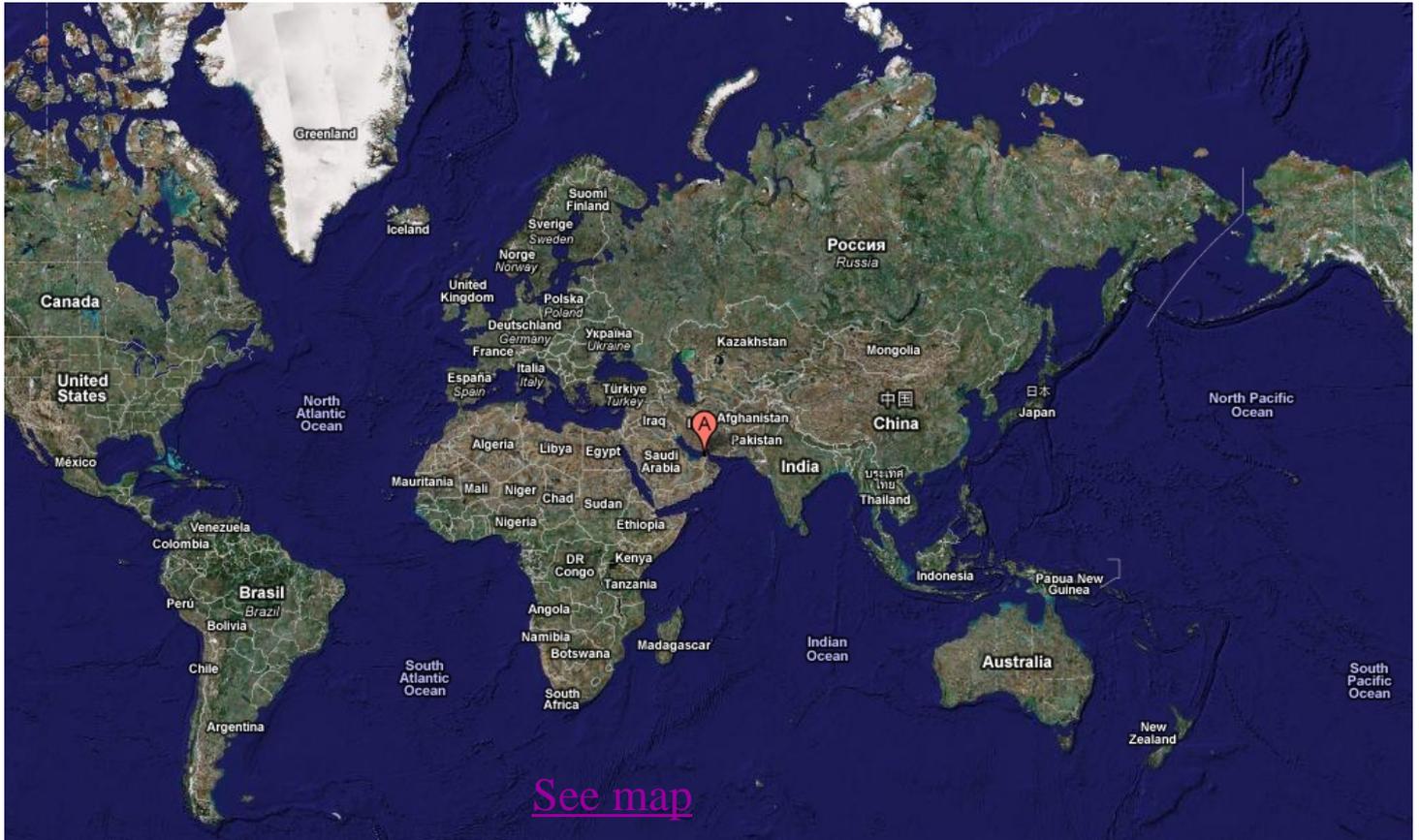
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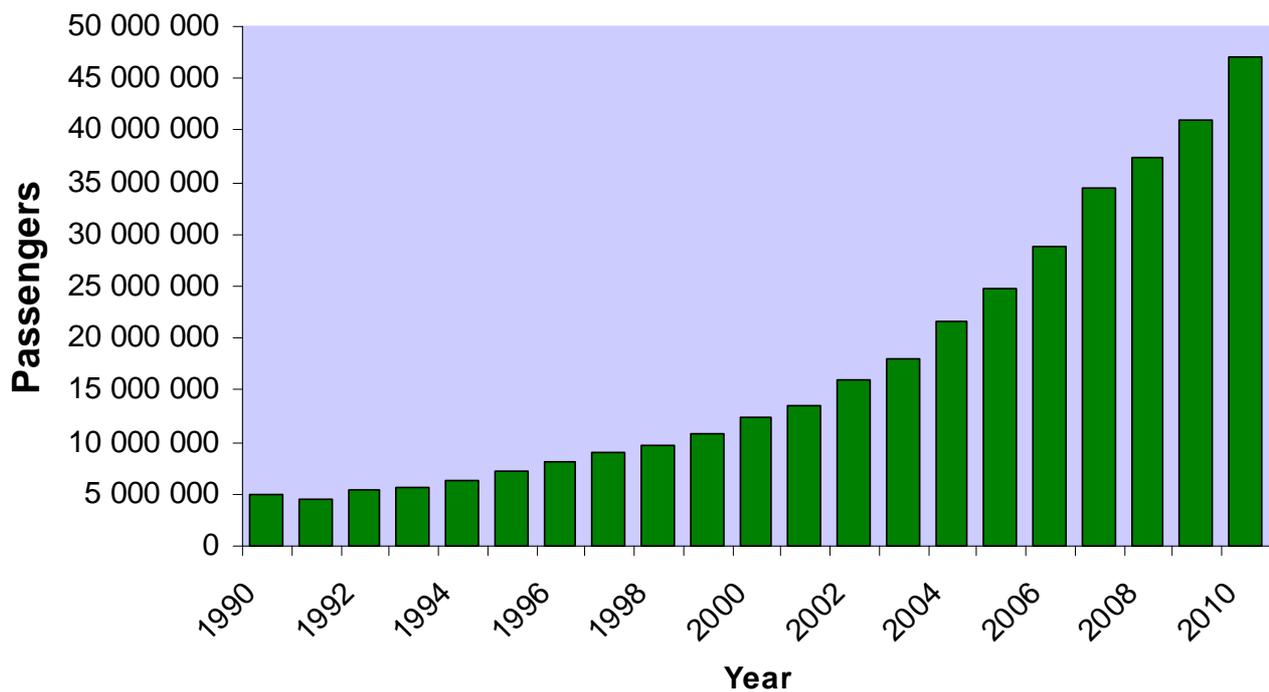
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Emirates in Dubai

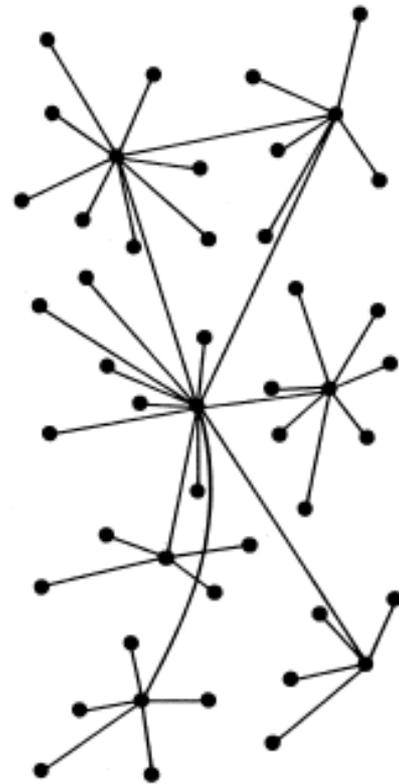


Traffic Evolution in DUBAI



The low cost carriers networks

- Low cost carriers have « bases » but no hubs
 - They do not manage connections at their bases
 - LCC networks are much more spread out
- Their networks are more like decentralized networks
 - Still some economies of scope/networks
 - No problems of congestion



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Compatibility in LCC networks

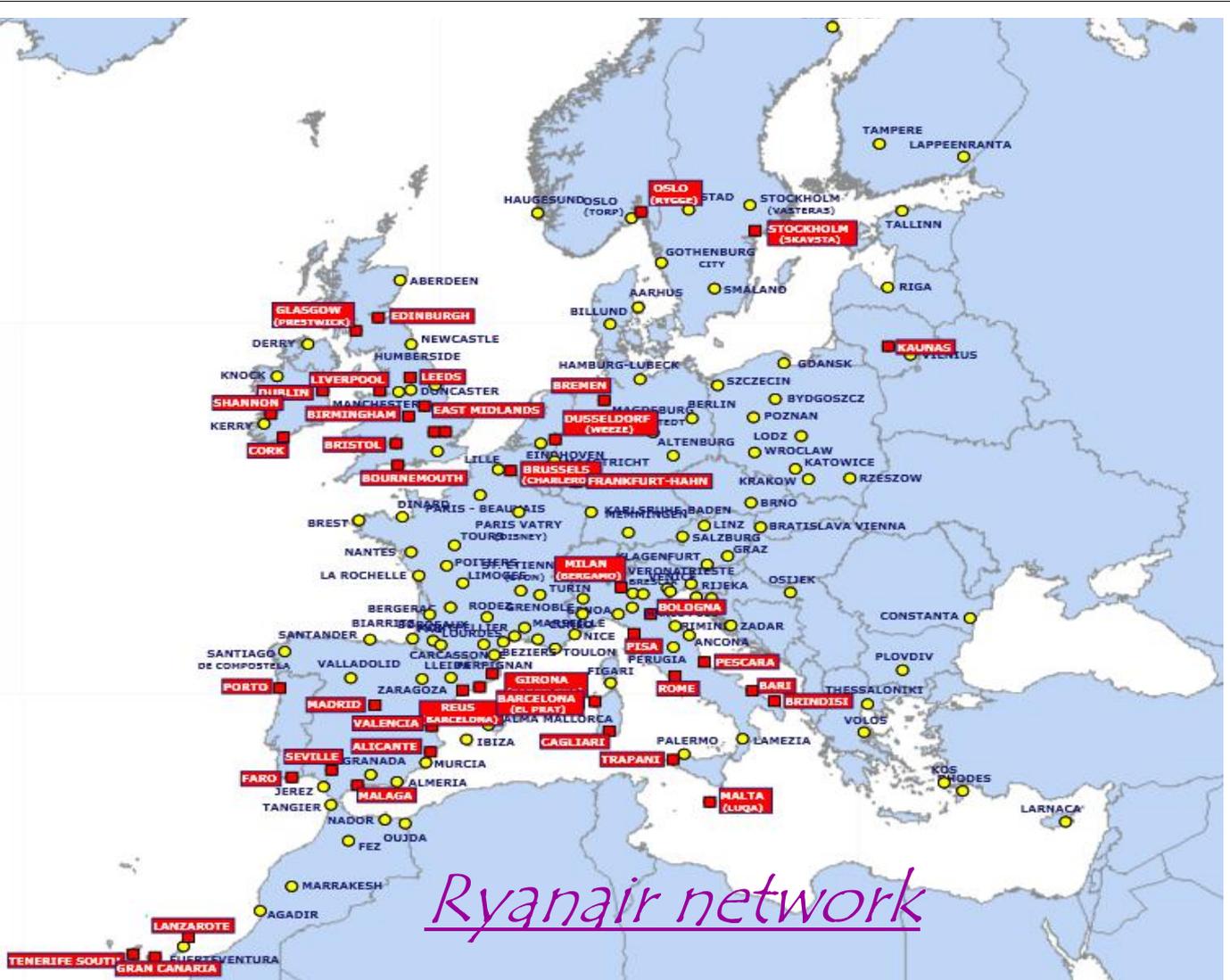
- Firms usually make their own network components fully compatible
 - In order to allow the users to combine components to make composite goods
- This is not the case of LCC networks in Europe
 - In this case « compatibility » means « connections management »
 - ⇒ because supposed benefits do not compensate costs
- The users are free to build their own connections
 - But they will not be acknowledged by the airline

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2-1 Hubs and competition

→ The hub network creates a very specific type of competition

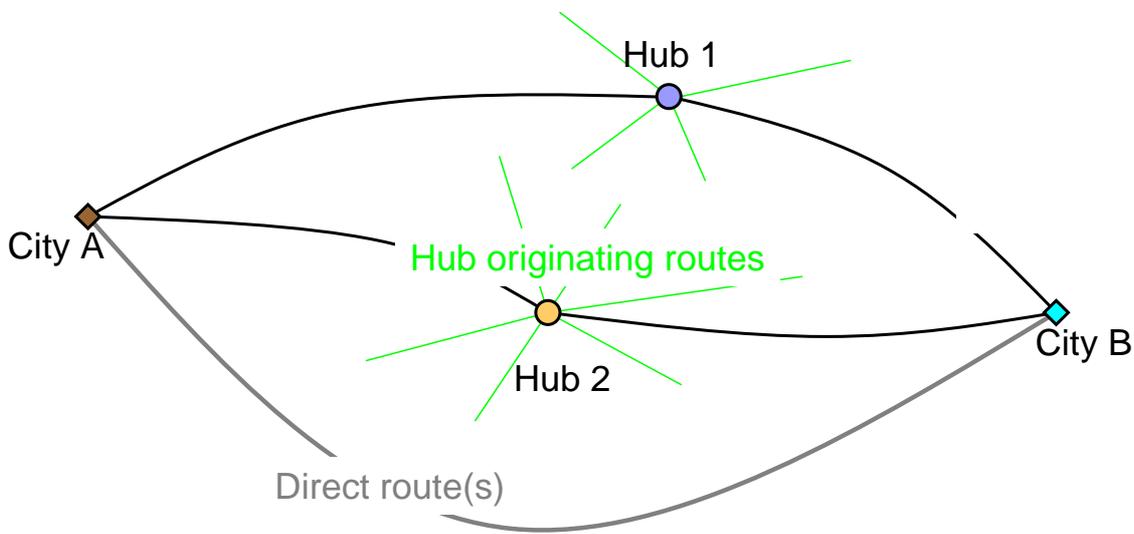
- Competition between hub airlines has to be understood as a competition between hub networks
- Size of network matters

→ The hub creates some perverse effects in terms of competition

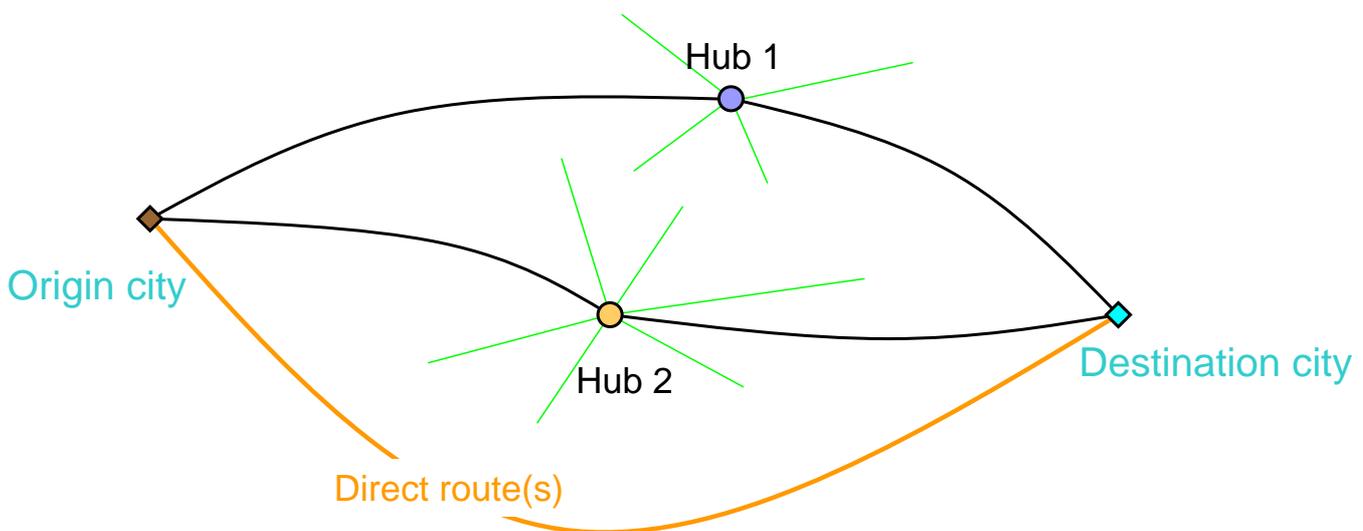
- “Fortress” effect
- Congestion
- With the result: higher fares
- The hub enables airlines to use successfully predatory behavior



The hub-specific type of competition



The hub-specific type of competition



Spoke-Spoke markets are competitive !



Competition between hubs : where we learn that size matters

- ➔ An extended network gives an advantage over competitors
 - the goal is to attract passengers wherever they want to go through connections at the hub
 - “production externalities”



Competition between networks : where we learn that size matters

- ➔ An extended network gives an advantage over competitors
- ➔ As a result, size and coverage of network matters !
 - Hub airlines have understood that the more destinations, the more passengers, and the more market share !
 - Bigger size (of network) does not necessarily mean less unit costs (economies of scope not unlimited) but more revenues !
 - Airlines are trying to obtain a global world coverage through alliances between hub airlines



Competition between networks : where we learn that size matters!

- An extended network gives an advantage over competitors
- As a result, size and coverage of network matters !
- As a consequence, in order to understand and analyze competition :
 - Looking at competition at the airport or at the route level is not sufficient (but still informative and useful)
 - We need to define the concept of origin-destination : what matters is the competition (whatever the route taken) between origin cities and destination cities



Enlarging networks: partnerships

- Partnerships aim at enlarging networks...
 - Alliance policies among all international airlines to achieve global world coverage in multi-hubs systems
 - Three main alliances : Oneworld, Skyteam, Star Alliance, with 55.5 % of world traffic in 2010 (ASKs)
- ...by making them compatible
 - Schedule coordination
 - Code sharing
 - Frequent Flyers Programs (FFP)



Alliances (Sept.2010)

	Destinations	countries served	capacity share	pax traffic share
Star Alliance	1130	181	25,9%	25,4%
Skyteam	815	169	15,3%	17,1%
Oneworld	679	146	14,2%	15,6%



Star Alliance (2011)





Skyteam (2011)



Oneworld (2011)

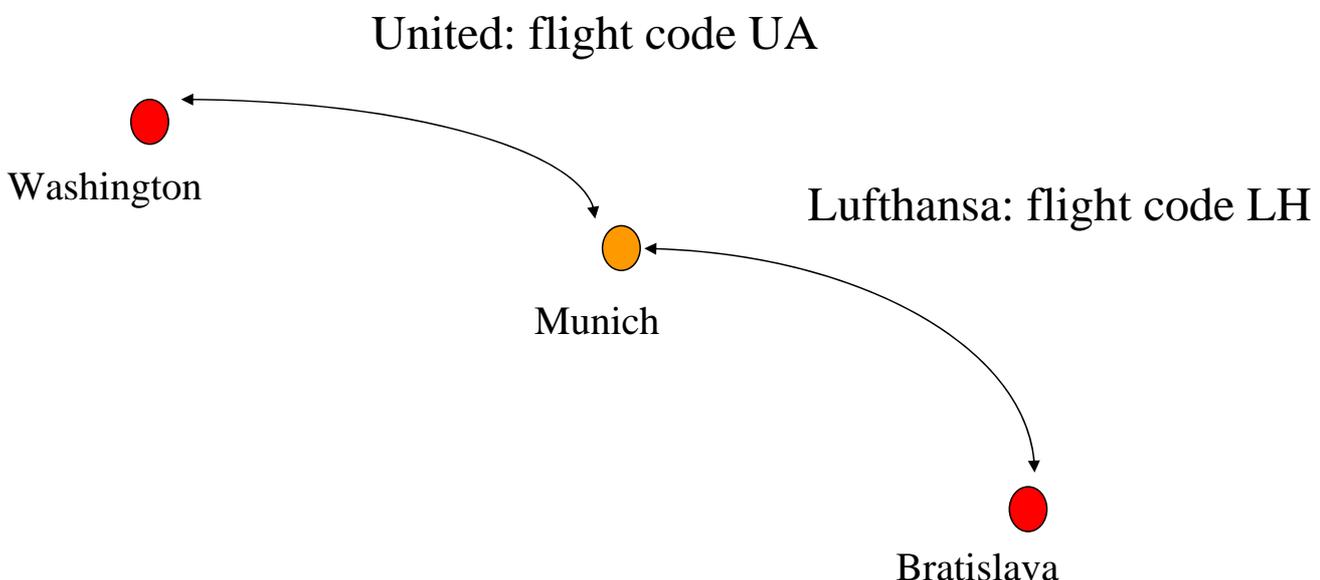


Code sharing

- Is the use of one airline flight code for flights on another airline
 - Airlines virtually buy blocks of seats on other airline and sell them under their own flight code
- Possible inside an alliance if authorities agree to it (US federal authorities, European commission)



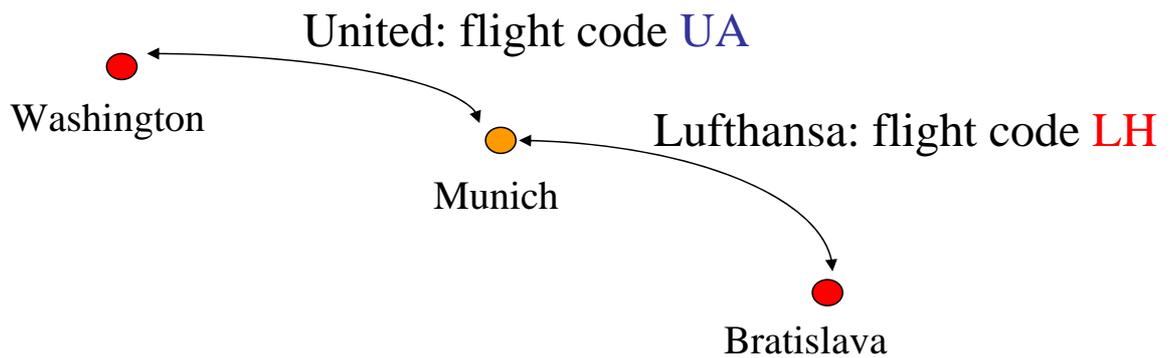
Code sharing: example



Code sharing: example

→ Flight UA 123 / LH 456

- Is also UA 123 / UA 789
- And LH 321 / LH 456



Code sharing

→ Same airline code means better display in reservation systems

- No apparent change of airline
- 75% of reservations made on first screen

→ For passenger:

- real coordination means better service (baggage, lounges, no missed transit)
- But often he does not know which airline he is flying with until on board!



Frequent flyers programs

- Offer advantages to customers for remaining « faithful »
 - In network economics language: increase “switching costs”
- Airlines offer « miles » for each flight, and rebates on additional services
 - Staying with the same alliance means accumulating miles and getting free tickets
- Each alliance has its program
 - Ex.: Flying blue for SkyTeam



Perverse effects of the hub system

- The hubs have anti-competitive effects :
 - The fortress effects: dominant airlines make entry difficult for competitors
- The hub network creates its own congestion
 - The more routes you have, the more congestion
 - Limitations to competition: problematic access to airports
 - (Pressure on costs for airports and airlines due to the need to over-invest)
- Fortress effect and congestion create market power on routes to and from hubs



Why is there less competition at hubs : the fortress effect

- Major airlines have tried to prevent entry at their hubs (and succeeded !)
 - by using all airport capacity : no room for others
 - On most hubs the dominant airline has more than 50% of traffic, and on some, more than 75%
 - by leasing gates on (very) long term contracts
 - In 1990, on 66 largest US airports, 85% of gate were rented through exclusive contracts (some until 2015)
 - by offering many flights on each route : entrants have to match capacity in order to succeed
 - The S shaped curve

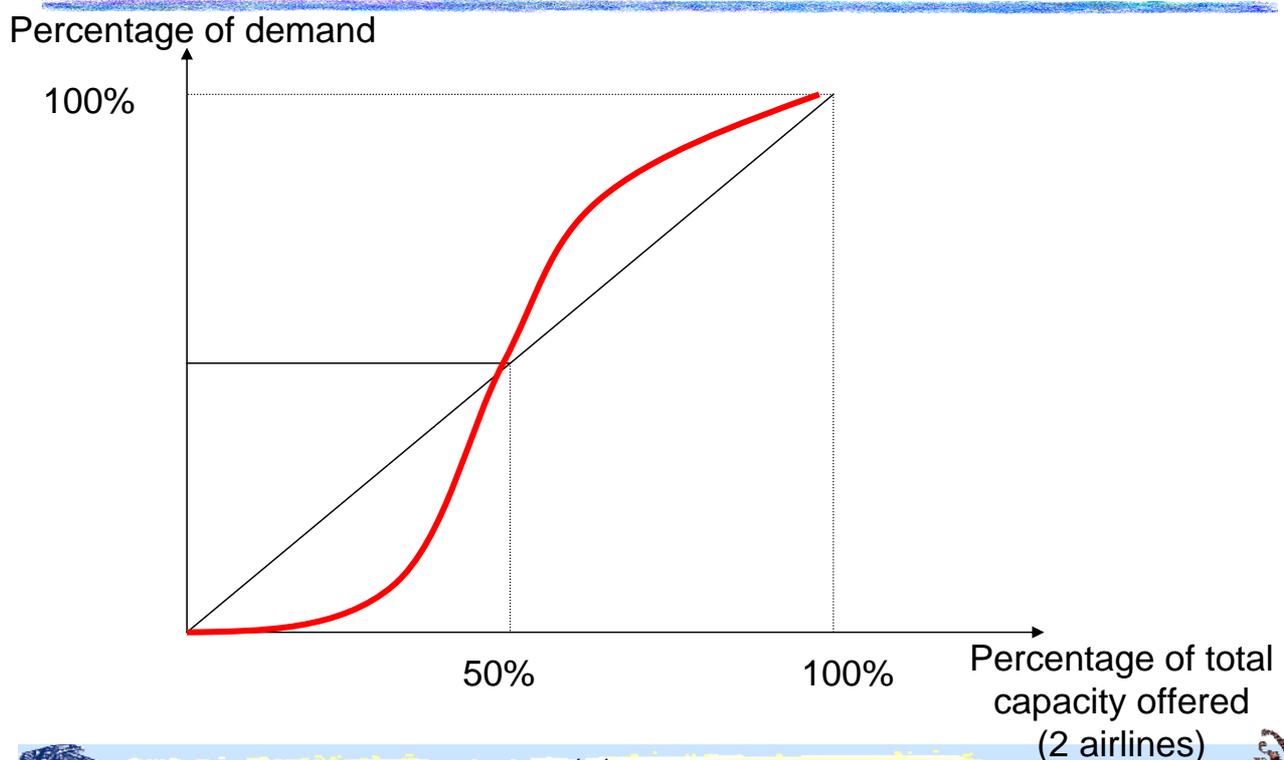
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The empirical S curve



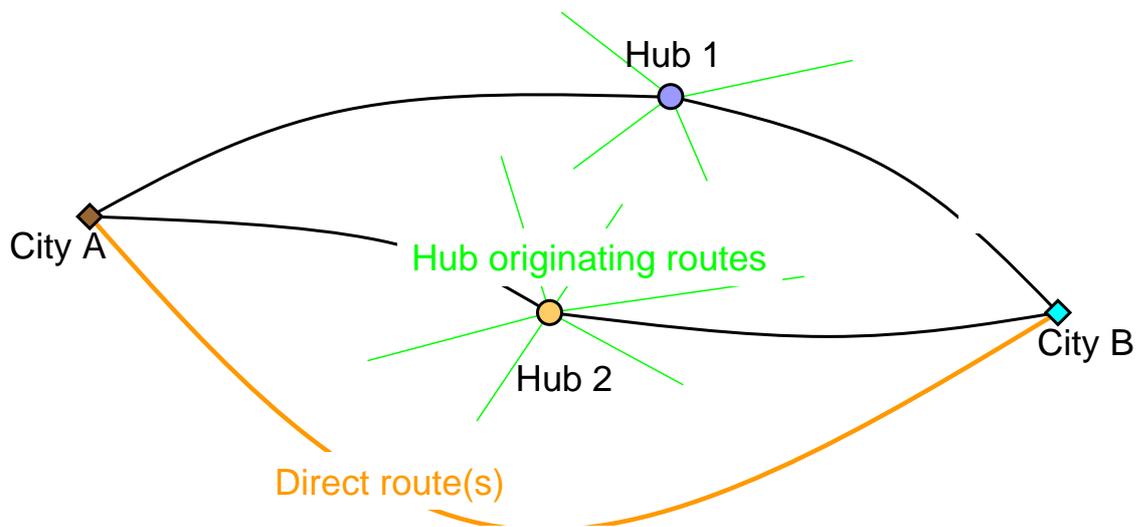
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Result of fortress effect



Spoke-Hub markets are much less competitive !



Hubs and congestion

- In the world, about 150 airports are constrained by capacity problems...
 - most are hubs
 - most major European airports are concerned
- ...and many others are congested
 - most important US airports face delays
- Several factors can explain capacity shortage
 - sheer lack of space (runways, but also gates)
 - but also concentration of flights during the day at hubs



How to deal with lack of space

- ➔ Different response in the US and in Europe
 - In Europe slots are defined in order to avoid delays
 - no (or few) delays but less landings and take-offs
 - In the USA, Airlines are supposed to coordinate their schedule in order to avoid delays
 - all capacity is used
 - except on a few slot controlled airports (Chicago, New York, Washington National)
- ➔ Results in different situations

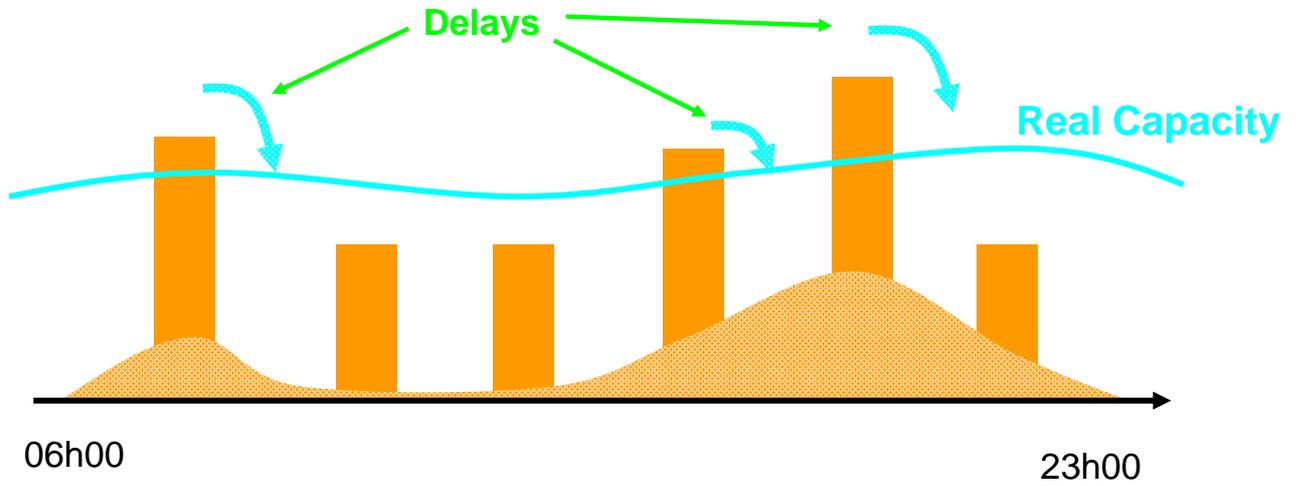


The US congestion problem

- ➔ Market is mostly self regulating through delays
 - everybody suffers from delays : passengers and airlines
 - huge amounts of money are lost every year
 - hub airlines suffer from bad image
 - Some are trying to “de-peak” their traffic
- ➔ Congestion is in itself a barrier to entry on US airports
 - access theoretically possible, but in fact no room for challengers except if they use secondary non congested airports (strategy of low-cost airlines)



Peak traffic at hubs (US case)



Hub airline arrival banks + other airlines traffic

Nb : real capacity is not fixed : it depends on weather, traffic homogeneity...

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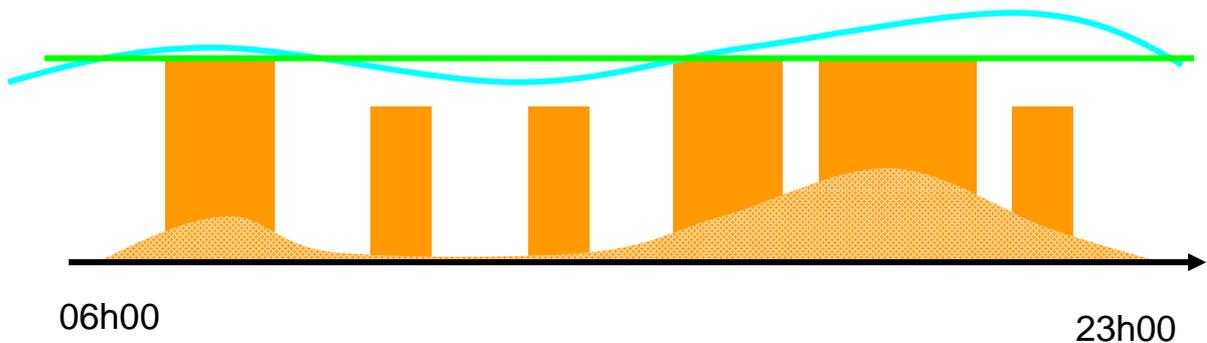


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"De-peaking" traffic at hubs

No Delays...
(only works if one airline
has large share of traffic !)



Hub airline arrival banks + other airlines traffic

— Estimated Capacity

— Real Capacity

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The European congestion problem

- ✈ On most major European airports, slots are allocated through historic rights
 - the “grandfather rights” system (once you get a slot, you keep it in the future, as long as you are effectively using it)
 - only non attributed slots (not many !) can be distributed to challengers
- ✈ No sufficient access possible for competitors on European main airports
 - non consistent with liberalization goal of promoting competition

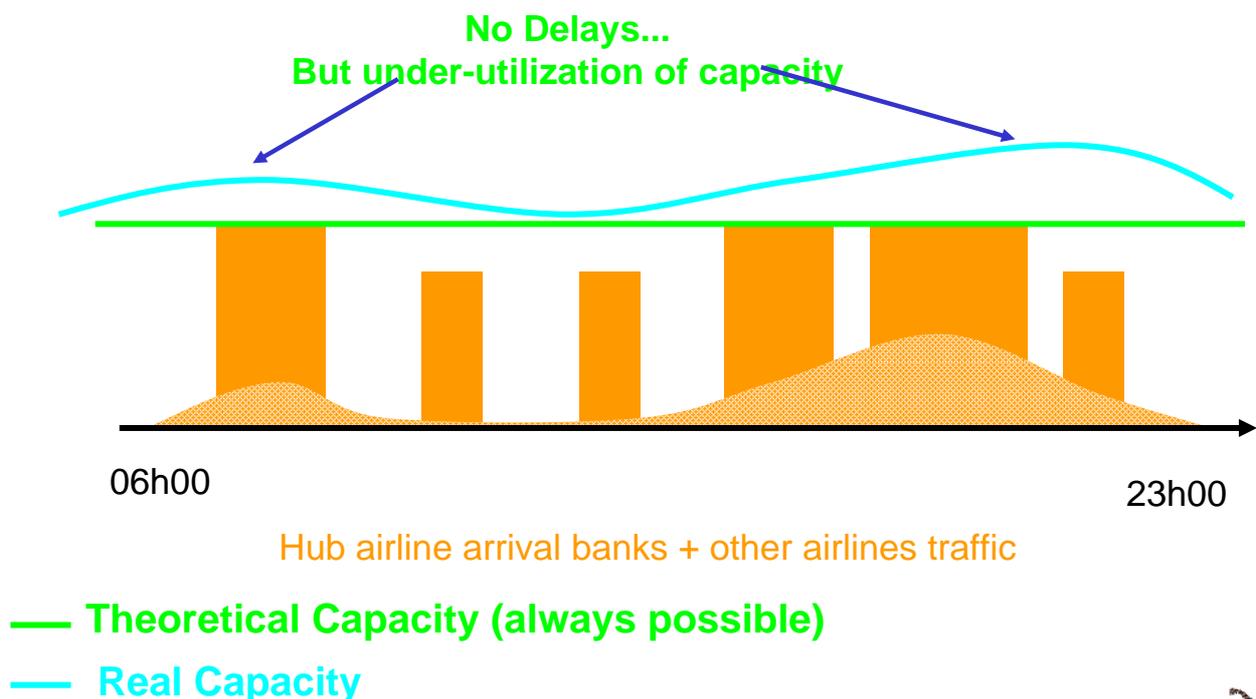
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Peak traffic at hubs (European case)



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Congestion : two approaches, no solution

- Whether in Europe or in the US, no real solution
 - Building infrastructures is costly and increasingly difficult
 - It may be preferable to use secondary airports more
 - The European Commission wants to revise the slot attribution process, in order to allow more entry, but hub airlines need space, in order to set up an efficient operation
 - Hubs create congestion by scheduling of flights
- Competition will remain limited on main hub airports in the years to come !
 - Problem inherent to the hub system



Hubs and market power

- Fortress effect and congestion are barriers to entry that create market power
 - a situation when one buyer or seller in a market has the ability to exert significant influence over the quantity of goods and services traded or the price at which they are sold (Definition from “the Economist”)
- Evidence of market power on routes to and from hubs
 - shown by higher prices



What is market power?

(a situation...) When one buyer or seller in a market has the ability to exert significant influence over the quantity of goods and services traded or the price at which they are sold. Market power does not exist when there is perfect competition, but it does when there is a monopoly, monopsony or oligopoly.

Definition from “the Economist”

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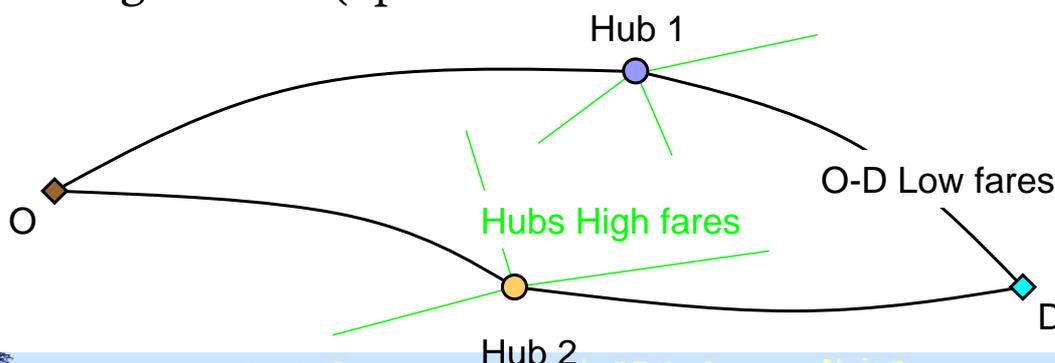


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Where do we see higher airfares ?

- Competition between hubs on O-D markets
 - low fares
- Less or no competition on routes to and from hubs
 - higher fares (up to +30% observed on the US market!)



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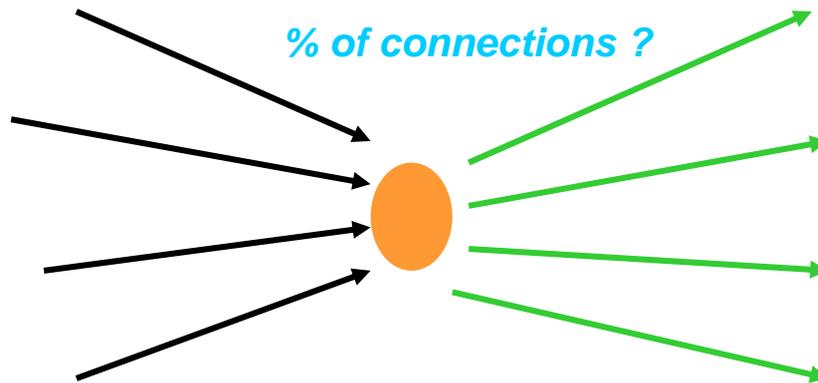


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Competition on hubs : how to measure it?

- ➔ By definition a hub is a connecting platform
 - the degree of hubbing can be measured by the percentage of connecting traffic



Competition on hubs : how to measure it?

- ➔ By definition a hub is a connecting platform
 - the degree of hubbing can be measured by the percentage of connecting traffic
- ➔ On major US hubs competition can be measured by concentration and fares :
 - concentration is high (few airlines) as measured by the Herfindhal index
 - airfares are higher



The Herfindahl index

- ➔ A market concentration index, called Herfindahl index, can be computed*. It is equal to the sum of the square of market shares:

$$H = \sum_{i=1}^n \alpha_i^2$$

- ➔ The higher the index (from 0 to 1), the more important the concentration on the market
 - ex: if two firms share the market 50/50, then $H=0.5$

*other measures exist



Table 3. Hubbing and Airport Concentration at the 30 Largest U.S. Airports

Airport	Percent Changing Planes	Airport Herfindahl	Airport Fare Premium	Rank by Size
Charlotte	75.7%	0.579	18.8%	20
Atlanta	69.0%	0.347	17.2%	3
Memphis	67.7%	0.355	27.4%	29
Dallas/Ft. Worth	65.8%	0.386	20.5%	2
Pittsburgh	62.1%	0.529	15.9%	16
Salt Lake City	61.3%	0.430	19.1%	28
St. Louis	56.2%	0.354	-4.0%	13
Chicago-O'Hare	55.7%	0.270	14.8%	1
Denver	54.1%	0.272	15.3%	7
Minneapolis	51.0%	0.418	31.5%	15
Houston-Intercontinental	49.5%	0.423	15.6%	19
New York-Kennedy	47.3%	0.202	2.9%	6
Detroit	43.6%	0.296	-0.7%	11
Baltimore	40.5%	0.299	9.1%	26
Phoenix	33.1%	0.205	-28.4%	9
Miami	31.0%	0.171	-14.3%	14
Seattle	27.3%	0.145	8.7%	24
San Francisco	25.3%	0.145	-1.5%	5
Los Angeles	25.2%	0.110	-5.3%	4
Philadelphia	24.9%	0.217	11.2%	22
Honolulu	22.4%	0.199	-20.8%	17
Newark	19.6%	0.292	11.5%	12
Las Vegas	18.9%	0.177	-27.8%	23
Houston-Hobby	17.5%	0.481	-23.4%	30
Orlando	16.8%	0.180	-15.6%	21
Boston	13.8%	0.120	9.0%	10
Washington D.C.-National	11.1%	0.125	10.7%	18
Tampa	11.0%	0.181	-12.4%	27
San Diego	6.6%	0.138	-18.1%	25
New York-La Guardia	6.2%	0.118	9.5%	8

Source: U. S. D. O.T. Databank IA, second quarter, 1990

Competition on hub airports

- ➔ Figures give evidence of market power on routes to and from hubs !
- ➔ If herfindahl > 0.3 then price premium positive !
 - Except Houston Hobby (not a hub, southwest)
 - Except St Louis



Using hubs for "unfair" competition: predatory pricing and behavior

- Refers to the strategies designed to get rid of competitors
 - used if profit after competitors get out compensates losses during predatory episode
 - Predatory pricing forbidden (it is forbidden to sell below cost almost everywhere)
- Although forbidden, it is used by airlines, because the "crime" is usually difficult to prove
 - cost is a fuzzy concept as well as price
 - behavior is more conclusive



Predatory pricing

- Evidence of it in the US airline industry
 - And suspicions in Europe but no data to prove it
- Points out to market power : ability to sustain high prices to recoup losses after predatory episode
- Signaling « game » : important to build a reputation for toughness, in order to deter entry
 - If predatory prices are not observed it may be because entry is effectively deterred !

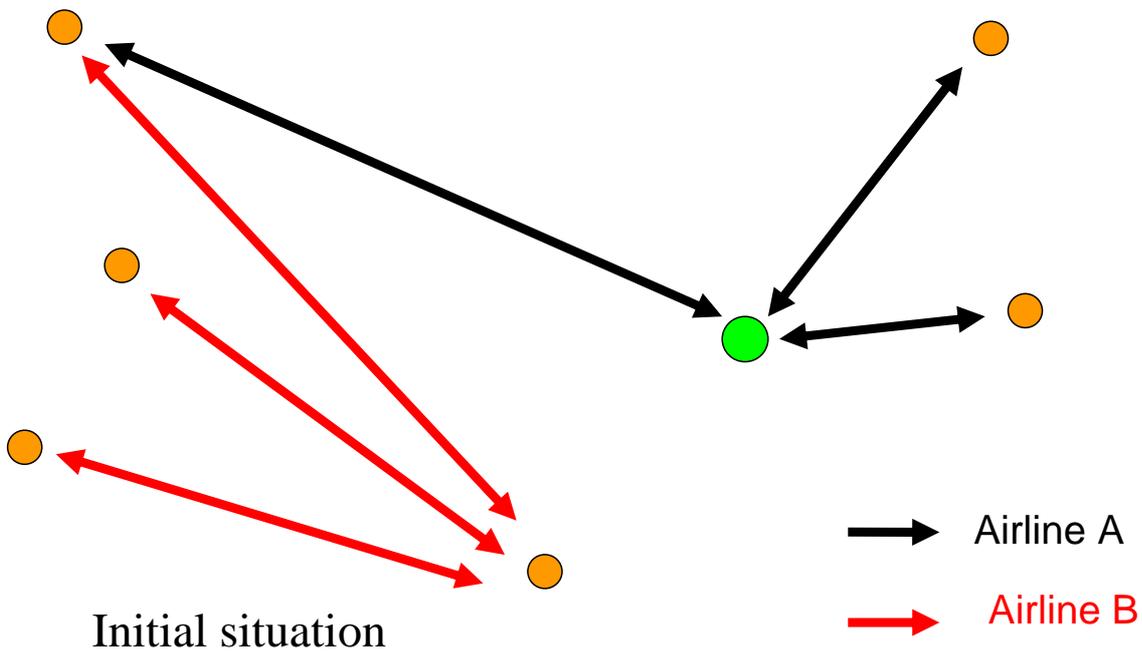


A story : setting

- ✈ We have two airlines :
 - Reno Air flies mainly from Reno
 - Northwest has a hub in Minneapolis



A story : setting



a story: entry phase

- We have two airlines :
 - Reno Air flies mainly from Reno
 - Northwest has a hub in Minneapolis
- In 1993 Reno Air opens service from Reno to Minneapolis

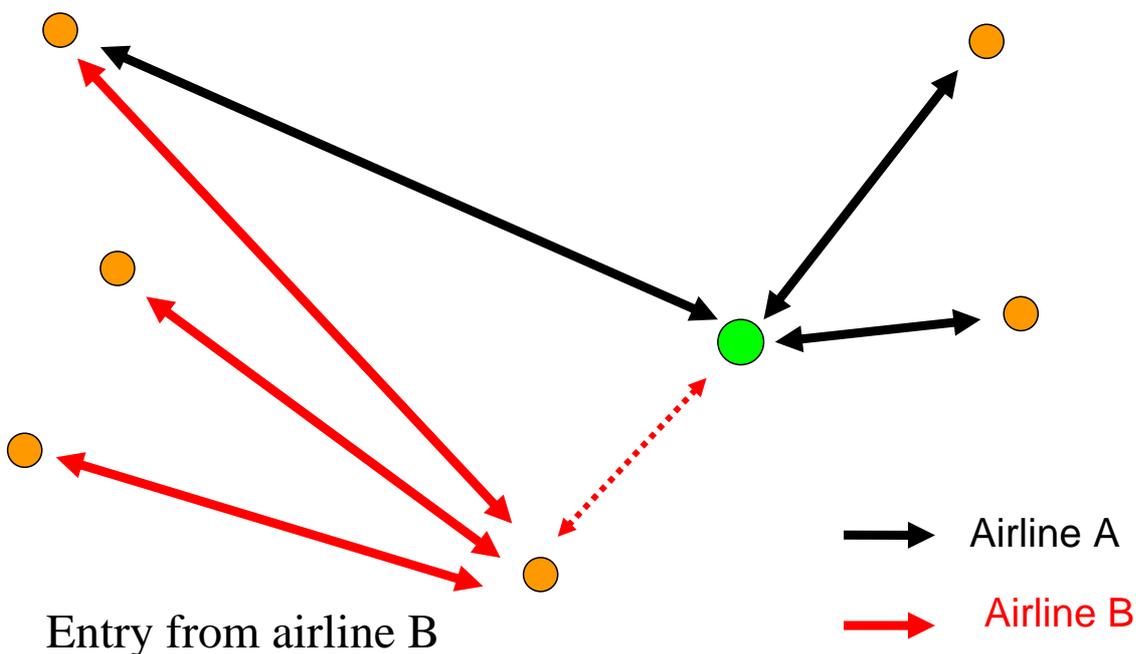
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a story: entry phase



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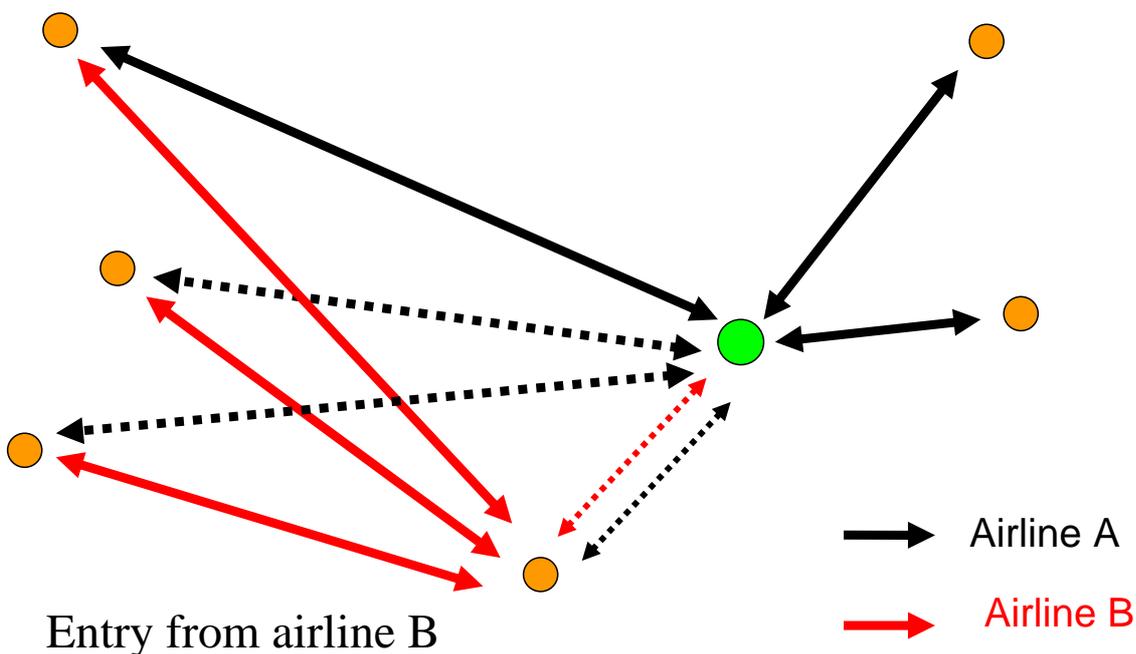


a story: reaction phase

- Northwest does the same, and open routes from Reno to LA, San Diego and Seattle where Reno Air operates
- Northwest set fares under those of Reno air, and offer overrides to travel agents for reservations to/from Reno
- Northwest fares from Minneapolis to LA, San Diego, and Seattle drop



a story: reaction phase



a story: end of war

- Reno Air exits the market
- Northwest exits the Reno market, and raises fares on Minneapolis markets

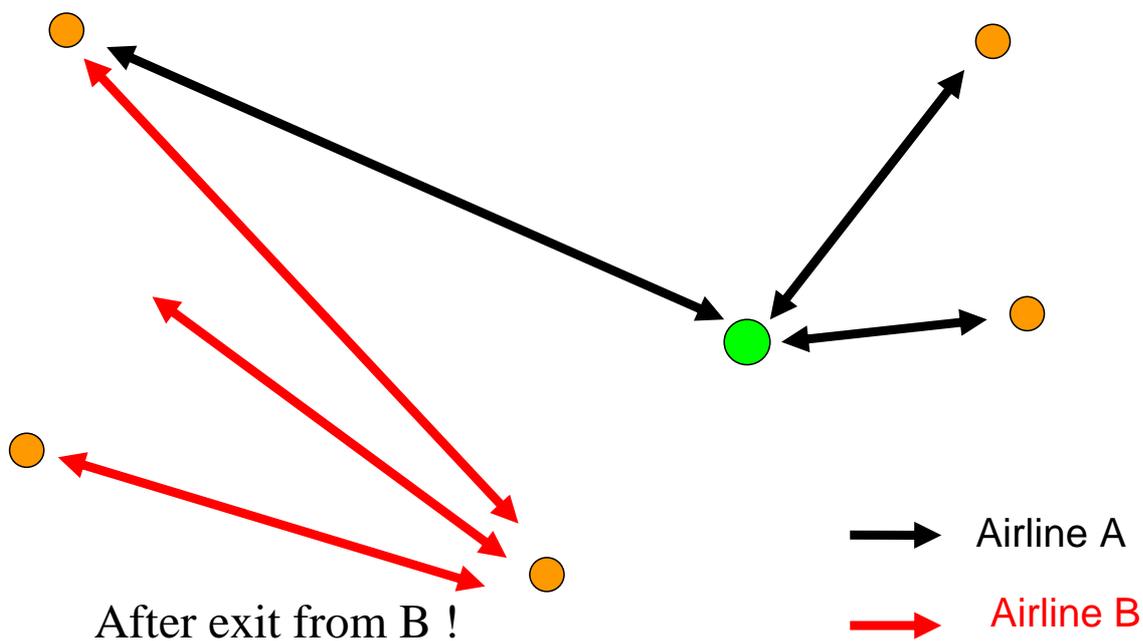
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a story: end of war



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Predatory pricing : a story

Looks a lot like predatory pricing/behavior!

- Northwest preserves its Minneapolis markets
- Passengers have higher fares
- Reno air is hurt



Predatory pricing : a story

- Airline A flies from its hub H (incumbent airline)
- Airline B (the challenger) comes to hub H and opens new service to D
- Reaction 1: Airline A does the same, and cut prices on new service : $p_A < p_B$
- After some time, airline B is driven out of the market, because it cannot match Airline A price
- Reaction 2: After Airlines B goes away, airline A does the same
- When is it normal behavior, and when is it not ?
 - Reaction 1 OK but Reaction 2 not OK !



Plan of presentation

- ➔ 1- Air transport networks
 - 1-1 Basics of networks economics
 - 1-2 Characteristics of networks
- ➔ 2- Networks and competition
 - 2-1 Hubs and competition
 - 2-2 Network strategy of the low cost carriers

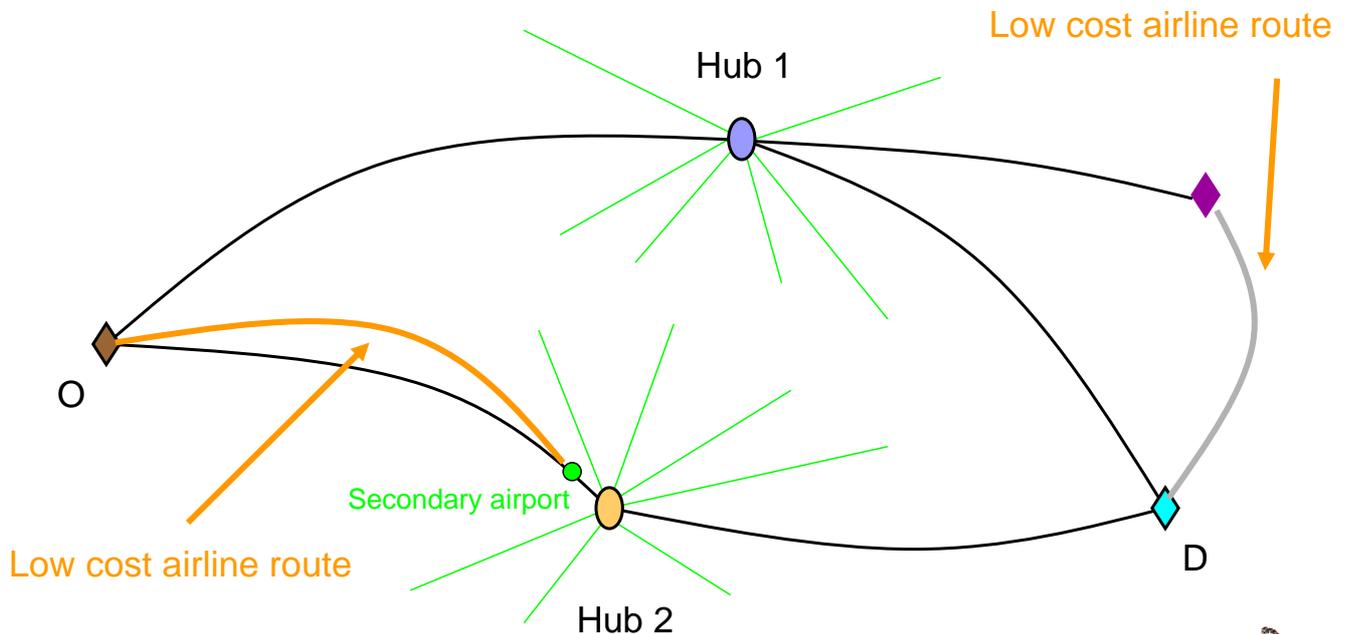


2-2 Network strategy of the low cost carriers

- ➔ The strategy of low-cost airlines is to « by-pass » the barriers erected by the majors
 - by using other airports : non hub airports
 - by offering mainly direct flights
- ➔ They endanger the hub model by draining the short haul “feeder” routes
 - USA
- ➔ They also develop new traffic
 - Europe, Asia



Competition between low-cost and majors



How to use secondary airports : The example of Washington-Baltimore



- ➔ 3 airports : Reagan Washington National (DCA), Washington Dulles (IAD), and Baltimore (BWI)
- ➔ Southwest entered the market in 1993 at BWI : low prices, high frequencies
- ➔ After a period of intense competition, UA and USAir had to cut back frequency at IAD and DCA



Result of low cost competition

Hub City	Carrier	Hub Premium			1997 Low-Fare Markets
		1988	1995	1997	
Atlanta	Delta	47%	38%	20%	24
Charlotte	US Airways	34%	51%	59%	0
Cincinnati	Delta	45%	64%	67%	1
Denver	United	-4%	13%	10%	17
Detroit	Northwest	2%	21%	15%	28
Memphis	Northwest	33%	36%	36%	6
Minneapolis	Northwest	23%	41%	44%	3
Pittsburgh	US Airways	12%	46%	57%	1
Salt Lake City	Delta	21%	-11%	-15%	28
St. Louis	TWA	24%	3%	14%	40

Source : predatory pricing in the US airline industry, C. Oster, J. Strong

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New routes in Europe: Marseille 2003-2007

- LCC routes
- Non LCC routes



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Source : ENAC Carte : P-E THURAT avec Philcarto

Conclusion : two models

- One dominant model of network : the hub
 - Centralized network
 - Coordination of schedules
 - Extensive use of connections
 - Partnerships between hub airlines
- The model : Large hubs, large aircraft flying between hubs
 - Need for shorter feeder routes
 - Need for additional local traffic to fill aircraft and generate revenues



Conclusion : two models

- One developing competing model : the low cost airlines
 - Decentralized network
 - Direct routes
 - No connections
 - Mostly short haul so far
- The model: decentralized networks, with direct flights, smaller aircraft
 - Sustainable only if demand sufficient on direct routes
 - More difficult to envision on long haul



Can they co-exist ?

- ✈ The problem is that LCC are “eating” into Hub airlines markets :
 - Take passengers away from hub airlines on short haul markets
 - Hub short feeder routes are making losses if airlines cannot add local passengers to connecting passengers
 - In the USA, local passengers increasingly use low cost airlines
- ✈ Future network shape will depend on demand evolution
 - Depending on energy prices, economic growth, environmental concerns
 - Decentralized networks require a large demand to sustain direct routes.

