

Social and Technological Network Analysis

Lecture 6: Information Cascades

Dr. Cecilia Mascolo

In This Lecture



-
- In this lecture we introduce the concept of “cascades” of information in networks and show examples and trade-offs for these to happen.

Decision Making and Behaviour Influence



- How is new behaviour adopted?
- How does technology usage spread?
- People influence on ideas?

- The social network plays an important role in the decision making process
 - We study how.

Early studies on Influence



- Ryan and Gross (1943) on adoption of hybrid corn in Iowa
 - Farmers learned of the corn from salesmen but were convinced on adoption by experience of neighbours in the community.
- Coleman, Katz and Menzel (1966) on adoption of tetracycline in US
 - Map of social connections among doctors.
 - Early adopter had higher socio-economical status and travelled more widely (also in corn case).
 - Decision on adoption was made in the context of the social structure (observing neighbours, friends and colleagues).



Model of Diffusion

- Nodes v and w and behaviours A and B
 - If both v and w adopt A , they each get payoff $a > 0$
 - If both adopt B , they each get a payoff $b > 0$
 - If they adopt opposite behaviour they both get a payoff of 0

		w	
		A	B
v	A	a, a	$0, 0$
	B	$0, 0$	b, b

Network Implications

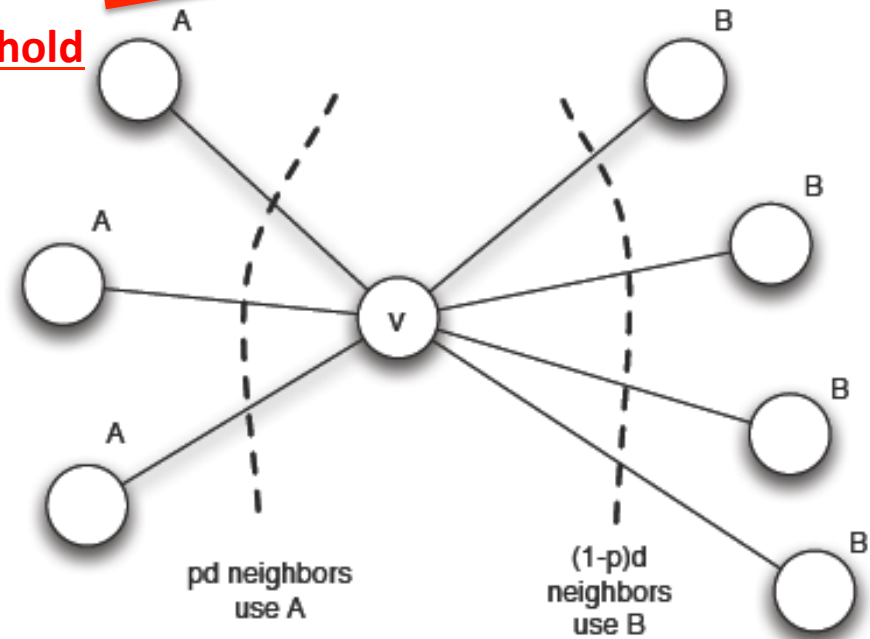


- p fraction of neighbours choose A
- $(1-p)$ choose B
- d neighbours then: pd choose A and $(1-p)d$ choose B

A better choice if : $pda \geq (1-p)db$

$$p \geq \frac{b}{a+b}$$

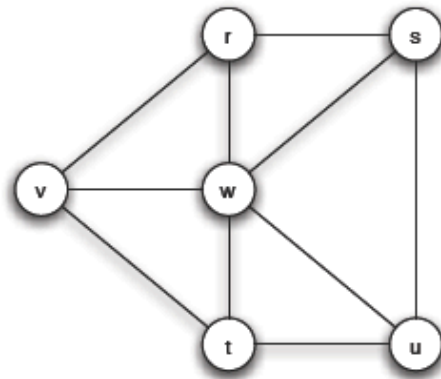
threshold



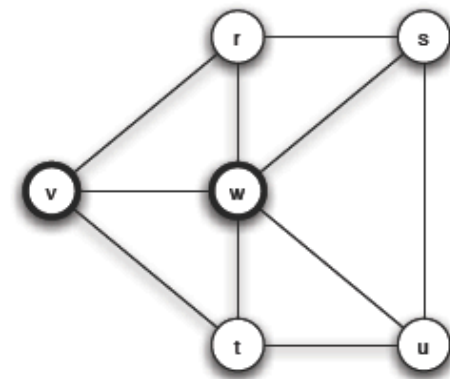
Larger Horizon



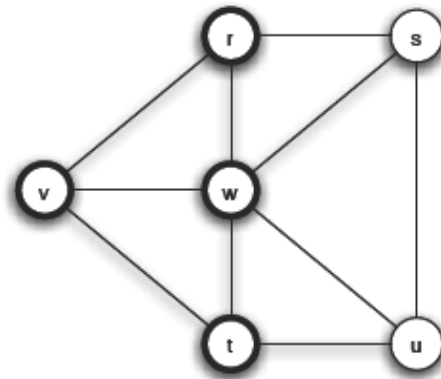
- A is new behaviour
- $a=3, b=2$
- $b/a+b=2/5$



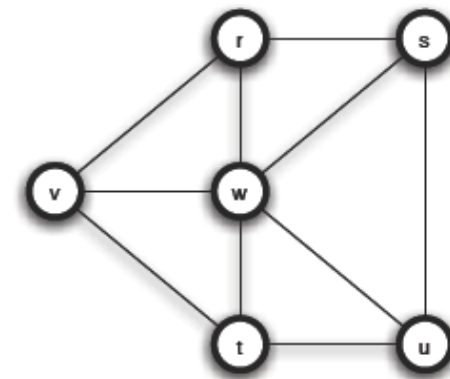
(a) *The underlying network*



(b) *Two nodes are the initial adopters*



(c) *After one step, two more nodes have adopted*



(d) *After a second step, everyone has adopted*

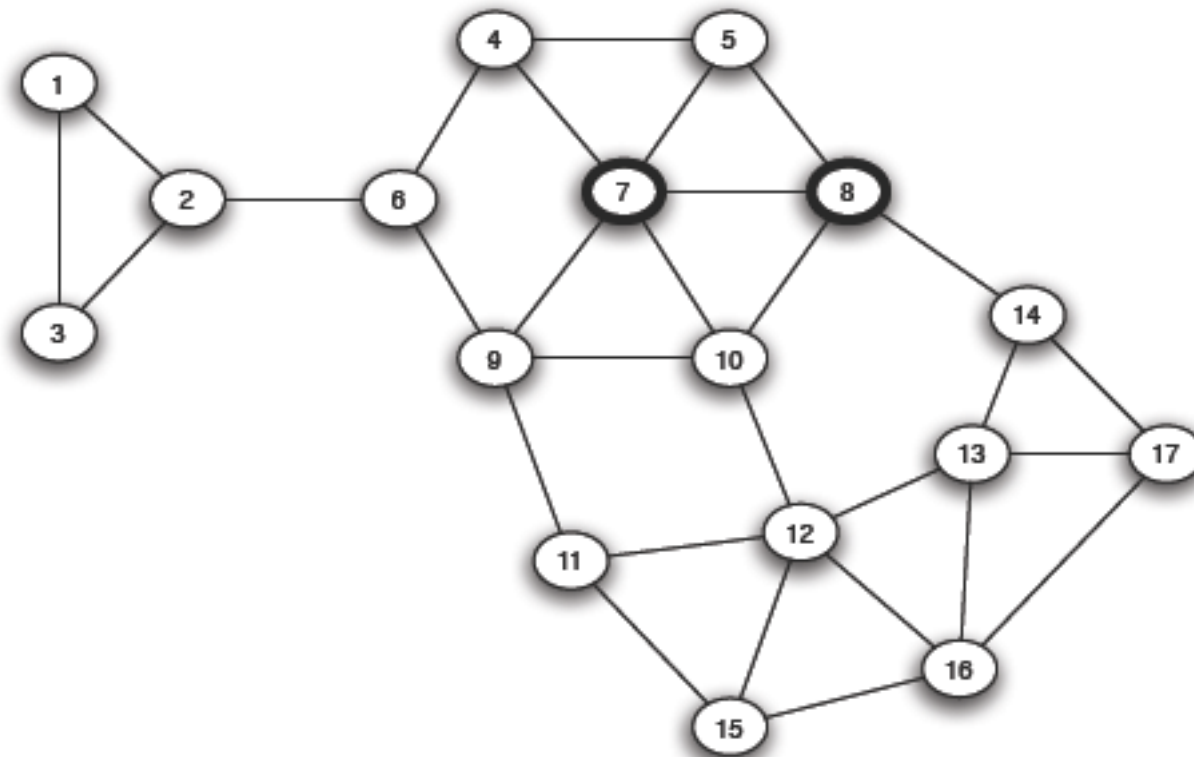
Light circles=B
Dark circles=A

Example explained

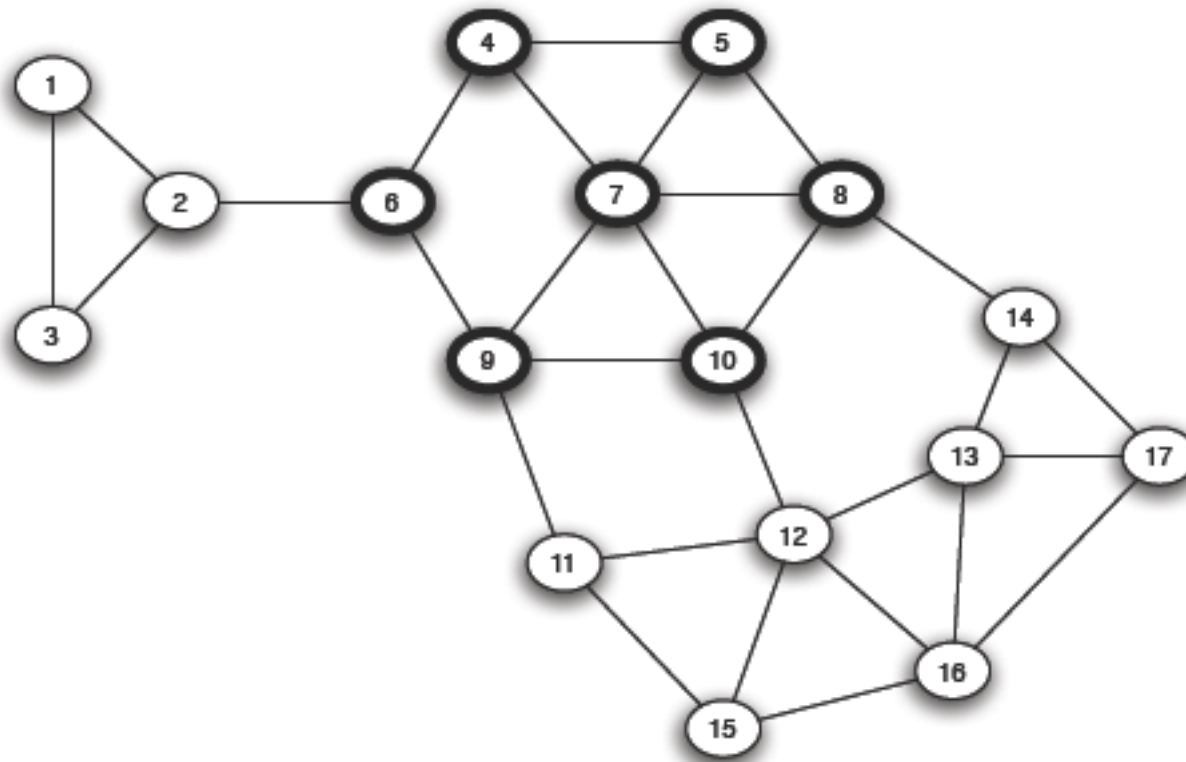
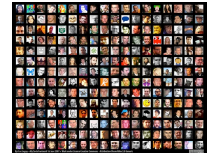


- 1st step: only v and w adopt A
- 2nd step: nodes r and t switch to A. $2/3 > 2/5$ of neighbours choose A. u does not switch: $1/3 < 2/5$ of neighbours chose A
- 3rd step: s and u switch to A

Chain Reactions



Cascade Stops!

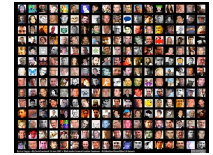


Cascades



- In some cases initial adoption by some nodes generate a **complete cascade** [for a specific threshold]
- Note that changing the threshold would change the behaviour in previous example
 - Threshold of $1/3$ would generate a complete cascade

Viral Marketing

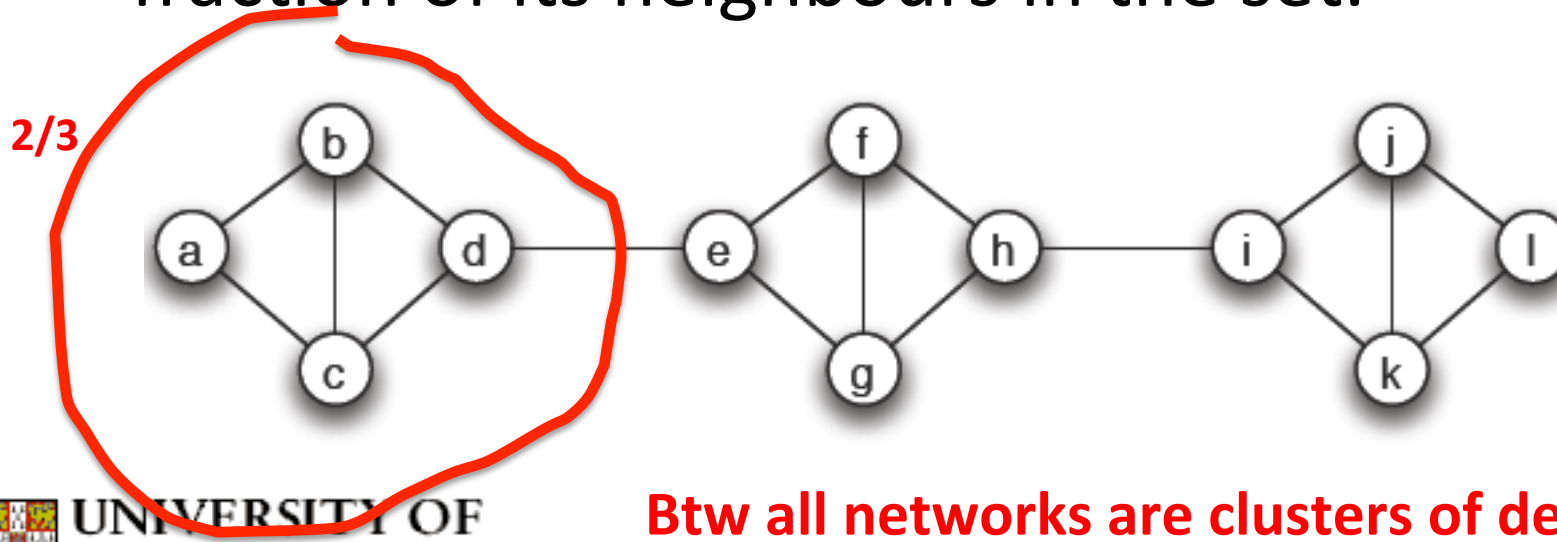


- How to penetrate new areas of the network
- Dissemination does not depend only on the network structure but also on this threshold!
 - Change the payoff! I.e., change the quality of the product [make a product slightly more attractive].
- When threshold cannot be changed
 - Convince key network nodes to switch (e.g nodes 12/13 good, but nodes 11 and 14 bad).

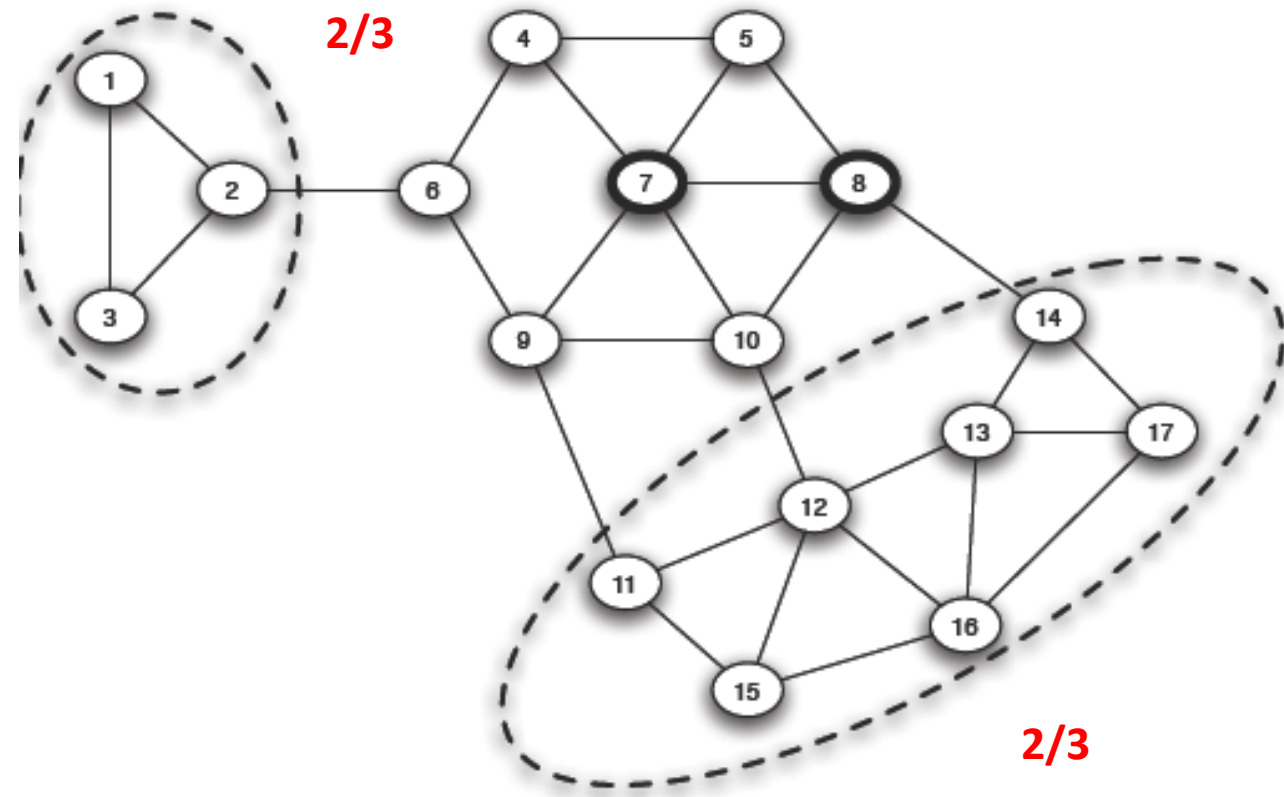
What Makes Cascades Stop?



- Tightly knit communities sometimes cannot be penetrated.
- A cluster of density p is a set of nodes such that each node in the set has at least a p fraction of its neighbours in the set.



Clusters as Obstacles to Cascades



Clusters and Cascades Relationship



- Set of initial adopters of A (S), threshold q
 1. If the remaining network contains a cluster of density greater than $1-q$ then set S will not cause a complete cascade.
 2. Whenever set S does not cause a complete cascade with threshold q the remaining network must contain cluster of density greater than $1-q$



Proof of Part 1

- Consider S and q in a network.
- Let's assume the network contains a cluster of density $>1-q$
- We need to prove:
 - *No node in the cluster will ever adopt A.*
- Let's assume that node v inside the cluster is the first to adopt A (at time t).
- At time $t-1$ no neighbour of v in the cluster adopted A.
 - Neighbours must be outside the cluster.

Proof of Part 1 Continued



- Since cluster has density $>1-q$, more than $1-q$ neighbours of v are inside and $<q$ neighbours are outside.
- The threshold to switch is q and number of v 's neighbours who have switched before time t is $<q$ so it is impossible that v switched.
- [we do not prove part 2 here]

Cascade Capacity of Networks



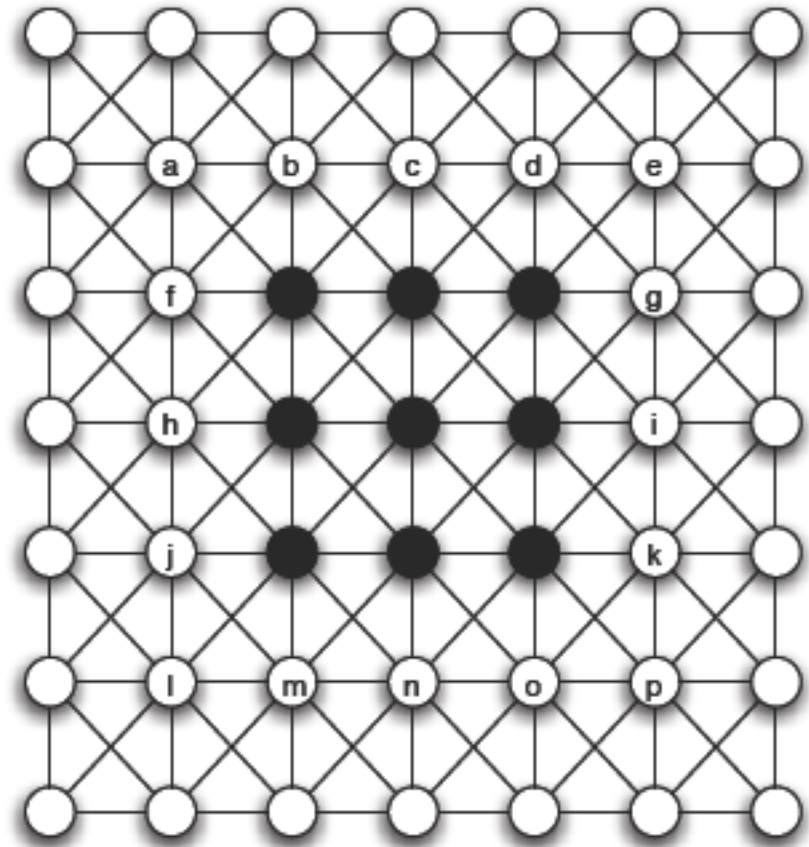
- **Cascade Capacity** of a network is the largest value of the threshold q for which some finite set of early adopters can cause a complete cascade
- In the following case cascade capacity is $\frac{1}{2}$
 - Even if the network is infinite



Cascade Capacity on a Grid



- If $q \leq 3/8$ there is a complete cascade
- If q is smaller (eg $2/8$) cascade spreads even faster.
- Cascade Capacity is $3/8$
- A network with a **large capacity** is one where cascades happen easily.



How large can Cascade Capacity be?



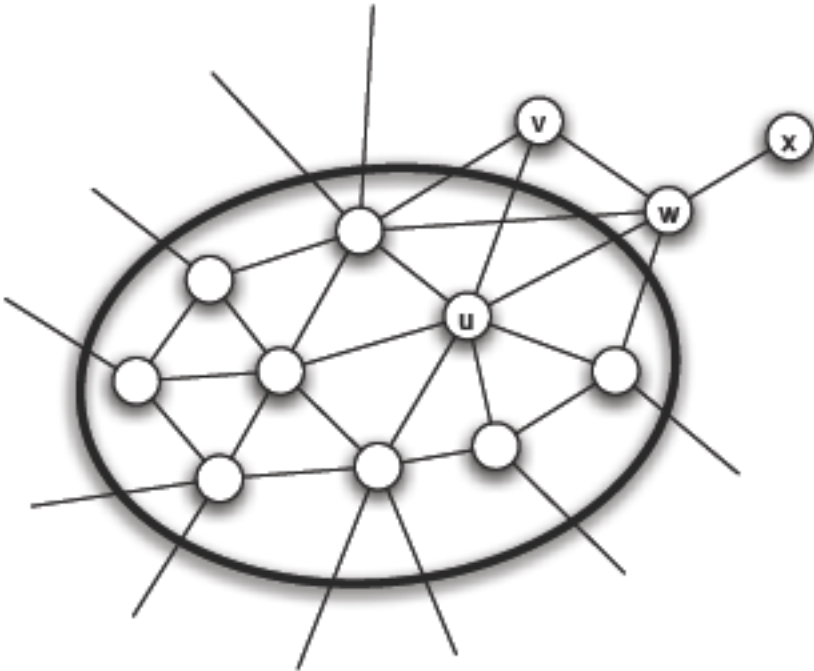
- Can it be higher than $\frac{1}{2}$?
 - This would mean for instance that an inferior innovation can displace a superior one even when the inferior innovation starts with few initial adopters.
- No: we will show that no network has a capacity higher than $\frac{1}{2}$.

No Network has Capacity $>1/2$

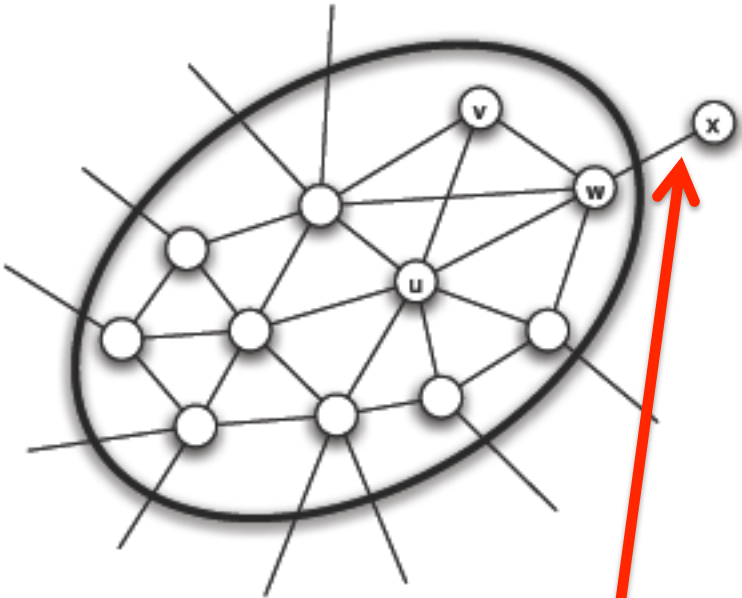


- We need to show that when $q > 1/2$ the spreading process cannot reach all nodes.
- *Interface set*: set of edges between A and B nodes.
- We will show that at each step the size of the interface set decreases.
- Initial interface set: finite I_0 from initial adopter set S.
- If interface set decreases, the process runs only for I_0 steps and terminates with only a finite number of nodes adopting A.

Example of interface set change



(a) Before v and w adopt A



(b) After v and w adopt A

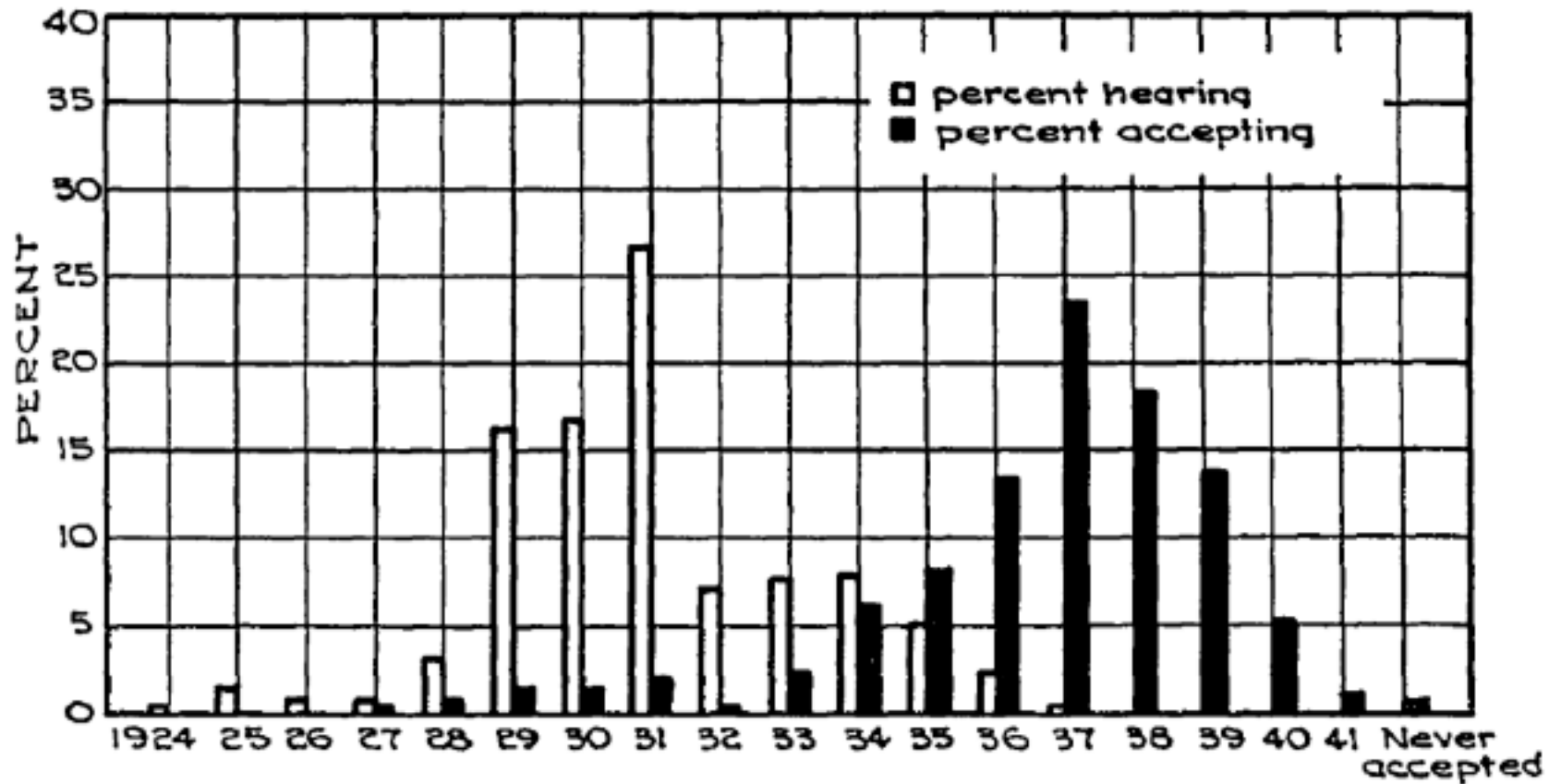
Edge xw is now an interface edge

Proof



- Let's consider node w switching at time t .
- At time $t-1$ w has " a " edges to nodes adopting A and " b " edges to nodes adopting B .
- w now switches to A so the " b " edges are now interface edges and " a " edges are not any longer.
- Since $q > 1/2$ and w switches, it must be that $a > b$.
- Hence the interface set decreases at each step.

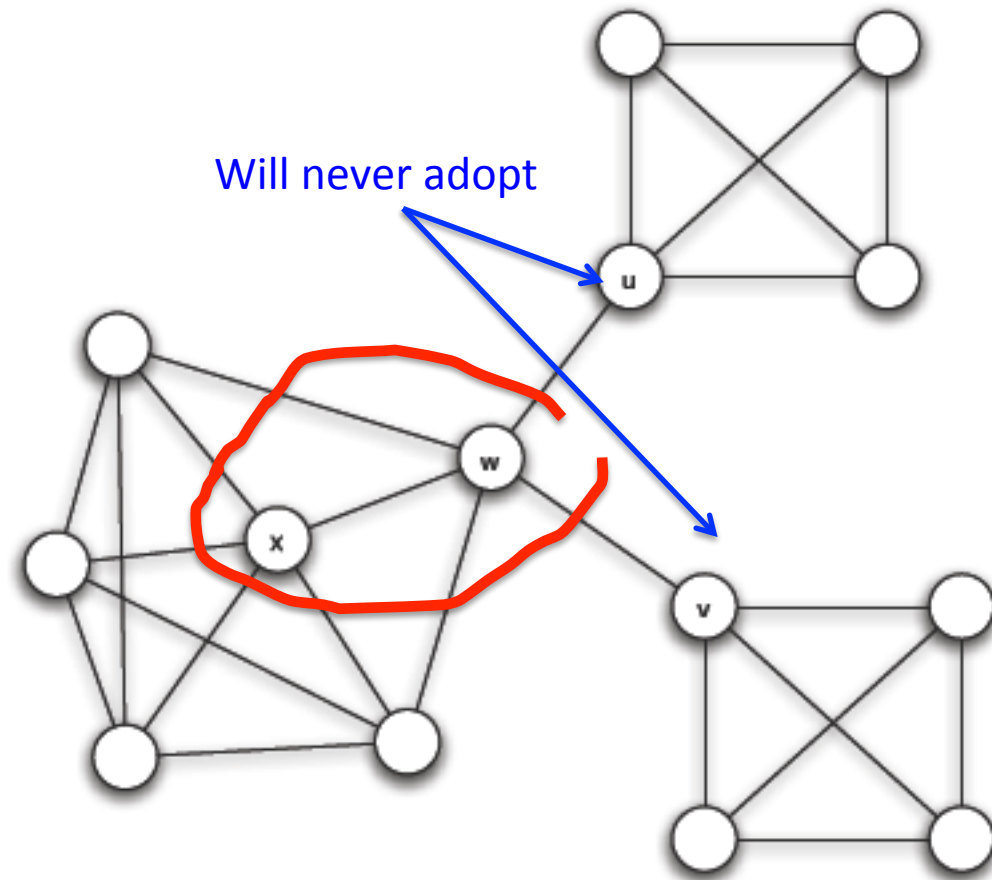
Learning versus Adopting



Role of Weak Ties



- v, w initial adopters
- $q=1/2$



Weak Ties Role and Behaviour Adoption



- Weak ties are very powerful in spreading new information.
- Weak ties are weak at transmitting behaviours that are somehow risky and costly to adopt.

Heterogeneous Threshold Model



- What if nodes value choices of different behaviour differently:

		w	
		A	B
v	A	a_v, a_w	$0, 0$
	B	$0, 0$	b_v, b_w

- Then
$$p \geq \frac{b_v}{a_v + b_v}.$$
- **Each node will have a different threshold (q_v)!**
- **Blocking cluster:** set of nodes (v) which have more than $1-q_v$ neighbours in the set (where q_v is different for each of the nodes!).
- Similar rule about complete cascade can be defined using the blocking cluster concept.

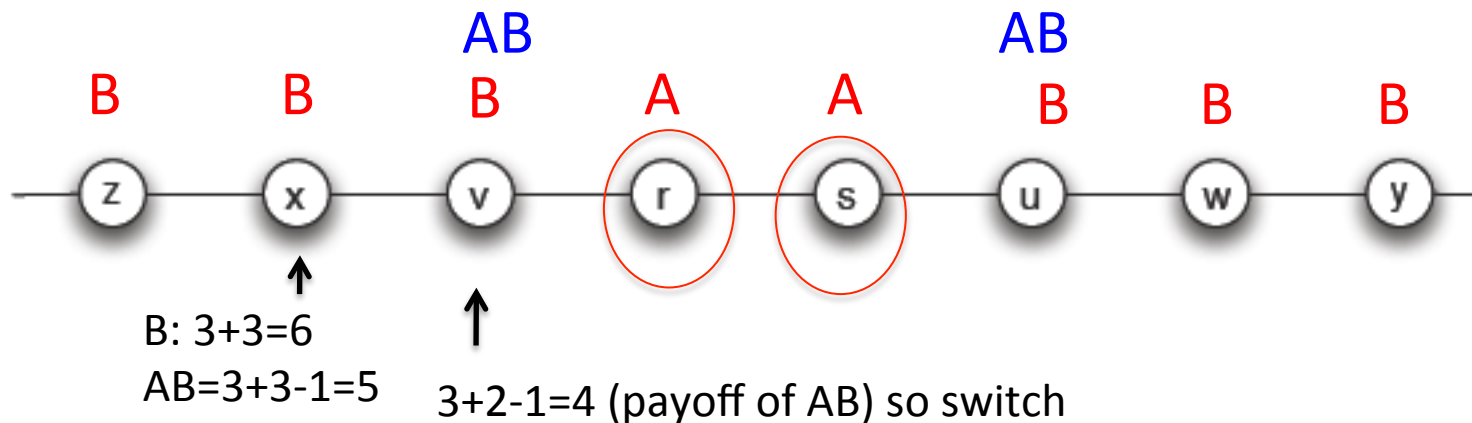
Cascades and Compatibility



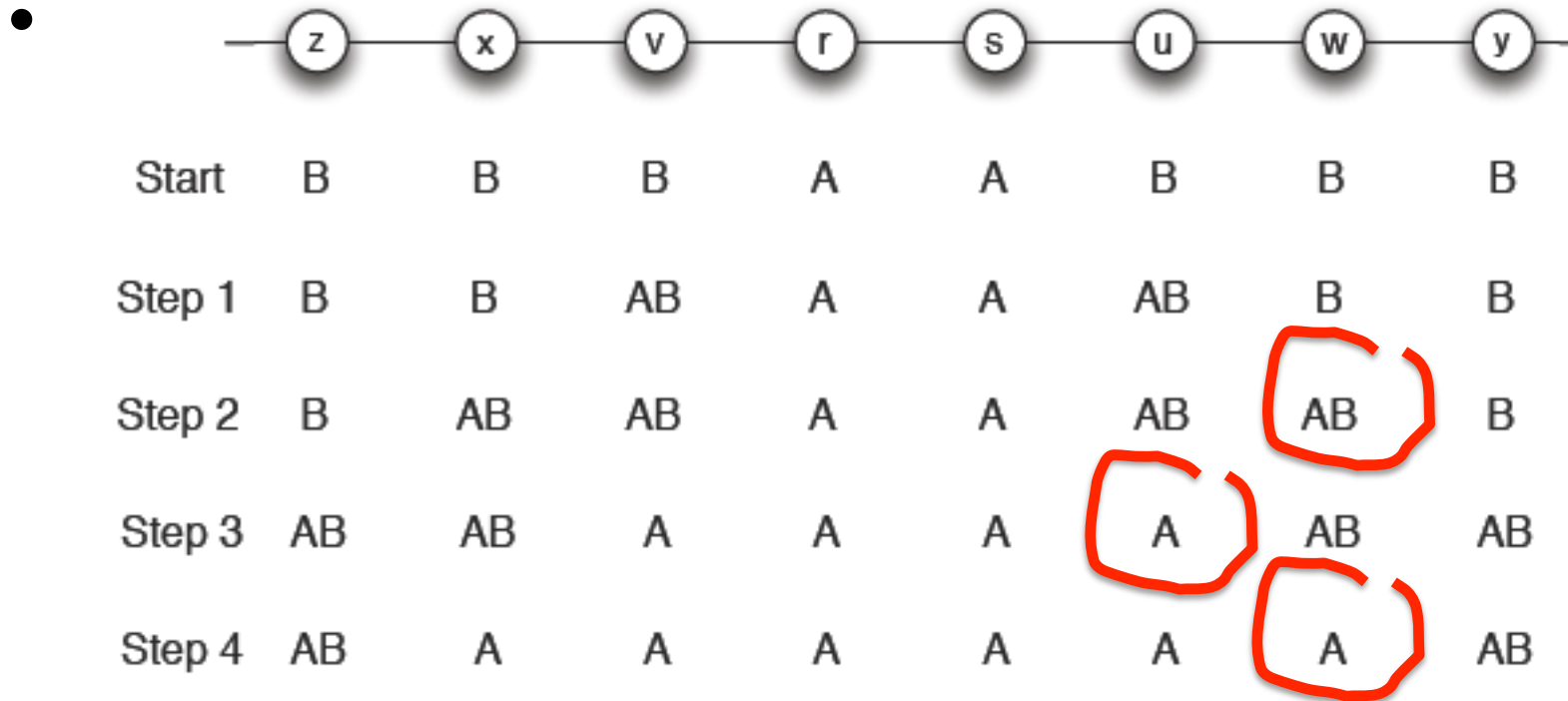
- Example of Bilingual behaviour
 - In some cases nodes may want to play 2 strategies

		<i>w</i>		
		<i>A</i>	<i>B</i>	<i>AB</i>
<i>v</i>	<i>A</i>	<i>a, a</i>	<i>0, 0</i>	<i>a, a</i>
	<i>B</i>	<i>0, 0</i>	<i>b, b</i>	<i>b, b</i>
	<i>AB</i>	<i>a, a</i>	<i>b, b</i>	<i>(a, b)⁺, (a, b)⁺</i>

← Max(a,b)



Another Example

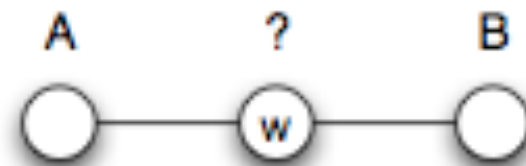


B will slowly disappear!

Capacity of Cascades (A,B, AB case)



- Let's fix b to 1 for simplicity.
- In this case it all depends on the relationship between a and c .
- What is the best strategy for node w in the following example?

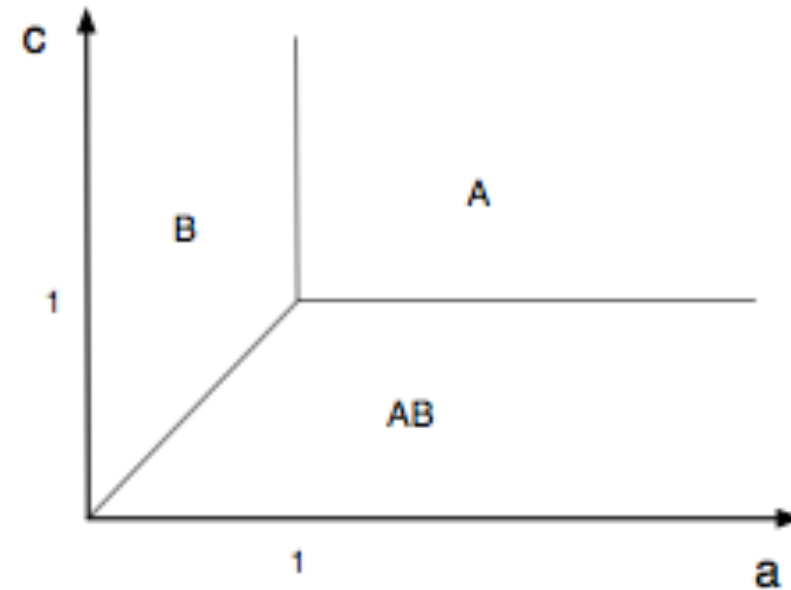
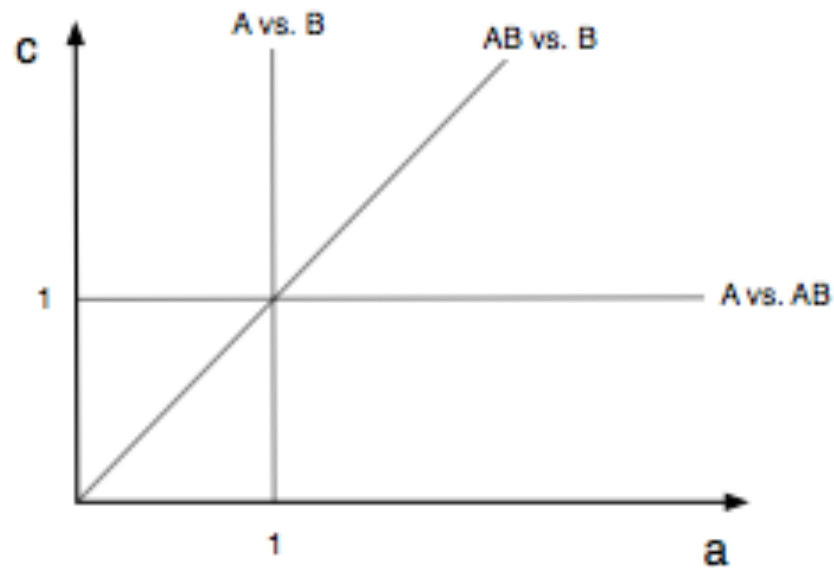


payoff from choosing A: a

payoff from choosing B: 1

payoff from choosing AB: $a + 1 - c$

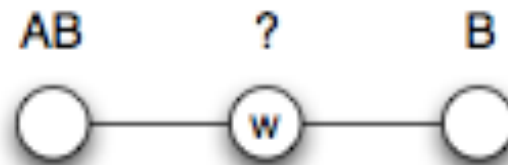
Dependency on a and c





Second case

- Payoff of B is now 2 as it can interact on both sides:

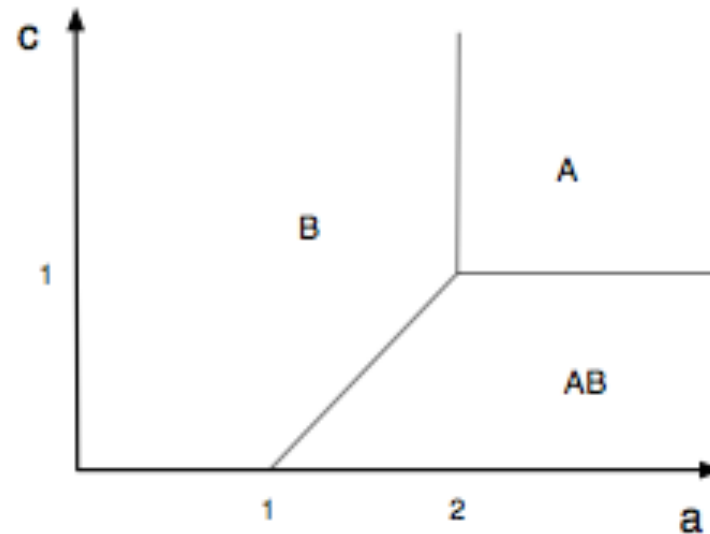
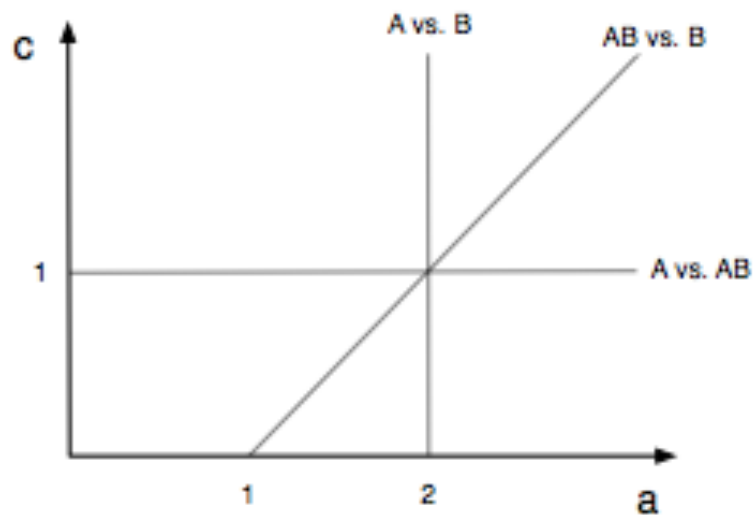


payoff from choosing A: a

payoff from choosing B: 2

payoff from choosing AB: $a + 1 - c$ (if A is better)

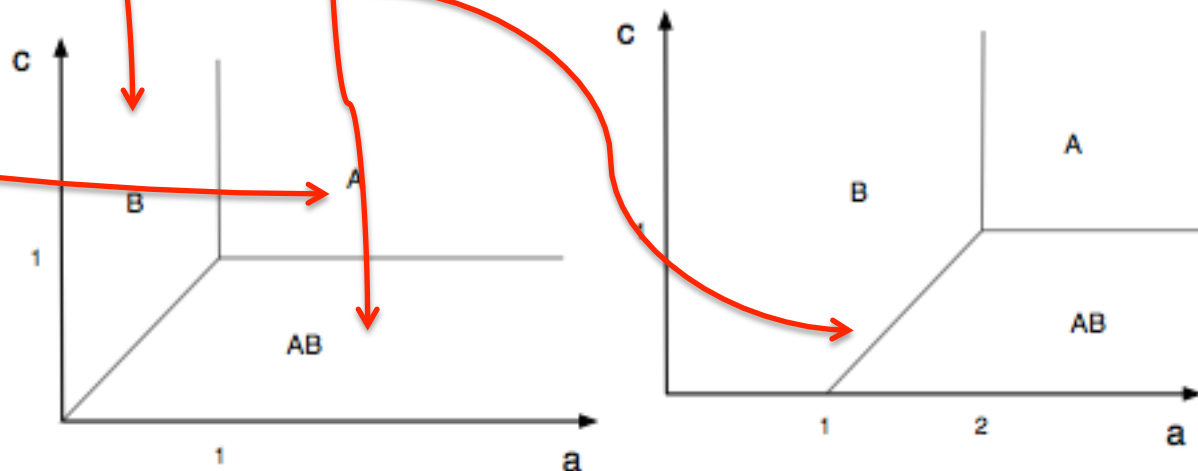
Graphically again...



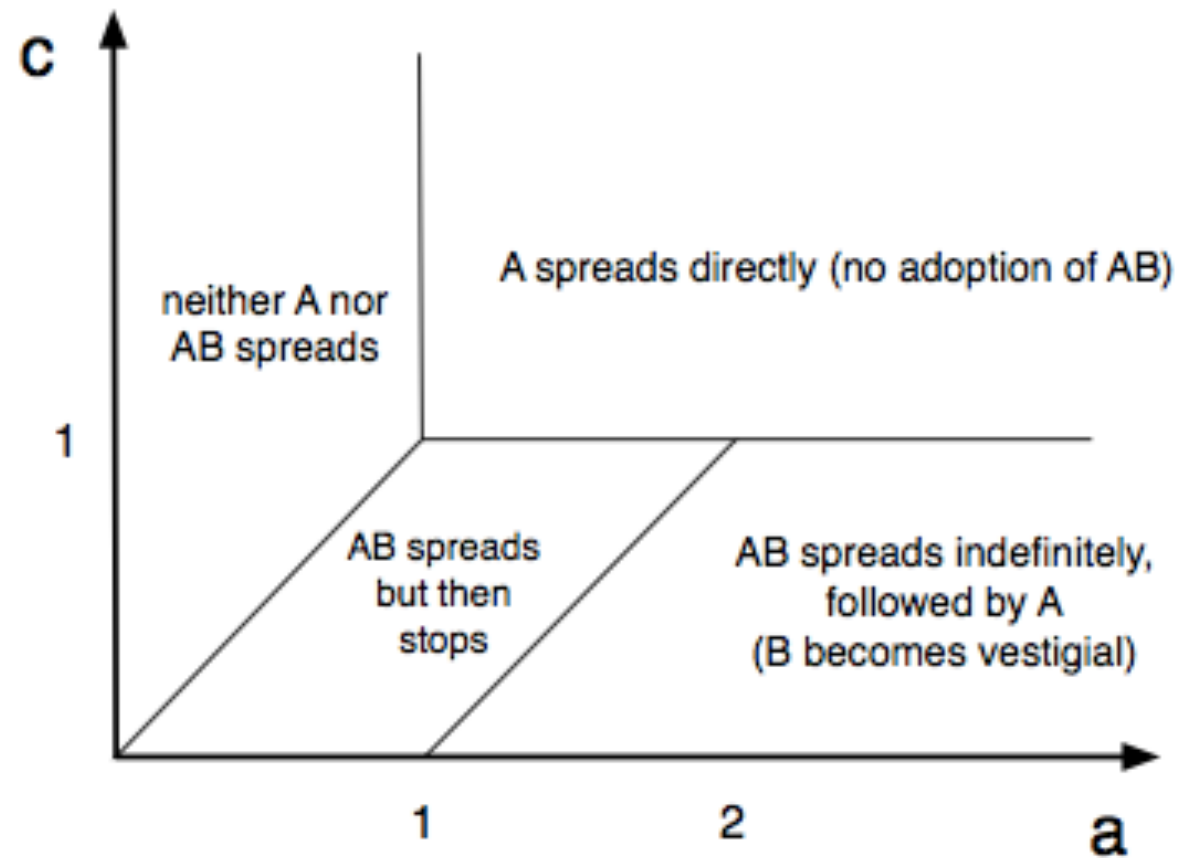


For what pair (a,c) does A spread?

- Consider u adjacent to initial adopter of A
- Here B will stay
- Here A will spread to the network (cascade)
- Node u will behave like here, but his next neighbour will be like here (but same values of a and c).



Summary



Discussion



- Tips for technology producers
 - Suppose $b=1$ and $a=1.5$ [new technology]
 - For which values of c is B surviving?
- If easy to maintain both technologies [they are compatible] then AB will spread and then A [as it is better].
- If incompatible boundary people will choose [some will choose A] and this will spread.
- If in between some regions will maintain B and some will switch and there will be a bilingual buffer in between.

References



- Chapter 19